SITE GOALS MET WITHIN 60 DAYS

CASE STUDY:
PlumeStop barrier eliminates offsite TCE migration 3 years to date

REGENESIS®

Summary

An innovative, large-scale groundwater chlorinated solvent treatment meets performance goals within 60 days and maintains long-term reduction

100% Reduction in TCE

TCE contribution to the plume was eliminated following the application.

REGENESIS Remediation Services Team (RRS) has completed a large-scale *in situ* groundwater treatment of trichloroethene (TCE) at a former industrial manufacturing facility that quickly achieved and then sustained performance objectives. TCE and low concentrations of other chlorinated volatile organic compounds (CVOCs), cis-1,2-dichloroethene, vinyl chloride, and 1,1,1-trichloroethane, were treated using an innovative sorption-enhanced reductive dechlorination (ERD) approach virtually eliminating contaminants by the first monitoring event within 60 days of application.

>3 Years Post Application

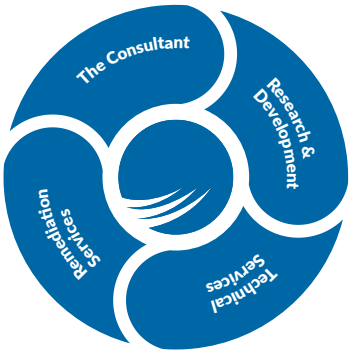
This reduction has been continuously maintained more than three years post-application.

An injected permeable reactive barrier (PRB), installed at the site property boundary, has maintained 100 percent reduction in TCE for over three years, meeting the remedial objectives by cutting off the site's contribution to a more extensive groundwater TCE plume. RRS applied the following remediation technologies to achieve these results:

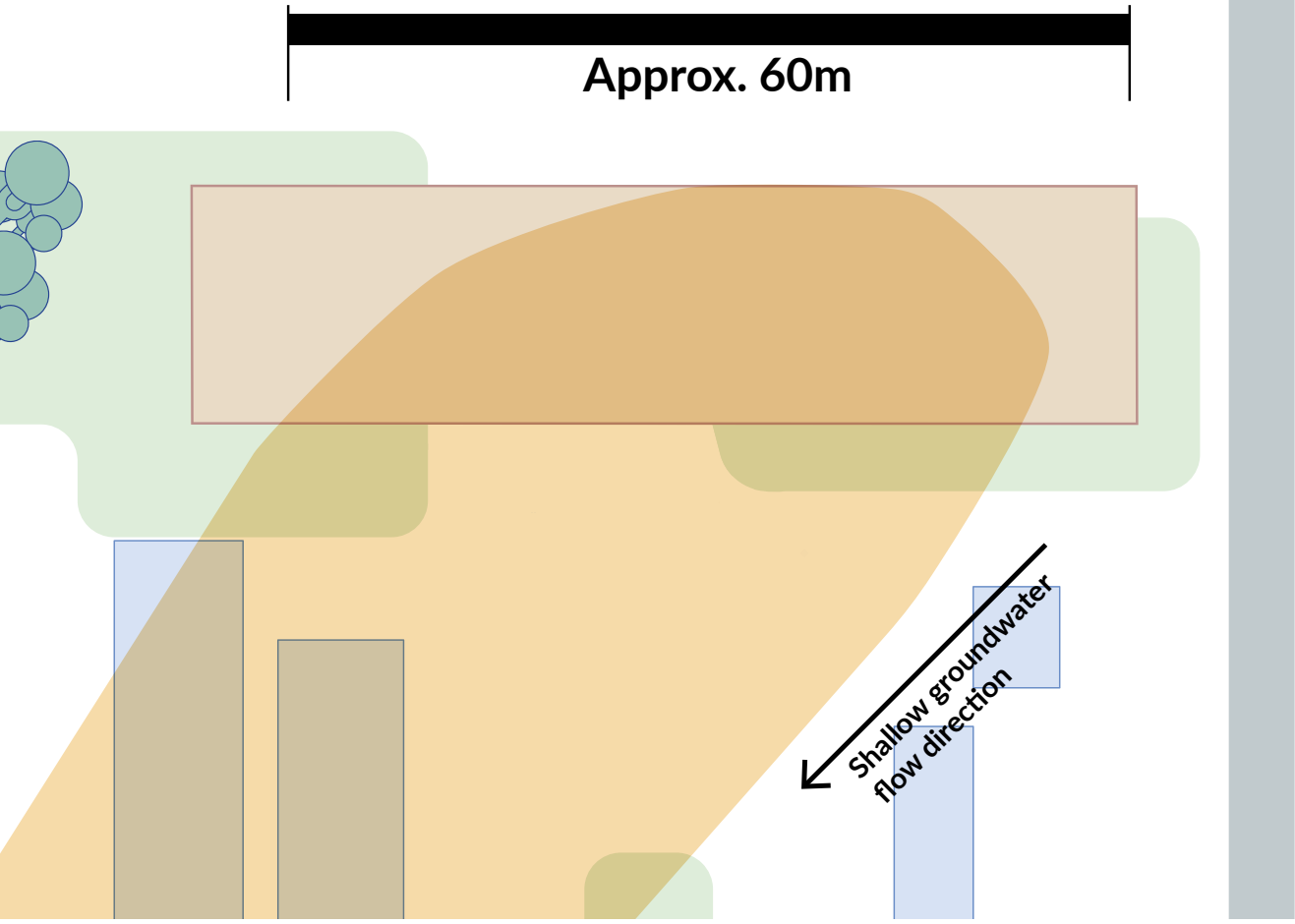
PLUME STOP® Liquid Activated Carbon

HRC® HYDROGEN RELEASE COMPOUND

BDI® PLUS BIO-DECHLOR INOCULUM



A collaborative remedial design and strategic implementation effort between REGENESIS and the consulting firm, resulted in the project's success. This collaboration led to a dynamic remediation application strategy entailing planned, in-field adjustment to the design based on information obtained and assessed during remediation. An innovative remediation approach was needed to meet a very stringent deadline for the works' completion. Through careful planning and scheduling, the REGENESIS injection team met the implementation deadline, which included work inside an active warehouse and retail business.



Background

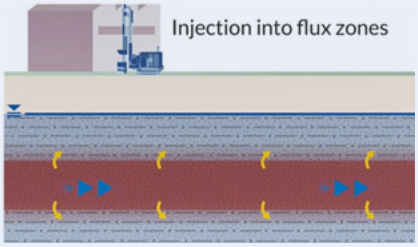
Eliminating TCE using a dynamic remediation approach

TCE plume extent in shallow groundwater (Approximate)

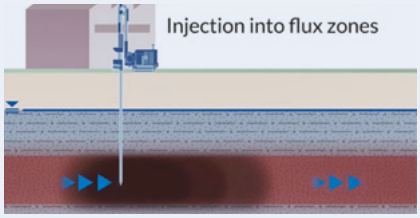
The site is comprised of a former manufacturing facility that currently operates as a commercial warehouse and retailer, and other nearby industrial properties. Historical operations at and nearby the site involved the use of solvents containing TCE, which had spilled and migrated into the groundwater, contributing to a TCE groundwater plume extending at least 400 meters beyond the property boundary. The surrounding area is a mix of industrial, commercial, and residential properties, and several nearby residences use potable wells. Although the full nature and extent of impacts upgradient and crossgradient were not yet defined at the time of treatment, the objectives were to eliminate the highest groundwater impacts, immediately halt further downgradient migration of impacts, and create an area of continued treatment to address any future impacts migrating through the treatment zone.

What is back diffusion?

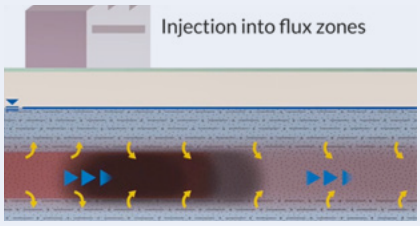
In aquifers composed of heterogeneous materials (e.g., sand and clay layers), the pollutant tends to flow primarily through higher permeability zones (e.g., sands). As higher permeability zones transport elevated pollutant concentrations, a diffusion gradient is established that drives the pollutant into adjacent lower permeability zones (e.g., clays). Over time, this can result in adjacent lower permeability zones storing significant masses of dissolved contaminants.



Most remediation approaches remove contaminant concentrations from the more permeable zones, leaving lower permeability zones less treated. This condition sets up a reversal in the contaminant diffusion gradient referred to as "back diffusion', in which dissolved contaminant concentrations stored in the lower permeability zones diffuse back into the areas of higher permeability where contaminants have been removed.



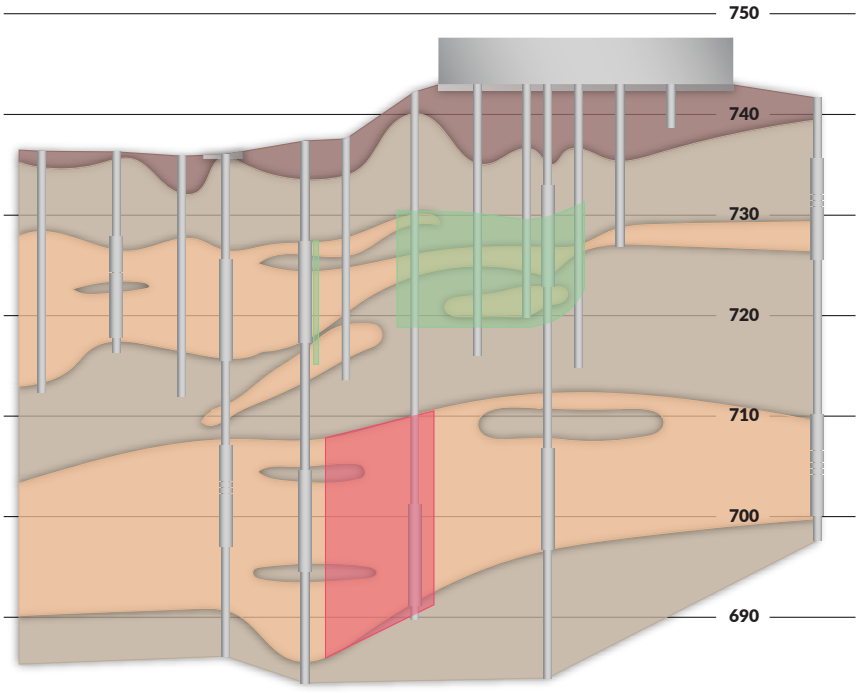
Back diffusion has been shown to occur over very long periods, causing persistent low-levels of contaminants to impact groundwater wells long after aquifer remediation attempts. PlumeStop was designed for and has demonstrated the ability to effectively address back diffusing contaminants from lower permeability zones in third-party performed case studies.



Remedial design development

Following years of extensive soil and groundwater characterization activities, the consultant developed a groundwater remediation plan to address the area of highest TCE concentrations and halt further downgradient migration. The remediation plan specified the use of PlumeStop® Activated Carbon™ along with electron donor and bioaugmentation substrates, HRC® and BDI Plus®, respectively.

The consultant worked with REGENESIS to develop the remediation design. The team completed a detailed site hydrogeological characterization, and used the data to create the conceptual site model (CSM). The CSM depicted TCE migrating downward from nearby and underneath the building, through fill materials and lower permeability soils into two underlying water-bearing sand units. The shallow water-bearing sand began at approximately 3m below ground level (BGL), and the deep water-bearing sand extended below 15m BGL. An intermediate clay separated these shallow and deep water-bearing units. Although TCE was present in groundwater in both water-bearing zones, the majority of the treatment was aimed to eliminate TCE and other CVOCs in the shallow zone, inhibiting further contribution to the larger TCE plume, and preventing against back-diffusion.

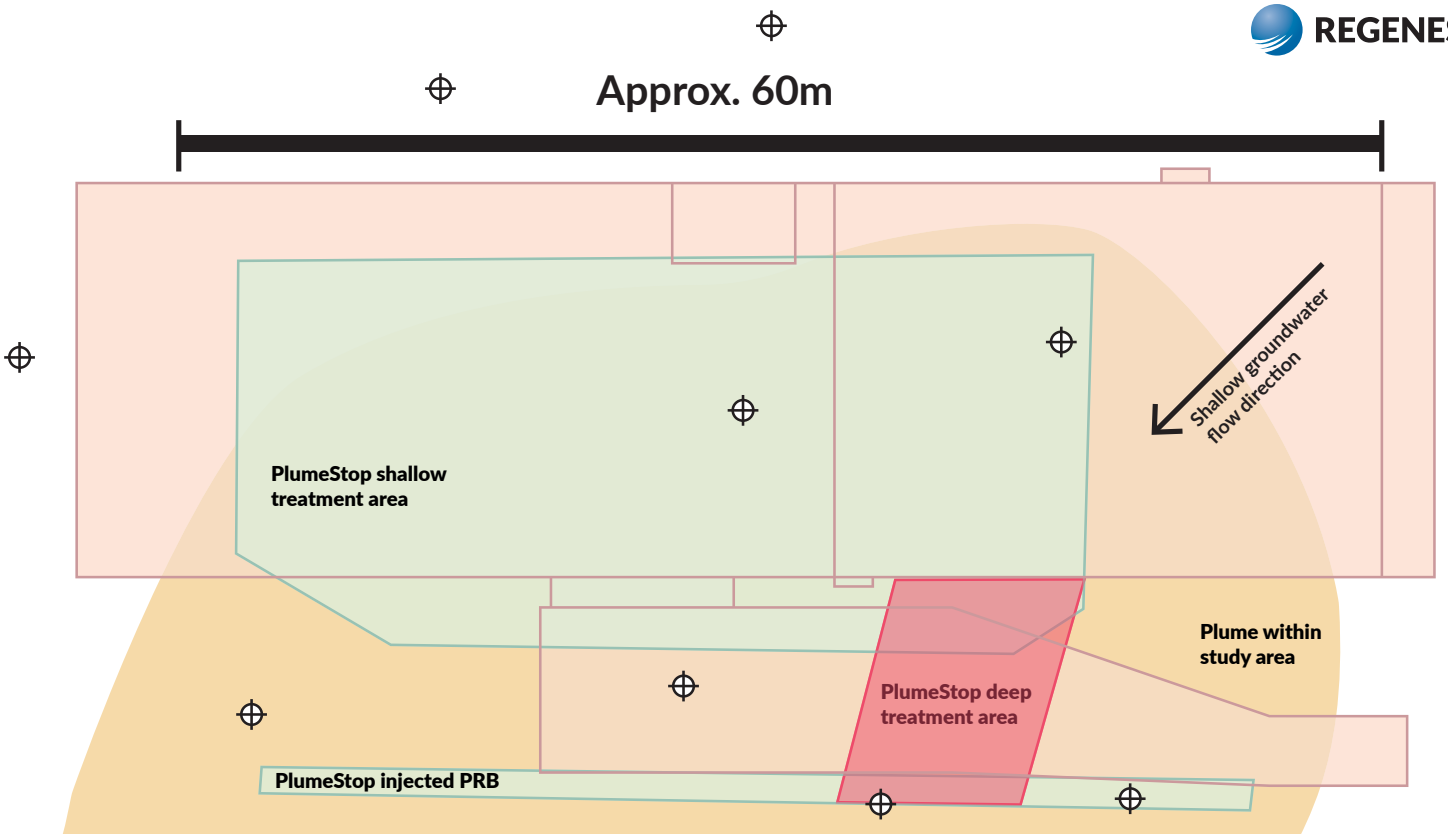


Lithology Key

- Concrete/Asphalt
- Fill/Top Soil
- Sand/Silt/Gravel
- Clay

Remedial Installation Key

- Well
- Screened Section
- Shallow Water-Bearing Unit
- Deep Water-Bearing Unit



Application design summary

Baseline TCE concentrations
(Upper sand unit maximums)

TCE within study area	127 µg/L
TCE at property boundary *(Downgradient)*	599 µg/L
Seepage velocity	60 m/yr

PRB construction

Application area	7,620 m^2
Injection points *(Direct push)*	82
Treatment intervals:	
Shallow	2.5-7.6 m BGL
Deep	10-15 m BGL
Application volume	243,000 L

Dynamic remediation

The project provided the specific challenge of working inside an active retail warehousing business under a strict project completion timeline. The application needed to occur quickly and needed to be controlled and correctly targeted to the proper TCE-impacted, water-bearing sand units. Although the overall distribution of contaminants was understood, the approach required detailed spatial mapping of the water-bearing sand units targeted for application in the relatively extensive treatment areas. The necessity for detailed mapping of the sand zones led the consultant and REGENESIS to develop a dynamic remediation application method where the remediation design would accommodate the information gained during remediation. The dynamic remediation process involved:

- Dividing the application areas into discretized sections;
- Collection of soil cores at each section to map the water-bearing sand unit depths targeted for application; and,
- Adjustment of the design in the field based on the sand thickness deviation from average.

This dynamic remediation method ensured accurate placement and dosing of PlumeStop while negating additional site characterization delays by performing adjustments in real-time.

Soil core sections

The soil core sections shown below were taken from the interval 3.5-5m BGL. The left image depicts a core sample taken prior to PlumeStop application, and the right post-application sample reveals gray staining, indicating the presence of PlumeStop within the target treatment interval.

Pre-application

Post-application

Application and results

After successful and timely application, TCE leaving the property was reduced by 100%

RRS mobilized to the site in May, 2017, beginning with design verification testing (DVT) at the southern property line PRB. DVT included injection distribution confirmation testing at the start of injection to confirm the estimated injection radius and injection point spacing for PlumeStop. Additionally, the field crew collected soil cores along the PRB to identify the upper sand unit and define point-specific vertical treatment intervals and injection volumes. This process was repeated for discretized application areas within larger treatment areas underneath and adjacent to the warehouse building. RRS adjusted the original application design based on the feedback obtained from these ongoing DVT activities.

The consultant and RRS worked closely with the current site owner to delineate and schedule specific work at the injection area sections within the building to allow for movement of warehouse inventory and set up of working injection zones. The coordinated effort between the business owner, the consultant, and RRS allowed the injection work to proceed smoothly while minimizing business interruptions and downtime.

PLUME STOP® Liquid Activated Carbon

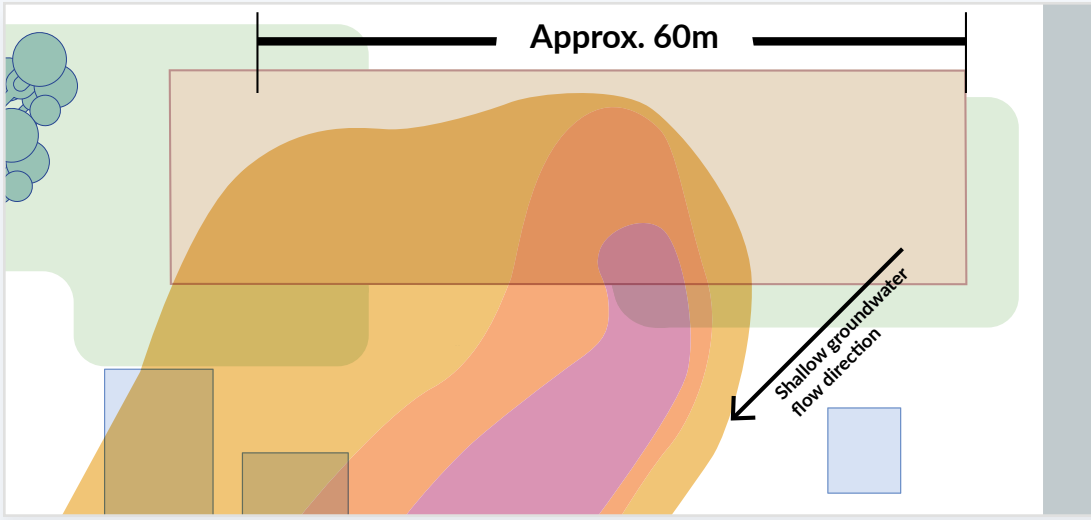
The highly controlled PlumeStop injection resulted in no surfacing inside the building.

The application was completed in one month, successfully meeting the aggressive timeline while accommodating the active retail warehouse business' operations. RRS maintained the application at moderate delivery rates and low injection pressures, ranging from 1 to 1.7 Bar. The adaptive but highly controlled application resulted in no incidence of product surfacing while completing the injection work inside the building, which was a key consideration for this project.

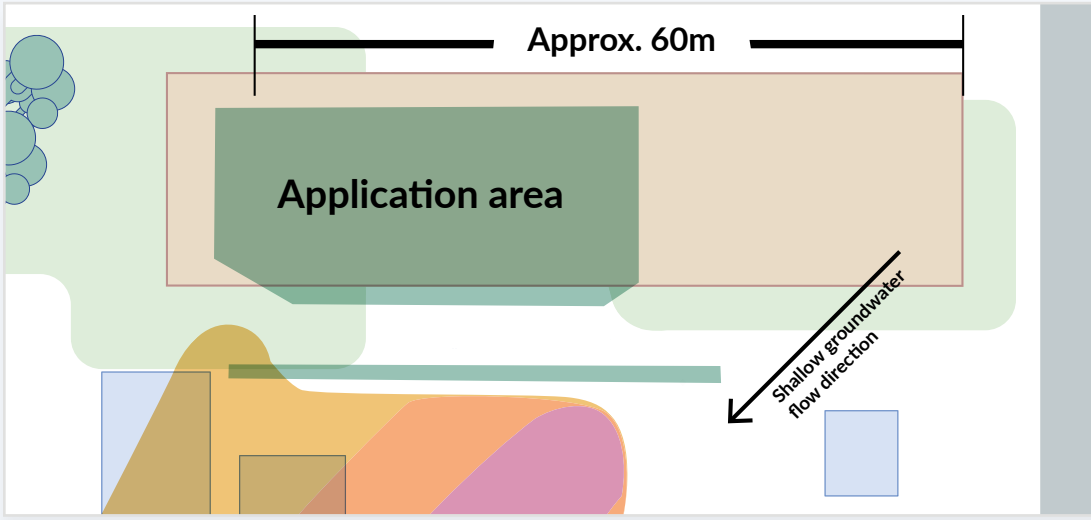
The consultant collected soil confirmation cores from the injection areas after the application. These cores showed even distribution throughout the target treatment interval.

Following the application, TCE was virtually eliminated onsite by the first sampling event at two months post-application.

TCE plume extent within study area
(Before application)



TCE plume extent within study area
(60 days post-application)



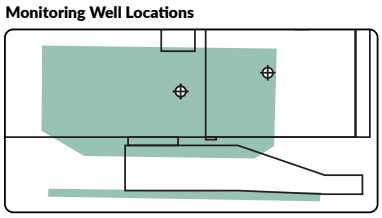
Key

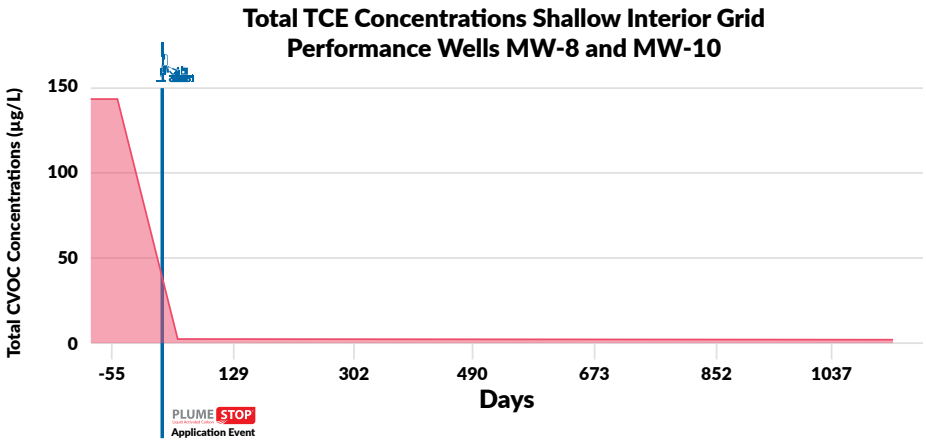
- >500 ppb TCE
- >100 ppb TCE
- >5 ppb TCE
- Application area

100% **Sustained TCE reduction**

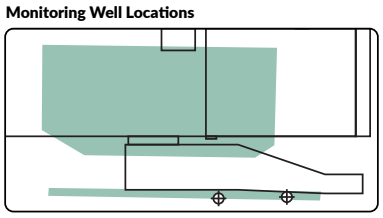
The remediation efforts have resulted in complete elimination of TCE at the property boundary for three years since the application, thus far.

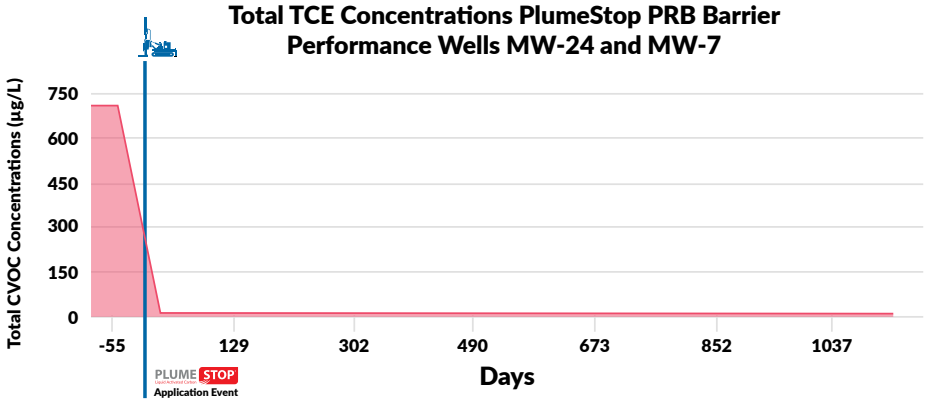
Within the building, at the two PRB performance wells, TCE has been eliminated maintaining 100 percent reduction since the application. No significant formation of of daughter products has been observed with total CVOCs having been reduced 95 percent, on average. Moreover, ethene has been detected in the PRB performance wells above 200 micrograms per liter, and an increase in chlorinated solvent degrading bacteria was observed, providing two lines of evidence for post-sorption degradation of TCE and other CVOCs.





Groundwater TCE concentrations within the treatment area reached 100% reduction within 60 days post-application and have remained at these levels to date, more than three years after the application event.





Groundwater TCE Concentrations at the barrier reached 100% reduction within 60 days post-application and have remained at these levels to date, more than three years after the application event.

In summary, the performance results met the project's performance objectives, quickly reducing dissolved phase contaminant concentrations, eliminating further contribution to the downgradient TCE plume, and serving as a continuing treatment zone to address any other contaminant transport through the area.

Technologies used

PlumeStop, HRC, BDI Plus

PlumeStop® Liquid Activated Carbon™ is a breakthrough groundwater remediation technology that stops dissolved phase contaminant plumes in days. The key innovation with PlumeStop is that it is composed of extremely fine particles of activated carbon (1-2µm) suspended in water through a proprietary dispersion chemistry developed by the REGENESIS Research and Development department. This allows the technology to flow into the subsurface at low pressure and achieve consistent, reliable distribution – a capability unlike any other form of activated carbon used for groundwater remediation today.

As a result, environmental professionals gain a certainty that the contaminants have been removed throughout the entire treated area. It also secures complete biodegradation of contaminants, and continually regenerates its sorptive capacity, allowing for long term treatment.

HRC® is an engineered, hydrogen release compound designed specifically for enhanced, *in situ* anaerobic bioremediation of chlorinated compounds in groundwater or highly saturated soils. Upon contact with groundwater, this viscous, poly-lactate ester material becomes hydrated and subject to microbial breakdown producing a controlled-release of hydrogen for periods of up to 18-24 months on a single application. HRC enables enhanced anaerobic biodegradation by adding hydrogen (an electron donor) to groundwater and/or soil to increase the number and vitality of indigenous microorganisms able to perform the naturally occurring process of enhanced reductive dechlorination.

Bio-Dechlor INOCULUM® Plus (BDI Plus) is designed for use at sites where chlorinated contaminants are present and unable to be completely biodegraded via the existing microbial communities. BDI Plus is an enriched, natural microbial consortium containing species of *Dehalococcoides sp.* (DHC) which are capable of completely dechlorinating contaminants during in situ anaerobic bioremediation processes. BDI Plus has been shown to stimulate the rapid dechlorination of chlorinated compounds such as tetrachloroethene (PCE), trichloroethene (TCE), dichloroethene (DCE), and vinyl chloride (VC). It also contains microbes capable of dehalogenating halomethanes (e.g. carbon tetrachloride and chloroform) and haloethanes (e.g. 1,1,1 TCA and 1,1, DCA) as well as mixtures of these halogenated contaminants.

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