REGENESIS®

PlumeStop Cost-Efficiently Eliminates PFAS Long-Term

In Situ Treatment Reduces Lifecycle Remediation Costs vs. Pump & Treat

Highlights

Site Type:
Industrial fire training area where PFAS-containing firefighting foams were historically used.

Project Driver:
The need to address persistent PFAS contamination derived from historical AFFF use, with an initial focus on petroleum hydrocarbons.

Contaminants:
PFOS and PFOA, with concentrations up to 3,260 ng/L and 1,450 ng/L, respectively, along with other PFAS and magnitudes higher concentrations of petroleum hydrocarbons.

Treatment:
In situ application of PlumeStop to adsorb and immobilize PFAS within the source zone, complemented by enhanced monitoring and data-driven adjustments to the treatment strategy.

Technologies:
PlumeStop CAC

Geology:
Shallow, unconfined, silty sand aquifer containing a prominent coarser sand lens.

Summary

PlumeStop® colloidal activated carbon (CAC), was applied as the first known full-scale in situ PFAS treatment worldwide at a manufacturing and former firefighting training site in Ontario, Canada. this approach significantly reduced PFAS concentrations in groundwater, achieving non-detect levels within three months post-application and maintaining these reductions for over eight years. This case exemplifies a pioneering and cost-effective strategy for mitigating PFAS migration and exposure risks long-term.

Results

- **PFAS concentrations reduced to non-detect within 3 months post-application, results maintained more than 8 years later**

Overview

The first known full-scale *in situ* PFAS treatment worldwide was completed in 2016 at a manufacturing and former firefighting training site in Ontario, Canada, where aqueous film-forming foams (AFFF) were used. Baseline PFAS concentrations in groundwater exceeded several thousand nanograms per liter (ng/L). The site was also impacted by petroleum hydrocarbons, which was the initial impetus for site remediation activities until later characterization revealed PFAS.

PlumeStop® was injected into the PFAS source zone, and within the first sampling event (three months post-application), concentrations were reduced to non-detect levels, with reductions maintained for eight years thus far. An independent fate and transport modeling expert predicts that PlumeStop will halt PFAS migration out of the treatment zone for more than 60 years, preventing exposure risk and reducing liabilities for the site owner.

Background

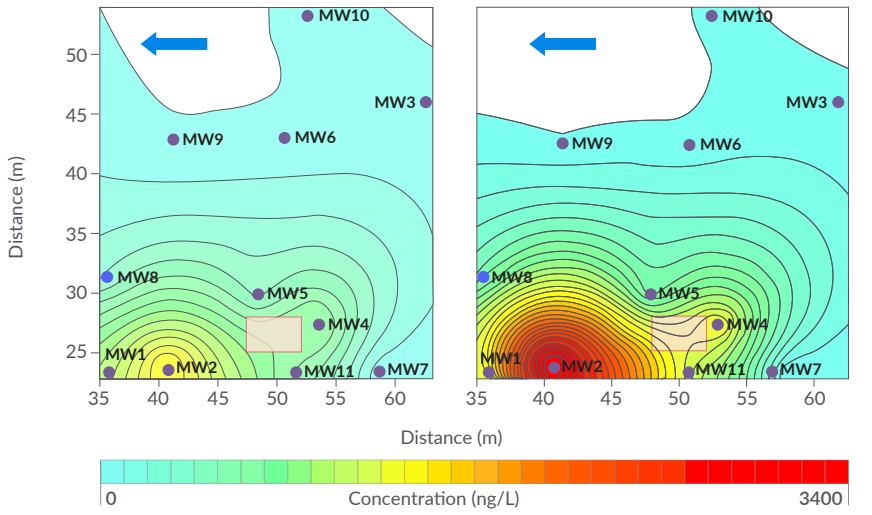
A former industrial site in Ontario Canada, the location also held firefighting training exercises using PFAS-containing aqueous film-forming foams (AFFF) during the 1970s and 1980s. Typical of many firefighting-training sites, the PFAS released from the foam moved through the subsurface and impacted the shallow groundwater. Baseline concentrations of perfluorooctanoic acid (PFOA) and perfluorooctane sulfonic acid (PFOS) were detected in groundwater at concentrations up to 3,260 ng/L and 1,450 ng/L, respectively. The PFAS and residual petroleum hydrocarbons were contained within a shallow, unconfined, silty sand aquifer containing a prominent coarser sand lens. PFAS appeared to be migrating away from the suspected source area over time based on the concentration profile relative to the groundwater flow direction.

InSitu Remediation Services Limited (IRSL), Canada's leading and most experienced *in situ* remediation company, completed the PFAS remediation program in collaboration with REGENESIS. IRSL has designed, implemented, and maintained soil and groundwater remediation programs in diverse geological environments worldwide. Rick McGregor, the Company's President and CEO, serves the industry as a PFAS remediation expert. McGregor selected PlumeStop for the project based on its overall performance and cost-effectiveness in treating various organic contaminants.

Figure 1

Site map showing monitoring well locations and dissolved concentrations of PFOA and PFOS. Images courtesy of InSitu Remediation Services Limited.

- Groundwater Flow Direction
- Suspected Source Area
- Monitoring Well Locations



Remedial Design and Performance Monitoring Program

IRSL Collects Critical Treatment Zone Information to Ensure Successful Application

Before implementation, IRSL collected samples for PFOS and PFOA according to United States Air Force protocols. Geochemical testing determined that the aquifer was pH neutral and anaerobic. IRSL conducted multiple rising head hydraulic conductivity tests, resulting in a Darcy velocity estimate of approximately 0.8 meters/day. Contaminant flux out of the source, a factor used to determine PlumeStop dosing, was initially estimated at 1.8 grams per year.

IRSL generated a conceptual side model and worked with REGENESIS to create a remedial plan for addressing the site, specifying PlumeStop dosage, volumetric loading rates, and injection point spacing. The remediation was initially designed to address PHCs, which encompassed a larger area of the site than the PFAS plume. Because the PHCs constitute most of the contaminant mass, the PlumeStop dose was determined to be appropriate for addressing PFAS.

IRSL installed seven wells to monitor remediation performance (six in the PlumeStop treatment area). Additionally, soil cores were collected, and baseline soil samples for organic carbon from the treatment area were analyzed. Several samples were spiked with PlumeStop and the results compared to the non-spiked samples. A calibration curve based on the known PlumeStop standards was generated, confirming the analytical method could detect PlumeStop post-treatment.

PFAS Plume Remediation Design Summary

Approximate PFOA/ PFOS Plume Area	800 m^2
Source Zone Treatment Area	200 m^2
PFOA Concentration	3,260 ng/L
PFOS Concentration	1,450 ng/L
Injection Points	20
Injection Interval	0.9-1.7 m
Mixed PlumeStop Volume Required	3,400 L

Note: The PlumeStop treatment area for the petroleum hydrocarbon plume extended beyond the PFAS treatment area. ORC® Advanced was added to promote aerobic bioremediation and regeneration of sorption sites on the PlumeStop CAC matrix.

Application

Low Injection Pressures Maintained

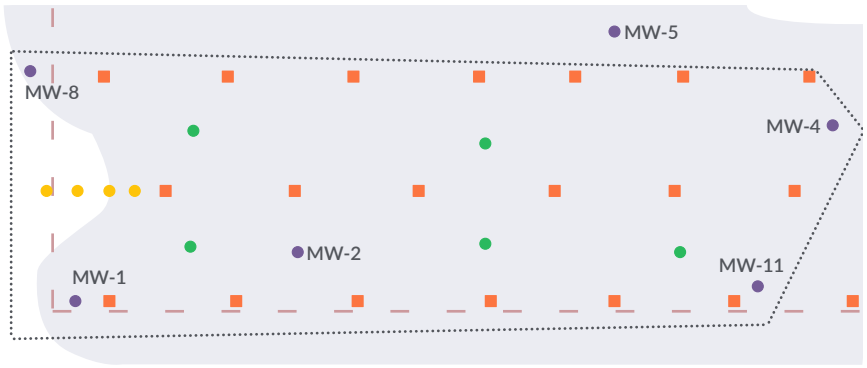
PlumeStop was applied using direct push (i.e., hydraulic percussion) injection in a grid array encompassing the PFAS source zone. During the applications, injection pressures were monitored and maintained at less than 25 pounds per square inch. The low injection pressures demonstrate PlumeStop's ability to permeate and coat the aquifer materials without friction. This feature, unique to PlumeStop's patented colloidal activated carbon (CAC) formula, allows even distribution and accurate placement of PlumeStop within the target treatment zone—a key to performance success.

To demonstrate that PlumeStop was accurately applied at this site, placement validation soil cores were collected and sampled for organic carbon, and the results were compared to baseline conditions.

Figure 2 Application Area

Plan view showing direct-push injection locations (squares), radius-of-influence cores (yellow circles) and distribution cores (green circles). Purple circles are monitoring wells. Image courtesy of InSitu Remediation Services Limited.

- Direct-Push Injection Location
- Monitoring Wells
- Distribution Cores
- Radius-of-Influence Cores



PlumeStop CAC vs PAC Distribution

At another site, McGregor demonstrated the substantial differences between colloidal activated carbon (i.e., PlumeStop CAC) and powdered activated carbon (PAC) in a pilot study assessing the PFAS remediation performance of six different amendments. The below exhibits Figures 3A and 3B compare PAC vs PlumeStop CAC distribution within the target treatment zone (red dashed lines at 1.7 to 2.1 m depth).

The PAC Figure 3A distributed in a narrow seam correlating to a higher K sand, leaving most of the target treatment volume untreated. In stark contrast, PlumeStop CAC Figure 3B encompassed the entire target treatment volume, as confirmed by a two-order-of-magnitude (i.e., >100-fold) increase in carbon measured at points 0.75 m, 1.5 m, and 3 m distance from the injection. PlumeStop CAC also permeated into the lower conductivity soil layer--an intended effect for addressing contaminant back diffusion.

Predictably, PlumeStop CAC was the only amendment out of the six tested to demonstrate complete removal of PFAS in groundwater over the entire pilot test performance monitoring period (18 months). All other amendments demonstrated little to no reductions or rebound of one or more PFAS to the baseline concentrations after six months.

Figure 3 PAC Distribution

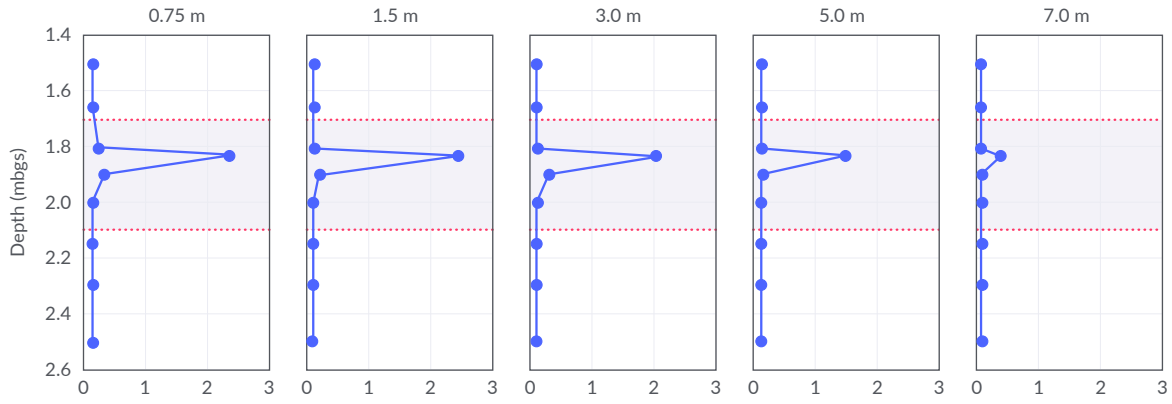
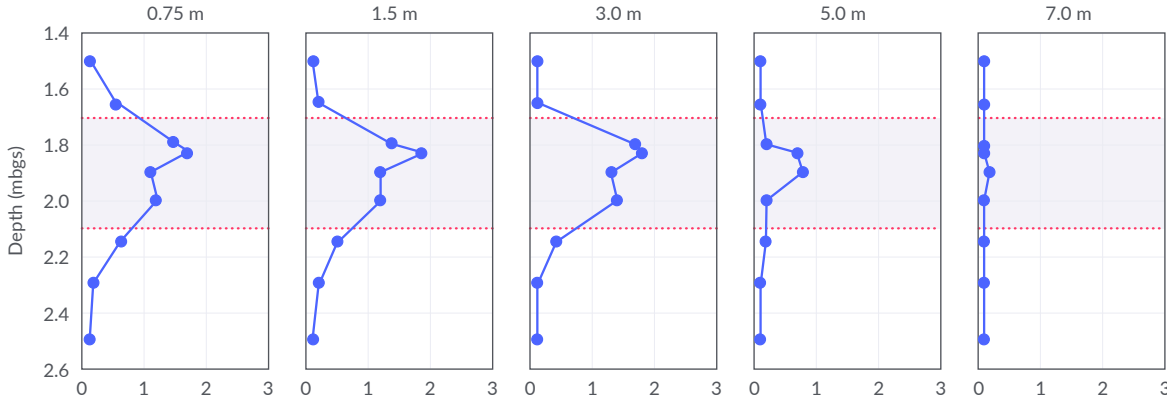


Figure 4 PlumeStop CAC Distribution



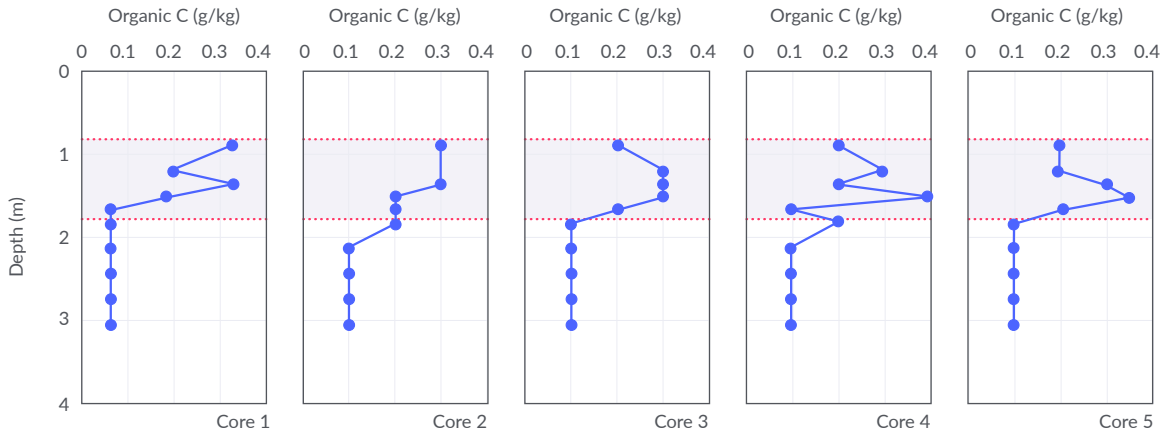
Images provided courtesy of InSitu Remediation Services Limited. For further details, see the published Research Article in the peer-reviewed industry journal *Remediation*

Results

Sampling Confirms PlumeStop Fully Distributed Through the Treatment Zone

Five PlumeStop placement validation soil cores were collected post-application, confirming PlumeStop's complete coverage within the treatment zone. Radius-of-influence testing confirmed distribution at distances up to 4.6 meters from an injection point.

Figure 5 Soil Core Sampling Results



Soil core organic carbon sampling results demonstrate complete PlumeStop coverage in the target treatment zone. Image provided courtesy of InSitu Remediation Servies Limited.

PFAS Eliminated in Groundwater within Three Months, with Results Sustained over Eight Years

PlumeStop reduced PFAS concentrations (i.e., PFOA and PFOS) to non-detect levels by the first sampling event three months after the application. These reductions have been maintained for eight years thus far. In addition to PFOA and PFOs, ten other PFAS were sampled, beginning with the 18-month sampling event. Based on the sample results, the sum of all PFAS remains less than 10 ng/L after eight years of monitoring.

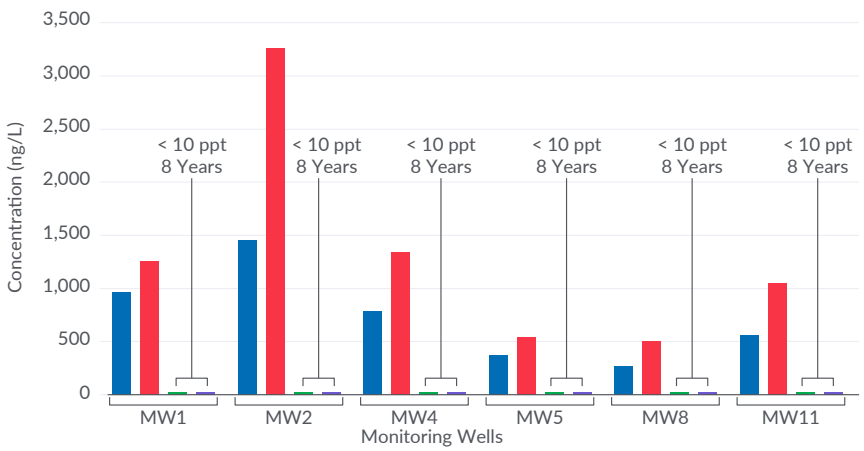
Additionally, the PlumeStop treatment has reduced petroleum hydrocarbons, initially present at much higher concentrations (i.e., magnitudes) than PFAS, to levels below regulatory standards.

Figure 6

PFOA and PFOS Groundwater Concentrations

Chart showing six monitoring wells within the treatment zone maintaining complete removal of PFOA and PFOS in groundwater for eight years thus far.

- PFOS Pre-Application
- PFOA Pre-Application
- PFOS Post-Application
- PFOA Post-Application



REGENESIS®

Over 60 Years of Treatment Effectiveness Predicted, Field Results Confirm Model Projections Through 8 Years

About the Model

IRSL approached Dr. Grant Carey, to evaluate the data using ISR-MT3DMS™, a reactive transport model which was updated to simulate the performance of PlumeStop® Colloidal Activated Carbon. The proprietary program demonstrated the long-term effectiveness of the approach.

Porewater Solutions
Expertise • Experience • Innovation

Porewater Solutions (PWS) is recognized as an industry leader in modeling consulting services for contaminated sites and water resources, with specialization in litigation and environmental forensics.

Dr. Grant Carey, Ph.D
President, Porewater Solutions

Eight years of successfully demonstrating the *in situ* treatment of PFAS is unmatched in the industry. Besides PlumeStop, no other injected amendment has consistently demonstrated the ability to eliminate PFAS in groundwater for more than a few months. However, there is much interest in solutions which remove PFAS from groundwater and eliminate exposure risk over multiple-decade timeframes. *In Situ* PFAS treatments that can persist for decades are in demand since *ex situ* approaches are energy-intensive (i.e., non-sustainable), often generate PFAS-laden waste materials, and are economically impractical to address most sites impacted with PFAS.

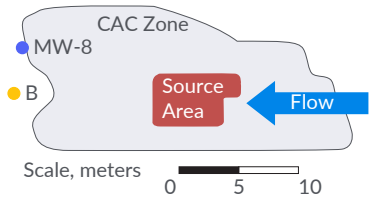
To assess PlumeStop's potential long-term effectiveness at this site, McGregor teamed with Dr. Grant Carey, President of Porewater Solutions and an expert in mathematical modeling and environmental forensics. With a Ph.D. in Civil Engineering from the University of Guelph, he has developed modeling and visualization software many in the industry rely on for groundwater assessment and remediation.

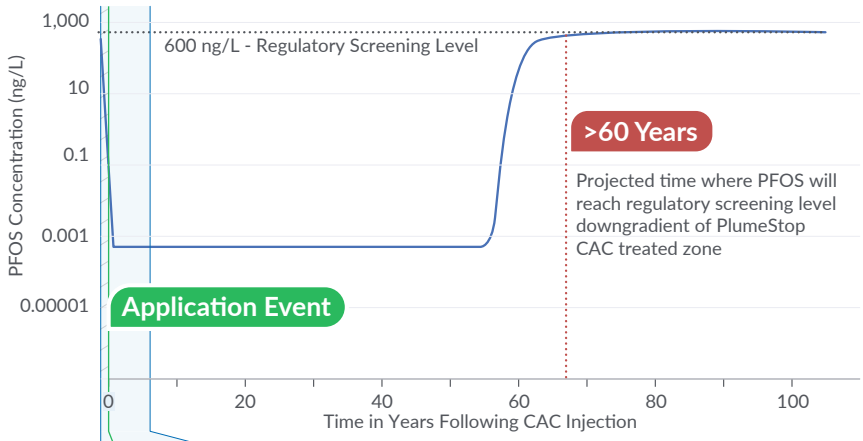
Carey was tasked with developing a model to estimate treatment longevity at the site. The modeling results, published in *Remediation*, indicate that the CAC treatment will prevent PFAS from migrating out of the treatment area above regulatory thresholds for more than 60 years, effectively eliminating downstream PFAS exposure risk. The results agree with the model prediction through eight years of performance monitoring completed thus far.

Figure 7

Hypothetical Well B - Predictive Model

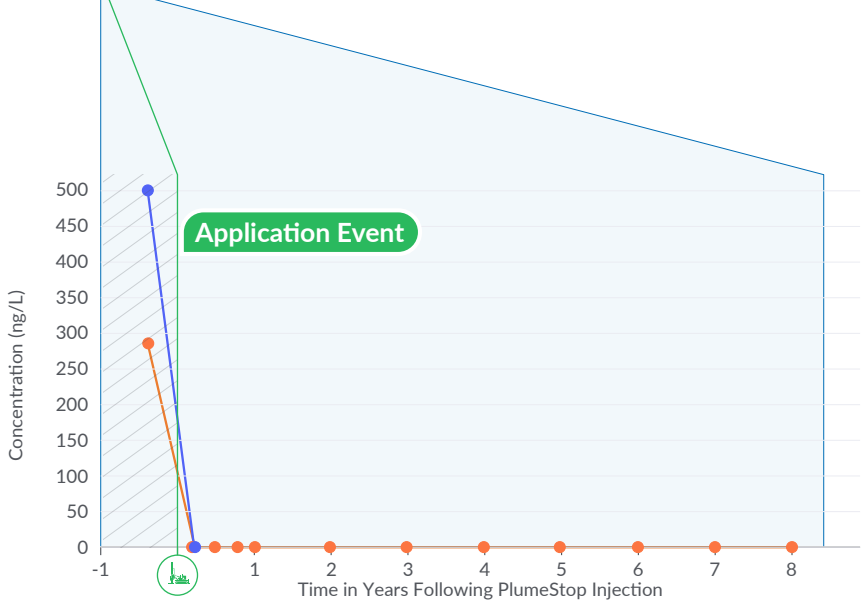
Predictive model output for PFOS concentration versus time downgradient of the PlumeStop treatment zone (Well B), modified after Carey et al. (2019).





MW-8 - Actual Site Results

PFOS and PFOA concentrations at MW-8 agree with model predictions at hypothetical Well B.



Conclusions

Treating PFAS with PlumeStop Already Realizes Project Life-Cycle Cost Benefits

The short-term and extended results of the first known full-scale field application of PlumeStop CAC on a co-mingled PHC and PFAS plume demonstrate its effectiveness at eliminating PFOS, PFOA, and other PFAS in groundwater.

Predictive modeling conducted by an independent modeling expert suggests that PlumeStop will prevent PFAS migration out of the treatment zone for more than 60 years. Performance monitoring through eight years supports the model's prediction of PFAS concentrations being maintained at non-detect levels at the downgradient edge of treatment.

PlumeStop was effectively distributed within the target zone, with organic carbon concentrations increasing by at least two orders of magnitude compared to pre-injection concentrations. PlumeStop's patented formula allows it to permeate and attach to aquifer materials and attain full coverage in a target treatment zone, which is key to the successful *in situ* remediation of PFAS. Other injectable sorptive amendments have not demonstrated the ability to distribute in the subsurface evenly.

Due to its passive approach, which does not require equipment installation or long-term maintenance, IRSL implemented the *in situ* treatment at a small fraction of the cost of operating a groundwater extraction and sorption treatment system, the other remedial alternative considered. Assuming a 20-year treatment longevity for PlumeStop, a conservative assumption relative to Carey's estimate, applying PlumeStop *in situ* to treat PFAS was projected to be 17 times more cost-effective than pump & treat. At this stage, the PlumeStop *in situ* approach has already demonstrated substantial cost savings for this project, serving as a model for effectively and sustainably mitigating PFAS risk.

Technology

PlumeStop Liquid Activated Carbon

PLUME STOP® Liquid Activated Carbon

PlumeStop Liquid Activated Carbon™ is a fast-acting groundwater remediation reagent which captures and biodegrades a range of contaminants, thus accelerating the successful treatment of impacted sites and leading to their permanent closure. As a science-based, *in situ* treatment technology, REGENESIS' PlumeStop rapidly removes contaminants from groundwater and stimulates their permanent degradation.

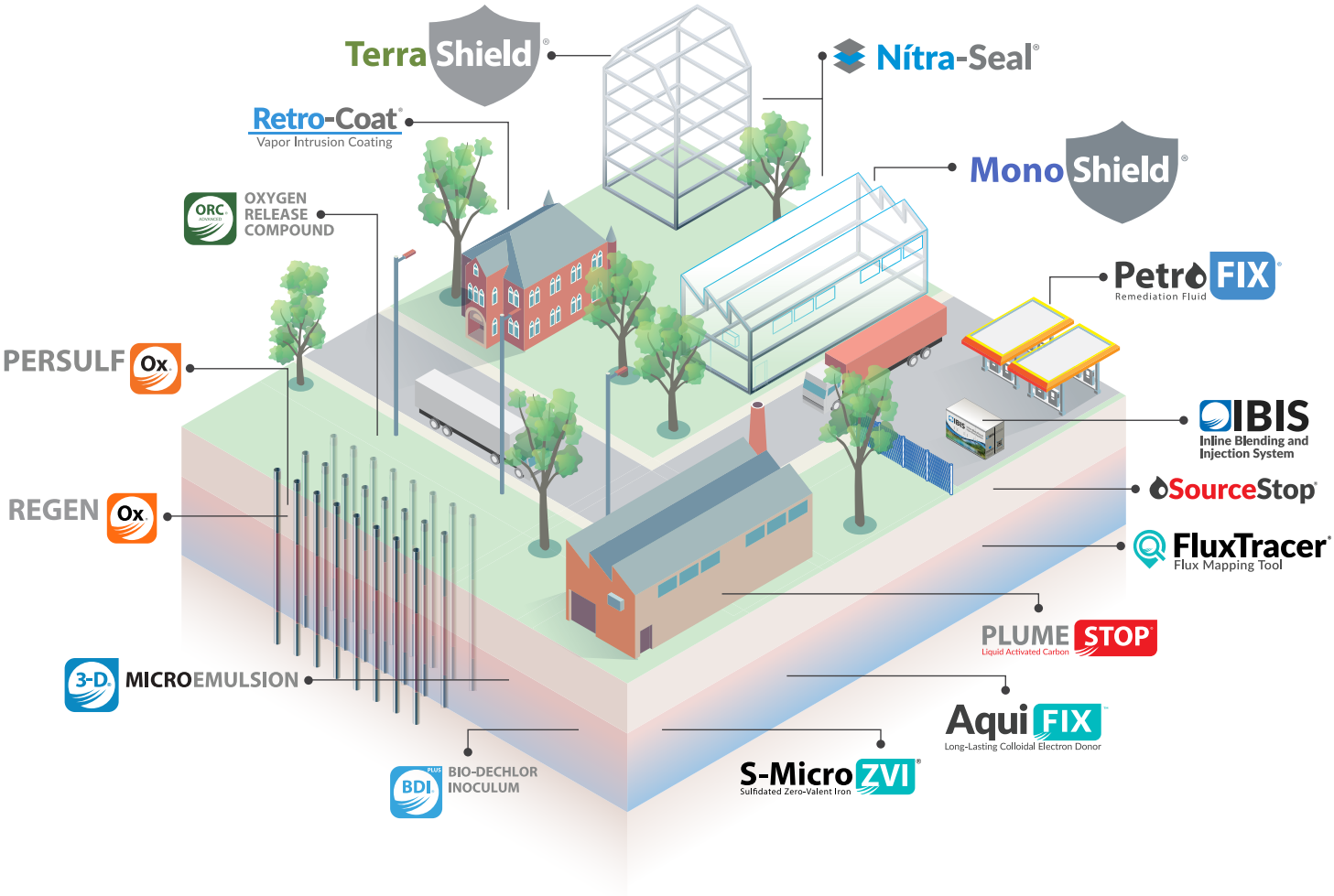
About the Consultant

About InSitu Remediation Services

One of Canada's most experienced remediation companies, InSitu Remediation Services Ltd. (IRSL) has designed, implemented, and maintained soil and groundwater remediation programs in diverse geological environments in North, Central, and South America, Europe and the Middle East.

About Rick McGregor

A respected environmental professional with over a quarter century in environmental assessment and remediation, Rick has designed and implemented remediation programs across the globe. An invited speaker at numerous international conferences and workshops, his knowledge leads the industry, based on his extensive experience, his innovative strategies, and his clear, pragmatic approach.



About REGENESIS

At REGENESIS we value innovation, technology, expertise and people which together form the unique framework we operate in as an organization. We see innovation and technology as inseparably linked with one being born out of the other.

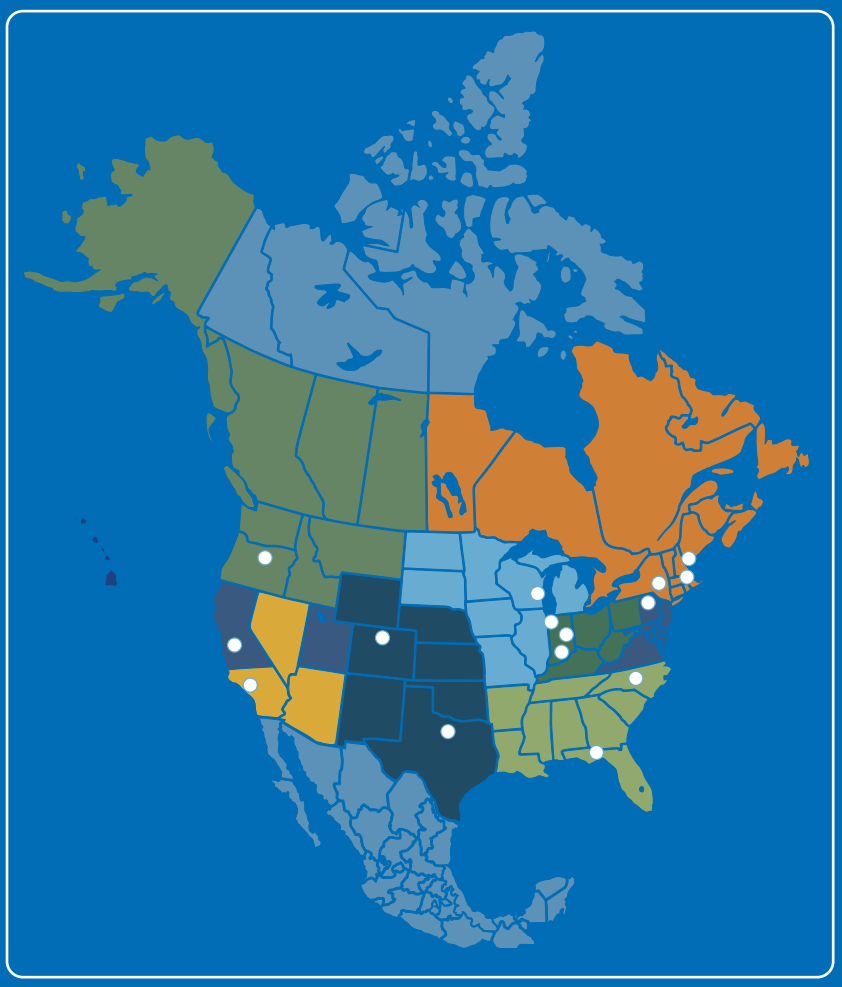
Inherently, innovation imparts new and better ways of thinking and doing. For us, this means delivering expert environmental solutions in the form of the most advanced and effective technologies and services available today.

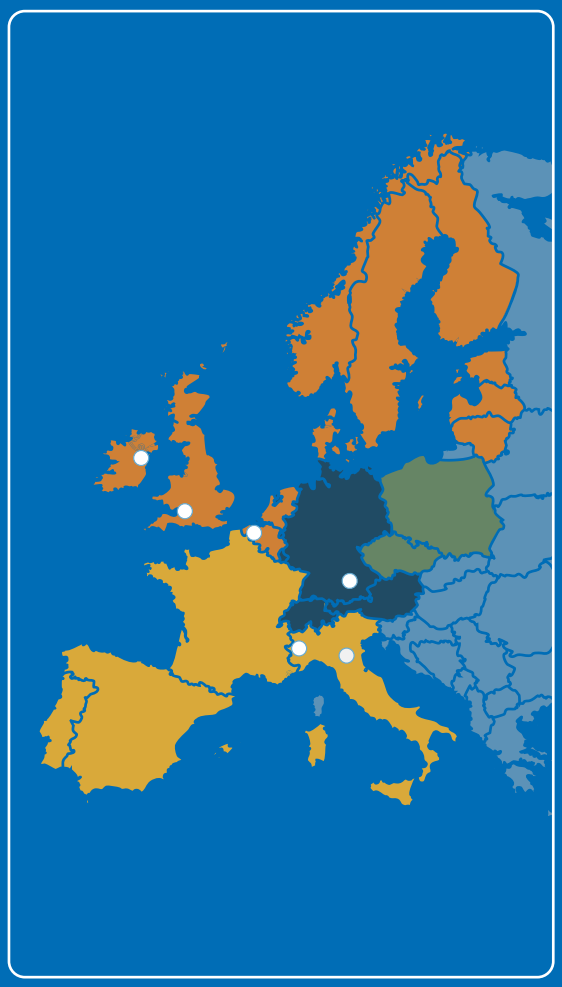
We value expertise, both our customers' and our own. We find that when our experienced staff collaborates directly with customers on complex problems, there is a high potential for success including savings in time, resources and cost.

At REGENESIS we are driven by a strong sense of responsibility to the people charged with managing the complex environmental problems we encounter and to the people involved in developing and implementing our technology-based solutions. We are committed to investing in lasting relationships by taking time to understand the people we work with and their circumstances. We believe this is a key factor in achieving successful project outcomes.

We believe that by acting under this set of values, we can work with our customers to achieve a cleaner, healthier, and more prosperous world.

We're Ready to Help You Find the Right Solution for Your Site





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