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Assessment of compliance with ground water protection standards in the 2008 performance assessment for the proposed high-level radioactive waste repository at Yucca Mountain, Nevada

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ABSTRACT

Extensive work has been carried out by the U.S. Department of Energy (DOE) in the development of a proposed geologic repository at Yucca Mountain (YM), Nevada, for the disposal of high-level radioactive waste. In support of this development and an associated license application to the U.S. Nuclear Regulatory Commission (NRC), the DOE completed an extensive performance assessment (PA) for the proposed YM repository in 2008. This presentation describes the assessment of compliance with ground water protection standards in the 2008 YM PA. The following topics are addressed: (i) regulatory background, (ii) analysis structure including characterization of uncertainty, and (iii) analysis results for each of the ground water protection standards. The present article is part of a special issue of *Reliability Engineering and System Safety* devoted to the 2008 YM PA; additional articles in the issue describe other aspects of the 2008 YM PA.

1. Introduction

The U.S. Nuclear Regulatory Commission (NRC) regulations for a high-level radioactive waste (HLW) repository at Yucca Mountain (YM), Nevada, require that the U.S. Department of Energy (DOE) demonstrate compliance with three separate and distinct radiation protection standards [1,2] (i) Individual Protection Standard after Permanent Closure (10 CFR 63.311), which is based on the required characteristics of the reasonably maximally exposed individual (RMEI) as described in 10 CFR 63.312, (ii) Individual Protection Standard for Human Intrusion (10 CFR 63.321), which is based on the Human Intrusion Scenario described in 10 CFR 63.322, and (iii) Standards for Protection of Ground Water (10 CFR 63.331), which are based on the representative ground water volume specified in 10 CFR 63.332.

This presentation describes analyses performed as part of the 2008 YM performance assessment (PA) to assess compliance with the Standards for Protection of Ground Water. The following topics are considered: regulatory background (Section 2); structure of analysis used to determine results for comparison with ground water protection standards (Section 3); and uncertainty and sensitivity analysis results (Section 4). The presentation then concludes with a summary discussion (Section 5).

Summaries of the analyses performed in the 2008 YM PA to assess compliance with the Individual Protection Standard after Permanent Closure and the Individual Protection Standard for Human Intrusion are presented in Refs. [3,4], respectively. Further, more detailed results underlying the assessment of compliance with the Individual Protection Standard after Permanent Closure are presented in Refs. [5–13], and a summary of the entire 2008 YM PA is available in Ref. [14]. A summary of the development of the YM repository is available in Refs. [15–24].

2. Regulatory background

The separate standards for protection of groundwater specified in 10 CFR 63.331 [1,2] require DOE to demonstrate a reasonable

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expectation that, for 10,000 yr of undisturbed performance after disposal, releases of radionuclides from the Yucca Mountain disposal system will not cause the level of radioactivity in a representative volume of ground water to exceed the following limits: (i) combined ^{226}Ra and ^{228}Ra activity concentrations (pCi/L) in groundwater not to exceed 5 pCi/L (including natural background); (ii) gross alpha activity (including ^{226}Ra but excluding radon and uranium isotopes) concentration not to exceed 15 pCi/L (including natural background); and (iii) combined doses from beta and photon emitting radionuclides to the whole body or any organ (based on drinking 2 l of water per day from a representative volume) not to exceed 4 mrem/yr (not including natural background).

As specified in 10 CFR 63.332, the representative volume of groundwater is 3000 acre-ft drawn from the groundwater with the highest concentrations of contaminants at the location of the RMEI (i.e., at a location in the Amargosa Valley 18 km from the proposed YM repository; this same volume of water and associated radionuclide concentrations are used in the determinations of doses to the RMEI presented in Refs. [3,6–13]). The term "undisturbed performance" is defined in 10 CFR 63.302 [1] to mean that "human intrusion or the occurrence of unlikely natural features, events, and processes do not disturb the disposal system." In turn, "unlikely natural features, events, and processes" (FEPs) are defined as "those that are estimated to have less than one chance in 100,000 per year of occurring and at least one chance in 100,000,000 per year of occurring" [1]. Simply stated, the performance demonstration for the groundwater protection standard requires that PA for the YM repository assess radionuclide releases caused by "likely" FEPs (i.e., having an annual frequency of 10^{-5}/yr or greater). Moreover the regulations do not require analysis results beyond 10,000 yr after repository closure.

3. Analysis structure

In general, the analysis structure used to obtain results for the individual protection standard [5–13] is also employed to obtain results for the groundwater protection standards. The analysis structure is modified to exclude unlikely FEPs as required by regulation. Specifically, the probability space describing aleatory uncertainty is restricted in the analysis for groundwater protection results to the following conditions/occurrences: nominal (i.e., undisturbed) conditions, early waste package (WP) failure, early drip shield (DS) failure, and seismic ground motion (GM) events. The scenario classes representing igneous intrusive events, igneous eruptive events, and seismic fault displacement events were excluded from consideration due to probabilities of occurrence that fall below the level specified for consideration. Moreover, the seismic GM scenario class was restricted to consider only those seismic events with frequency exceeding 10^{-5}/yr, implemented by truncating the seismic hazard curve ([12], Fig. 1). Because nominal processes do not result in radionuclide releases to the accessible environment in the time period [0, 10^4 yr], results for the groundwater protection standards are obtained from the early failure scenario classes and the restricted seismic GM scenario class.

Models describing evolution of the repository system are the same as those used for the nominal, early failure and seismic GM scenario classes ([14], Section 6; [25]). Epistemic uncertainty in analysis inputs is propagated using the same Latin hypercube sample (LHS) from the probability space describing epistemic uncertainty as used in the analyses for the individual protection standard ([5], Section 11 and App. B). Consequently, results presented here for groundwater protection standards are comparable with results for the individual protection standard presented

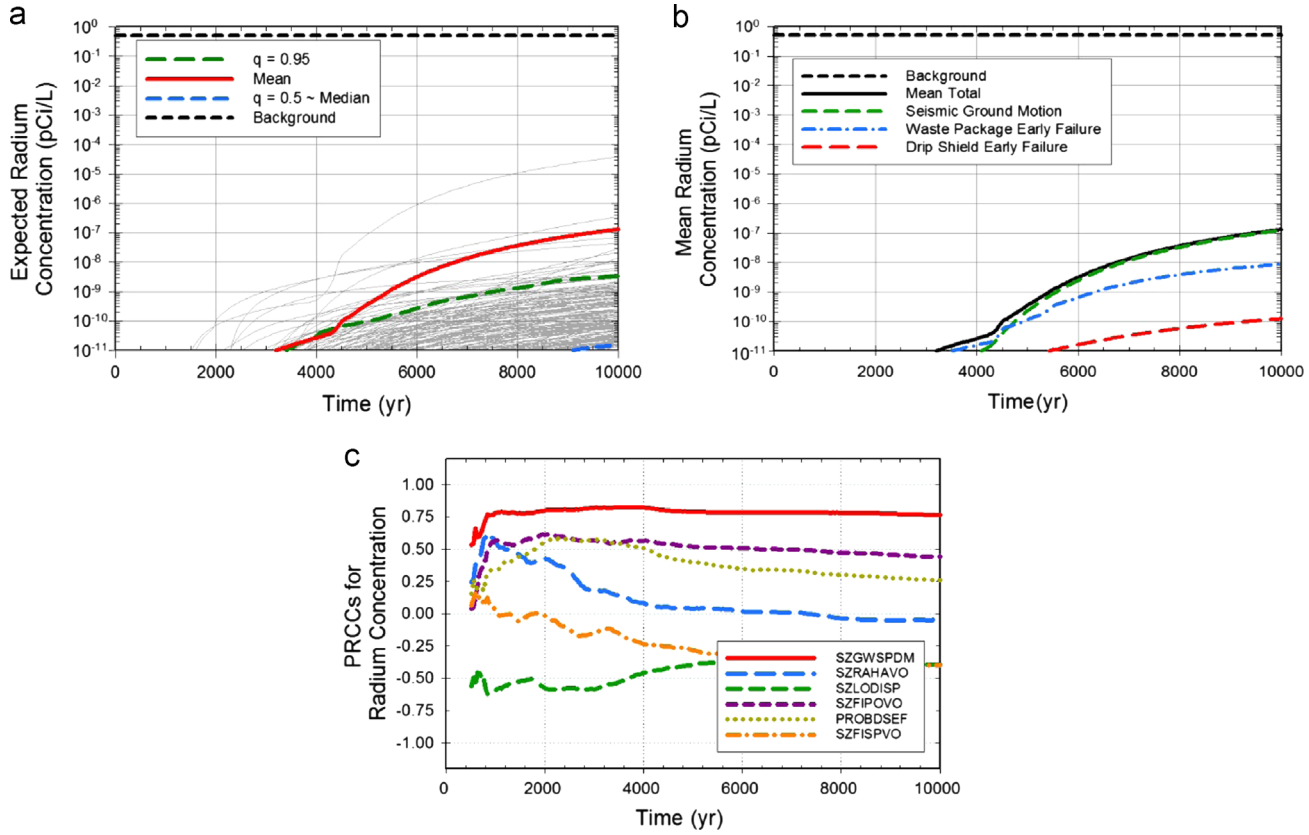

Fig. 1. Time-dependent expected activity concentrations for radium at the location of the RMEI obtained with an LHS of size *nLHS*=300: (a) epistemic uncertainty in expected activity concentration for radium, (b) contributions of individual scenario classes to expected (mean) activity concentration, and (c) PRCCs for expected activity concentrations ([14], Figs. 8.1-9[a] and 8.1-10[a]).