Treatment of TCE to 30 Meters in Fractured Granite: How to Address a Site When You Cannot Drill and Sample the Rock?

Steffen Griepke Nielsen (griepke@terratherm.com), Gorm Heron, Amber Bonarrigo, Anthony Caravella (TerraTherm, Gardner, MA, USA)
Erik Pearson and Carol Serlin (Ramboll Environ, Irvine, CA, USA)

Background/Objectives. Deep fractured rock sites with DNAPL contamination were considered almost impossible to treat, just a few years ago. A TCE DNAPL spill at a site in southern California had created a source zone to a depth of 30 meters, with the bottom half of the site consisting of fractured, hard granite bedrock. The site presented several challenges:

- The exact source zone and treatment volume was still to be refined.
- TCE was present in fractures deep below the water table.
- The fracture network was not well understood – but vapor recovery was essential.
- A novel method for determining remedial completeness was needed, due to the difficulty of collection of rock samples in the middle of the well-field during operations.

These challenges were addressed with an innovative, staged implementation of thermal conduction heating.

Approach/Activities. An adaptive, staged implementation was developed. As the drilling commenced, TCE concentrations were evaluated in near real time to make adjustments to the design. The TCE source zone changed dramatically as a result of the collected data, from a rectangular shape to a more compact, larger square area. Every borehole was completed as either operational or monitoring wells/borings, saving substantial resources and cost. For the thermal design every heater boring was equipped with a co-located soil vapor extraction well, allowing for the steam vapors generated in situ to flow out, ensuring pneumatic control. The concentration of TCE in these vapor streams from individual wells were then used to gauge remedial completeness. After the mass removal had peaked, and asymptotic levels were reached, three successive rounds of sampling of these extracted vapors were done to document the low TCE levels remaining.

Results/Lessons Learned. The flexible implementation proved essential for this site – the target zone looked very different once the work was completed, which shows how valuable it is to collect data as you install a system. TCH then proceeded to remove the TCE source material, with relatively uniform heating achieved to the full treatment depth of 30 meters. Perimeter monitoring showed no signs of TCE or steam spreading, due to the vacuum applied to every heater boing. Extracting from every available fracture meant good pneumatic control. The heating was ended, with DTSC review and approval, using an innovative, holistic view of the available data, in the absence of confirmatory rock samples, which could not be collected during heating due to the size of the drill rig needed to reach 30 meters in the competent granite. The site reached target temperatures throughout. Then heating was continued until the mass removal rate dropped to very low levels (asymptotic removal rates). The final evidence of progress towards completeness came from analyzing the TCE content in the vapors extracted from each well. By showing a reduction in TCE concentrations on the order of 10,000-fold from samples taken before treatment, three weeks in a row, the data from the extraction wells was used to achieve approval to cease heating. The result was achieved via excellent communication with the DTSC, where the alignment of expectations early on in the project proved very valuable.