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Goodbye to Barriers

No trenches mean less disruption to city streets and beyond.

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Deep Permeable Reactive Barriers

By Grant Hocking

GeoSierra recently patented Azimuth Controlled Vertical Hydraulic Fracturing, or Trenchless PRB Placement, for in-situ installation of zero-valent iron permeable reactive barriers (PRBs) at depths that are impossible to reach using conventional methods.

It is well known amongst environmental professionals that zero valent iron PRBs can remediate chlorinated solvent contaminated groundwater by abiotic degradation of the halogenated volatile organic compounds into harmless non-toxic end products. Iron PRBs can also be used to precipitate or immobilize numerous heavy metals dissolved in groundwater. The conventional means of installing vertical iron PRB walls is by braced excavation, continuous trencher or slurry wall techniques. These conventional installation methods share five major limitations:

1. They are incapable of installing an iron PRB wall at depths greater than 40 ft. bgs.
2. They include little QA/QC to ensure and validate that a PRB is built to specifications.
3. They cause substantial disruption of the surface and subsurface where the iron PRB is to be installed.
4. The excavated soil requires special handling and controlled disposal.
5. The trenching, especially in the case of slurry wall constructed PRBs, can cause parts of the PRB to be impermeable.

Trenchless PRB Placement represents a new method of placing iron PRBs in-situ that allows it to be installed at depths much greater than conventional technologies. The system has been used to install iron PRBs at many sites composed of silts, sands and gravel at both shallow and moderate depths greater than 100 ft. A vertical iron PRB installed by the trenchless method can be as thin as three or as thick as nine inches at a height and length necessary to remediate an entire plume.

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The method installs iron PRBs without soil excavation and is ideal for sites with surface facilities or underground utilities or sites that are located in urban settings. During installation, the fracture geometry is monitored in real time by resistivity imaging technology developed specifically for this application. Before and after installation of the PRB, installers conduct hydraulic pulse interference tests to verify that the PRB has not impeded the conductivity and permeability of the formation.

History and development of trenchless PRB placement

Concept discovery (1992-1993)

GeoSierra conceived the installation technology from results of an extensive series of hydraulic fracturing experiments in soils and weakly cemented sediments. Some 250 tests were conducted in a variety of soil conditions and the experiments were excavated to verify the extent, orientation and thickness of the resulting vertical hydraulic fractures. These experiments proved an earlier discovery that a controlled vertical fracture could be created at the required azimuth in the subsurface and what will then become an iron PRB wall could be injected following the fracture to a prescribed point. Additionally, the experiments demonstrated that a continuous iron PRB wall could be constructed by coalescing the fractures between multiple injection wells. The end result was the construction of a continuous PRB wall built to specifications in terms of height, depth, length and thickness and not a single trench had been dug.

Demonstrated proof of concept (1994)

Under contract to the U.S. Army Corps of Engineers, one of the forerunners to this technology was field demonstrated as a Proof of Concept at a New Hampshire site in 1993. These demonstration tests utilized the earliest form of the fracture initiation device consisting of a driven flat-faced probe with an inflatable packer mounted above the probe. The Proof of Concept demonstrated, from the initiation and propagation of 23 vertical hydraulic fractures, that fracture azimuth could be controlled and maintained, fracture coalescence of multiple injected fractures could be assured, and fracture thickness of up to nine inches could be accomplished.

Advances in fracture initiation (1995-1997)

The first commercial fracture initiation device developed by GeoSierra was a 12 ft. long, six inch diameter chainsaw cutting device that was inserted into a 6.25 inch diameter PVC casing pre-drilled and grouted into the soil the full depth of the required fracture. Upon insertion to the required depth, the device cut the PVC casing and grout and could create a five-ft. long vertical cut in the soil that extended upwards 20 ft. This fracture initiation device was developed for two markets: the shallow environmental application of constructing vertical groundwater permeable treatment walls (iron PRBs) and the much deeper application for petroleum recovery applications in existing hydrocarbon reservoirs.

Early permeable reactive barrier installations (1997-1998)

The first two PRB installations used the chain saw fracture initiation tool for fracture initiation, and also utilized the first generation fracture iron-gel mix design. These PRB installations were constructed at the Caldwell Superfund site in Fairfield, N.J. and at the Massachusetts Military Reservation, Cape Cod, Mass. Both PRB installations were successful injecting iron filings into the subsurface at the required azimuth and to the full height of the vertical treatment wall. However, both of these early installations required additional quantities of enzyme to be injected into the sub-surface to further break down the fracture gel and reduce it to water.

No deep trenches and large piles of soil are required.

After installation, well heads will be capped and hoses removed.

Breakthroughs in gel design, rapid gel breaking enzyme and fracture initiation technology (1998-1999)

Two major technology advances occurred during 1998 and early 1999:

1. The development of a rapid breaking enzyme capable of breaking even the highest pH iron/gel mixtures.

2. The development of the orientated, all metal fracture initiation casing system that allowed repeated multiple fracture injections at various depth (stacked) horizons in order to form a continuous vertical wall.

The new enzyme breaker assured the rapid (within hours), clean breakdown of all iron gel mixtures, even those with pH >10. The new casing system had major advantages for the construction of PRBs, namely:

1. A stronger and more robust casing system for the fracture injections.

2. Repeated fracture injections at the same horizon

3. Increased productivity due to logical sequencing of tasks and simplicity of the system.

4. Fracture coalescence could be ensured between injection wells, even with slight drilling offsets and/or casing orientation misalignment, by the use of casing delimiters and controlled direction of pore pressure relief.

Commercial use of new gel, new enzyme breaker and casing technology (1999)

The first applications of the new gel, new enzyme breaker and new casing technology as part of GeoSierra's overall Trenchless PRB Placement were successfully utilized at the following sites:

Fairfield, N.J. Superfund site, 1999 - Construction of the PRB extension at the Caldwell Superfund Site in Fairfield. The installation of the PRB extension was constructed at record productivity rates and achieved clean breakdown of the iron-gel mixtures in one to two hours.

Centerville, Iowa Superfund site, 2000 - Installed a 240 ft. long, 75 ft. deep iron PRB as the major groundwater remedy at that site. The Centerville PRB was completed in late October 1999 and has delivered excellent performance since then.

Oakley, Calif. Fortune 50 client site, 2001 – Installation of a pilot PRB, 110 ft. in length and moderate depths of 45 ft. to 115 ft. bgs, was completed in January 2001 and proved to be so successful that three months later the existing pump-and-treat system was shutdown in order to accurately monitor the effectiveness of the PRB. The PRB results allowed the pump-and-treat system to be dismantled nine months after the installation of the PRB.

Montross, Va. Superfund site, 2002 – Installation of the longest continuous PRB at 1,175 ft. in length and from a depth of five ft. to 44 ft. was completed in June 2002.

Herlong, Calif. DOD facility, 2003 – Installation of a pilot PRB, 100 ft. in length and from a depth of 95 ft. to 115 ft. bgs was completed in April 2003.

Gardena, Calif. Fortune 50 client site, 2003 – Installation of a pilot PRB 100 ft. in length and from a depth of 18 ft. to 100 ft. bgs was completed in August 2003. The fully completed barrier will be about 775 ft. long, which will be scheduled within 18 months of the pilot completion date.

Patents issued on the trenchless PRB placement:

U.S. Patent No: 5,944,446 — Injection of mixtures into subterranean formations
Issued Aug. 31, 1999

U.S. Patent No: 6,216,783 — Azimuth controls of hydraulic vertical fractures in unconsolidated and weakly cemented soils and sediments
Issued April 17, 2001

U.S. Patent No: 6,443,227 — Azimuth controls of hydraulic vertical fractures in unconsolidated and weakly cemented soils and sediments
Issued Sept. 3, 2002

Patent issued on the real-time imaging technology:

U.S. Patent No: 6,330,914 — Method and apparatus for tracking hydraulic fractures in unconsolidated and weakly cemented soils and sediments
Issued Dec. 18, 2001

Real-time imagery of fracture injections

The active resistivity method of providing real-time images of injected fracture geometry during construction were conceived and developed over a number of years. The first commercial application of the technology was for the installation of the iron PRB at the Caldwell Superfund Site in Fairfield, N.J. in 1998. Since then, the real time imaging technology has been used at all trenchless PRB installations to ensure that each PRB is constructed as planned according to quality assurance specifications for thickness and continuous coalescence.

Hydraulic pulse interference test

The hydraulic pulse interference test was initially developed for characterizing petroleum reservoir permeability and hydraulic connection between production wells. The method was enhanced and the equipment was developed further to prepare the technology for use in characterizing shallow groundwater sites and to act as a quality assurance technology for both iron PRB and slurry wall constructed systems. The first commercial application of the hydraulic pulse interference test equipment was at the initial iron PRB installation at the Caldwell Superfund site in Fairfield, N.J. in 1998. Since then the hydraulic pulse interference testing equipment, procedures and interpretation software have been utilized at a number of iron PRB installations for both site characterization and quality assurance testing in an effort to ensure that the constructed iron PRB was permeable and did not impede groundwater flow.

Inclined profiling of PRB thickness

Inclined soil resistivity probing technology has been developed to determine iron thickness of the PRB by driving the resistivity probe on a 30-degree angle through the PRB. The contrast in resistivity of the iron PRB and the native soils enabled precise measurement of the installed PRB thickness.

Summation

Trenchless PRB Placement and installation methods have advanced significantly in the past five years. Lessons learned, along with patented tools and processes to remediate groundwater plumes, have allowed installation of iron PRB walls that in some cases, because of their depth, would otherwise be impossible to reach. **PE**