REGENESIS®

Vertase FLI

# High Levels of TCE Remediated at Historic Chemical Works, UK

## *In Situ* Treatment of DNAPL Achieves Remedial Goals


## Summary

3-D Microemulsion (3DME)® and S-MicroZVI® were injected to remediate a highly contaminated chemical factory in the UK, undergoing redevelopment into a new manufacturing and logistics campus. Once considered among the most environmentally contaminated sites in the UK, the site had particularly high levels of TCE contamination in groundwater, with concentrations above 100,000 micrograms per litre (µg/L) in multiple locations, suggesting dense non-aqueous phase liquids (DNAPL) were present.

The combined enhanced reductive dechlorination (ERD) and *in situ* chemical reduction (ISCR) treatment lowered trichloroethene (TCE) concentrations by 85% within a year while also minimizing further cis-1,2-dichloroethene (DCE) and vinyl chloride (VC) generation. The rapid and dramatic reduction of the TCE plume in both magnitude and extent exceeded the remedial goal, surpassing expectations and allowing the site redevelopment to continue apace.

# Project Background

Factory shift change c. 1918

Aerial overview showing the extent of the chemical works in the 1990s

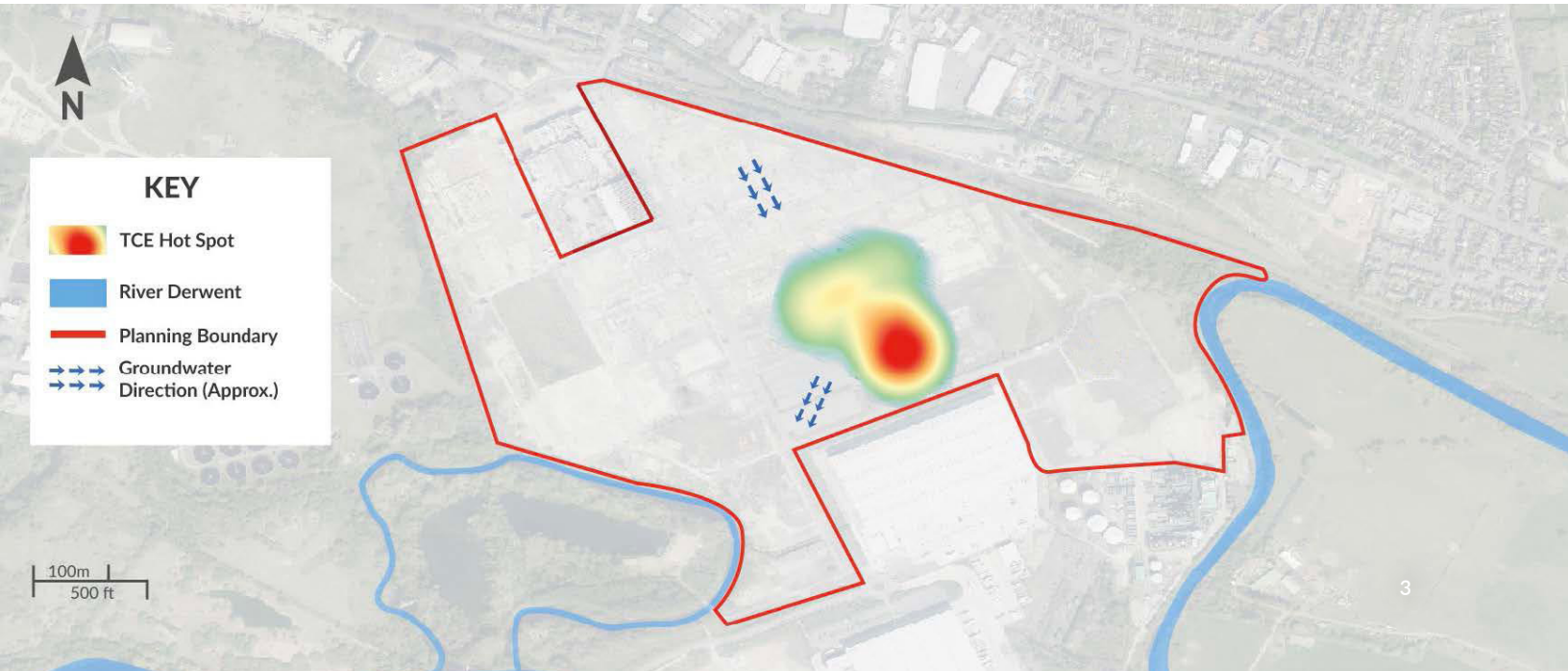
Soil remediation works being carried out by Vertase © Vertase FLI

**Below:** Site plan showing the TCE source zone.

Beginning in 1918, the chemical works quickly grew, employing around 20,000 people in its heyday. When the plant eventually closed in 2012, legacy contamination remained in the soil and groundwater. This included chlorinated solvents - predominantly TCE, resulting from bulk storage leaks and drainage - as well as petroleum hydrocarbons and asbestos. Remediation was required to reduce contaminant mass and mitigate the risk of off-site migration of the chlorinated solvent contamination.

With many site investigations and remediation attempts made over >30 years by other consultants and contractors, Vertase FLI was appointed to undertake the design, management and ultimate sign off of the remediation works which included earthworks, *ex situ* bioremediation, asbestros management and a complex upfront site investigation and verification excercise. Vertase employed REGENESIS to remediate a portion of the site where the groundwater was found to be highly contaminated with TCE and lesser concentrations of cis-1,2 DCE. REGENESIS provided an *in situ* treatment strategy and turnkey solution for the chlorinated solvent source area.

The overall goal for this large contaminant hotspot was mass reduction and improvement of the subsurface environment. This involved showing a declining trend of dissolved-phase TCE and demonstration of ongoing ERD through the analysis of attenuation parameters. However, the challenge here was that the concentrations were so high, that the majority of the TCE mass was contained in the soil and DNAPL phases and not in the dissolved phase. To achieve success, all of the contamination needed to be treated as dissolved phase concentrations quickly equilibrate to the surrounding TCE mass. Thus, the TCE degradation needed to be highly effective at a range of concentrations, provide rapid treatment given the contaminant mass and the short programme, and further daughter product generation needed to be minimised.



## Site Characterisation

Additional site investigation helped target the *in situ* remedial design.

The geology consists of a shallow sand and gravel aquifer over mudstone. Two key source areas had been identified, both dominated by TCE with concentrations ranging from 150,000 – 830,000 µg/L, indicating a DNAPL source. The wider plume, mostly comprised of daughter products, including VC, demonstrating complete reductive dechlorination was likely already occurring in some areas on-site.

Vertase and REGENESIS, working together, decided that a limited pre-remedial site investigation would allow for a more accurate remedial design and ensure the key zones would be targeted. Vertase undertook this work, further delineating the source zone and installing a network of monitoring wells to improve validation. Additionally, prior to commencing the *in situ* treatment, Vertase investigated and removed all potential sources of TCE DNAPL such as drainage runs, foundations and former bulk storage areas.

# Remedial Design

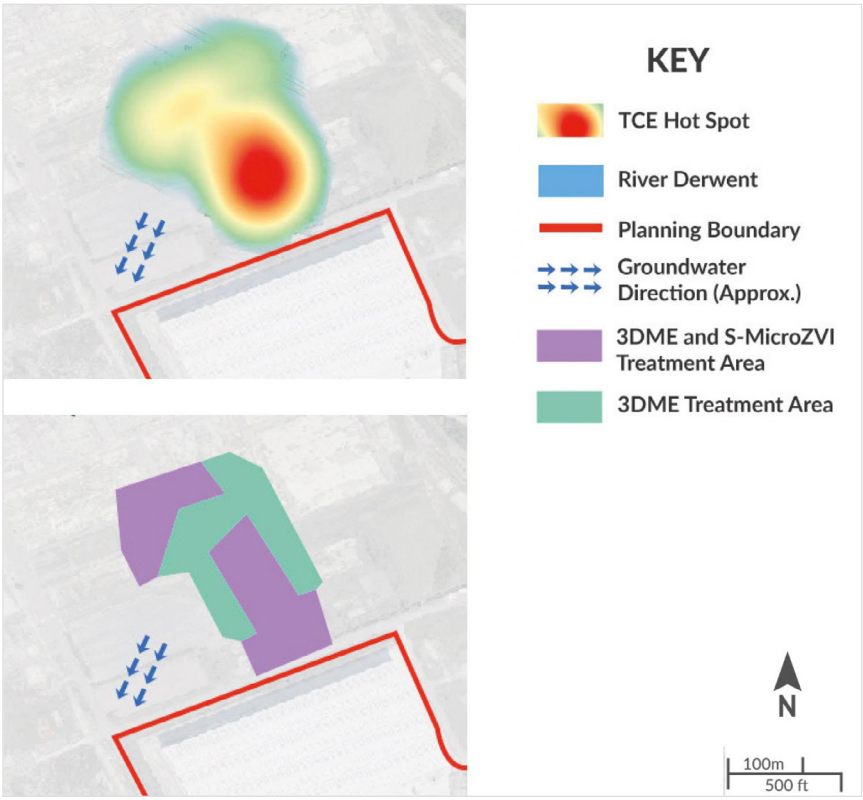
Vertase and REGENESIS worked collaboratively to design a suitable and pragmatic groundwater solution in the context of the redevelopment of the site.

The target area for the remediation was 12,300m$^2$ with a 3.5m vertical interval (2.0-5.5m BGL). For the 8,000m$^2$ TCE-dominated source area, a combined ERD and ISCR approach was adopted, injecting 3DME along the full vertical interval and S-MicroZVI at the base of the gravels to target the zone with the highest contaminant concentrations. This unique, highly efficient, sulfidated zero-valent iron amendment was co-applied with the 3DME in the lower two meters of the injection interval to rapidly boost the abiotic TCE degradation pathway-a process that speeds up TCE degradation and minimises daughter product formation substantially, relative to the biotic ERD pathway.

The wider plume covered 4,300m$^2$ and consisted of lower concentrations and a greater proportion of daughter products. Here, 3DME was used as a standalone technology in an asymmetric grid design to provide the most cost-effective solution. Figure 1

## Figure 1 3DME and S-MicroZVI Treatment Areas

Plan showing the combined 3DME and S-MicroZVI treatment zones and standalone 3DME treatment area.

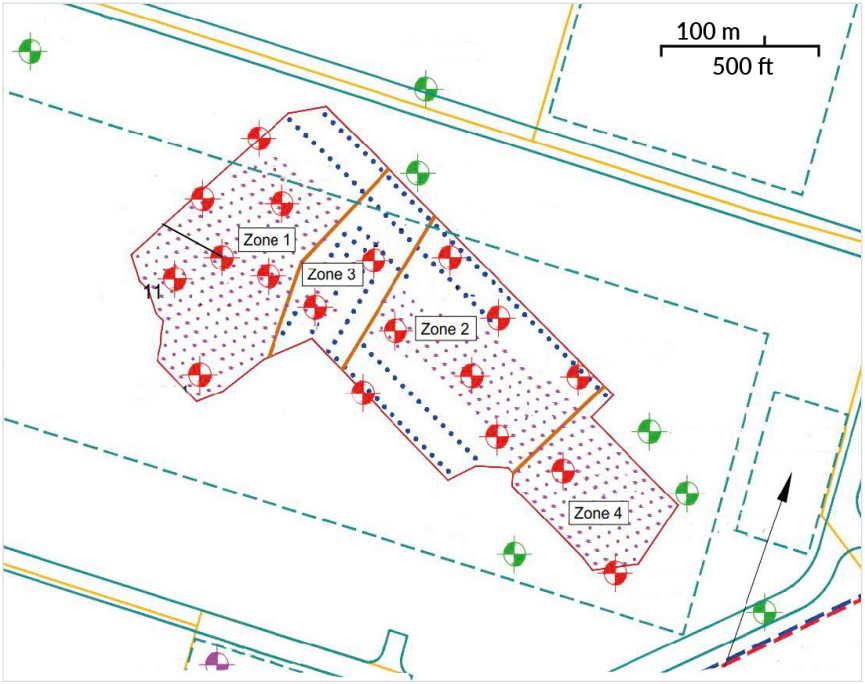



# Application

REGENESIS was employed to complete the injection works using specialised injection equipment developed in-house. The target remediation area was divided into 4 injection zones, based on Vertase's programme for the wider remediation works, so that the injection works could be carried out safely and without hampering the redevelopment. Figure 2

## Figure 2 3DME and S-MicroZVI Treatment Areas

Injection plan showing the zoning and monitoring boreholes




*"The subcontract was really easy to manage. REGENESIS had a great team onsite. We set out the contract ...and it was delivered as discussed and agreed. That was a real pleasure."*

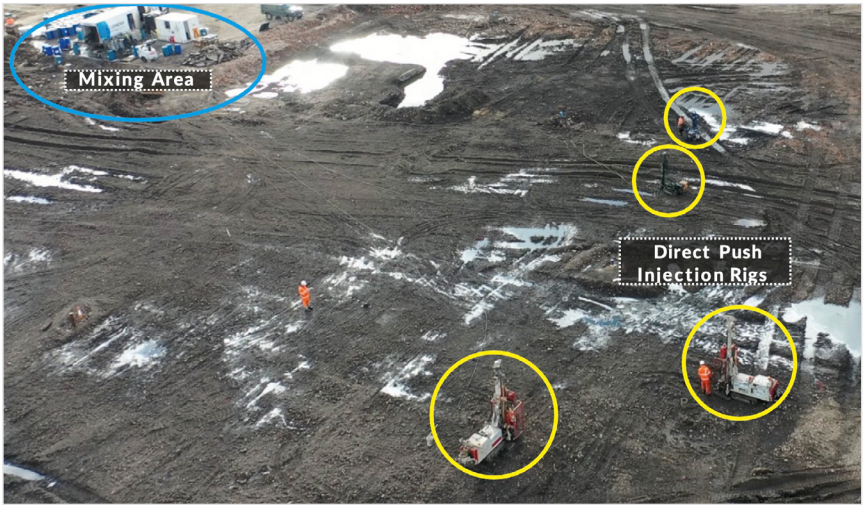
**Claire Lilley,**
Project Director,
Vertase FLI

Using REGENESIS' large mixing trailer, up to 4 direct push injection rigs were operated concurrently to maximise efficiency and minimise time onsite. A total of 248,269L of products were injected across 611 injection points, organised into 4x4m grids (source and plume) and asymmetric rows (plume only).

The injection works were completed within a 12-week period, safely and methodically, minimising risk to the workforce, other contractors working onsite, and the environment. Figure 3

## Figure 3 Onsite Multi-Point Injection

**Onsite Application:** REGENESIS injection trailer and mixing station allowing up to 4 Direct Push injection rigs to be operational at the same time.




*"During the injection works, we were really pleased and impressed there were no Health and Safety (H&S) incidents from the REGENESIS Team.*

*The team took a very high regard for H&S and worked closely with our management team to ensure the works were not only done according to the programme but safely, which is the most important thing."*

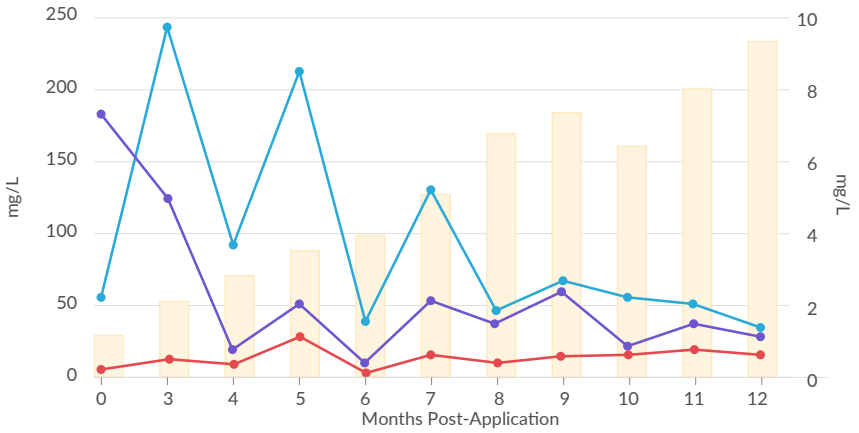
**Alice Roberts**, Bid Manager, Vertase FLI

# Results

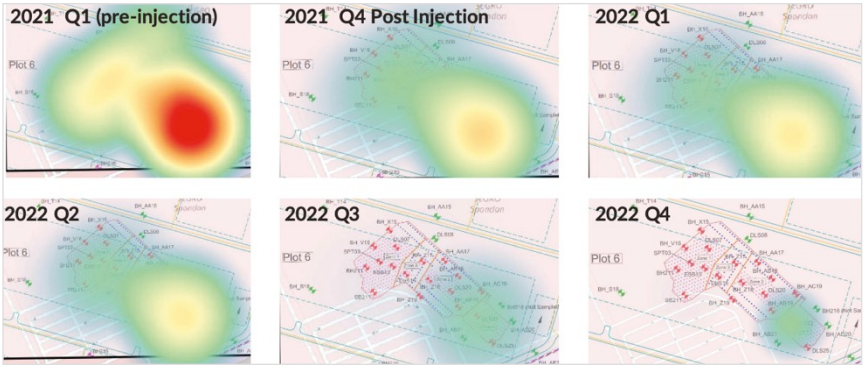
Remediation performance validation over a 12-month period since the 3DME and S-MicroZVI injection showed an 85% reduction in TCE concentrations and significant plume shrinkage, starting from hundreds of parts-per-million concentrations levels. DCE and VC were degraded concurrently. Figure 4 Figure 5

## Figure 4 Average Contaminant Concentrations Over Time

Graph depicts average concentrations of ethene, vinyl chloride, cis-1,2-dichloroethene and trichloroethene over time.




## Figure 5 TCE Hotspot Concentrations Mapped Over Time




Additionally, the following lines of evidence suggested high rates of dechlorination continued to occur and that full mineralisation of the contamination was being achieved:

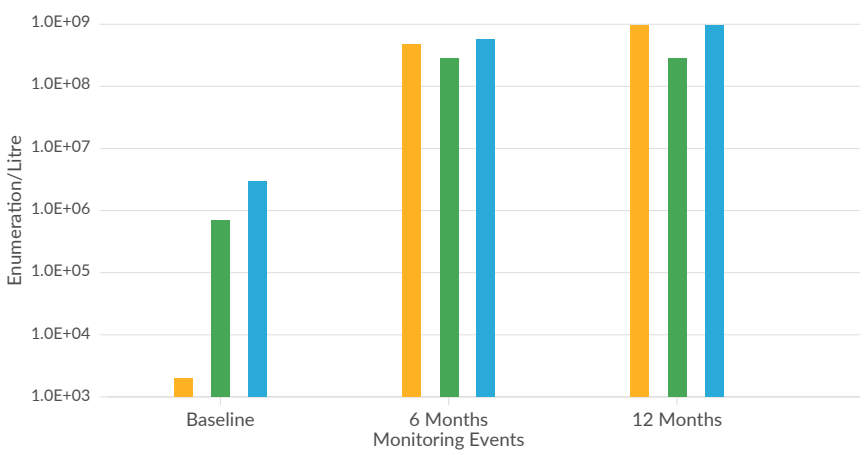
- Ethene concentrations increased throughout the treatment area,
- *Dehalococcoides sp.* (DHC) populations, which were detected prior to the injection, rose between two and five orders of magnitude after the injection, ranging between $10^8$ to $10^9$ cells per litre, and

- Corresponding to the rise in DHC populations, functional genes, including TCE reductase (tceA) and vinyl chloride reductase (vcrA), increased by three to five orders of magnitude post-injection. Figure 6 Figure 7

> *"The microbial analysis demonstrates that the subsurface conditions are suitable for ongoing, long-term, complete reductive dechlorination without VC stall."*
>
> **Alice Roberts**, Bid Manager, Vertase FLI

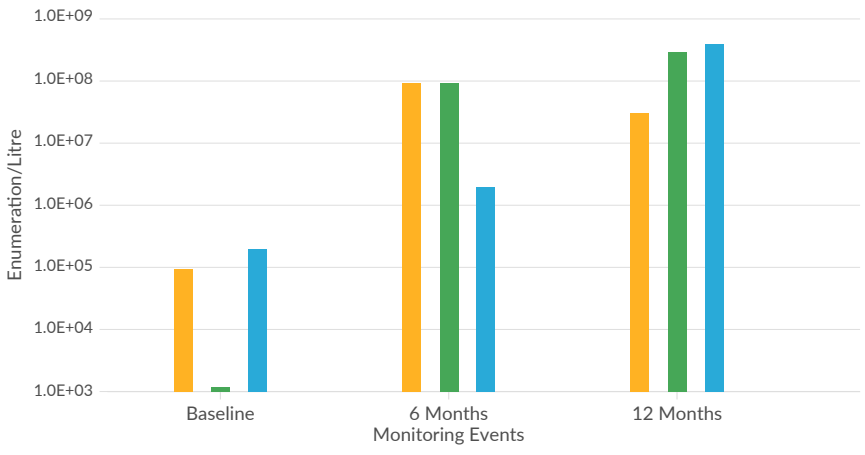
## Figure 6 Dehalococcoides (DHC)

Graph depicting *Dehalococcoides sp.* populations over time




## Figure 7 Vinyl Chloride Reductase (vcrA)

Graph depicting Vinyl Chloride Reductase over time



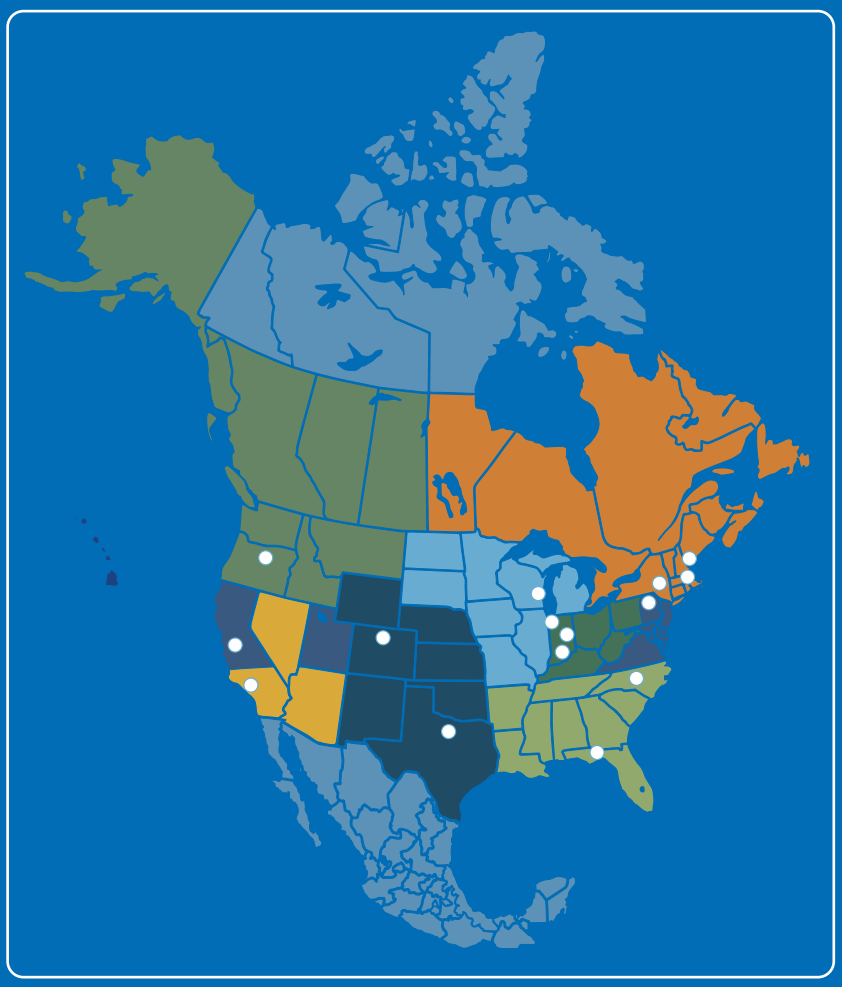
# Conclusion

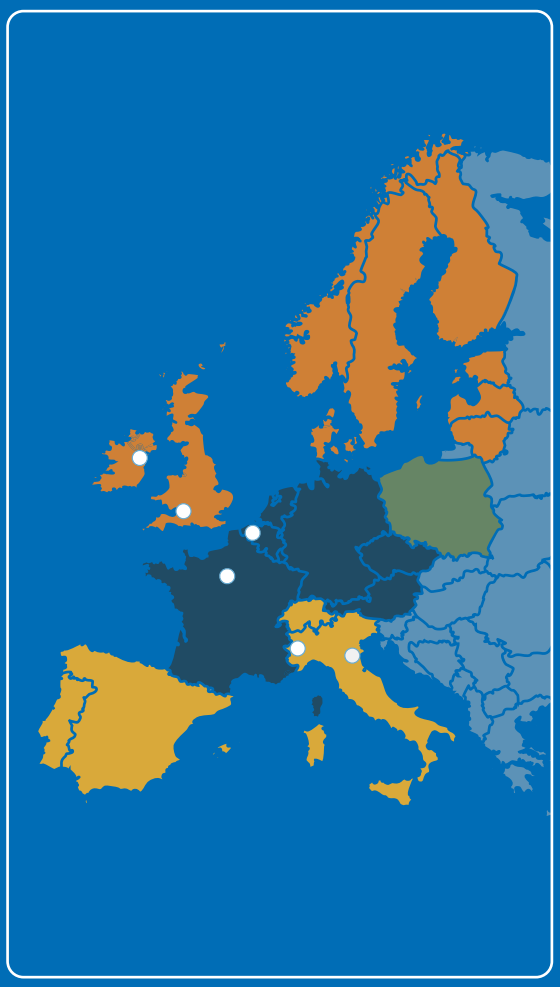
The integrated ERD/ISCR treatment has achieved the site's remedial objectives rapidly and cost-effectively, allowing the site redevelopment to continue apace. The *in situ* application continues to effectively degrade the chlorinated solvent contaminants, reducing the contamination concentrations, overall plume footprint, and exposure risk.

The approach has succeeded in providing effective remediation in a challenging high-contaminant-concentration environment where previous approaches have failed. The treatment serves as a model for an effective plume management strategy for large-scale, high-concentration chlorinated solvent sites, including those with significant DNAPL mass.

REGENESIS®

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






## 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) 57 35 97 28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