Drift-Scale Testing and Observation of Fracture Flows in Unsaturated Tuff

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To quantify the liquid seepage into drifts at Yucca Mountain, flow tests are being conducted at two sites in the fractured Topopah Spring welded tuff unit along the main drift of the underground Exploratory Studies Facility. The first test site is in a relatively brecciated zone between the Sundance Fault and a cooling joint with high ^{36}Cl readings, which are indicators of potential presence of fast flow paths. The second test site is in a relatively competent rock mass with low fracture density and free of fast path indicators. The test sequence at each site includes cross-hole pneumatic testing in a borehole cluster, liquid release of dyed water in selected borehole intervals, excavation of a niche (up to 10 m deep) of unsaturated tuff to observe dyed water distribution, sealing of the niche from main drift ventilation, and additional liquid release tests above the niche to quantify diversion of liquid flow by the mined opening.

This paper focuses on the flows observed during the niche excavations. Finite amounts (less than one liter) of dyed water were released with essentially no pressure buildups in borehole intervals (1 foot long, 3 inch in diameter). The volumes of water released are correlated well with the air permeability values of the injection intervals. From the dye distributions observed during excavation, the dyes were transported over a few meters within ten days and the extents of front advance are approximately proportional to the liquid volumes. The dyes are distributed along a few distinct fractures, with fracture infills along the main fracture and small side branches partially stained. On fracture surfaces, dyes are distributed non-uniformly in patchy patterns. Limited extents of dye imbibition into the tuff matrix were observed.

Both borehole drilling and niche excavation were conducted dry to eliminate the impacts of construction water. Dry excavation also allows easy visual identification of water distribution. In a zone over 10 feet away from the liquid release tests, a long damped feature from the crown to the invert was observed on the end wall of the first niche after dry excavation. The feature dried up within hours due to ventilation which effectively removed moisture in the tunnel air. The observation of this damped feature strongly suggests that localized flow paths exist within deep unsaturated zone. Localized flow paths could effectively transport percolation and young water over long distances. Both the liquid tests with controlled releases and direct observation of localized flow paths lead to better understanding of the flow field in the unsaturated fractured tuff at Yucca Mountain.