Selected FRx Fracturing Experience

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The following is a partial list of projects performed in the past few years. Since inception in 1994, FRx has completed over 200 projects.

Iron Project	Large Project	Federal Project	Deep Project	Client, Location, Date & Contact	Project Description and Assessment	Publication
●	●			✳ CH2M Hill Canada ✳ Sarnia, Ontario ✳ August 2010 ✳ Ms. Leanne Austrins Kitchener, Ontario	Creation of 99 hydraulic fractures filled with 212000 lb of granular zero valent iron in combination with vegetable oil substrate solutions to promote biodegradation of solvents. Also created fractures with 14 fractures with 2500 gal of emulsified zero valent iron.	Manuscript drafted
		●		✳ URS Group, LBNL, AFCEE ✳ FE Warren AFB ✳ June 2010 ✳ Ms. Belinda Butler Veytia, Denver	Creation of two sand-filled hydraulic fractures and collection of performance data as part of a demonstration and validation of methods to assess in situ distribution of remediation materials injected by diverse methods.	Manuscript prepared
	●	●		✳ SAIC ✳ p-Area, SRS ✳ April 2010 ✳ Mr. Steve Conner Oak Ridge	Twenty five hydraulic fractures were created with 42,000 lb of sand from fourteen PVC casings that had been installed previously. The large diameter PVC casing permitted subsequent construction of 4-inch diameter wells that are being used in SVE and oxidant delivery.	Report under review

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●		●		✳ Acuity Environmental Solutions ✳ Ft Benj. Harrison ✳ August 2010 ✳ Mr. Steven Irvin Fischers, IN	This project demonstrated the creation of iron filled fractures, some using jet-fracturing techniques, to support treatment design for a plume emanating from the facility landfill.	Report under review
		●	●	✳ Eichleberger, TetraTek, & US EPA ✳ Hazleton, PA ✳ October 2090 ✳ Mr. Bruce Rundell, US EPA, Philadelphia	Hydraulic fracturing equipment was used to mix and deliver a slurry of potassium permanganate suspended in water. Target formations were weathered and fractured bedrock systems. This was the first application of granular potassium permanganate in bedrock.	Rundell, B., B. Khona, B. White, N. Teamerson, and B Dynkin (2010.) "Enhanced Potassium Permanganate Slurry Injection in Fractured Bedrock Utilizing Hydraulic Fracturing." 7th International Conf. On Remediation of Chlorinated and Recalcitrant Compounds, Session D089., Monterey, CA.
		●	●	✳ ERM West ✳ Cheyenne, WY ✳ May 2009 ✳ Mr. Anthony Griego Phoenix	Various remediation materials were used to create hydraulic fractures in soil contaminated with chlorinated solvents. One object of the project was to compare reductive versus oxidative feasibility, so some fractures were created with EHC and others with persulfate.	
	●			✳ Toxicological and Environmental Associates ✳ Sarnia, ON ✳ July 2008 ✳ Mr. Russ Copeland Baton Rouge	Sand-filled hydraulic fractures were created to promote groundwater flow and root growth of willow trees that were planted as part of this phyto-remediation project.	Copeland, R., Campbell, W., Slack, W. W., E. G. Gatliff, C. Creber (2009.) "Enabling Phytoremediation of Chlorinated Solvents in Tight Soils by Use of Hydraulic Fracturing" 10th International Symposium on In Situ and On-Site Bioremediation, Baltimore, MD.

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●	●			✳ CH2M Hill Canada ✳ Sarnia, ON ✳ November 2008 ✳ Mr. Chris Peace Kitchener, Ontario	Creation of hydraulic fractures filled with granular zero valent iron in combination with organic substrate solutions to promote biodegradation of solvents. Also created fractures with emulsified zero valent iron. Some of the fractures were dyed with rhodamine to permit better identification in subsequent cores and exploratory trenches.	Austrins, L. M. and C. Peace (2010) "Integrated Approach to the Remediation of Chlorinated Organic Compounds in Low Permeability Soils – A Field Study." The Remediation Technologies Symposium (RemTec), October 22, 2010. Banff Springs, Alberta. Peace, C. and L. M. Austrins (2010) "Evaluation of the Propagation of Secondary Fractures from Hydraulic Fracture and Injection to Create a Treatment Zone in Low Permeability Fractured Clay Soils."The Remediation Technologies Symposium (RemTec), October 22, 2010. Banff Springs, Alberta.
●		●		✳ Burns & McDonnell Engineering ✳ Katy, KS ✳ November 2007 ✳ Mr. John Hesemann St Louis	Jet fracturing techniques were used to deliver reductive agents into non-cohesive soils that otherwise would not support conventional hydraulic fracturing	Confidential, private site.
		●		✳ Washington Savannah River Co ✳ M-Area, SRS ✳ August 2008 ✳ Mr. Brian Riha Savannah River Site	Sand-filled hydraulic fractures were created to support SVE actions.	Riha, B. D., K. L. Dixon, et al. 2005. Evaluation of Enhanced VOC Removal with Soil Fracturing in the SRS Upland Unit. Savannah River National Laboratory. Aiken, SC. WSRC-TR-2005-00415

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	●	●	●	✳ URS Group ✳ FE Warren AFB ✳ December 2006 ✳ Ms. Belinda Butler Veytia, Denver	Creation of 734 fractures using __ lb of sand and __ lb of HRC for subsequent bioremediation by injected cultures.	Butler-Veytia, B., N. Cochran, B. Powers, S. Hrabovsky, and J. Wright. (2008) "Full-Scale Implementation: Bioremediation Using Hydraulic Fracturing for HRC® Emplacement and KB-1TM Injection." 6th International Conf. On Remediation of Chlorinated and Recalcitrant Compounds, Session E027., Monterey, CA. Butler-Veytia, B., N. Cochran, B. Powers, S. Hrabovsky, and J. Wright. (2008) "Pilot Test Update: Bioremediation Using Hydraulic Fracturing for HRC® Emplacement and KB-1™ Injection." 6th International Conf. On Remediation of Chlorinated and Recalcitrant Compounds, Session E041., Monterey, CA.
	●	●	●	✳ URS Group ✳ FE Warren AFB ✳ August 2006 ✳ Ms. Belinda Butler Veytia, Denver	Creation of __ fractures with __ lb of solid potassium permanganate granules for the purpose of establishing passive in situ ISCO conditions.	Butler-Veytia, B., R. Coringrato, B. Powers, S. Hrabovsky, and J. Wright. (2008) "Full-Scale Implementation: ISCO Using Hydraulic Fracturing for Potassium Permanganate Emplacement." 6th International Conf. On Remediation of Chlorinated and Recalcitrant Compounds, Session E031., Monterey, CA.
●				✳ ARM Group / GeoCleanse Intrnl. ✳ Richmond, VA ✳ June 2005 ✳ Dr. Dan Bryant GeoCleanse, NJ	Twenty iron-filled fractures were created with 30,000 lb of iron across a 2 acre site at depths between 15 and 27 feet. The distributed iron established sufficient reducing conditions to drive remediation to closure.	Duchene, M., B. Slack and D. Bryant (2006) "Placement of Zero-Valent Iron by Hydraulic Fracturing." Fifth International Conference on Remediation of Chlorinated and Recalcitrant Compounds, Monterey, California. pages C-20.Battelle Press, Columbus, OH

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●				✳ Burns & McDonnell Engineering ✳ Dallas, TX ✳ July 2005 ✳ Mr. John Hesemann St Louis	Six iron-filled fractures were created to intercept drainage before discharging into the Trinity River. The combined treatment schemes at the facility have won closure of the site.	Duchene, M., B. Slack and D. Bryant (2006) "Placement of Zero-Valent Iron by Hydraulic Fracturing." Fifth International Conference on Remediation of Chlorinated and Recalcitrant Compounds, Monterey, California. pages C-20.Battelle Press, Columbus, OH Moline, J., C. Mathenia, and M. Dingens. (2009) “Cleaning Up Groundwater in Place.” Pollution Engineering. P24. November 2009.
●	●			✳ US EPA, Lasagna Program ✳ Rickenbacker ANGB, Columbus, OH ✳ July - December 1996 ✳ Dr. Wendy Davis-Hoover, EPA, Cincinnati	Iron filled hydraulic fractures were created as treatment units within the groundwater mobilization fields that were induced by electro-kinetics in this research and development project. This may have been the first use of iron as a hydraulic fracturing proppant.	Davis-Hoover, W. J., M. C. Kemper, P. R. Cluxton, S. Al-Abed, M. H. Roulier, L. T. Bryndzia, W. W. Slack, L. C. Murdoch and S. Al-Abed (1998) "In situ horizontal lasagna treatment of TCE in soil using bioremediation and zero-valent iron dechlorination compared to natural attenuation: a preliminary report." International Conf. On Remediation of Chlorinated and Recalcitrant Compounds, Session D.6., Monterey, CA.

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●		●		✳ US DOE, Oak Ridge National Lab, Martin Marietta Energy Systems ✳ Portsmouth Uranium Enrichment Plant, Piketon, Ohio ✳ July - September, 1996 and July - September, 1997 ✳ Dr. Bob Siegrist, Colorado School of Mines	A TCE plume is available for demonstrations and tests of innovative and enhanced technologies in low permeability media. Target soil is a ~20 ft thick surficial clay unit. The current year project will test four technologies, all of which will utilize hydraulic fractures as enhancements. Steam and hot air will be injected into sand filled fractures while adjacent fractures are connected to conventional SVE or pump and treat systems. Extensive temperature measurements will permit estimates of efficiency of the processes. Two in situ chemical processes will be tested at other location s at the site. Fractures will be created with iron and with encapsulated permanganate to test iron catalyzed reduction of chlorinated hydrocarbons and to test destructive oxidation of contaminants.	Siegrist, R. L., K. S. Lowe, L. C. Murdoch, T. L. Case, D. A. Pickering and T. C. Houk (1998) "Horizontal Treatment Barriers of Fracture Emplaced Iron and Permanganate Particles." in NATO/CCMS Pilot Study: Evaluation of Demonstrated and Emerging Technologies for the Treatment of Contaminated Land and Groundwater (Phase III) Special Session: Treatment Walls and Permeable Reactive Barriers, Pages 77-83. USEPA, Washington, DC. Siegrist, R. L., K. S. Lowe, L. C. Murdoch, W. W. Slack and T. C. Houk (1998) X-231A demonstration of in situ remediation of DNAPL compounds in low permeability media by soil fracturing with thermally enhanced mass recovery and reactive barrier destruction. ORNL/TM-13534. Oak Ridge National Laboratory, Oak Ridge, TN. Siegrist, R. L., K. S. Lowe, L. C. Murdoch and A. M. Struse (2000) "In situ chemical treatment using hydraulic fracturing to emplace Fe metal and KMnO4 reactive solids." EPA/625/R-99/012 (85-92.)
	●		●	✳ Square D Corp, ERM ✳ Bordentown, NJ ✳ 2001 ✳ Dr. Richard Brown, ERM, Ewing	Ancient metal plating activities polluted deep soils as well as a thick column of overlying industrial fill. An innovative hydraulic fracturing injection technology (jet fracturing – thru fixed casings) was used to deliver reactive solids that stabilized the heavy metal contaminants in the soil.	Robinson, D., R. A. Brown, C. Christiansen, R. Patel and W. W. Slack (2002) "In Situ Treatment of Copper Contamination using Direct Injection of Lime Slurries." The Second International Conference on Oxidation and Reduction Technologies for In Situ Treatment of Soil and Groundwater, Toronto, Ontario.