Use of One-On Analysis to Evaluate Total System Performance of the Proposed Yucca Mountain Nuclear Waste Repository

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The Yucca Mountain Site Characterization Project is currently evaluating the future performance of the proposed U.S. high-level nuclear waste repository. Using the Total System Performance Assessment (TSPA) model, a stylized analysis was conducted to evaluate the relative importance of natural and engineered barriers to movement of radionuclides from the proposed repository. These stylized “one-on” analyses consist of sequentially adding features, components, and processes, associated with the natural and engineered barriers, incorporated within the TSPA model and evaluating the effect of these elements on repository performance, as measured by the total mean annual dose to a reasonably maximally exposed individual. The analyses are “stylized” in the sense that they are performed to gain insight only. They are not meant to represent a real physical system in most cases, and in some cases allow the TSPA model to simulate results using parameter ranges outside the normal bounds of the TSPA model. In particular, the analyses provide insight into the relative contributions of repository features and processes in a way that is not possible using the full TSPA performance-assessment model. For example, in the nominal scenario of the TSPA model, the contribution of the natural system is masked by the contribution of the engineered system.

For these analyses, “barrier” is defined as “any material, structure, or feature that...prevents or substantially reduces the rate of movement of water or radionuclides from the Yucca Mountain repository to the accessible environment, or prevents the release or substantially reduces the release rate of radionuclides from the waste” (10 CFR Part 63.2). The results of the analyses should not be construed as a quantitative measure of the relative importance of any one barrier or process. Rather, the results provide an indication of the relative contribution of these barriers to the overall performance of the...
integrated repository system. The analyses presented here considered the nominal-
performance scenario only and did not consider unlikely disruptive events such as
volcanic or seismic activity.

The barriers considered for the analysis were grouped into three broad categories: (1) Waste-form Barriers that treat waste as if it were deposited on the land surface with no protection, including processes such as waste-form degradation, radionuclide solubility limits and colloid stability in water, and commercial-spent-nuclear-fuel cladding; (2) Natural-system Barriers that include the unsaturated zone above and below the proposed repository, including capillary-induced reduction of water flow into the repository due to the presence of the emplacement tunnels, and the saturated zone between the repository and the accessible environment; and (3) Engineered-system Barriers that consider the primary engineered systems such as the drip shield, the waste package, and the invert beneath the waste package.

The One-on Analysis begins with the theoretical placement of bare waste on land surface at Yucca Mountain, a condition that would result in the maximum possible dose to the accessible environment. The Waste-form, Natural, and Engineered Barriers were then added sequentially to the TSPA model and the resulting dose to the accessible environment was simulated for each successive barrier. The results of the model simulations show that adding all natural and engineered barriers reduced the peak mean dose by more than 14 orders of magnitude within the first 10,000 years. For the sequence analyzed, the analyses also demonstrate that the Natural Barriers (the unsaturated zone and saturated zone) may contribute about 8 orders of magnitude in dose reduction within the first 10,000 years and that the Engineered barriers (waste package and drip shield) provide a substantial additional reduction in dose—indicating that the Engineered Barrier System in combination with natural barriers, radiological exposures to the reasonably maximally exposed individual are within the limits specified by the U.S. Nuclear Regulatory Commission at 10 CFR 63.311. The analysis also showed that different orders of barrier addition could result in slightly different results.