# HETEROGENEOUS SEEPAGE AT THE NOPAL I URANIUM MINE, CHIHUAHUA, MEXICO

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## RESEARCH OBJECTIVES

The primary objective of this analogue study is to evaluate flow and transport processes of relevance to the proposed Yucca Mountain repository. Seepage data obtained from this study will be used to constrain flow and transport models being developed for the Nopal I system.

## APPROACH

A water collection system, consisting of 240 separate 30 cm × 30 cm compartments that are each connected to a 125 mL bottle, was installed in April 2005 within the +00 m adit of the Nopal I mine, to collect water that had infiltrated from the +10 m level and seeped into the adit. This system was upgraded in November 2005, when instrumentation was added to six collector sites to measure seepage rates continuously. An automated weather station was installed at the site in March 2006 to permit correlation of local precipitation events with seepage.

## ACCOMPLISHMENTS

Rainfall in central Chihuahua is seasonal, with most precipitation occurring during the summer monsoon period. Initial modeling of infiltration and seepage through a series of planar, vertical fractures was conducted to evaluate flow transit times and seepage rates (Ghezzehei et al., 2006). Using a range of fracture apertures and frequencies, and assuming no fracture-matrix interaction, infiltration through the 8 m high vertical fracture system and seepage into the adit was predicted to occur within 24 hours after a 6-hour rainfall event.

Monitoring of seepage within the adit between April 2005 and December 2006 indicated that seepage is highly heterogeneous in both time and space. Within the back adit area, there were a few zones where large volumes of water have been collected. These large volume seepage events (Figure 1) were linked to fast flow path fractures (<4 h transit times) and are associated with heavy rainfall (>25 mm). In most locations, however, there was a significant (1–6 month) time lag between major precipitation events and seepage within the adit, with longer water residence times observed for the front adit area.

## SIGNIFICANCE OF FINDINGS

The wide variability in the location, timing, and amount of seepage occurring within the Nopal I adit suggests that a number of fast-flow fracture pathways are active immediately after large rainfall events. Flow focusing along these pathways may explain the heterogeneous seepage distribution. However, delayed seepage observed in many locations within the adit indicate that even a relatively thin (8 m) rock mass can exert a noticeable damping effect on infiltration, and that flow and transport models must incorporate fracture flow heterogeneity. Processes such as evaporation and flow diversion resulting from flow focusing or capillary barrier effects may be responsible for the low seepage volumes relative to the total precipitation for most seepage locations. The capillary barrier effect may be dominant in the back adit region (where there are three walls adjacent to the seepage collectors), as this region experienced the lowest amount of seepage. The initial results of this work are consistent with the fast-flow-path model postulated for Yucca Mountain.

## RELATED PUBLICATIONS

Ghezzehei, T.A., P.F. Dobson, J.A. Rodriguez, and P.J. Cook, Infiltration and seepage through fractured welded tuff. 2006 International High Level Radioactive Waste Management Conference, April 30–May 4, 2006, Las Vegas, NV, American Nuclear Society, La Grange Park, IL, pp. 105–110, 2006.

## ACKNOWLEDGMENTS

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Figure 1. Cumulative rainfall and seepage amounts for instrumented collectors from Nopal I +00 m adit.