REGENESIS®

Rapid, Multi-Colloidal In Situ Treatment Achieves Site Goals

Sustained Performance Using PlumeStop, S-MicroZVI and AquiFix on an Industrial Site



Summary

In partnership with REGENESIS, Antea Group implemented a multi-colloidal in situ remedial approach at a former oilfield chemical facility in the southwestern United States, achieving rapid and sustained reductions in chlorinated solvent concentrations using a multi-colloidal amendment blend. The treatment combined PlumeStop® Liquid Activated Carbon, S-MicroZVI®, AquiFix®, and Bio-Dechlor-INOCULUM® Plus bioaugmentation to create a layered remedy addressing both abiotic and biological degradation processes. Building on a targeted characterization phase that incorporated FluxTracer® and microbial analysis, the full-scale application achieved a 99% reduction in chlorinated solvent concentrations plume-wide within two months.

99% Reduction

reduction in chlorinated solvent concentrations plume-wide

Fast Results

reductions achieved within 2 months

Site type

Former oilfield chemical facility undergoing active redevelopment

Contaminants of concern

Mixed chlorinated solvents, including:

- trichloroethene (TCE)
- cis-1,2-dichloroethene (cis-DCE)
- 1,1-dichloroethene (1,1-DCE)
- vinyl chloride (VC)
- and minor concentrations of chlorinated ethanes

Geology

Silts, silty clays, and clays with strong upward hydraulic gradient

Diagnostics

FluxTracer mass-flux testing and QuantArray-Chlor® microbial analysis

Treatment

Sorption, Abiotic Reduction, Enhanced Reductive Dechlorination, Bioaugmentation

Technologies applied

PlumeStop, S-MicroZVI, AquiFix, and BDI Plus





Background

The site, a former oilfield chemical facility in the Southwest U.S., was impacted by chlorinated solvent releases in shallow groundwater. The subsurface is dominated by a mix of silts, silty clays, and clays, which normally challenge amendment distribution. Groundwater flows west–southwest with a strong upward (almost artesian) gradient. Analytical data from the application area indicated a mixture of CVOCs, including TCE, cis-DCE, 1,1-DCE, VC, and minor concentrations of chlorinated ethanes. This contaminant profile suggested that partial reductive dechlorination had already occurred but was incomplete, warranting a treatment approach capable of addressing all degradation stages.

Antea Group targeted three areas for excavation of impacted vadose-zone soils and in situ groundwater treatment using an advanced colloidal amendment blend that combines rapid sorption with biotic and abiotic reduction of chlorinated solvents. Concurrent site development necessitated a groundwater remedial strategy capable of rapidly reducing chlorinated solvent concentrations to maintain the construction schedule.

Remediation Approach

The selected remedy integrated complementary technologies to address immediate contaminant flux, abiotic reduction, and long-term biological treatment. The approach combined microbially facilitated reductive dechlorination with direct chemical reduction, supported by a sorption matrix that enhanced contaminant contact time and overall treatment efficiency.

PlumeStop functions as the foundational sorption medium, reducing contaminant migration and extending residence time within the treatment zone. By immobilizing dissolved-phase mass, PlumeStop enabled both the abiotic reactions from S-MicroZVI, and the biologically mediated degradation driven by AquiFix and BDI Plus, to proceed efficiently to completion (Figure 1). This synergy between physical containment, chemical reduction, and microbial activity produced rapid contaminant reductions and sustained long-term performance.

PLUME STOP® Liquid Activated Carbon

Sorption – PlumeStop Liquid Activated Carbon

Colloidal activated carbon (<2 µm) permeated and coated the subsurface matrix, delivering immediate containment via adsorption of dissolved chlorinated solvents and creating a reactive surface for microbial colonization.

S-Micro ZVI® Sulfidated Zero-Valent Iron

Abiotic Reduction – S-MicroZVI

Supplied sulfidated, colloidal zero-valent iron for rapid abiotic dechlorination of residual parent and daughter compounds.

AquiFIX™ Long-Lasting Colloidal Electron Donor

Enhanced Reductive Dechlorination – AquiFix

Delivered a long-lasting colloidal electron donor to sustain anaerobic conditions and drive sequential biotransformation to ethene and ethane. Distribution was optimized using FluxTracer results.

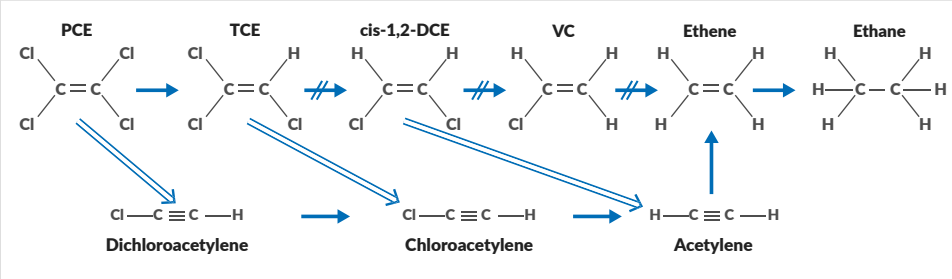
BDI PLUS BIO-DECHLOR INOCULUM

Bioaugmentation – BDI Plus

Introduced a mixed microbial consortium rich in *Dehalococcoides spp.* to accelerate complete reductive dechlorination.

Figure 1 Dechlorination pathways for chlorinated ethenes

This diagram illustrates the sequential transformation of tetrachloroethene (PCE) through trichloroethene (TCE), dichloroethene isomers (DCEs) and vinyl chloride (VC) to ethene, highlighting both microbial-facilitated (biotic) reductive dechlorination and iron- or mineral-mediated (abiotic) reduction pathways. Source: adapted from Tobiszewski et al. (2012) "Abiotic degradation of chlorinated ethanes and ethenes in water"



Together, these components formed a layered treatment system capable of immediate mass-flux reduction and long-term biological stability. The **colloidal formulation enabled low-pressure injection and uniform distribution within fine-grained soils**—conditions that often restrict the effectiveness of conventional amendments.

Excavation of shallow, high-concentration soils was completed prior to injection to reduce mass transfer from the vadose zone into groundwater. To further mitigate residual impacts, Persulfate was added to the excavation when backfilled, and PersulfOx®, an all-in-one oxidant-activator blend, was injected in an area around the excavation to oxidize remaining chlorinated compounds in soil.

Long-Term Performance and Closure Outlook:
By combining fast-acting sorption and abiotic processes with sustained biological activity, the amendment system is expected to maintain low contaminant concentrations for years without additional energy input, supporting the site's path toward regulatory closure.



Application

Phase 1: Remedial Characterization and Pilot Test

Prior to amendment design, the project team completed an extensive characterization program to establish baseline conditions and optimize injection parameters.

- **Analytical and Historical Data Review:** Confirmed residual chlorinated compounds and identified declining but persistent trends in MW-28.
- **Geochemical Profiling:** Field and laboratory measurements characterized redox conditions, confirming a mildly reducing environment suitable for enhanced reductive dechlorination.
- **Microbial Analysis:** Microbial Insights' QuantArray®-Chlor platform indicated the presence of dechlorinating organisms at low to moderate abundance prior to treatment. Combined with an elevated daughter-to-parent CVOC ratio, indicating anaerobic degradation potential for chlorinated ethenes and ethanes (Figure 3).
- **FluxTracer® Testing:** Provided mass flux and Darcy velocity data, showing active flow between 17 and 18 ft bgs (cis-DCE flux ≈ 260 mg/m²/day; velocity ≈ 6.5 cm/day). The tracer confirmed that contaminant migration was mostly confined to a narrow, lower interval—critical for targeting amendment delivery. Fine-grained contaminant storage zones prone to back-diffusion were included in the treatment to prevent rebound and ensure long-term stability.

FluxTracer® Flux Mapping Tool

These diagnostics informed the final amendment blend and injection design in the pilot test area (Figure 2).

Figure 2 Site Location Map and Pilot Test Remediation Area

The left panel shows the overall site layout, including the target remediation areas outlined in yellow. The right panel provides a close-up of the pilot test area (outlined in red) surrounding monitoring well MW-28, where the multi-function amendment blend was applied.

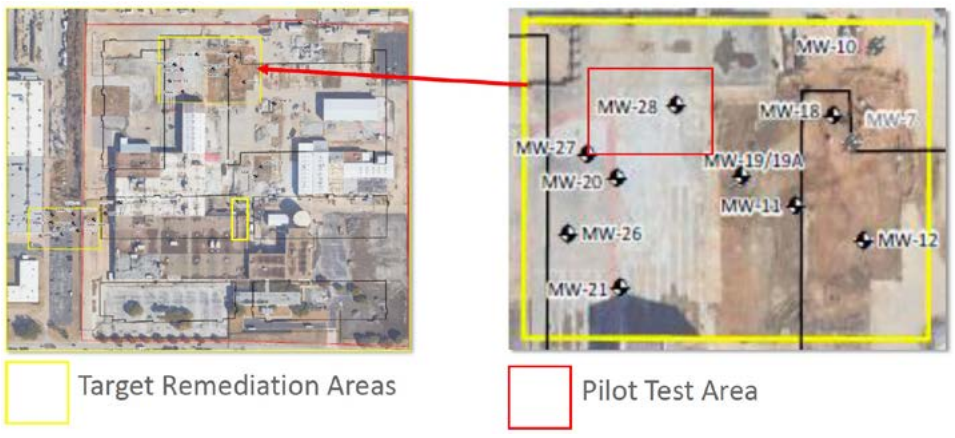
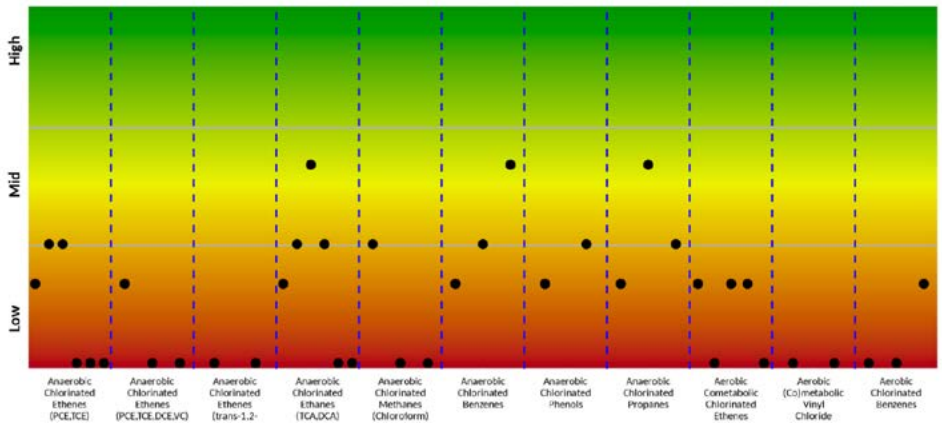


Figure 3 Microbial Community Profile (QuantArray-Chlor Analysis)

Results from Microbial Insights' QuantArray-Chlor platform showing relative abundance of functional genes associated with anaerobic and aerobic degradation pathways for chlorinated solvents. The data indicate low-to-moderate baseline levels of reductive dechlorination potential and limited aerobic co-metabolic activity prior to amendment injection.



REGENESIS Remediation Services (RRS) performed the injection and in-field monitoring, including placement validation to confirm uniform amendment distribution throughout the treatment zone. Amendments were injected using bottom-up direct-push drilling with 2- and 3-ft retractable screens for precise placement in low-permeability soils.

Injection Depth	21–9 feet below ground surface (bgs)
Tooling	5-ft-long, 1.5-in-diameter rods
Layout	12 points (three rows of four), spaced 5 ft within rows and 8 ft between rows
Average Flow Rate	2.4 gpm
Average Pressure	20 psi
Injection Date	March 2023

Visual confirmation ("black water") in both the piezometer and MW-28 verified amendment delivery. MW-28 was flushed with five casing volumes of clear water post-injection. PlumeStop concentration was visually estimated using calibrated reference standards. To manage minor surfacing, injectate concentration was increased and volumes redistributed among points, maintaining even coverage and consistent pressures.

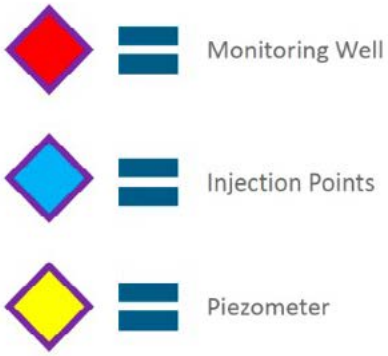


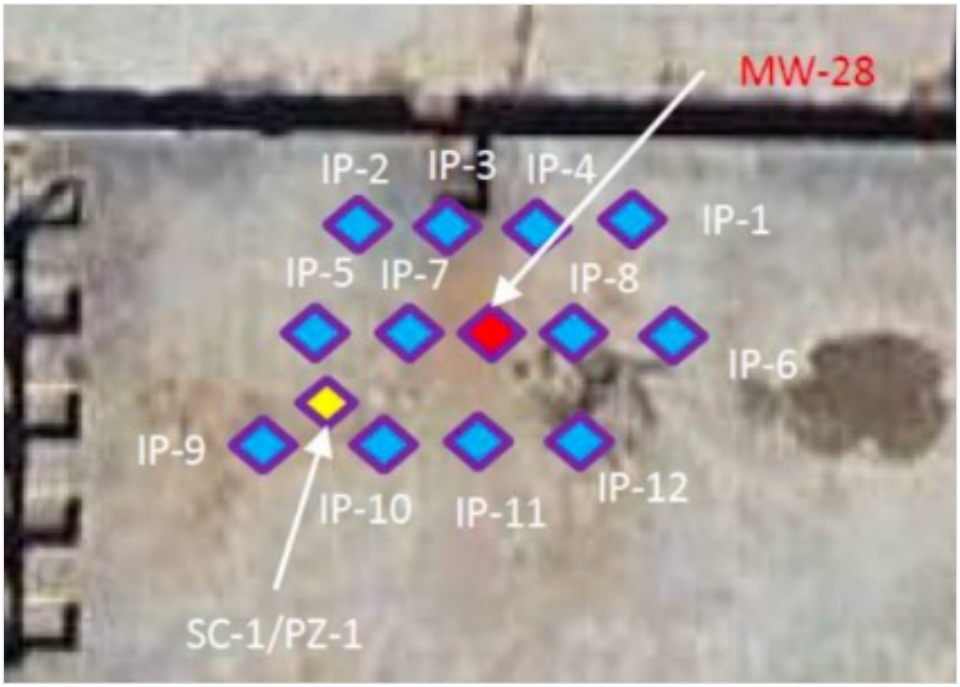
Injection through direct push upgradient of monitoring well.

Layout: Twelve injection points (IP-1 – IP-12) surrounded MW-28, with a downgradient piezometer (SC-1/PZ-1) installed for pressure monitoring and validation of subsurface amendment movement (Figure 4).

Figure 4 Pilot Test Treatment Area Layout

Plan view of the MW-28 pilot test grid showing twelve direct-push injection points (IP-1 through IP-12) arranged in three rows surrounding monitoring well MW-28. A downgradient piezometer (SC-1/PZ-1) was used to monitor pressure response and confirm amendment distribution during injection.







Injection trailer with mix tank and makeup water tank.

Phase 2: Full-Scale Implementation

Following the successful implementation at MW-28, a series of 11 permeable reactive barriers were installed across the plume in December 2023 to provide full plume treatment coverage. The full-scale remediation design (Figure 5) was informed by pilot-verified injection parameters and subsurface characterization data. In select areas, the Inline Blending Injection System (IBIS) was utilized to dynamically mix and deliver multiple amendments in real time, improving application efficiency and ensuring uniform amendment distribution under variable subsurface conditions.

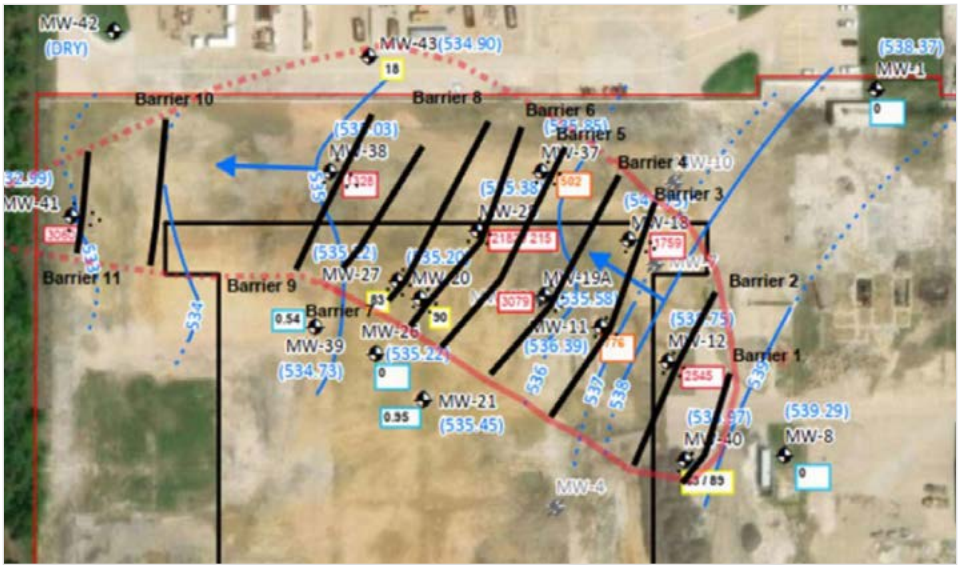
Full-Scale Design Summary:

Total Barrier Length	2,165 linear feet
Number of Barriers	11
Injection Points	360
Injection Interval	9 to 23 feet bgs with depths varying across the plume to match contaminant flux zones.
Total PlumeStop Injected	80,800 lbs
Total AquiFix Injected	41,200 lbs
Total S-MicroZVI Injected	15,500 kg
Total BDI Plus Inoculum	149 L
Total Injection Volume	121,635 gallons
Injection Date	December 2023

Figure 5

Full-Scale Design Map

Map shows the configuration of 11 treatment barriers aligned perpendicular to groundwater flow to intercept and treat the chlorinated solvent plume.





IBIS In-Line Blending and Injection System was used to inject remedial amendments in select locations.

Results

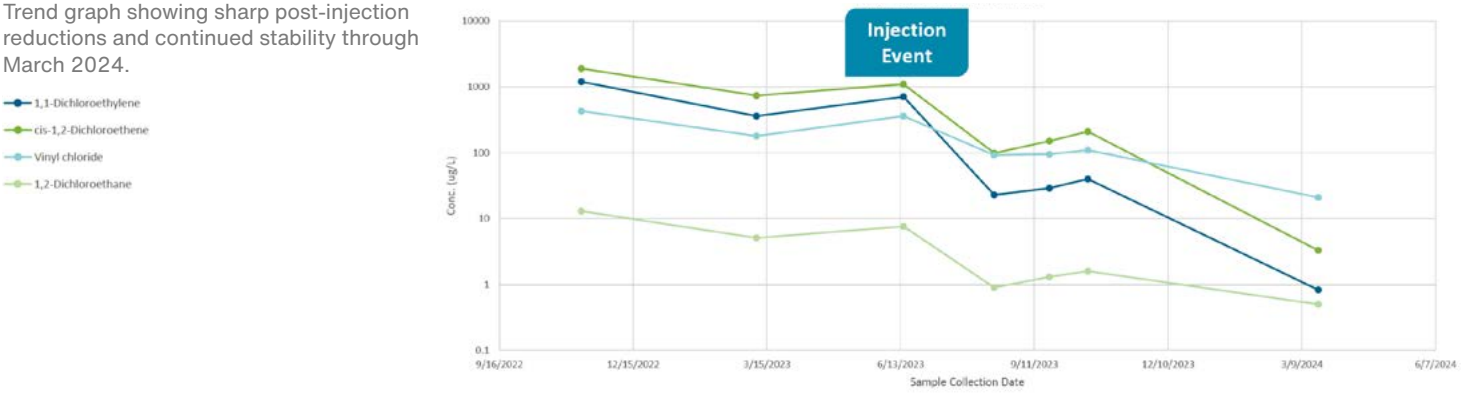
Initial Phase Application Results

During the initial phase application, monitoring well MW-28 showed dramatic declines in all chlorinated compounds within months of injection, which continued achieving 95% or greater reduction for all CVOCs through 12 months (Figure 6):

Compound	Baseline (11/10/22)	3/20/24	% Reduction
1,1-Dichloroethane	75 µg/L	0.4 µg/L	>99%
Trichloroethene	72 µg/L	0.5 µg/L	>99%
1,1-Dichloroethene	1,200 µg/L	0.83 µg/L	>99%
cis-1,2-Dichloroethene	1,900 µg/L	3.3 µg/L	>99%
Vinyl Chloride	430 µg/L	21 µg/L	≈95%
1,2-Dichloroethane	13 µg/L	0.5 µg/L	>96%

Figure 6 MW-28 Concentration vs. Time

Trend graph showing sharp post-injection reductions and continued stability through March 2024.



These results demonstrated rapid mass removal, with initial sorption and abiotic reduction effects observed within 60 days and sustained biological polishing through 180 days and beyond. The information gained and outcomes established in this initial phase application established clear performance expectations for the full-scale remedy, giving regulators confidence in the effectiveness and scalability of the approach.

Field and Geochemical Indicators

- **Dissolved Oxygen (DO):** Decreased steadily after injection.
- **Oxidation–Reduction Potential (ORP):** Shifted negative, confirming strongly reducing conditions.
- **Geochemical Indicators:** Elevated ferrous iron and reduced species corroborated active reductive processes.

Microbial Response

QuantArray-Chlor monitoring revealed a ≥2-order-of-magnitude increase in dechlorinating organisms and gene functions within 180 days post-injection, verifying enhanced biological activity consistent with the observed contaminant reductions.

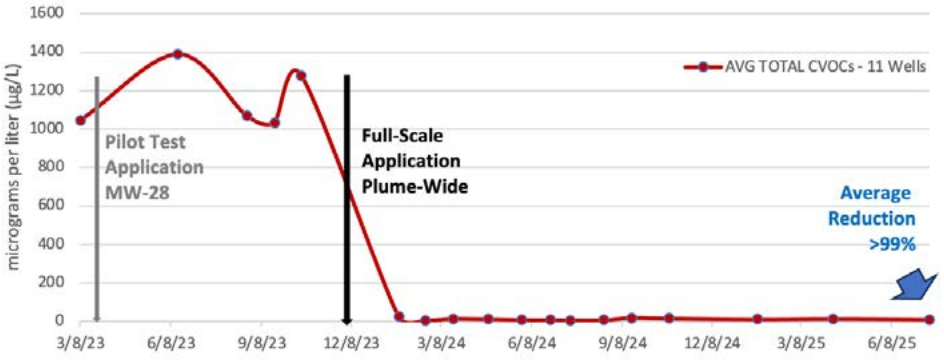
Full-Scale Results

Performance monitoring across 11 wells following the full-scale application showed a plume-wide average reduction of approximately 99% in total chlorinated volatile organic compounds (CVOCs) within one year of injection. Both average and median concentration trends demonstrate a rapid and sustained decrease immediately following the full-scale amendment installation, with concentrations approaching or below regulatory criteria in most wells.

As shown in Figure 7, total CVOC concentrations declined sharply after the December 2023 full-scale application, confirming consistent treatment performance across the site. This rapid mass reduction, maintained over subsequent monitoring events, validates the scalability of the pilot design and the effectiveness of the multi-function amendment blend under variable subsurface conditions.

Figure 7 Total CVOC Concentrations Over Time

Chart shows average total CVOC concentrations from 11 monitoring wells across the site. Steep reductions followed the full-scale application, with plume-wide concentrations decreasing by approximately 99% and remaining stable through 2025.



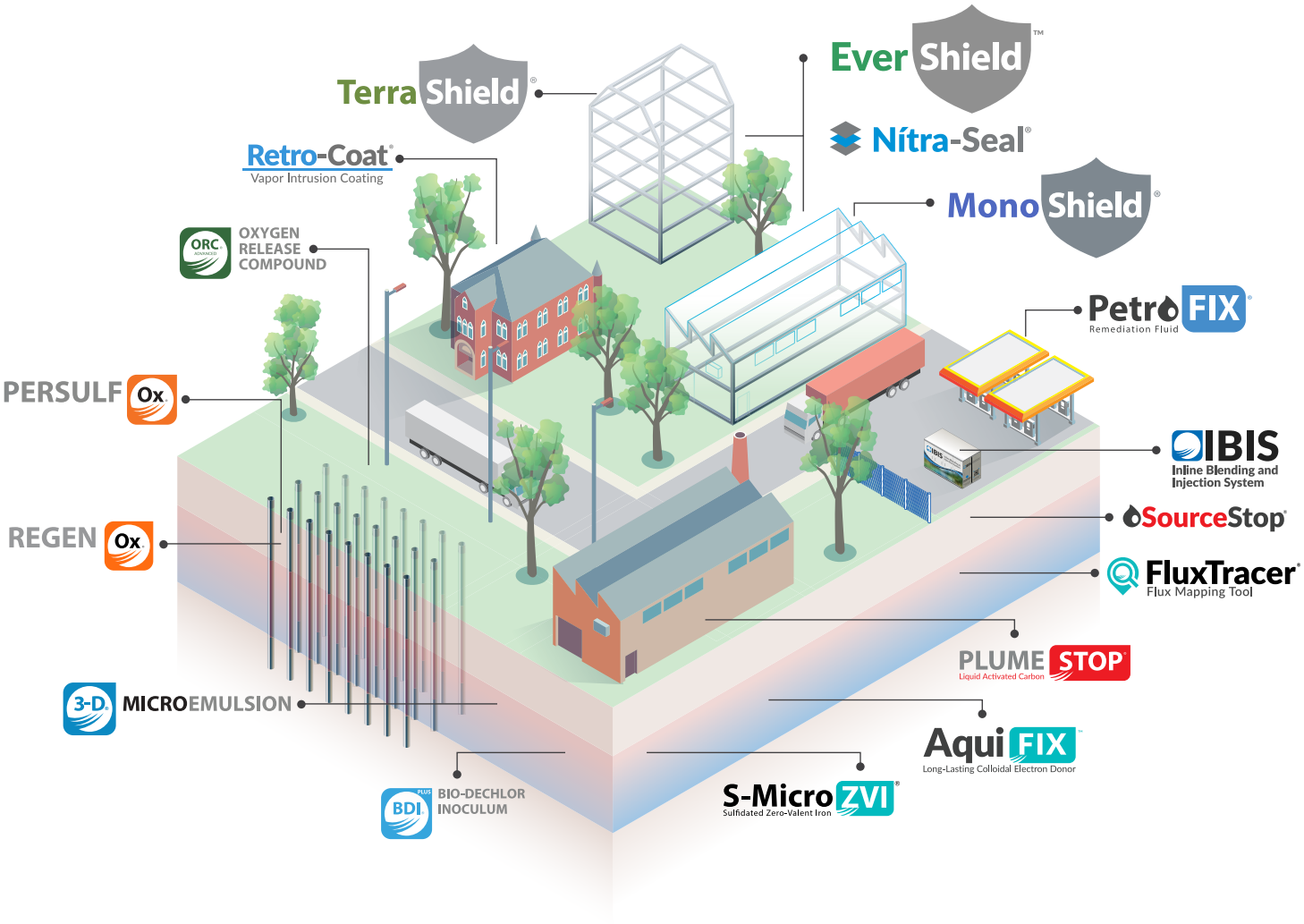
Lessons Learned: Implementation under challenging hydrogeologic conditions yielded several key operational takeaways.

- **Direct-push injection under artesian conditions** was achieved by maintaining low pressures (<30 psi) and flow rates (<5 gpm) and sequencing injections to balance formation loading. These controlled rates were maintained throughout the application, even though the subsurface was predominantly fine-grained.
- **Sorption and abiotic reduction** dominated the early phase; bioremediation became the key driver beyond 90 days.
- **Mass-flux and microbial diagnostics** (FluxTracer and QuantArray-Chlor) proved essential for optimizing design and confirming treatment response.
- The pilot's success supported **full-scale implementation** with 360 injection points using the same multi-function amendment blend.

Conclusion

The Antea Group pilot test demonstrated the effectiveness of an integrated amendment approach that combines sorption, abiotic reduction, and biological degradation to remediate mixed chlorinated solvent plumes under complex geologic and hydraulic conditions. The collaborative work between Antea Group and REGENESIS achieved rapid contaminant reduction, long-term stability, and a scalable design that aligns with redevelopment timelines.

This low-impact, in situ solution minimized disruption to ongoing construction, avoided waste generation, and required no ongoing energy input—accelerating site redevelopment while poising the site for regulatory closure.



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.

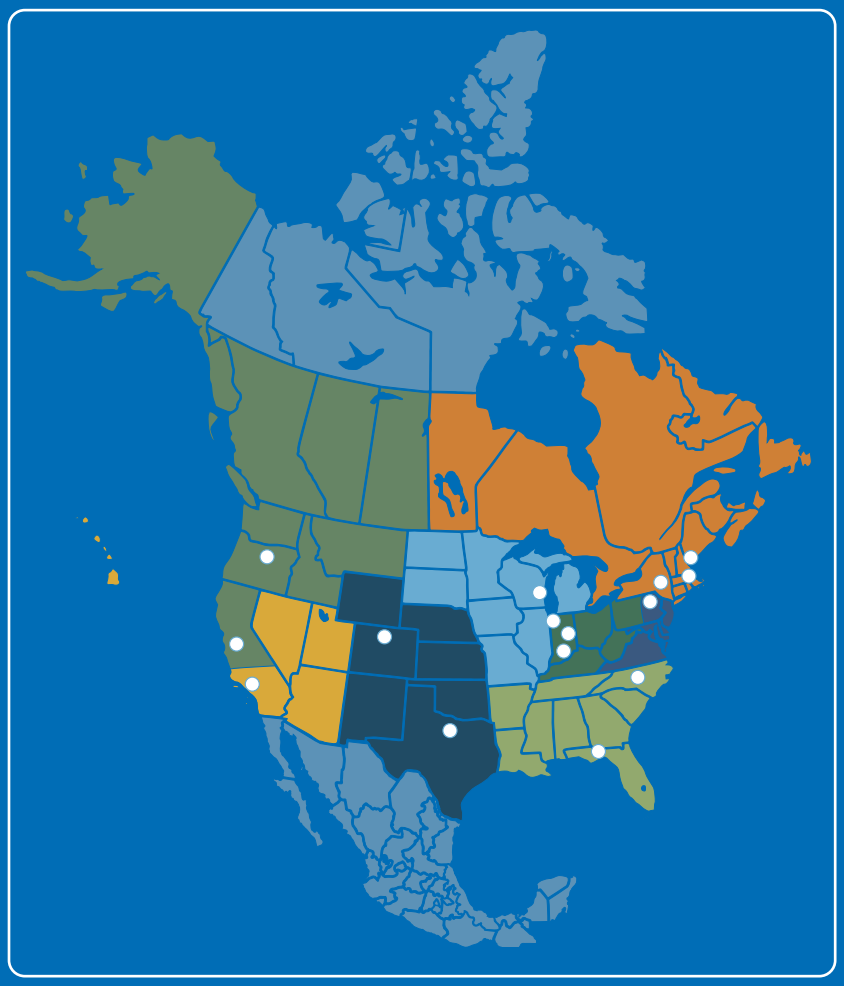
At REGENESIS we are driven by a strong sense of responsibility to the people charged with managing the complex environmental problems we encounter and to the people involved in developing and implementing our technology-based solutions. We are committed to investing in lasting relationships by taking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

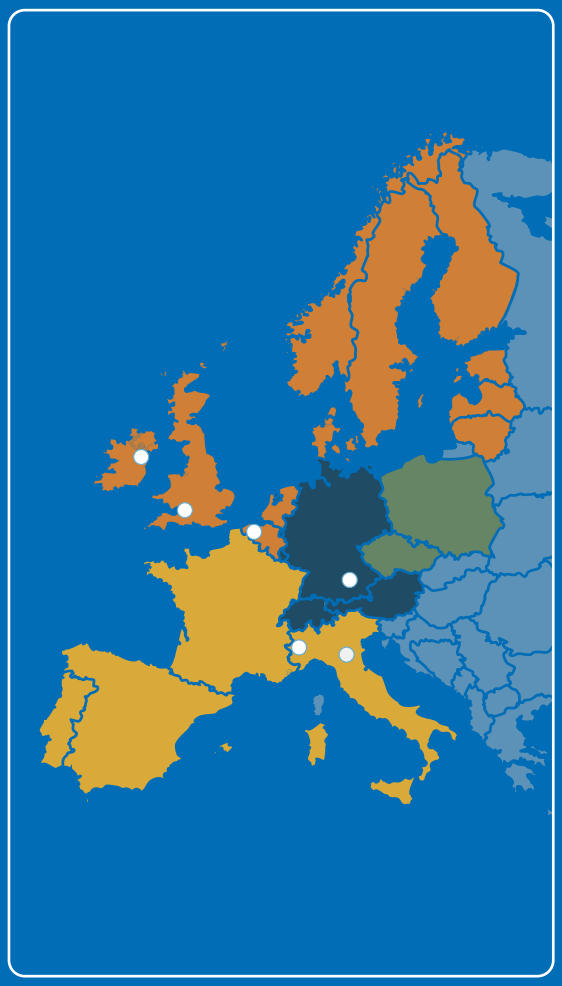
We believe that by acting under this set of values, we can work with our customers to achieve a cleaner, healthier, and more prosperous world.

REGENESIS®

Have a challenge? Let's solve it together.

Contact us today to discuss your specific needs.





Global Headquarters

1011 Calle Sombra
San Clemente, CA 92673 USA

Ph: (949) 366-8000
Fax: (949) 366-8090

Europe

Bath, United Kingdom
Ph: +44 (0) 1225 61 81 61

Dublin, Ireland
Ph: +353 (0) 9059 663

Torino, Italia
Ph: +39 338 8717925

Ieper, België
Ph: +32 (0)498 57 26 90



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