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EFFECTS OF EXPLORATORY STUDIES FACILITY CONSTRUCTION WATER ON RADIONUCLIDE RELEASE

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I. INTRODUCTION

The Exploratory Studies Facility (ESF) is a planned underground laboratory to conduct subsurface exploration and testing in support of site suitability determination and license application for a potential high-level nuclear waste repository at Yucca Mountain. The ESF design includes a 7.6 m diameter, 7.8 km long tunnel loop consisting of two main access ramps from the surface down to a main drift along the conceptual repository horizon in a fractured, welded tuff called the Topopah Spring member of the Paintbrush Tuff. The ESF main drift is planned to be at least 37 m from the closest waste package emplacement zone. Standard underground excavation methods require the use of water, primarily for dust control. The unsaturated condition of rock comprising the potential repository horizon is an important characteristic that will be affected by the introduction of construction water. An analysis bounding the effects of water lost to the geologic environment on radionuclide release from waste packages has been developed to help identify appropriate controls for ESF construction water use. The approach is to determine the dominant radionuclide release process, estimate natural variability in radionuclide release, and then bound water saturation changes so that changes in radionuclide release stays within natural variations.

II. RADIONUCLIDE RELEASE MECHANISMS; DIFFUSIVE AND ADVECTIVE TRANSPORT

Radionuclide release is affected by the fuel pellet alteration rates, radionuclide solubilities, and transport mechanisms. Water saturation may also influence waste package corrosion, but is not considered here. Of these phenomena, radionuclide transport processes are expected to be most affected by water saturation. Materials that may be in contact with the waste packages are crushed tuff or the existing rock matrix[1]. The effective aqueous solute diffusion coefficient[1], D(S), and effective hydraulic conductivity[2], K(S), are expressed as empirical functions of water saturation, S. The function K(S) requires values for the shape parameter[3] and saturated hydraulic conductivity[4] in rock matrix at the repository horizon. The ratio of the advection and diffusion time scales is given by $\phi SD(S)/LK(S)$, where L represents the length scale for the engineered barrier system (assumed to be $\approx$ 1 m), ϕ denotes the rock matrix porosity[4], and the potential gradient is assumed to be 1. This ratio decreases from about 4 to 1 over a saturation range of 0.65 to 0.9 in the Topopah Spring rock matrix. (Based on a similar analysis, crushed tuff in capillary equilibrium with an unsaturated rock matrix is expected to have an advection/diffusion time scale ratio $> 10^5$). These results suggest that transport is dominated by diffusion.

III. SYSTEM VARIABILITY

Sensitivity studies concerning the variability of integrated radionuclide release[1] versus pH indicates that a conservative estimate for anticipated natural variability is about a factor of 1.8. Variability in release overall should be less than the variability in the diffusion coefficient because at least some of the release is controlled by the matrix alteration and dissolution rates. The relationship between diffusion coefficient and saturation may be used to determine the limiting water saturation increase that leads to an increase in the

diffusion coefficient by a factor of 1.8 above existing conditions at a saturation of 0.65. The limiting water saturation in rock matrix is found to be 0.90.

IV. WATER SATURATION AT THE CLOSEST WASTE PACKAGE

A bounding analysis for water movement to the closest waste package assumes movement in the matrix only, because fracture flow is likely to disperse the water beyond the near-field environment. The added water is assumed to initially saturate the rock matrix below the main drift. The movement of this water is approximated as a one-dimensional, gravity driven saturation perturbation (or pulse) that moves toward a waste package 37 m away. Neglecting the effects of capillary forces in this calculation helps to provide a conservative bound on the likely maximum saturation perturbation at the waste package because capillary forces will disperse the saturation pulse in three dimensions. Incorporating these approximations into Darcy's law for partially saturated flow and combining with a one-dimensional material balance expression for water results in a nonlinear, first-order hyperbolic equation describing the evolution of water saturation. The solution is obtained using a method-of-characteristics technique[5]. Although capillary driving forces are neglected, nonlinear advection disperses the one-dimensional saturation pulse along the direction of motion.

Using this bounding model, the peak water saturation at the closest waste package may be computed as a function of the water input. Figure 1 shows that the peak water saturation remains below 0.9 if the construction water input is less than 7.4 m^3/m of ESF tunnel, which is equivalent in the model to an initially saturated zone 7.6 m wide and 23 m into the rock along the ESF tunnel.

The propagation of a saturation pulse initially 23 m long is illustrated on a characteristics diagram shown in Figure 2. The maximum saturation in the spatial profile occurs at the shock wave leading the pulse, and is shown to dissipate and slow due to interaction with the centered expansion waves emanating from the trailing edge of the pulse. The asymptotic profile for the initially square pulse is a triangular wave.

V. SUMMARY

The use of water during excavation of the ESF is expected to have negligible effects on radionuclide release from waste packages, provided the volume of water lost to the geologic environment is limited to 7.4 m^3/m of linear excavation.

NOMENCLATURE

D(S)	aqueous solute diffusion coefficient
K(S)	effective hydraulic conductivity
L	length scale of engineered barrier system
S	water saturation
ϕ	rock matrix porosity

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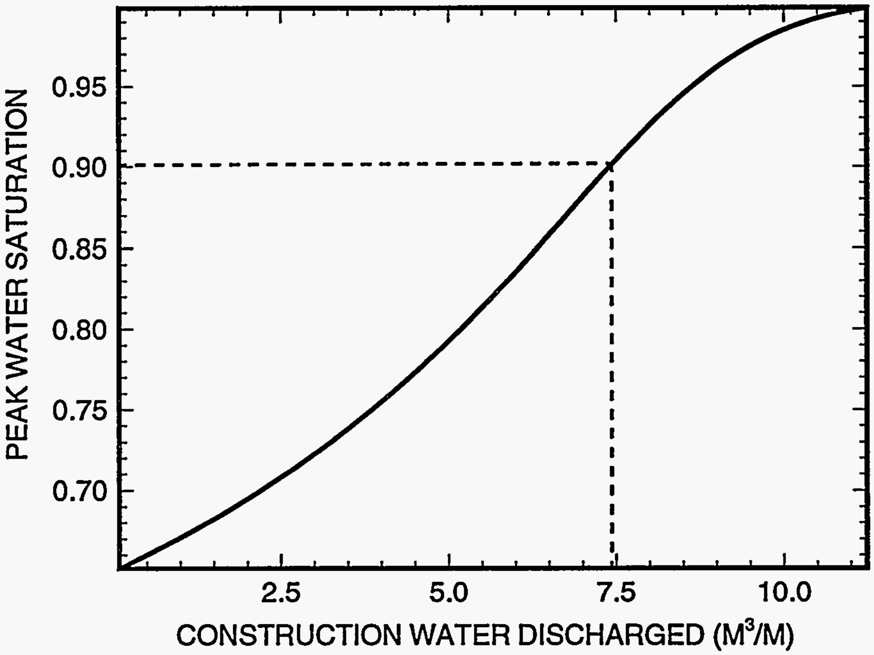

Figure 1: Peak Water Saturation at Nearest Waste Package

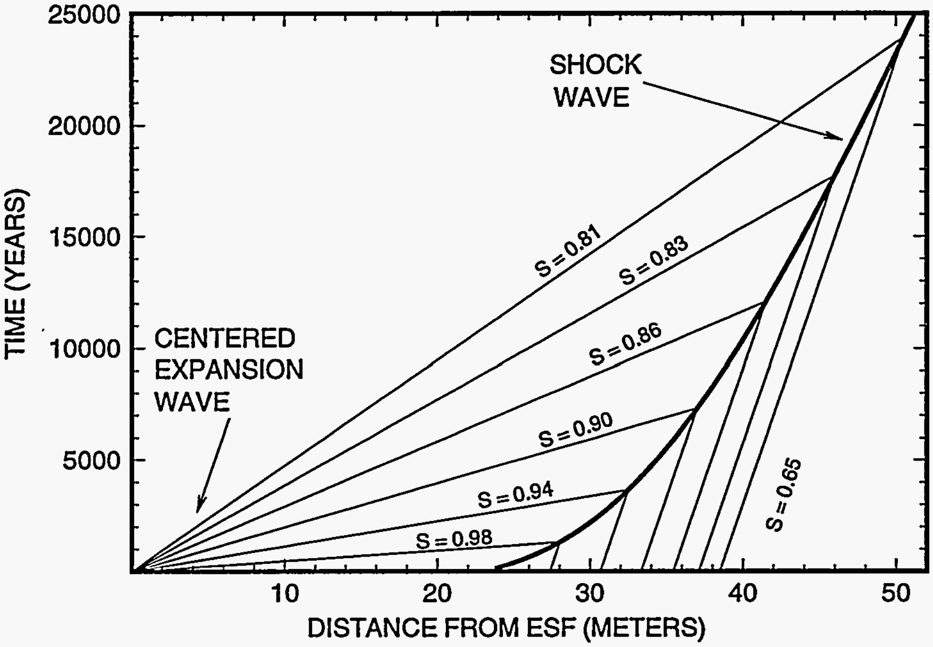

Figure 2: Propagation of Saturation Pulse