GREATER CONFINEMENT DISPOSAL OF HIGH ACTIVITY AND SPECIAL CASE WASTES AT THE NEVADA TEST SITE: A UNIFIED MIGRATION ASSESSMENT APPROACH*

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ABSTRACT

The DOE Nevada Field Office (DOE/NV) has disposed of a small quantity of high activity and special case wastes using Greater Confinement Disposal (GCD) facilities in Area 5 of the Nevada Test Site (NTS). Because some of these wastes are transuranic radioactive wastes, the U.S. Environmental Protection Agency (EPA) standards for their disposal under 40 C.F.R. Part 191 apply. These regulations require a compliance assessment. Review of GCD inventory revealed potentially land disposal restrictions (LDR) hazardous wastes. The regulatory options for disposing of LDR wastes consist of 1) treatment and monitoring, or 2) developing a no-migration petition. Given that the waste is already buried without treatment, a no-migration petition becomes the primary option. EPA guidance on developing a no-migration petition indicates that there are some common regulatory issues with 40 C.F.R. Part 191. In addition, these same similarities can be found in the regulatory requirements (DOE Order 5820.2A) for low-level radioactive wastes which are also contained in GCD facilities.

Based on these common regulatory issues and a desire to minimize costs associated with site characterization and performance assessment, a single approach has been developed for assessing compliance with 40 C.F.R. Part 191, DOE Order 5820.2A and developing a no-migration petition. The approach consists of common points of compliance, common time frame for analysis, and common treatment of uncertainty. The procedure calls for conservative bias of modeling assumptions, including model input parameter distributions and adverse processes and events that can occur over the regulatory time frame, coupled with a quantitative treatment of data and parameter uncertainty. This approach provides a basis for a defensible regulatory decision. In addition, the process is iterative between modeling and site characterization activities, where the need for site characterization activities is based on a quantitative definition of the most important and uncertain parameters or assumptions.

INTRODUCTION

In 1953, the first trench for low-level radioactive waste (LLW) was established in Area 5 of the NTS for the disposal of on-site LLW generated as a result of weapons testing activities. Prior to this date, there was no centralized location for the disposal of on-site LLW. Area 5 continues to serve in this capacity today. In 1974, this location also began serving as an interim storage for Lawrence Livermore National Laboratory transuranic (TRU) wastes intended for disposal at the Waste Isolation Pilot Plant (WIPP) in New Mexico.

In 1978, DOE Headquarters established the National LLW Management Program, which later became the Defense LLW Management Program (DLLWMP), to address emerging technical and regulatory issues for generating and disposing of LLW.(1) One of the early goals established was to find improved methods for disposing of mobile radionuclide species, in particular, tritium.

The NTS was among a number of DOE disposal sites concerned with small volumes of highly-concentrated tritium waste that had been placed in shallow land-burial trenches or pits. Minute quantities of tritium were soon detected at environmental monitoring stations located on the perimeters of the disposal site(2). Because of this detection, DOE decided that shallow land-burial did not provide sufficient confinement for these wastes.

DOE/NV proposed the development of an intermediate depth disposal project. This project was to utilize large diameter boreholes to address the issue of GCD relative to shallow land burial.(3,4) In October 1979, the DLLWMP requested that DOE/NV prepare a report on the criteria necessary for development of an intermediate depth disposal facility. Later, the scope was expanded to address DOE defense high-specific activity LLW streams. In addition, the U.S. Nuclear Regulatory Commission (NRC) indicated that LLW that were greater than Class C (GTCC) were unsuitable for shallow land

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burial. Subsequently, NRC, DLLWMP, and the DOE agreed that the GTCC wastes required disposal methods which provided greater confinement than shallow land burial. In 1981, directed by the DLLWMP, a project with the specific goal of demonstrating GCD technology in an arid region was initiated at the NTS. Finally, it was decided that the wastes would not be limited to tritium and GTCC wastes, but a variety of wastes considered unsuitable for shallow land burial would be used. This included TRU waste that cannot be sent to WIPP either because it does not meet the WIPP waste acceptance criteria. NTS began GCD borehole operations in 1984.

Based on the inventory disposed of in the GCD boreholes(5) several regulations were identified as being applicable or potentially applicable. The tritium and GTCC LLW are covered under DOE Order 5820.2A,(6) which provides for management of radioactive waste that is generated by DOE. For the TRU waste, EPA's 40 C.F.R. Part 191(7) applies. In conducting a preliminary 40 C.F.R. Part 191 compliance assessment(8), review of the GCD inventory revealed potential hazardous wastes that are LDR under the Resource Conservation and Recovery Act (RCRA).(9) Given that the waste has been disposed of, the primary option is to petition for a "no-migration" variance, which is regulated under 40 C.F.R. Parts 268 and 271(10). In an attempt to minimize costs associated with site characterization and performance assessment, we are proposing a single approach to assessing compliance with 40 C.F.R. Part 191, DOE Order 5820.2A and developing a "no-migration" petition. In the following sections, a brief description of the applicable regulations is provided and the elements of commonality between the regulations are presented along with proposed consistent definitions of terms. This discussion is followed by our proposed procedure for implementing a unified approach for demonstrating regulatory compliance.

APPLICABLE REGULATIONS

The following sections provide a brief background and description of each of the regulations that are applicable to the disposal of waste in the existing GCD boreholes.

40 C.F.R. Part 191

40 C.F.R. Part 191 is the EPA's Environmental Radiation Protection Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level, and Transuranic Radioactive Wastes.(7) These standards were promulgated in 1985, but in 1987 the U.S. Court of Appeals for the First Circuit remanded the disposal standards, Subpart B, to the EPA for further consideration.(11) One of the main reasons the court overturned this regulation was because EPA failed to consider the interrelationship between 40 C.F.R. Part 191 and the Safe Drinking Water Act, and thus failed either to reconcile the two regulatory standards or to adequately explain the divergence. In the recent WIPP Land Withdrawal Act(12) congress reinstated the 1985 disposal standards except for sections 191.15 (Individual Protection Requirements) and 191.16 (Groundwater Protection Requirements) and requires EPA to repromulgate 40 C.F.R. Part 191 by mid-1993. The EPA has issued a proposed rule(13) revising sections 191.15 and 191.16 to address the court's concerns.

40 C.F.R. Part 191 contains three quantitative requirements for disposal: 1) Containment Requirements (191.13), 2) Individual Protection Requirements, and 3) Groundwater Protection Requirements. The Containment Requirements place limits on cumulative releases of radionuclides to the environment, which are based on protecting a population. The Individual Protection Requirements limit dose to any member of the public. The Groundwater Protection Requirements limit concentrations of radionuclides in groundwaters, which provides protection for a resource.

DOE Order 5820.2A

DOE Order 5820.2A(6) establishes the policies, guidelines, and requirements for the management of radioactive waste that is generated by the DOE for the purpose of protecting public health and safety. For DOE LLW, Chapter III of this order requires that a site-specific radiological performance assessment be conducted to demonstrate compliance with the specific performance objectives set forth in the Order. These objectives place limits on dose to any member of the public as well as dose limits for individuals who inadvertently intrude into the facility after the loss of institutional control (100 years after closure).

RCRA No-Migration Variances

The 1984 Hazardous and Solid Waste Amendments (HSWA)(14) of RCRA required the EPA to ban the land disposal of hazardous wastes under a set schedule. The HSWA amendments set rigid schedules for EPA to implement these LDRs which embody a phased cessation of land disposal for different types of wastes. The HSWA amendments also defined five conditions under which land disposal of wastes could continue. The first is treatment of the waste. The HSWA amendments required EPA to establish treatment standards for wastes subject to the land disposal restrictions; wastes treated to these standards may then be land disposed. EPA regulations establish these standards based on the best demonstrated available technology. The other four conditions or variants to the restrictions on the land disposal of hazardous waste are: national capacity variances, case-by-case extensions, treatability variances, and "no-migration" variances. National capacity variances, case-by-case extensions, and treatability variances are rooted in expediency; land disposal of waste must continue because no other alternative is available. A national capacity variance allows EPA to extend the land disposal prohibition dates for up to two years due to a lack of national treatment capacity. Similarly, EPA may grant a one-year case-by-case capacity extension, which can be extended once, upon a demonstrated shortfall of treatment or disposal capacity. A "no migration" variance propounds a different theory: LDRs are inapplicable to the disposal of hazardous wastes at a facility where wastes will not migrate and endanger human health and the environment.

40 C.F.R. Parts 268 and 271(10) provide the standards and procedures for "no-migration" variances for units other than injection wells. The procedures for injection well "no-migration" variances are contained in 40 C.F.R. Part 148.(15) The "no-migration" process entails a demonstration that the LDR prohibition is not necessary "to protect health or the environment, for as long as the waste remains hazardous, taking into account long-range uncertainties, the goals of proper waste management, and the persistence, toxicity, mobility and propensity to bioaccumulate of the wastes which are the subject of the petition."(10)

A CASE FOR A UNIFIED MIGRATION ASSESSMENT APPROACH

There are many common regulatory themes among 40 C.F.R. Part 191, DOE Order 5820.2A and 40 C.F.R. Parts 268 and 271 and associated guidance. These similarities can be divided into five areas: 1) stated intent, 2) use of modeling, 3) point of compliance, 4) time frame for analysis, and 5) future conditions at the site. In addition, a consistent approach to treating uncertainty and the data requirements associated with a consistent regulatory approach must be addressed. Each area is discussed in the following sections and provides the basis for a unified migration assessment approach.

Stated Intent

The stated intent of DOE Order 5820.2a and EPA's 40 C.F.R. Parts 268 and 271 is to protect of human health and the environment. With respect to TRU waste, EPA's responsibilities (inherited from the Atomic Energy Commission) under the Atomic Energy Act(16) are similarly focused because the agency is directed to take those functions " . . . of the Commission [that] consist of establishing generally applicable environmental standards for the protection of the general environment from radioactive material."(16) Under this directive, EPA established 40 C.F.R. Part 191. In DOE Order 5820.2A, this same purpose is stated in the policy section as: " . . . radioactive and mixed wastes shall be managed in a manner that assures protection of the health and safety of the public, DOE, and contractor employees, and the environment."(6)

In order to protect human health and the environment, 40 C.F.R. Part 191 limits integrated contaminant release, dose to an individual, and radionuclide concentrations in groundwater, while DOE Order 5820.2A limits dose to an individual and dose to an inadvertent intruder. As discussed above, RCRA states that obtaining a "no-migration" variance consists of demonstrating that "there will be "no migration" of hazardous constituents from the disposal unit or injection zone for as long as the wastes remain hazardous."(9) According to 40 C.F.R. Parts 268 and 271, "EPA interprets this statutory language to require that petitioners demonstrate that hazardous waste constituents will not migrate from the land disposal unit in hazardous concentrations for as long as the wastes remain hazardous."(10) Therefore, "no migration" does not mean zero release but allows releases that do not exceed health-based levels. EPA adopted this interpretation of "no migration" in its final standards for underground injection wells under 40 C.F.R. 148(15), and incorporated this approach in its review of petitions for "no migration" variances submitted under section 268.6(10). In addition, EPA's interpretation was sustained in the *Natural Resources Defense Council v. EPA*(17) litigation.

Given the above discussion, it is evident that none of these regulations equates protection of human health and the environment with zero release, even in the case of "no migration." Instead, each regulation is concerned with limiting migration of hazardous or radioactive constituents to levels less than specified health-based standards. The only difference with respect to the meaning of "no migration" is between the quantities that the calculated values are compared with (*e.g.*, integrated discharge, dose, minimum concentration levels). Therefore assessing compliance with all of these regulations is amenable to a consolidated approach.

Use of Modeling

40 C.F.R. Part 191 and DOE Order 5820.2A specifically identify performance assessment modeling as the means of assessing compliance with the quantitative performance objectives. EPA's draft guidance manual for developing a petition for a "no-migration" variance states that "the petition must contain sufficient modeling and theoretical, long-term projections to ensure that migration will not occur to any medium for as long as the waste remains hazardous."(18) All of the regulations that have been identified require modeling analyses to assess compliance with each respective performance objective, and this forms the common basis for performing compliance assessment.

Point of Compliance

40 C.F.R. Part 191 identifies the accessible environment as the point of compliance for the Containment Requirements, Individual Protection Requirements, and Groundwater Protection Requirements. The accessible environment is defined to be the atmosphere, land surface, surface waters, oceans, and all lithosphere that is beyond no more than 5 km in any direction or 100 km^2. For the "no-migration" variance, the compliance point is identified by EPA as "the unit boundary for all environmental media: groundwater, surface water, soil, and air."(10) EPA goes on to define the unit boundary as " . . . the outer most extent of the engineered barrier of the unit" and for units that do not contain engineered barriers, " . . . the petitioner and the petition reviewer must use best professional judgment to set the unit boundary." For migration via air and no engineered barrier, EPA more specifically defines a point of compliance that is " . . . the downwind edge of the unit at a height of 1.5 meters."(10) DOE Order 5820.2A is especially vague in that a point of compliance is not specifically defined at all. However, the DOE LLW Performance Assessment Review Panel recommends that transport pathways be developed under which radionuclides contribute to *off-site* doses.(19) This implies that the facility boundary is the compliance point, although a specific definition of the location of the facility boundary is not given.

The common regulatory theme is that the point of compliance allows for some area where contamination can exceed the prescribed limits. Beyond that boundary, the prescribed limits cannot be exceeded. Of the three regulations identified above, 40 C.F.R. Part 191 provides the most specific guidance for a compliance point in its definition of the accessible environment. The other two regulations are not as specific, hence, allowing for more interpretive definitions of the specific point of compliance. Therefore, we propose the use of the 40 C.F.R. 191's accessible environment as the common point of regulatory compliance.

Time Frame for Analysis

In the original promulgation, 40 C.F.R. Part 191 set a time limit for the Containment Requirements as 10,000 years and for the Individual Protection and Groundwater Protection Requirement as 1,000 years. This discrepancy was identified by the courts in 1987 as "arbitrary and capricious."(11) The most recent draft to amend 40 C.F.R. Part 191(13) changes the time frame from 1,000 years to 10,000 years for the Individual Protection and Groundwater Protection Requirements in order to be consistent with the Containment Requirements.

(The Groundwater Protection Requirements were replaced with Subpart C - Environmental Standards for Groundwater).

DOE Order 5820.2A does not specify a time limit for the performance assessment analysis. However, in practice,(20) 10,000 years has been used. The DOE LLW Performance Assessment Review Panel states that " . . . at this time [Oct. 1991] no DOE policy states the required period for compliance with the performance objectives of DOE Order 5820.2A",(19) and they recommend that the analysis be extended to include the peak dose seen as a function of time.

EPA states that "no migration" should be assured for as long as the waste remains hazardous. In defining 'for as long as the waste remains hazardous' the draft guidance manual for obtaining a "no-migration" variance states that the time frame for analysis " . . . is a waste- and site-specific determination".(18 However, in this same document EPA does note that the Underground Injection Program considers a " . . . demonstration of no migration for 10,000 years to be sufficient, given the nature of wastes that are disposed of through underground injection."(18) Therefore, we recommend that the time frame for the unified migration assessment should be 10,000 years.

Future Conditions at the Site

As discussed above, the site should protect human health and the environment for a very long time, i.e., 10,000 years. Therefore, all of the regulations (with their associated guidance) require some analysis of possible future conditions that would adversely effect the ability of the site to contain the waste. 40 C.F.R. Part 191 Containment Requirements specifically call for an analysis of all likely naturally-occurring and human-induced changes to the system, specifically including direct human intrusion into the repository. EPA's individual and groundwater protection requirements under 40 C.F.R. Part 191 state that the requirements apply to "undisturbed conditions." While undisturbed conditions clearly do not include such events as human intrusion, highly-likely natural changes may need to be addressed.

EPA's guidance on "no-migration" variances (18) states that estimates of "potential impacts and consequences of events with a reasonable probability of occurring" during the time the waste remains hazardous must be made. The guidance goes on to say that the natural and human-induced events must be accounted for. However, EPA's examples of human-induced events are changes to the characteristics of the natural system such as disturbances in the hydrologic regime and do not include direct exposure via intrusion.

DOE Order 5820.2A(6) does not specifically define potential future conditions that should be analyzed other than by implication through a direct limit on the maximum dose to an intruder. In practice,(20) DOE LLW performance assessments have included both naturally-occurring and human-induced changes to the disposal system.

Each regulation with its guidance and applications have demonstrated the need to analyze plausible future site conditions. Therefore, a scenario analysis developed for addressing 40 C.F.R. Part 191 could also be used for addressing compliance with EPA's no-migration petition requirements and DOE Order 5820.2A. Perhaps the only difference lies in the need to address human intrusion. However, EPA is consistent in this regard. That is, protection of an individual or a resource (i.e., groundwater) under 40 C.F.R. Part 191 is equivalent with protection of an individual under 40 C.F.R. Parts 268, 271, and 148 and none of these regulations call for an analysis which includes direct exposure via human intrusion.

Treatment of Uncertainty

Uncertainty is inherent in assessing the fate and transport of hazardous materials through the geosphere and biosphere over long periods of time. Uncertainty exists in conceptual models of the site, data and parameters, models, and future conditions of the site. Regardless of whether any of the regulations specifically address uncertainties (40 C.F.R. Part 191 and RCRA guidance on "no migration" do) they must be treated in the compliance assessment. The issue in need of resolution here is the manner and degree of formality used in treating these uncertainties and the presentation of final results. We propose formally addressing and quantifying uncertainty because this provides for regulatory defensibility and transparency of the performance assessment process. Specifically uncertainty will be treated by developing conservative models and data distributions, using Monte Carlo analysis for the treatment of parameter uncertainty, and applying formal scenario analysis for assessing the impacts of potential future events and processes. Our approach to modeling is based on biasing the analyses toward conservatism to be consistent with the "no-migration" variance guidance document.(18) This document states that "model assumptions and input data should be conservative and tend toward overestimating rather than underestimating migration."(18) The DOE LLW Performance Assessment Review Panel also recommends repeatedly throughout their review guide(19) that modeling assumptions should be conservative, but reasonable with respect to the site-specific information.

Data Requirements

The proposed unified migration approach is iterative with sensitivity analysis of the assessment results used to define site characterization activities. This approach is consistent with EPA's guidance on obtaining a "no-migration" variance which states that " . . . data needs are dependent on the methods chosen to demonstrate that migration will not occur".(18) The use of performance assessment to drive site characterization not only provides for efficient use of resources and an endpoint for the assessment, more importantly, it provides regulatory defensibility where it is needed. The pitfall of undirected site characterization activities, besides wasted resources, is to raise concerns that are not directly related to site safety and to build false confidence based on data that are not important for the *regulatory* compliance.

UNIFIED MIGRATION ASSESSMENT APPROACH

Given the commonalities of 40 C.F.R. Part 191, DOE Order 5820.2A, and a "no-migration" variance petition, a unified approach has been developed to compliance assessment. The approach is based on the performance assessment methodology developed by Sandia National Laboratories (SNL) for the NRC in assessing compliance with 40 C.F.R. Part 191(21) and the approach taken by SNL for assessing compliance with 40 C.F.R. Part 191 for the TRU waste contained in the NTS GCD boreholes.(8,22) The approach is based on the common compliance point, time frame of analysis, and treatment of uncertainty that were defined in the previous section. Also as described above, the strategy is based on biasing the modeling assumptions to be conservative with respect to the available information and the quantitative treatment of parameter uncertainty. The approach is iterative whereby the assessment results define future site characterization activities and the results of those data collection activities are used to update the assessment. The stopping points for this process are: demonstrated compliance with a particular regulation; expense of site characterization and engineering design is not worth continuing the process; and the discovery of an obvious uncorrectable problem with the site.

The specific procedure for the unified migration assessment consists of the following steps:

1. Develop assessment models that are conservative with respect to the available information about the disposal system. This includes assumptions about model parameters and the evolution of the site over the time frame of analysis. Because of the different regulatory performance measures (*e.g.*, integrated discharge, concentration) and contaminants (*e.g.*, radionuclides, hazardous chemicals) the specific models may be different. For example, modeling transport of hazardous chemicals does not require that radioactive decay is accounted for, where models of radionuclide transport do. In addition, the basis for what is or is not conservative may change depending on the specific performance measure; a zero flux boundary condition is conservative for a concentration-based performance measure but not for a flux-based (*e.g.*, integrated discharge) one.
2. Perform consequence modeling using the models developed in step one to calculate each respective regulatory performance measure and its uncertainty. Uncertainty in parameters, models, and future conditions will be propagated to the model results via Monte Carlo analysis.
3. Compare results to regulatory limits. If compliance is demonstrated, then the assessment is complete and defensible based on the conservative bias of the models and complete quantification of data uncertainty. If compliance is not shown, then sensitivity analysis is performed to identify the modeling assumptions and data that have the largest influence on the modeling results.
4. Perform site characterization activities to reduce uncertainties or relax conservatism on the most important modeling assumptions. At this point it may be decided that it is not economically reasonable to perform additional site characterization; therefore, the disposal site should not be used.
5. Update modeling assumptions based on new site characterization information. Again, the assumptions should be conservative relative to the information available.
6. Repeat steps (2) - (5) until: compliance is demonstrated; until it is not economically feasible to obtain additional site information necessary to demonstrate compliance; or when a disqualifying feature is found.

SUMMARY

A unified migration assessment approach has been developed for assessing compliance with 40 C.F.R. Part 191, DOE Order 5820.2A, and developing a petition for a "no-migration" variance. The basis for such an approach is the common regulatory issues among these three regulations and the desire to minimize costs associated with site characterization and performance assessment. The approach consists of common points of compliance, time frame for analysis, and treatment of uncertainty. The procedure calls for conservatively biased modeling assumptions, including assumptions about model input parameter distributions, Monte Carlo treatment of parameter uncertainty, and the analysis of potential adverse processes and events that can occur over the regulatory time frame. This approach provides a basis for a defensible regulatory decision. In addition, the process is iterative between modeling and site characterization activities, where site characterization activities are defined based on the most uncertain and important aspects of system safety as determined by performance assessment.

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