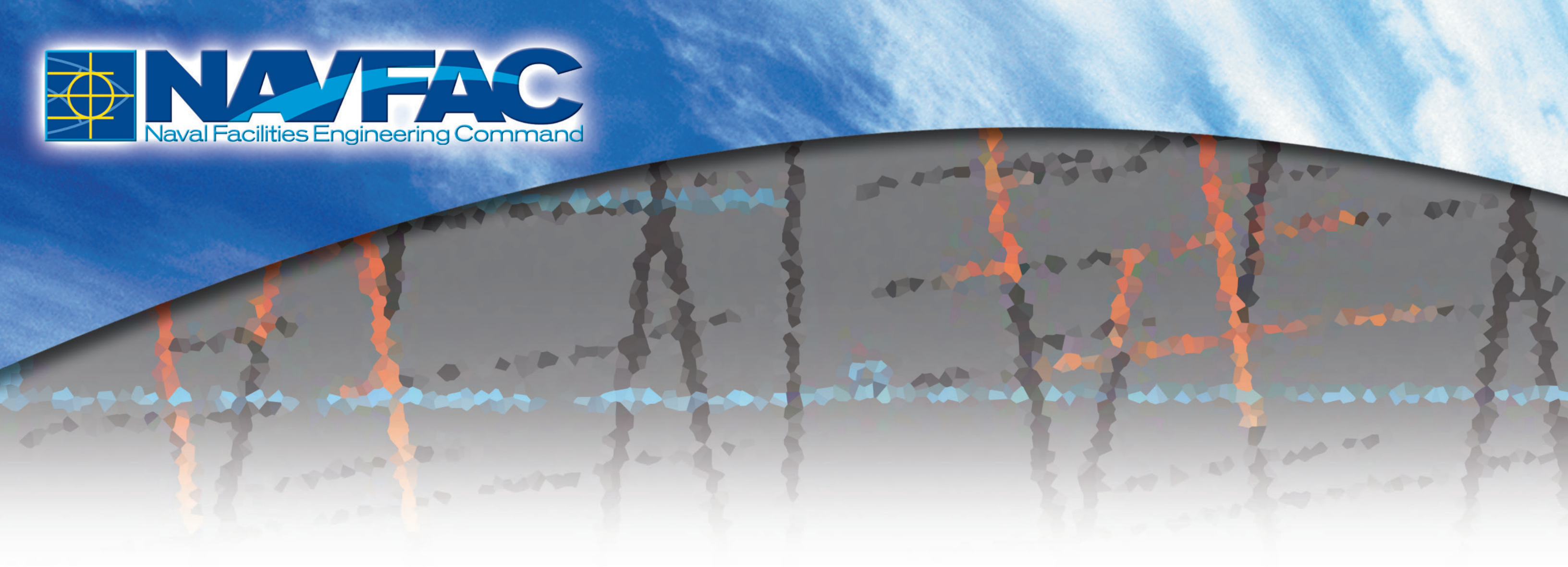

ENVIRONMENTAL RESTORATION

# Site Characterization and Remediation in Fractured Rock

## Introduction

Site characterization and remediation in fractured rock affords a unique set of challenges not typically associated with unconsolidated soil, due to increased complexities associated with fate and transport characteristics. Traditional site characterization and remediation technologies are often ineffective, and challenges associated with meeting cleanup goals often result in fractured rock sites being considered too difficult or costly to remediate. Recently, significant research has been performed to enhance the understanding of fractured rock environments. This fact sheet provides a summary of advances in developing successful characterization and remedial strategies for addressing contamination in fractured rock. The following topics are presented:

- Types of fractured rock environments
- Characterization methods for fractured rock sites
- Remediation approaches in fractured rock
- Considerations and lessons learned from fractured rock sites

Finally, several case studies of site characterization and remediation in fractured rock will be presented, including Naval Support Activity (NSA) Mechanicsburg and Naval Air Warfare Center (NAWC) Trenton. Further details about site characterization and remediation in fractured rock can be found in the resources listed at the end of this fact sheet.

### Summary of Fact Sheet Contents

## Overview of Fractured Rock Environments

A thorough review of the conceptual site model (CSM) is an essential first step for evaluating subsurface contamination in fractured bedrock. Information to consider when formulating and evaluating the CSM include the geologic terrane and geomorphology, fluid migration characteristics, and contaminant fate and transport.

**Geologic Terrane and Geomorphology.** Understanding the geologic terrane (rock types and formations) and geomorphology provides an initial foundation for the fractured rock investigation. Important characteristics to consider include regional and local physical setting, erosional features, lithology, structural characteristics, anisotropy, heterogeneity, and hydrology. This information can be used to develop an initial understanding of the boundary conditions, hydraulic gradient, and groundwater flow directions within the study area.

**Fluid Migration.** The CSM is further supplemented with information relative to fluid migration (groundwater and gases) in fractured rock. Fractured rock characteristics that influence fluid migration include depositional features (bedding planes, channel deposits, etc.), rock matrix type and fracture orientation, aperture, infilling, density, and connectivity. Fluid migration is influenced by pressure and density gradients, and the scale of the investigation (e.g., macroscopic versus microscopic) should be taken into consideration during the evaluation.

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**Contaminant Fate and Transport.** A common challenge associated with fractured rock sites is understanding the direction and rate of subsurface contaminant transport. Contaminant fate and transport within fractured rock is dependent on interactions between the physical and chemical properties of the contaminants and the rock matrix and the hydrologic nature of the fracture flow. Mechanisms that influence contaminant fate and transport include fracture flow processes (e.g., advection and dispersion/diffusion), diffusion into the rock matrix, sorption/desorption, and biogeochemical and abiotic transformations.

## Site Characterization Methods

Site characterization can be performed to address any data gaps identified in the CSM and enhance the overall understanding of the fractured rock system. Numerous characterization tools and methods are available for use; selection should focus on ensuring data quality objectives (DQOs) are achieved so the collected data can be effectively used to support remedial decisions. Surface geophysics can be applied to evaluate the site-specific and local geologic terrane and depositional environment.  Boreholes can be installed using a variety of methods, and numerous geophysical testing and aquifer and hydraulic profiling techniques can be implemented to better understand local conditions. Combining numerous site characterization tools will allow for a more thorough evaluation of site conditions. A summary of available fractured rock site characterization tools is presented to the right.

## Remedial Approaches

Numerous unconsolidated remedial technologies are applicable to fractured rock environments. However, fractured rock environments create a unique set of challenges to ensuring successful technology application. These challenges are primarily associated with ensuring the proposed remedial approach is applied to the impacted portion of the rock matrix to allow for effective treatment. The selection, design, and implementation of remedial technologies in fractured rock requires careful consideration of all aspects of the CSM, with a focus on rock type, flow conditions, and contaminant characteristics. A summary of remedial approaches that have shown success in fractured rock environments is included below. Often, several technologies, including natural attenuation, are combined to provide a more successful and efficient remedial strategy.

## Considerations and Lessons Learned

Fractured rock sites are different from unconsolidated overburden sites in numerous ways that affect the evaluation of characterization methods and remedial alternatives. Several considerations are summarized below.

- Groundwater flow and contaminant transport in fractured rock are inherently different than in unconsolidated materials. Fluid flow in fractured rock is characterized by either dual-porosity systems or secondary porosity systems. Anisotropy, heterogeneity (over several orders of magnitude), and matrix diffusion are often dominant characteristics of fractured rock systems. Accordingly, groundwater flow in fractured rock is generally subject to more uncertainty than in unconsolidated aquifers, which affects remedy design and performance monitoring.

- Location, orientation, heterogeneity, and scale of contamination is likely to be greatly influenced by the fracture network (i.e., secondary porosity), which may result in a larger plume size.

- Detailed site characterization is essential to identifying key fractures or fracture sets controlling contaminant flux. Care should be taken to identify and monitor water-bearing fracture zones. Multiple lines of evidence (e.g., geophysical testing, hydraulic testing, and discrete depth groundwater sampling) should be used to develop a comprehensive understanding of the groundwater flow system.

- Remedial investigations and remedial actions in fractured rock are typically costlier than in unconsolidated material due to several factors, such as drilling and well installation methods, and the multitude of investigation techniques often required to reduce the level of uncertainty. Fractured rock remedial actions also typically require a longer period of time to meet remedial goals due to contaminant mass release and/or diffusion from existing porosity and matrix storage domains. Technical impracticability (TI) waivers may be appropriate depending on the presence of NAPL and the depth and extent of contamination.

EPA's CLU-IN website (https://clu-in.org/products/fracrock/viewsites.cfm) features a searchable database that includes a large number of fractured rock characterization and remediation case studies, including associated challenges and lessons learned.

## Site Characterization for Fractured Rock

| Characterization Tool | Description |
|---|---|
| **Surface Geophysics** | |
| **Ground penetrating radar (GPR)** | Subsurface images (two- and three-dimensional [2D and 3D]) based on the reflection of an electromagnetic (EM) pulse from boundaries between layers of different dielectric properties. Can be used to identify stratigraphic layers and contacts; depth generally limited to 60 ft below ground surface (bgs). |
| **High-resolution seismic reflection** | Creates 2D or 3D subsurface images based on the reflection of a seismic pulse between the layers of contrasting mechanical properties. Capable of profiling multiple stratigraphic layers to depths >100 ft. |
| **Seismic refraction** | Subsurface imaging based on estimating travel of seismic energy to boundaries between layers of differing seismic velocity. |
| **Electrical resistivity tomography (ERT)** | Creates 2D or 3D subsurface images based on ground-based variations in electrical resistivity. |
| **Very low frequency (VLF)** | Creates 2D or 3D subsurface images using the magnetic components of the EM field generated by long-distance radio transmitters in the VLF band. |
| **Electromagnetic conductivity (EC)** | Maps variations in EC using a local primary field with a frequency- or time-based system. |
| **Borehole Installation/Evaluation** | |
| **Rock coring** | Extract continuous competent rock cores (2-5 ft sections) for ex-situ logging/screening. |
| **Rock core analysis** | Collect rock core samples for analysis of contaminants of concern and physical parameters. |
| **FLUTe™** | Hydrophobic liner used to evaluate presence of non-aqueous phase liquid (NAPL) in the formation; in-situ or ex-situ application. |
| **Heat-pulse flowmeter (HPFM)** | Evaluates direction and magnitude of borehole water movement; used to identify water producing and/or receiving zones |
| **Video logging** | Visual inspection of open boreholes to identify lithology and fracture locations. |
| **Borehole Geophysics** | |
| **Caliper log** | Provides continuous record of borehole diameter; used to identify fractures and lithology. |
| **Natural gamma log** | Measures natural gamma radiation; used to correlate geologic units between wells. |
| **Fluid-resistivity log** | Measures the electrical resistivity of the water column; used to identify water producing/receiving zones. |
| **Fluid-temperature log** | Provides continuous record of temperature variation in a well; used to identify water producing/receiving zones. |
| **Single-point resistivity log** | Measures electrical resistance of the formation; used to correlate geology between wells and identify water-producing zones. |
| **Acoustic televiewer log** | Sonic imaging tool that uses an acoustic beam to evaluate fracture location and orientation. |
| **Hydraulic Testing** | |
| **Packer testing** | Use of straddle packers to isolate a discrete depth for hydraulic testing (e.g., slug tests, pumping tests). |
| **FLUTe™ profiling** | Obtains a continuous transmissivity profile in the open borehole. |
| **Slug tests and pumping/ recovery tests** | Induce changes in hydraulic head to characterize aspects of a fractured rock system, such as hydraulic conductivity, fracture connectivity, and hydrogeologic properties of water-bearing zones. |
| **Tracer test** | Tracer added to a well and observation well(s) monitored for breakthrough; performed under ambient or pumping conditions; designed to evaluate fracture connectivity. |
| **Hydraulic tomography** | Multi-well hydrologic testing method that uses systematic short-term varied pumping configurations and pressure head monitoring to evaluate fracture flow characteristics. |
| **Groundwater Monitoring** | |
| **Packer testing** | Use of straddle packers to isolate a discrete depth for groundwater sampling; generally focused on water-bearing fractures. |
| **FACT FLUTe™** | Screening tool designed to evaluate distribution of dissolved contaminants in an open borehole via diffusion to a hydrophobic liner. |

## Remedial Approaches for Fractured Rock

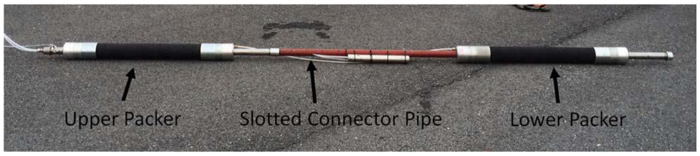
| Remedial Approach | Description |
|---|---|
| **Physical Removal** | Excavation of contaminated fractured rock may be possible if it is accessible at a relatively shallow depth below ground surface. This remedial approach is typically limited to weathered rock found at the overburden/rock interface and to softer rock types (e.g., sandstone). |
| **Groundwater Pump and Treat** | Hydraulic control is a common remedial approach in fractured bedrock, but design and implementation are more challenging than in unconsolidated systems due to heterogeneity. Special considerations include: multiple discrete or interconnected fracture zones may necessitate multiple pumping zones within an aquifer/well, dead-end fracture zones may limit the volume of extracted water, and communication between rock fractures and overlying overburden/weathered rock may result in intermigration between zones. |
| **Permeable Reactive Barriers (PRBs)** | PRBs are implemented in fractured rock by injecting a reactive material (e.g., zero valent iron [ZVI] or solid potassium permanganate) into fracture zones; however, achieving a continuous reactive wall across all interconnected water-bearing fractures can be challenging. Low-solubility reactive materials can persist for an extended period (i.e., years), which allows for the treatment of contaminants diffusing from less-transmissive primary porosity or matrix storage zones. However, chemical or biological changes due to the injections can alter the ambient fracture flow system and potentially reduce treatment efficacy. |
| **In-Situ Thermal Technologies (ISTTs)** | ISTTs rely on heating the subsurface to enhance the removal or destruction of organic contaminants by one of the following means: electrical resistance heating (ERH), thermal conductive heating (TCH), or steam enhanced extraction (SEE). A significant advantage of ISTTs is that direct contact with the contaminant is not necessary, which minimizes the challenges associated with bedrock remediation. For ERH, essentially all heat generated is in the fractures, making ERH applicable in bedrock with high primary porosity. TCH uses direct conduction to heat the rock matrix itself, and is therefore applicable to rocks with low primary or secondary porosity. Heat and vacuum can be applied to achieve elevated temperatures (100 to 325˚C), depending on heater spacing and groundwater influx. SEE uses steam injections into the formation to mobilize and vaporize contaminants. SEE is limited in maximum temperature depending on ambient pressure and is generally limited to sites with high secondary porosities and larger fractures. |
| **In-Situ Chemical Oxidation (ISCO)** | ISCO involves the injection of chemical oxidants (e.g., Fenton's reagent, sodium and potassium permanganate, sodium persulfate) into rock fractures where the oxidants destroy contamination (e.g., chlorinated solvents and petroleum hydrocarbons). Similar to PRBs, dispersing the oxidant into all contaminated fractures is challenging and can impact the remedy's effectiveness. Because oxidants remain active for a relatively short time, it is difficult to distribute oxidants to both primary porosity and matrix storage zones; thus back-diffusion can be an issue, requiring multiple oxidant applications. |
| **In-Situ Chemical Reduction (ISCR)** | ISCR involves injecting a reducing agent into rock fractures to remediate contaminants (e.g., chlorinated solvents, metals, and anions). Often, the reducing agent is ZVI in a water or oil emulsion slurry. While ZVI does not disperse after injection and does not diffuse into the primary porosity or matrix storage domains, ZVI is relatively long-lived, which increases the ability of treating the back-diffusion of contaminants. Other reducing agents (e.g., calcium polysulfide and sodium dithionite) are available although they are commonly less effective due to limited reactivity lifetimes and inability to diffuse into matrix storage. The challenges and limitations outlined for ISCO earlier in this section also apply to ISCR. |
| **In-Situ Bioremediation (ISB)** | A wide variety of amendments have been successfully introduced to enhance ISB at fractured rock sites. The amendments offer a wide range of longevity, physical composition, and mode of injection, and can therefore be applied under a variety of site-specific fractured rock conditions. ISB application requires a comprehensive understanding of the CSM and shares many of the limitations associated with implementation of ISCR, ISCO, and PRBs; consideration should be given to the anticipated lifetime of ISB substrates relative to the objective of the remedial effort. |
| **In-Situ Biogeochemical Transformation (ISBGT)** | ISBGT is the abiotic transformation of contaminants in groundwater by reduced iron minerals, which can be present naturally or formed by microbial activity. Similar to ISCO and ISCR, implementation involves injection of amendments (typically sulfate, reduced iron, and an electron donor) into rock fractures to generate iron sulfide and stimulate ISGBT, which will abiotically transform contaminants such as chlorinated solvents directly to acetylene and other non-volatile products. |
| **Monitored Natural Attenuation (MNA)** | Natural attenuation mechanisms do not differ significantly between unconsolidated and consolidated environments. MNA may be considered for use alone or after more active treatment at fractured rock sites. |

## Case Study 1 – NSA Mechanicsburg

**Introduction.** Site 3 at NSA Mechanicsburg consists of two former burn pits where historical activities resulted in numerous volatile organic compounds (VOCs; including trichloroethene [TCE], cis-1,2-dichloroethene [DCE], vinyl chloride [VC], and chlorobenzene) being discharged to the subsurface. A thin (<10 ft) veneer of clayey soils overlies fractured carbonate bedrock comprised of dolomite and limestone, with groundwater present in upper and lower aquifer zones within the fractured rock. Despite several remedial efforts designed to reduce contaminant levels, including excavation of unconsolidated soil and two rounds of ISCO injections using hydrogen peroxide and a chelated iron catalyst, VOCs in groundwater persisted at concentrations above regulatory levels. An additional remedial effort, consisting of HRSC in the source areas followed by targeted ISBGT amendment injections, was designed to further reduce VOC concentrations in the source areas.

**Source Area Rock Core (Courtesy of Battelle)**

**Site Characterization.** HRSC activities in the Burn Pit source areas consisted of borehole installation, rock core collection, sampling, analysis, borehole profiling, and discrete depth groundwater sampling. These activities were designed to determine the location of fractures and better understand the geology, groundwater flow, and distribution of chemical concentrations. One borehole was completed in each source area bedrock to a depth of 250 ft bgs as an open hole completion. Continuous 5-ft cores were collected and logged by a licensed geologist, screened with a photoionization detector, and wrapped with FLUTe™ liners to evaluate the presence of NAPL. Rock core samples were collected from discrete depths coinciding with evidence of NAPL staining, lithologic contacts, and/or fractures, and submitted for VOC analysis using microwave-assisted extraction, gas chromatographic (MAE GC) methods. Rock core samples also were analyzed for magnetic susceptibility, x-ray diffraction (XRD), scanning electron microscopy-energy dispersive spectroscopy (SEM-EDS), and optical imaging.



**Straddle Packer System Used for Groundwater Sampling (Courtesy of Battelle)**

Geophysical imaging was performed in each open hole boring using the following methods: video profiling, caliper logging, natural gamma logging, fluid and temperature resistivity logging, and acoustic televiewer logging. In addition, a heat-pulse flowmeter (HPFM) was used to identify the presence, magnitude, and direction of fracture flow.  Results from the geophysical imaging, coupled with the borehole logging and rock core analysis, were used to identify depths of water-bearing fractures and potential VOC contamination for subsequent discrete depth sampling, which was performed using a straddle packer system. Discrete-depth groundwater samples were collected from up to seven depths per borehole and analyzed for water quality parameters, geochemical parameters, VOCs, and dissolved metals. Microbial analysis and compound-specific isotope analysis (CSIA) also was performed on the samples. In addition, discrete depth groundwater samples were collected from adjacent existing monitoring wells with long open intervals. Groundwater sample analysis results were used to identify treatment depths and to design the ISBGT amendment formulation.

**Video Image of Borehole Showing Fracture (Courtesy of Battelle)**

**Remediation.** ISBGT was implemented in the former burn pits to promote biogeochemical transformation of VOCs in groundwater.  Liquid amendments were injected at up to three discrete treatment depths in each borehole with the straddle packer system, using results of the borehole HRSC and discrete depth groundwater sampling to identify injection depths focused on the presence of water-bearing fractures and high VOC concentrations. The amendment formulation was designed to produce sulfate-reducing conditions and consisted of a sodium lactate and ferrous sulfate solution dissolved in water. A push-pull approach followed by a recirculation approach was used to distribute amendments in the formation. This involved injecting amendments at discrete high concentration zones in select wells and groundwater was extracted from adjacent monitoring wells. Groundwater monitoring was performed monthly to evaluate remedy effectiveness. The resultant data suggest that both abiotic and biological degradation has been promoted at Burn Pit #1 and Burn Pit #2; however, contaminant rebound occurred in some boreholes once the sodium lactate had been depleted. A second set of amendment injections was performed at one location in Burn Pit #1 and at four locations in Burn Pit #2 based on select monitoring criteria, including total organic carbon, sulfate, and VOC concentrations, to further promote the efficacy of the remedy. Monthly monitoring is currently being conducted to assess performance of the amendment injection.

## Case Study 2 – NAWC Trenton

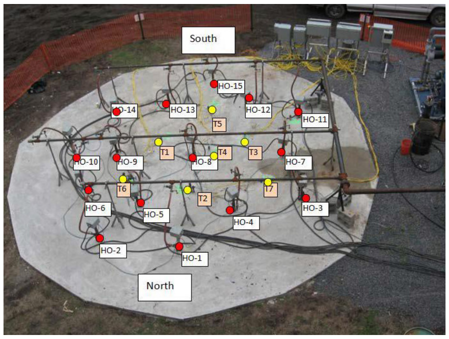
**Introduction.** At the former NAWC Trenton, historical operations resulted in an estimated 100,000 gallons of TCE being discharged to the subsurface through leakage and spills.  Dense, non-aqueous phase liquid (DNAPL) has been identified at the site and a large dissolved plume (TCE and daughter products cis-1,2-DCE and VC) is present at concentrations several orders of magnitude above regulatory levels. The subsurface consists of interbedded siltstones and mudstones that are heavily weathered at shallow depths (0-5 ft bgs), with weathering generally decreasing with depth. A groundwater pump-and-treat system has been in place since the mid-1990s to contain the dissolved plume and prevent downgradient migration. The site has been extensively characterized using numerous HRSC techniques, including downhole geophysical logging, hydraulic testing (including packer testing), discrete depth groundwater profiling, surface seismic surveys, and tracer tests. HRSC revealed that shallow TCE at depth has not biodegraded, with TCE mass having dissolved, diffused, and adsorbed to the solid rock matrix. In cooperation with the Navy and the United States Geological Survey (USGS), the NAWC Trenton site is designated as a fractured rock research site, and numerous pilot-scale innovative remedial approaches have been applied for evaluating treatment of the TCE in fractured rock, including bioaugmentation and thermal conductive heating (TCH).

**Bioaugmentation.** A pilot study was implemented at the NAWC Trenton site in 2005 to evaluate whether bioaugmentation would be successful at reducing concentrations of TCE and associated daughter products.

**NAWC Trenton Bioaugmentation Pilot Study (Courtesy of USGS)**

The spatial extent of the study area was 9,000 ft$^2$ and extended to a depth of 115 ft bgs. Four wells were used as injection and extraction points for KB-1, a culture containing dechlorinating microorganisms, an electron donor (emulsified edible oil and lactate substrate), and a tracer (deuterated water). The injections were designed to target identified water-bearing fracture zones. Following injection, groundwater monitoring was performed for six years from multi-level monitoring points to evaluate concentrations of VOCs, substrates, tracers, microbial communities, and stable carbon isotopes. Monitoring results indicated that enhanced biodegradation was achieved at distances away from the injection well along fracture flow paths that received the amendments, and that the bioaugmentation stimulated removal of contaminants rom within the unfractured rock matrix. The results highlighted the challenges associated with removing contamination beyond the area surrounding the injection site and from the rock matrix.

**TCH.** Under an Environmental Security Technology Certification Program (ESTCP) research study, a TCH pilot study was implemented at the NAWC Trenton site to evaluate the application of thermal heating in fractured bedrock (Lebron et al., 2013). Prior to implementation, detailed numerical modeling was performed to evaluate the influence of inflowing groundwater on the ability to heat and maintain elevated temperatures in fractured rock.



**NAWC Trenton TCH Pilot Study Layout (Courtesy of USGS)**

The modeling concluded that TCH was feasible, but that understanding influx rates and fracture apertures and spacing is critical in evaluating the applicability of TCH at a fractured rock site. Bench-scale testing also was performed to evaluate optimum temperature and application duration for TCH in various rock types at the site. The TCH field demonstration consisted of 15 heater borings ranging from 5 to 55 ft bgs (740 yd$^3$ treatment volume) equipped with a vapor extraction screen. Electricity was applied to the borings at a rate of 210 kilowatt (kW) to reach a target temperature of 100°C. The system was operated continuously for 106 days, with a heating period of 97 days, and a total electricity usage of 493,000 kilowatt hours. A detailed monitoring program was implemented, consisting of groundwater, rock, condensate, and vapor sampling and analysis, process flow, pressure, and temperature monitoring, as well as ambient air monitoring. During the heating period, depths of 0 and 35 feet bgs reached temperatures between 99 and 110°C, although deeper zones of 40 to 50 feet bgs did not reach the 100°C target, achieving temperatures between 70 and 80°C. From the pilot area, over 500 lbs of total VOCs were removed by vapor extraction, with an estimated additional 30 lbs removed from the extracted water and condensed steam. Total VOC rock concentrations after heating ranged from below 5 mg/kg to 275 mg/kg, with average TCE concentrations reduced by 41 to 69%. The higher results were likely associated with distinct fracture zones that had an influx of cold groundwater during the treatment. Overall contaminant mass reduction was calculated to range between 69 and 84%. Anticipated groundwater extraction rates between 0.1 to 0.2 gallons per minute (gpm) were exceeded by actual rates of 2 to 3 gpm, which initiated native groundwater flow from outside the pilot area through the bedrock fractures and likely limited subsurface heating and VOC removal. The total cost of the TCH field demonstration was roughly $1M, which correlates to a cost of $1,350 per yd$^3$.

## Resources

### Web Sites

U.S. EPA CLU-IN Fractured Bedrock Project Profiles
https://clu-in.org/products/fracrock/viewsites.cfm

U.S. EPA CLU-IN Fractured Rock Website
https://clu-in.org/contaminantfocus/default.focus/sec/Fractured_Rock/cat/Overview/

USGS Office of Geophysics
https://water.usgs.gov/ogw/bgas/
ITRC Characterization and Remediation in Fractured Rock
http://www.itrcweb.org/Team/Public?teamID=69

ESTCP Fractured Rock Characterization Studies
https://www.serdp-estcp.org/Program-Areas/Environmental-Restoration/ER-201567-T2/ER-201567-T2

https://www.serdp-estcp.org/Program-Areas/Environmental-Restoration/Contaminated-Groundwater/Persistent-Contamination/ER-201118/ER-201118

USGS NAWC Trenton Bioaugmentation Study
https://toxics.usgs.gov/investigations/fractured_rock/index.php

### Presentations

NAVFAC OER2 Webinar on HRSC at NSA Mechanicsburg
https://navfac.navy.mil/navfac_worldwide/specialty_centers/exwc/products_and_services/ev/erb/oer2.html

Chlorinated Solvent Source and Plume Behavior in Fractured Sedimentary Rock from Field Studies
https://clu-in.org/products/siteprof/2007fracrock/028Parker,B.pdf

### Documents

NRC. 2015. *Characterization, Modeling, Monitoring, and Remediation of Fractured Rock.* National Academies Press, Washington, D.C. 244 p.

Golder Associates, Ltd. 2010. Fractured Bedrock Field Methods and Analytical Tools, Volumes I and II. Submitted to Canada Ministry of Environment by the Science Advisory Board for Contaminated Sites in British Columbus. April.

Lebron, C.A., Phelan, D. Heron, G., LaChance, J., Nielsen, S., Kueper, B., Rodriguez, D., Wemp, A., Baston, D., Lacombe, P., and F.H. Chapelle. 2013. Dense Non-Aqueous Phase Liquid (DNAPL) Removal from Fractured Rock Using Thermal Conductive Heating. CR-NAVFAC ESC-EV-1202. January. Available at: https://www.serdp-estcp.org/Program-Areas/Environmental-Restoration/Contaminated-Groundwater/Persistent-Contamination/ER-200715/ER-200715

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