A Rigorous Demonstration of Permeability Enhancement Technology for In Situ Remediation of Low Permeability Media

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Abstract

At sites with low hydraulic conductivity of approximately 1 to 10-4 cm/s, in situ techniques are slowed and sometimes need to be abandoned. This has raised interest in permeability enhancement (PE) technologies as a viable option for addressing such sites.

The three most prevalent methods include hydraulic permeability improvement (HPI), hydraulic permeability enhancement (HPE), and permeability enhancement (PE) technologies. HPE is a technique implemented using pressurized injection of a fluid, generally water, into the formation to create an emulsion to improve the permeability of the formation. The technique has been demonstrated at three Department of Defense (DoD) sites and has been implemented at the Marine Corps Base Camp Pendleton (MCB-CP) to improve the delivered distribution of treatment amendments in low permeability carbonate formations.

This demonstration has been used to establish the effectiveness of the method of injection, as well as to quantify emplaced fracture networks. An analysis of the state-of-the-art injection technology has been utilized to assess the injection characteristics and fracture networks created. The injection characteristics were assessed using tiltmeter, electrical resistivity tomography (ERT), and gamma-ray logging data. In addition, a geophysical monitoring technique was utilized to detect and monitor distribution of injected treatment amendments.

Technology Application

This demonstration has provided a rigorous comparison of the costs of using PE technologies such as hydraulic fracturing and pressurized pneumatic approaches for enhancing permeability (PAH) and treatment effectiveness. The study will evaluate the performance of different injection strategies and geometries using standard hydraulic injection techniques.

The demonstration project succeeded in providing the data necessary to complete a robust analysis of using permeability enhancement in a variety of media. HPE was successfully implemented at all three DoD sites and achieved—in some cases exceeded—the desired distribution goals, greatly enhancing amendment delivery and distribution.

The entire target volume of solutes was injected into the subsurface, with minimal surfacing despite the shallow depth. The estimated ROI reached 22.5 to 25 feet, with visual evidence of treatment distribution observed in monitoring wells and confirmation boreholes. Previous injection has not generated any evidence of direct amendment delivery at monitoring wells. BTEX data were processed for confirmation of ROI and 3D imaging. The results were generally in qualitative agreement with the amendment distribution measurement by other techniques. CE results generally did not show a strong correlation with analytical verification of the emplaced amendments seen at nearby confirmation boreholes. Based on the limited EC data obtained at GFAFB, EC did not appear to be an effective geophysical monitoring tool at the level of permeability and treatment effectiveness targeted at sites and beyond.

Future efforts should focus on refining injection strategies and geometries to enhance the effectiveness of permeability enhancement, as well as developing new technologies to improve the efficacy of in situ remediation efforts.