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Addressing Public Confidence in the Case for Yucca Mountain Safety

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Abstract

The Department of Energy's 2008 Yucca Mountain Total System Performance Assessment[1] is a product that mathematically considers and integrates many disciplines and points of information. It describes the likely evolution of a complex system: complex in terms of processes and events that are both likely and unlikely that act on the repository, and complex in terms of the varying spatial and temporal scales involved. Analyses of uncertainties show that there is a range of possible outcomes that come out of the performance calculations, with regulatory compliance focusing on the mean, or average, and median, or midpoint, of the estimates. To properly understand this result takes familiarity with mathematics, statistics, and a variety of scientific disciplines, from materials science through a host of geosciences, to climatology and biology. The question the public may well ask is, given this complexity and uncertainty, why should I have confidence that this calculation provides the basis for concluding that the proposed Yucca Mountain repository is safe? To assist interested persons, the Department of Energy has prepared a qualitative discussion of the case made for the long-term safety of Yucca Mountain, a broader, more understandable "safety case" for the public.

I. Introduction

The operational ("preclosure") phase of the repository's life will be observable, and as appropriate, DOE will employ standard nuclear industry tools and practices that have proven safety records and for which there are published work and management oversight procedures. The tool for evaluating safety and optimizing the operational phase to preclude accident scenarios, and mitigate consequences should one occur, is the standard Probabilistic Safety Analysis tool that is in use around the country and around the world. This tool itself is complex and is difficult to describe in detail to the public and other stakeholders. However, the fact that this preclosure safety evaluation tool has been in use for a long time and has credibility with the scientific community and the regulator should help make the case for operational safety more credible and acceptable to the public.

Similarly for the postclosure period, the tool being used to perform the forward projections of system performance after the system has been closed and sealed is called (in the Yucca Mountain Project) the Total System Performance Assessment or TSPA. The TSPA is a product that integrates many disciplines and points of information mathematically. It is a complex analysis describing the likely evolution of a complex system: complex in terms of processes and events that are likely or unlikely to act on it, and complex in terms of the time and spatial scales involved. Analyses of uncertainties show that there is a range of possible outcomes that come out of the postclosure performance calculations, with regulatory compliance focusing on the mean, or average, and median, or midpoint, of the estimates.[2] To properly understand either the preclosure or the postclosure modeling requires a working knowledge of mathematics and statistics. In addition, the postclosure analyses represent work from a variety of scientific disciplines ranging from materials science through a host of geosciences, to climatology and biology.

In view of this system complexity and mathematical as well as conceptual uncertainty, the question the public may well ask is "why should I have confidence that this calculation provides the basis for concluding that the proposed Yucca Mountain repository is safe?" These are legitimate and reasonable questions.

The Department of Energy's case for Yucca Mountain safety has thousands of very technical documents supporting the Safety Analysis Report.[3] which is itself a document written by specialists for specialists. To address this problem of communicating such a large amount of information in a succinct and

understandable way, the Department of Energy has posted a document on its web site that explains, in lay terms, what the repository is and how it works, how safe the Department feels it to be, and why the Department feels there is a sufficient basis for confidence to request a Construction Authorization from the Nuclear Regulatory Commission at this time. It is a publicly accessible and understandable "safety case."[4]

II. What is a safety case?

In generic terms, the Safety Analysis Report constitutes a comprehensive safety case[5]. The NRC's regulatory requirements for Yucca Mountain do not call for a safety case as defined in the international publications on the subject.

However, the advisory geologic disposal standards jointly sponsored by the International Atomic Energy Agency and the Organisation for Economic Cooperation and Development Nuclear Energy Agency[6] describe a content that is covered under what is required for the Safety Analysis Report. In that IAEA-published document, the safety case is described in terms that can be abstracted in this manner (from Section 3.40[6]):

> . . . The safety case substantiates the safety, and contributes to confidence in the safety, of the geological disposal facility. The safety case is an essential input to all the important decisions concerning the facility. It includes the output of safety assessments . . . , together with additional information, including supporting evidence and reasoning on the robustness and reliability of the facility, its design, the design logic, and the quality of safety assessments and underlying assumptions. The safety case may also include more general arguments relating to the need for the disposal of radioactive waste, and information to put the results of the safety assessments into perspective. Any unresolved issues at any step in the development, operation and closure of the facility will be acknowledged in the safety case and guidance for work to resolve these issues will be provided.

The license application has been submitted to the U.S. Nuclear Regulatory Commission, together with the Final Environmental Impact Statement (DOE, 2002)[7] and a Supplementary Environmental Impact Statement (DOE, 2008).[8] Taken together, these documents address each of the above points in terms of recommended safety case content.

These documents are very lengthy, detailed and technical. They are not readily understood by the public, although all these documents have been made available to the public.

As far back as 2002, the NRC recognized the likely need for DOE to present a publicly available simplified case for repository safety. The NRC sponsored contractor work to explore some of the difficulties inherent both in creating a very complex safety case that is traceable and transparent, and satisfying audiences with different levels of technical knowledge.[9]

Beginning in 2002, the DOE has suggested[10] (NWTRB transcript for 2002 Full Board meeting) that at the time of submitting the license application, DOE would prepare an easy to understand, publicly accessible and understandable explanation of why the DOE felt it had done sufficient scientific work, sufficient design work, and sufficient safety evaluation work to request a Construction Authorization from the Nuclear Regulatory Commission. This suggestion was reaffirmed at an international symposium in 2007.[11] This product is now available on the Office of Civilian Radioactive Waste Management web site at http://www.ocrwm.gov/ .

III. Describing safety for the operational period

The Department of Energy's license application and environmental documentation describe the proposed Yucca Mountain repository design, operational phase performance, and long-term performance. The operations period for the Yucca Mountain repository is proposed to be on the order of 100 years, with several decades of waste receipt, several more decades of packaging and emplacement of waste underground, and then decades of monitoring the system until there is sufficient societal confidence that it can be permanently sealed and closed. Even then there will remain a federal presence to safeguard the site. The types of facilities that are analyzed in the Preclosure Safety Analysis (PCSA) are schematically illustrated in Figure 1.

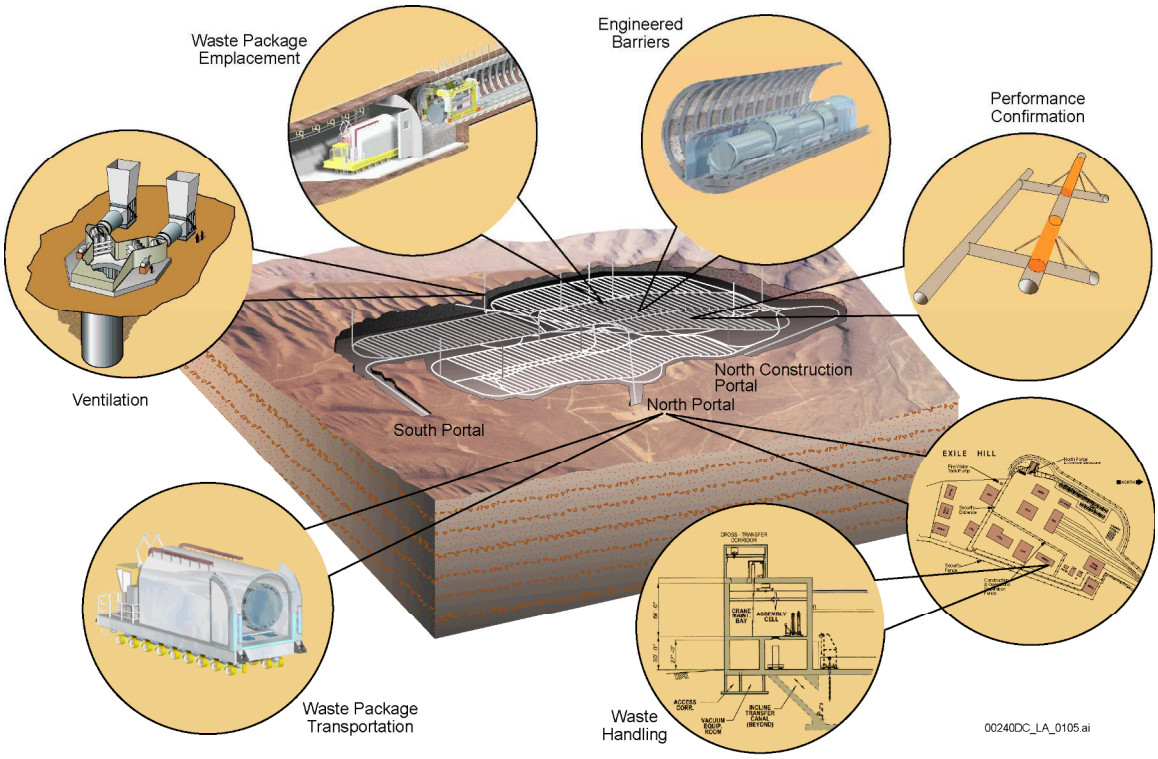

Figure 1. Artist's rendition of the surface and subsurface facilities addressed in the preclosure safety analysis

A U.S. repository is a national undertaking mandated by federal law. In the future, society is to make the decision to close the repository. Under current planning, it is anticipated that decision will be made in approximately a hundred years, but DOE has also considered that the time period could be extended up to 300 years from the start of operations, a period of time exceeding the entire history of the U.S. as a nation.

Alternatives to permanent closure may be possible, and wastes can be retrieved prior to permanent closure if needed. Whether society decides to close the repository at 100 years or 300 years, the challenge remains to monitor performance throughout the operational period. It is anticipated DOE will study the facility as it is being excavated to ascertain if new information confirms or calls into question the basis for the system model. Once waste is placed underground there will be monitoring to ascertain if the evolution of a loaded drift, for a relatively short time, follows the predicted path in terms of temperature and humidity. Ground support will prevent rockfall prior to closure, but inspections will be remotely made to assure that there is no rock debris to interfere with the installation of metal "drip shields" prior to final closure. If rockfall occurs, remote controlled equipment will be used to ensure its removal prior to drip-shield installation. If new information is developed in the future, prior to permanent closure, the repository content can be retrieved and a different disposal decision can be considered. A retrieval capability is mandated by regulation.

Preclosure operations are expected to be safe, well within the allowable doses defined in the regulations. This is demonstrated by the DOE's Safety Analysis Report as well as in the simplified description document posted on DOE's web site.

IV. Describing safety after permanent closure of the repository

Figure 2 illustrates the main features and processes evaluated in the postclosure Total System Performance Assessment.

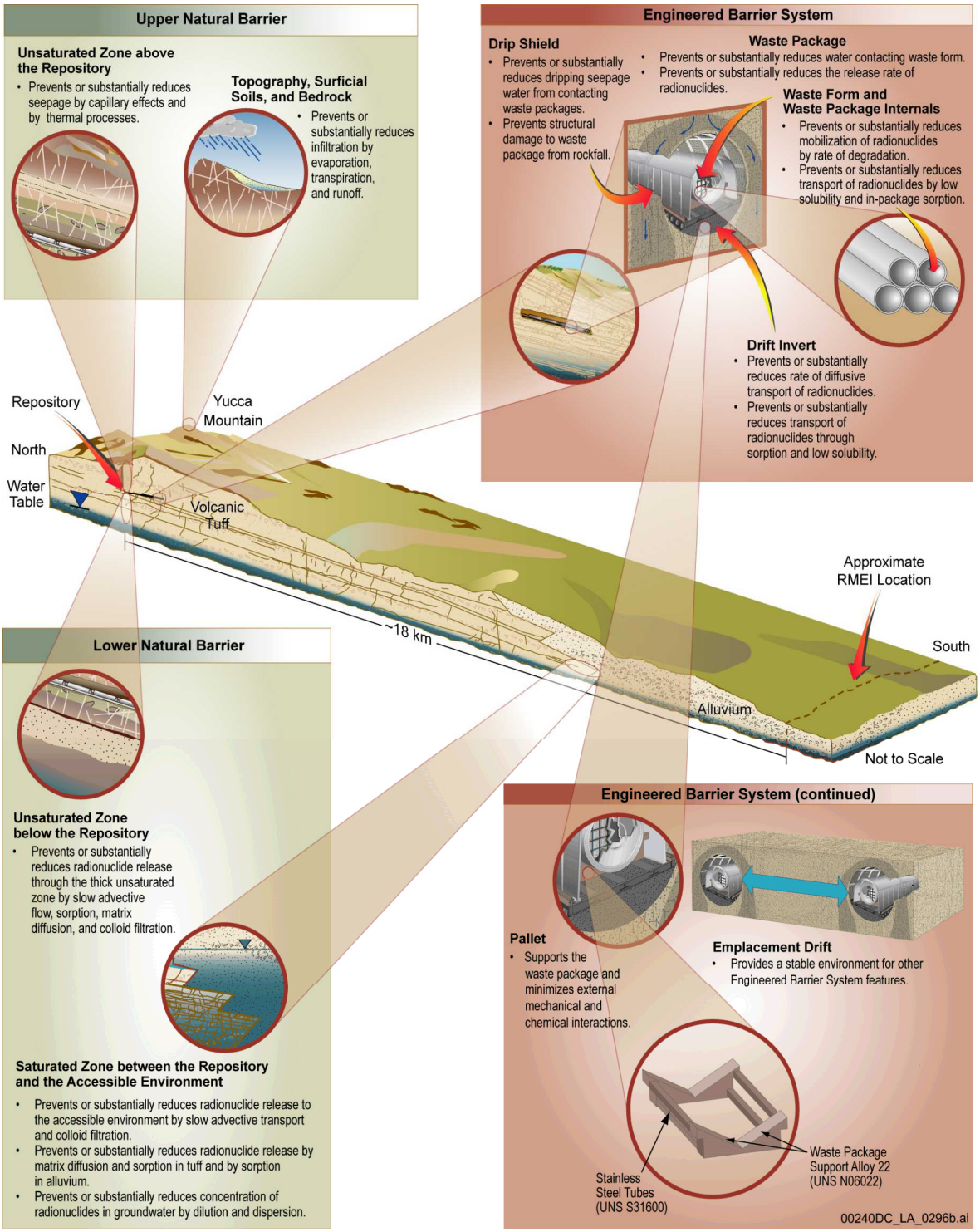

Figure 2, Features evaluated in the postclosure Total System Performance Assessment

Figure 2 only illustrates features and their functions and mentions some of the important related processes. In addition to these features and processes, however, just as there were events anticipated by the operational design and planned against in terms of both prevention and mitigation, there were also postclosure events such as climate changes (will happen and

are included as steps in time), ground motion from earthquakes (will happen, but timing and severity are probabilistically evaluated), and unlikely igneous intrusions and even less likely volcanic eruptions associated with a dike from a hypothetical future volcanic center near Yucca Mountain (probabilistically evaluated). Figure 3 illustrates the possible degradation of the underground repository over a very long time, after many earthquakes have damaged the integrity of the mined openings and engineered barriers.

Figure 3. Artist's interpretation of the changes in the underground structure of the repository modeled in the Total System Performance Assessment: drip-shield failure and rock falls in response to accumulating damage from earthquakes

Figure 4 is an illustration of a hypothetical magma intrusion into and eruption through the repository. All of these potential events are evaluated mathematically in terms of timing and intensity and effects.

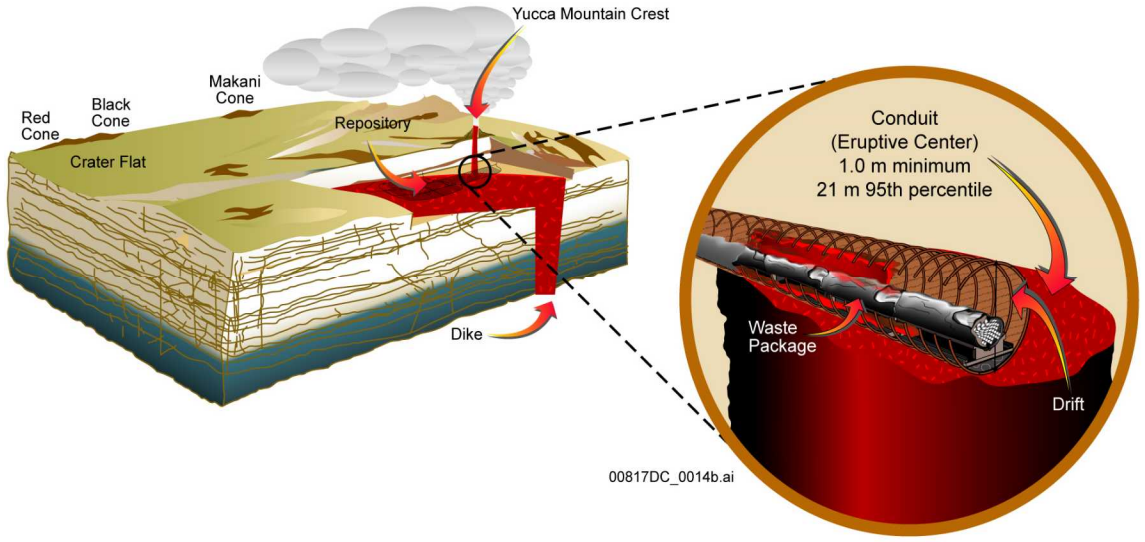

Figure 4. Artist's rendition of the volcanic intrusive and eruptive events: intrusion spreads through the repository, eruption is a localized phenomenon

Figure 5 shows the calculated outcome of these evaluations for the postclosure period of interest, which is a million years.[12] The more likely outcome is expected to be a dose of less than a millirem per year to the conservatively defined individual mandated by the regulation.

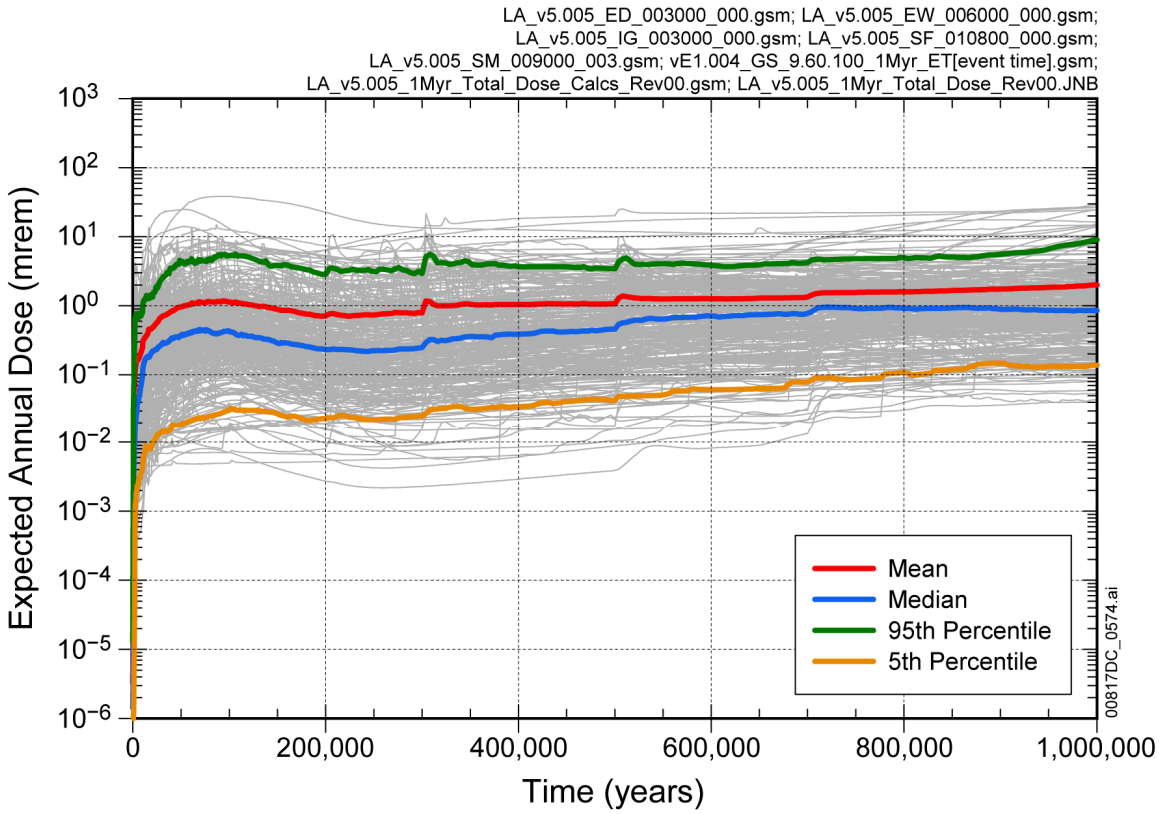

Fig. 5. Total expected annual dose, summed over all scenario classes, for 1,000,000 years (from Ref. 12, Figure 8.1-2[a]).

V. Conclusions

It is a testament to the DOE's confidence in its case for repository safety, operational safety as well as long-term safety after permanent closure, that the license application has been submitted to request a Construction Authorization from the Nuclear Regulatory Commission. The analyses described in the Safety analysis report for preclosure and postclosure safety provide a technical basis for concluding that the Yucca Mountain repository will be safe. DOE has distilled these highly technical analyses into a more readily understandable safety case, currently available on the DOE's web site.

DOE's work is consistent with international guidance such as the 1995 Collective Opinion on the *Environmental and Ethical Basis for Geological Disposal,* to which the DOE contributed. That document states:[13]

> There is today a broad international consensus on the technical merits of the disposal of long-lived radioactive wastes in deep and stable geological formations. Through a system of multiple containment barriers, this strategy would isolate the wastes from the biosphere for extremely long periods of time, ensure that residual radioactive substances reaching the biosphere after many thousands of years would be at concentrations insignificant compared for example with the natural background of radioactivity, and render the risk from inadvertent human intrusion acceptably small. Such a final disposal solution would be essentially passive and permanent, with no requirement for further intervention or institutional controls by humans, although it may be assumed that siting records and routine surveillance would in practice be maintained for many years if society evolves in a stable manner.

The Yucca Mountain repository's expected performance is comparable to several recent performance assessments produced in European

countries.[14] This helps make the case for repository safety with audiences such as the international and national technical communities.

Disclaimer: The statements expressed in this article are those of the authors and do not necessarily reflect the views or policies of the United States Department of Energy or Sandia National Laboratories.

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