

Innovative Use of a Pressure-Pulse Injection Tool to Increase Transmissivity in a Collection Trench

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ABSTRACT

Pressure pulse injection tools are widely used in the oil and gas extraction industry to increase well production yields; however, they have been sparingly used in the environmental industry. These injection tools work by applying a pressure pulse to the subsurface that can open subsurface pore throats in unconsolidated material, increasing yields or increasing a radius of influence from a substrate injection. Collection trenches at an industrial site were installed to increase recovery of number two fuel oil in the subsurface and maintain hydraulic control of the contaminant plume. However, after operating for seven years, significant reduction in recovery was observed. Diminished recovery was attributed to biofouling, iron fouling, and/or excessive scaling. A pilot test was conducted in 2009 to determine if a pressure-pulse injection tool could be used to inject an anti-fouling agent and rehabilitate two of the Site collection trenches. The pilot test was successful in increasing transmissivity of both trenches with an order of magnitude increase in groundwater recovery at Collection Trench 1 and a 50% increase in recovery at Collection Trench 2. The trench rehabilitation using the pressure pulse injection tool was conducted at 2 other Site Collection Trenches in 2010 with similar success and is now proposed as part of regular maintenance of the trenches on an as needed basis.

INTRODUCTION

An industrial site adjacent to a tidal river experienced a release of several hundred thousand gallons of No. 2 fuel oil in the late 1990s. Emergency responses were conducted upon discovery of the release that included soil excavation and installation of recovery wells and trenches. Groundwater and product recovery rates at a number of those site recovery wells (RWs) located within the recovery trenches had been decreasing over time. Annual recovery rates decreased from over 100,000 gallons the first year (2001) to only a few hundred gallons in 2007. Separate phase light non-aqueous phase liquid (LNAPL) was still observed at several monitoring wells throughout the site. Observations made during recent attempts at recovery well rehabilitation indicated the need for a more aggressive rehabilitation strategy. Previous recovery well rehabilitation conducted in 2008 included flushing of recovery lines using a mild acid solution, scrubbing recovery well screens, and surge and blocking of recovery wells. These are standard rehabilitation techniques to address fouling of well screens and sandpacks; however, given the construction of the recovery trenches (gravel-filled in the saturated zone), it was considered highly probable that the entire gravel-filled trenches had some type of iron fouling, biofouling, mineral scaling, silting, or some combination thereof. Two recovery trenches were chosen for pilot testing of a pressurized injection of an anti-fouling agent using a pressure pulse injection tool. The pressure pulse injection tools (the Hornet and Sidewinder Injection Tools) were provided by Wavefront Technology Solutions USA, Inc. of Raleigh, North Carolina.

The Hornet and Sidewinder injection tools provide applications of pressure pulsing to enhance the introduction (or in this case, extraction) of fluid into (or out of) saturated porous media. This pulsing is referred to by Wavefront as “Primawave” technology. Primawave technology is applied to environmental remediation projects to increase the effective distribution of remedial products through standard injection wells or direct push rods, as well as to produce prolonged increase in NAPL recovery rates. Primawave is adapted from Powerwave™ technology that was developed for the energy sector and has been established for many years to support secondary and tertiary crude oil recovery efforts. In both cases, the application of a pressure pulse through the injected liquid is modulated by controlling the frequency of the pulsing to maximize injection rates at minimal pressures to minimize blow-by and day-lighting, and also optimize the radius of influence and distribution of the injected fluid in the aquifer. Primawave (via Hornet and Sidewinder injection tools) has been used with numerous remedial products including electron donors, electron acceptors, chemical oxidants, acid/base slurries, and surfactants. The technology has been applied in a wide variety of unconsolidated lithologic conditions ranging from tight clay to relatively permeable sandy aquifers.

Methods and Materials

To address the entire trench and the potential combinations of fouling, a more aggressive approach was developed that included pilot testing the pressurized injection of an anti well-fouling solution (10 to 20 percent hydroxyacetic acid solution) utilizing a pressure-pulse injection tool, such as the Hornet and Sidewinder Injection tools. The pressure pulse tool is attached ex situ to the top of a metal well to distribute the pressure pulse with a positive displacement pump supplying the pressurized fluid to the tool. The injection tool must be attached to a metal well or rod to distribute the pulse to the subsurface since plastic would dampen the pulse. The pressure pulse is applied to the subsurface material with the result being an increase in pore throat size. The increase in the pore throat size allows for the mobilization of silts and dislodges other fouling agents that can improve the flow of fluids in the subsurface while also increasing the distribution of anti-fouling solutions.

The pilot test was conducted in two separate events at the RW-1 trench in February 2009 and at the RW-2 trench in October 2009. The RW-2 trench rehabilitation pilot test (trench rehab) was not conducted until October due to the fact that recovery of product at RW-2 had increased by February 2009. It was decided at the conclusion of the RW-1 trench rehab pilot test to wait until recovery had decreased at RW-2 before performing the rehab at that location. Recovery at RW-2 started to decrease in August and dropped considerably in September; therefore, the rehab pilot test was scheduled and conducted in October 2009. Exhibit 1 shows the location of the injection/remediation points (IR-1, IR-2A, and IR-2B) inside the collection trenches and the associated recovery wells.

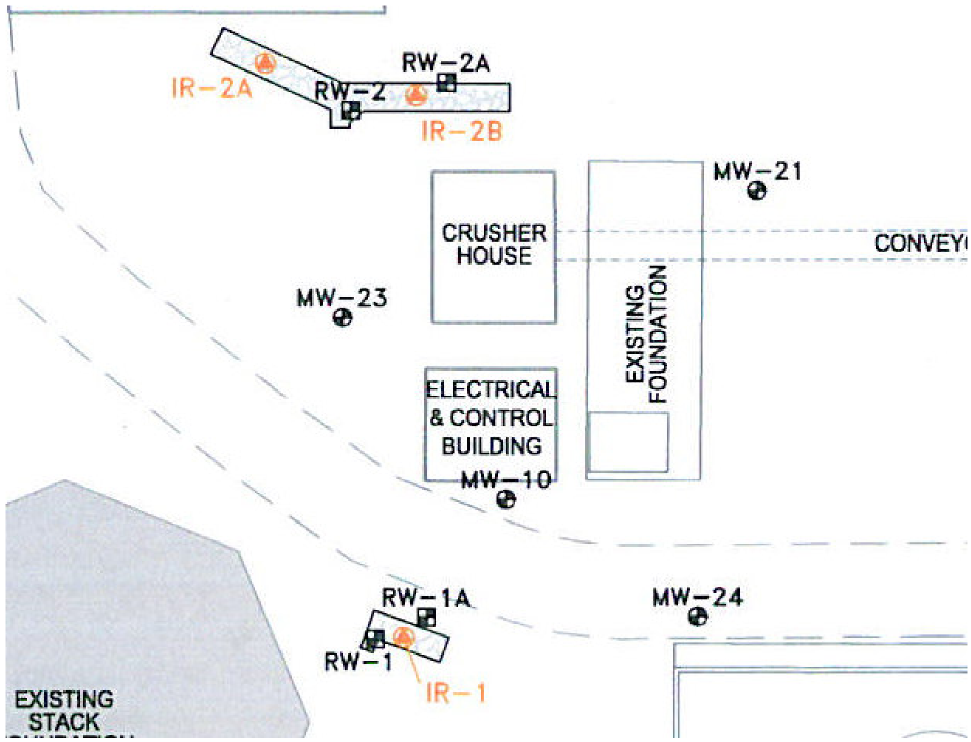

Exhibit 1. Plan view of the collection trenches, the associated recovery wells (RW-1 and RW-2) and the injection/remediation points (IR-1, IR-2A and IR-2B) where the injection tools were connected.

The first step of the trench rehabilitation pilot test included the installation of the injection points into the collection trenches. A single 4-inch low-carbon steel injection well was installed within Collection Trench Number 1 approximately 12 feet from the recovery well also located in the trench. Collection Trench 1 is approximately 5 feet wide by 20 feet long by 17 feet deep and is gravel filled from 5 to 17 feet below ground surface (bgs). Two 4-inch low-carbon steel injection points were installed in Trench 2, one into each leg of the trench connected to the recovery well. The injection wells were screened from 7 to 17 feet bgs at all three wells. The wells were finished with a bentonite/grout slurry from just above the sand pack to the ground surface to minimize short-circuiting of injected fluids up the annulus of the well.

The second step of the pilot test was to dewater the trenches to allow for the injection of the hydroxyacetic acid solution and also to minimize the potential for short-circuiting of the injected fluid. Approximately 2 pore volumes (approximately 2,200 gallons) of groundwater were pumped from the recovery well using a high-flow trash pump placed at the bottom of the recovery well. The groundwater was collected and pumped into the Site's water treatment system. Prior to commencing the fluid injections, an inflatable packer was installed in the observation well adjacent to the injection well to prevent short-circuiting into the observation well.

The third step included installing the injection tool onto the injection well, mixing the hydroxyacetic acid solution, and injecting the solution. Approximately 1,200 gallons of fluid were injected into the collection trench at a rate of about 20 gallons per minute (gpm) and a pressure of 35 pounds per square inch (psi) using a progressive cavity pump connected to the injection tool. A total of 110 gallons of hydroxyacetic acid solution was injected into Trench 1 over a 2-day period.

Exhibit 2. The Hornet injection tool connected to injection well IR-1, the injection tool control box (to the right of the tool) and a small compressor used to maintain pressure on the packer in the adjacent observation well. A drum of the hydroxyacetic acid is also located next to the compressor.

The same procedure was conducted at Collection Trench 2 in October 2009; however, due to the size of that trench (approximately 2 times the size of Trench 1), twice as much groundwater was extracted (approximately 4,500 gallons). The total amount of hydroxyacetic acid injected was 220 gallons over a 4-day period into IR-2A and IR-2B in

Trench 2. Trench 2 also had an observation well; however, the packer was not necessary due to the well being filled with sediment. Flow rates were increased to 40 gpm in both IR-2A and IR-2B at a pressure of 35 psi.

The final step of the pilot test was to allow the injected fluid to sit in the collection trenches for 24 hours and then extract an equal amount of groundwater from the recovery wells. The waiting period was intended to allow the acid solution to dissolve the various fouling problems whether bio, mineral, or iron. The extraction of fluid was performed to aid in distributing the acid solution throughout the trench and to extract any dissolved materials out of the trench that may have contributed to fouling. The water was collected, adjusted for pH as needed, and disposed of in the Site water treatment system. Approximately 1,200 gallons was extracted from RW-1 and 2,500 gallons was extracted from RW-2. The water was observed to be lower in pH than the normal groundwater (pH of 3 instead of the normal 6.5) and also exhibited a noticeable odor (described as similar to hydrogen sulfide or rotten eggs).

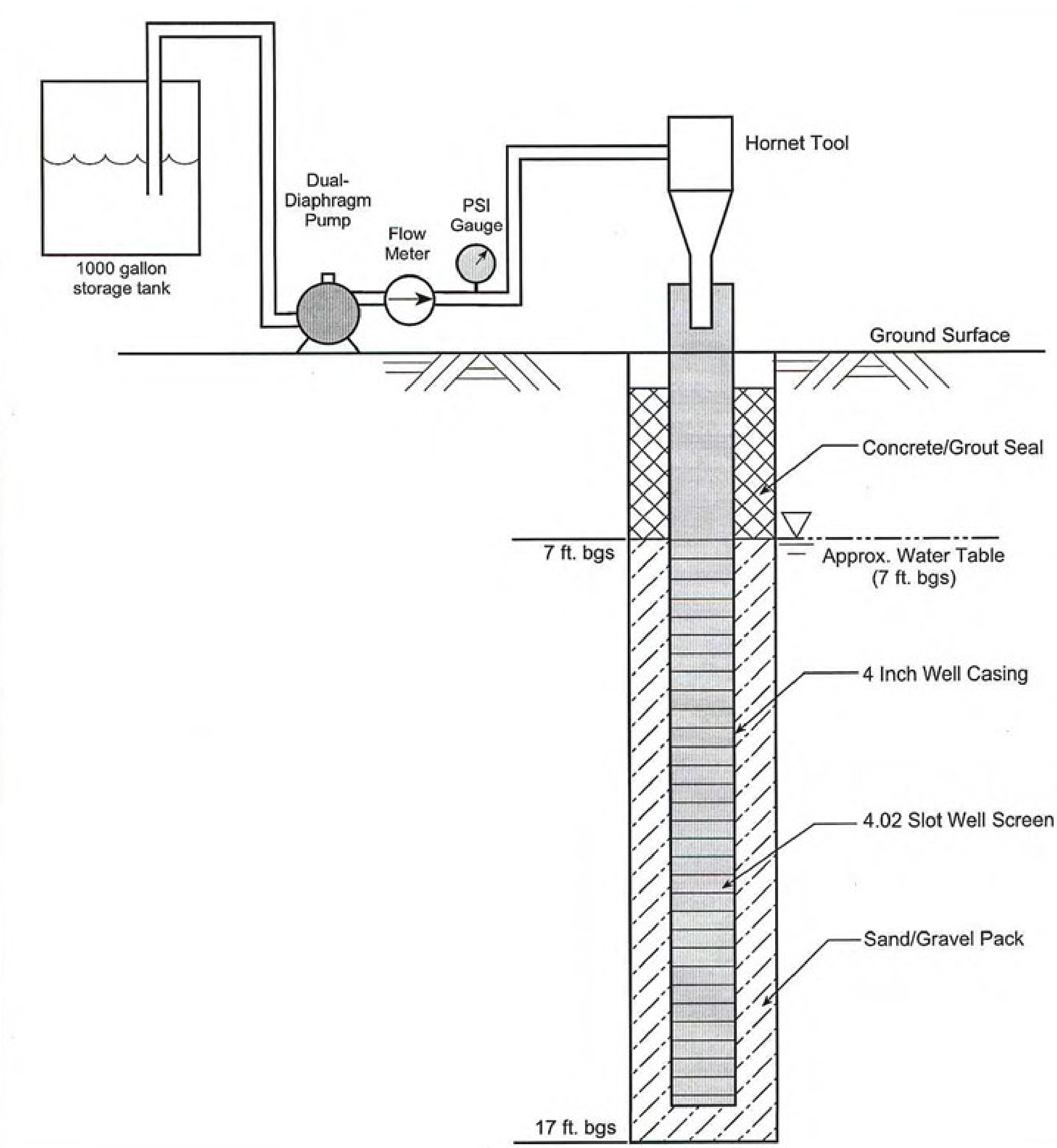

Exhibit 3. Typical cross-section of injection well with simplified process flow diagram of injection process with tool.

Results and Discussion

Prior to the trench rehabilitation pilot testing at RW-1, groundwater recovery rates were observed to be approximately 0.1 gpm for several years. Post pilot testing, the groundwater recovery rates from RW-1 have remained consistently at approximately 1 gpm. This indicates approximately an order of magnitude increase in the groundwater extraction flow rate for recovery well RW-1.

Another interesting observation included oil recovery at RW-2 approximately 150 feet downgradient of the IR-1. Prior to the pressure pulse injection event, oil recovery at RW-2 was intermittent, averaging approximately 60 gallons per month. After the injection event, oil recovery increased to almost 100 gallons per month for several months. This consistent recovery rate had not been observed at this location for over 4 years. One possibility is that the pressure pulse injection at Collection Trench 1 may have increased transmissivity in the area surrounding Trench 2 increasing oil recovery similar to the effect the pressure pulse tools have in the oil exploration industry.

After the initial dewatering step, groundwater recovery at RW-2 was slow and groundwater was not observed to cascade into the well through the screen. While waiting to dispose of the groundwater, the recovery was measured 0.1 feet every 20 minutes. After the second dewatering step, recovery in RW-2 was measured to be 0.1 feet every 5 minutes, four times the rate initially observed before the pressure pulse injections. Also, approximately midway through the injection, the solution was observed to cascade through the screen as shown in Exhibit 4.

Exhibit 4. Looking into RW-2 while the hydroxyacetic acid solution is being injected into IR-2B. Notice the solution that is cascading in through the well screen.

Groundwater recovery at RW-2 had decreased to approximately 1.5 gpm by September of 2009. Post injection, the groundwater recovery rates have averaged approximately 3 gpm, a 50 percent increase in the groundwater recovery rate.

CONCLUSIONS

The increases in the recovery rates at both RW-1 and RW-2 are an indication that the Recovery Trench Well Rehabilitation pilot test was successful and would be a useful tool for increasing recovery at other trench locations. In April 2010, plans were developed to implement pressure pulse injections at two other trench locations. Those injections were conducted in a similar manner as those at Trench 1 and Trench 2 and were also successful at increasing recovery rates. The pressure pulse injection is now included as part of the regular maintenance of the collection trenches and recovery wells and will be conducted on an as needed basis.

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