Lessons Learned from High-Resolution Site Characterization of Many Dual-Porosity Fractured Rock Sites

Seth Pitkin (spitkin@cascade-env.com) (Cascade Technical Services, Montpelier, VT, USA)

Background/Objectives. DNAPL contamination in fractured rock is widely regarding as one of the most complex and difficult types of subsurface contamination problems to address effectively. These problems are even more complex when they comprise dual porosity systems with transport in the fractures and contaminant mass storage in the matrix. Unfortunately many investigations of these sites include use of long open boreholes for sampling and monitoring which leads to the spreading of contamination and obfuscation of actual site conditions. Further, the focus of these investigations is often on a few of the most transmissive fractures in the borehole. This leads, in turn to erroneous conceptual site models and often to ill-advised remedial approaches. Over the past decade we have had the opportunity to work on the characterization of many of these sites with a variety of rock types and conditions from sandstones in California to Schists in New Hampshire, karstic limestone in New York, gneiss in South Carolina, rhyolite in Massachusetts, andesite in the Virgin Islands, mudstones in New Jersey to shale in the United Kingdom. Performing high resolution matrix sampling and analysis in conjunction with other high resolution approaches has yielded substantial insight as to the behavior of these types of sites.

Approach/Activities. Investigations which incorporate high resolution methods such as rock matrix sampling and analysis, FLUTe Activated Carbon Technology (FACT), borehole geophysics, fracture water concentration profiling and hydrophysics and liners to prevent open hole cross contamination provide the data necessary to build robust CSMs and reduce the uncertainty associated with site management decisions, remedy selection and design. A few holes on a site are cored and the rock is sampled in a high resolution manner. Rock samples are extracted using microwave assisted extraction and analyzed either with a GC/micro ECD approach or a GC/MS. The lab can either be present on site for use in dynamic investigations, or remote for more static investigations. Once the hole is drilled it should be immediately sealed with a flexible liner or a FACT. The FACT is left in place for 2 weeks then removed, sampled and analyzed. This provides a high resolution screening view of contaminant distribution associated with fractures. This work is followed by borehole geophysics and transmissivity and hydraulic head profiling. Ultimately these data are used to design a multilevel monitoring system which feeds into development and revision of the CSM and in some cases discrete fracture network numerical modelling.

Results/Lessons Learned. These types of investigations have revealed that on older dual porosity sites (e.g., where the release was several decades ago) most of the DNAPL may be depleted and the contaminant mass is present mainly in solute and sorbed form in the rock matrix (primary porosity). In most cases the location of the contaminant mass is not proximal to the few very transmissive fractures, but is often located at smaller lower flow zones, The data from these investigations also reveals that there are many active fractures rather than just a few as borehole flow metering might suggest, These factors combine to result in plumes that are significantly retarded in terms of transport distance and are often typified by a high degree of transverse dispersion. The presence of large amounts of contaminant mass located in the rock matrix adjacent to low and moderately permeable fractures has significant implications for remedy selection and design.