

Fracture-Emplacement and 3D Mapping of a Micro-Iron/Carbon Amendment in TCE-Impacted Sedimentary Bedrock

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An *in situ* pilot remediation project was carried out on behalf of the US Army Corps of Engineers (Omaha District) at the F.E. Warren Air Force Base (AFB) Former Atlas “E” Missile Site No. 12 (Atlas 12) in Colorado, that featured an innovative application of drilling, treatment, fracture-emplacement, and geophysical technologies to mitigate impacts from chlorinated volatile organic hydrocarbons.

The former missile site complex is located outside of Windsor, Colorado, and is underlain by silty sandstone bedrock sediments impacted by trichloroethene (TCE) exceeding 3,000 micrograms per liter ($\mu\text{g/L}$) and associated volatile organic hydrocarbons. The origin of the chlorinated aliphatic hydrocarbons was from operational disposals of TCE during 1960-1965. The purpose of the Pilot Test was to evaluate the performance of technologies prior to developing the proposed remedy. Two pilot test areas (source area and dissolved plume area) were selected to evaluate the effectiveness of biotic and abiotic *in situ* chemical reduction (ISCR) for reducing trichloroethene concentrations to less than maximum contaminant levels (MCLs).

The pilot work involved the emplacement of over 100 tons of a micro-iron/complex carbon treatment amendment (EHC-G®) into deep bedrock sediments to attain optimal distribution throughout the contaminant plume, including underneath the former Launch and Service Building. The coarse iron used in EHC-G is suited to provide the effect of enhancing permeability in the same way that the addition of sand would prop fractures. Due to the limited fracture volume in the source area, the use of EHC-G will maximize the amendment volume that can be applied without compromising the in-situ chemical reduction effects. A total of 206,000 lb. of EHC-G amendment was emplaced at 9 locations within the pilot test area. Hydraulic fracturing was conducted in pre-drilled boreholes to deliver the amendment slurry at 5 ft. increments between depths of 35 ft. to 63 ft. in bedrock. Between 6,000 lb and 32,000 lb of micro-iron/carbon amendment was emplaced at each borehole by mixing it as a biodegradable, linear protein gel slurry to carry the amendment in a uniform suspension. Upwards to 6,400 lb. of the treatment amendment was delivered in each fracture in this manner. Tiltmeter geophysics was used to verify the final distribution and geometric configuration of the micro-iron fractures placed. Field observations and tilt response showed that the radius of fracture-emplacement in the bedrock was upwards to 60 ft., with a typical fracture overlap of 30 to 50%.