REGENESIS®

Combined Remedy Rapidly Achieves Targets to Address Chlorinated Solvent Impacts

CVOC Groundwater Impacts Effectively Treated Using PlumeStop and S-MicroZVI, Expediting Closure

Highlights

Site Type:
Industrial

Project Goal:
Reduce chlorinated VOCs below background levels in soil, soil vapor and groundwater

Contaminants:
Chlorinated VOCs, including up to 400 parts per billion PCE and TCE

Geology:
Silty sand in treatment zone, underlain by low-permeability confining unit

Treatment:
Sorption-enhanced chemical reduction

Technologies:
PlumeStop and S-MicroZVI

Quantity Injected:
>54,000 gallons applied

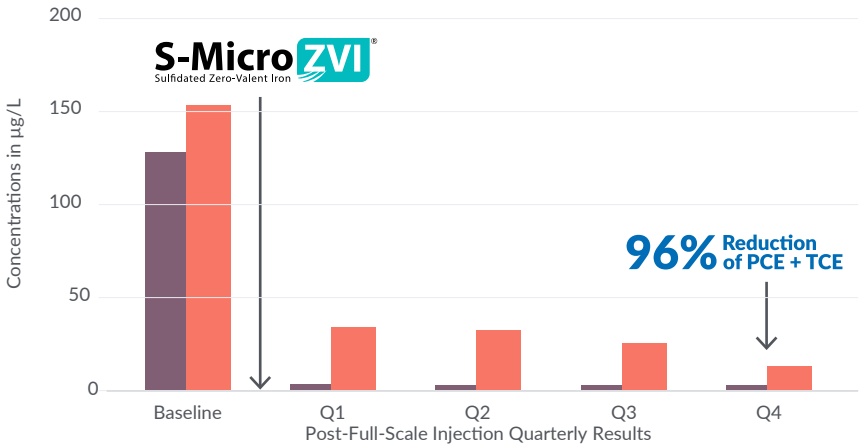
Other Site Considerations
Injections completed below an active commercial business

Summary

A combined remedy to treat chlorinated solvents was implemented at a former printing facility in Southern California. The remediation incorporated PlumeStop and S-MicroZVI injections in the saturated zone and soil vapor extraction in the vadose zone beneath an active commercial business. These remediation efforts led to swift reductions of the PCE and TCE contaminants, including a 96% reduction in shallow groundwater below the site building, reductions to below background contamination levels in offsite groundwater, and a 99% reduction in soil concentrations to achieve the site remediation goals.

Results

- **Groundwater TCE and PCE concentrations reduced by 96%**
- **99% reduction in soil concentrations of PCE and TCE**



Background and Site Characterization

Active Industrial Facility in Southern California Impacted by CVOC contamination

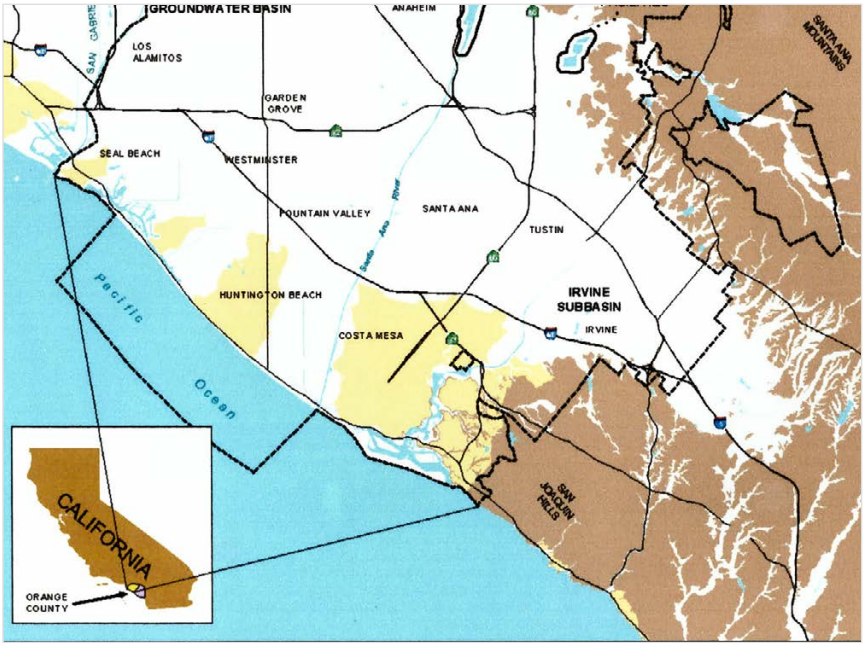
Chlorinated solvent usage at a former printing facility in Orange County, California contaminated the soil, soil vapor, and groundwater with tetrachloroethene (PCE) and trichloroethene (TCE), requiring remediation. Much of the contamination (i.e., the source area) was identified beneath the site building of an active business. Soil vapor sampling completed at the site indicated a vapor intrusion risk due to the contaminant release.

The property owner responded proactively following the discovery, reaching a settlement with the site tenant, and negotiating with the State of California, Santa Ana Regional Water Quality Board (Water Board), the entity responsible for overseeing site remedial activities, for developing a path forward.

Figure 1 Site Location and Timeline

Project Timeline

- **2015**
  Investigations identified Tetrachloroethene (PCE) and trichloroethene (TCE) in groundwater, soil, soil vapor, and indoor air
- **2016**
  Water Board engagement and limited shallow excavation
- **2017**
  Roux retained by property owner
- **2020**
  Feasibility Study and Remedial Action Plan
- **2021-Present**
  Remediation and monitoring



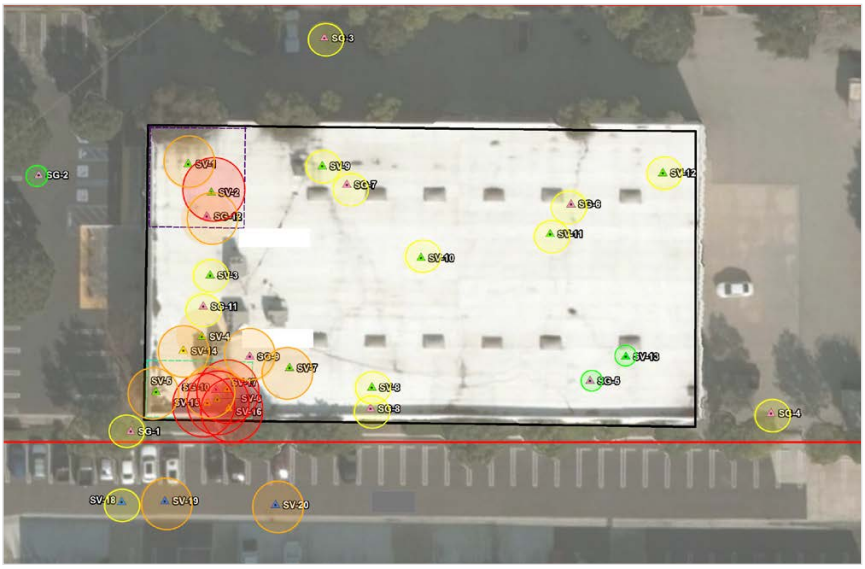
The soil vapor sampling revealed that most of the chlorinated volatile organic compounds (CVOCs) were concentrated beneath the building's southern corner. As an interim response, shallow CVOC impacted soils from this area were excavated and disposed of.

Figure 2

Bubble Plot Diagram

Bubble plot diagram showing logarithmic-scale TCE concentrations in soil vapor beneath the building. PCE in soil vapor (not shown) was similarly distributed.

- ≥ 100,000 µg/m³
- ≥ 10,000 µg/m³
- ≥ 1,000 µg/m³
- ≥ 100 µg/m³
- < 100 µg/m³

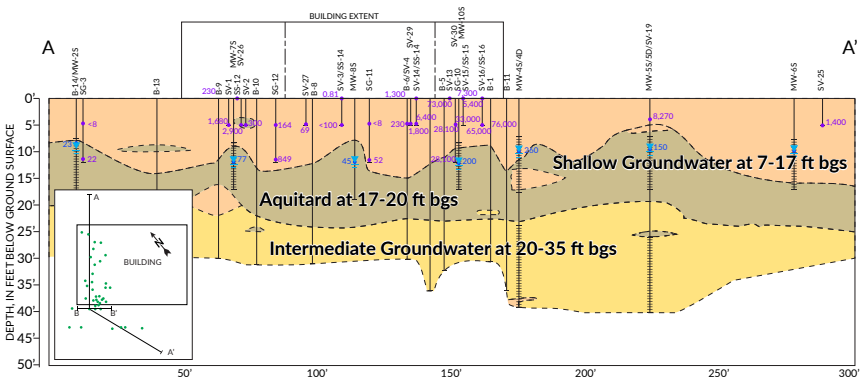


The CVOCs had also impacted the shallow groundwater and migrated beyond the property boundary, exceeding background contamination levels related to an offsite release. An aquitard restrained the contaminants vertically, separating the impacted shallow groundwater from a deeper, intermediate aquifer. This deeper groundwater zone was impacted by a separate, offsite CVOC release source.

Figure 3

Cross Section A-A'

Cross section A-A' shows shallow and intermediate aquifers, separated by an aquitard.



Remedial Approach

A Multi-Faceted Remedial Solution Mitigates CVOC Contamination Beneath an Active Business and Offsite

In 2017, the Client retained Roux, a leading environmental remediation consultant, working from its Long Beach, California office to complete the remediation project.

With access to the contaminants restricted by the building, further remediation efforts had to be coordinated with the site tenant to minimize business interruptions while aggressively advancing the site toward regulatory closure. Specifically, the remedy needed to achieve the following:

- Reduce CVOCs in soil, soil vapor, and groundwater to background contamination levels,
- Minimize disruption to the site tenant occupying the building,
- Coordinate with offsite property owners to complete the work, and
- Complete all work within established budgets and timeframes.

Roux assessed the available remedial strategies to achieve these goals in a 2020 Feasibility Study and Remediation Action Plan (FS/RAP). Alternatives eliminated from consideration in the FS/RAP included thermal treatment, and dual-phase extraction. Ultimately, Roux proposed a multi-faceted remedy targeting media in two areas of concern.

AOC-1 Source Zone	
Media Targeted	Soil vapor and groundwater
Soil Vapor Remedial Approach	Soil vapor extraction (SVE) and sub-slab depressurization (SSDS), beginning with SVE (active vapor removal phase) and ending with SSDS (passive phase)
Shallow Groundwater Remedial Approach	*In Situ* chemical reduction (ISCR) of CVOCs via injection of S-MicroZVI

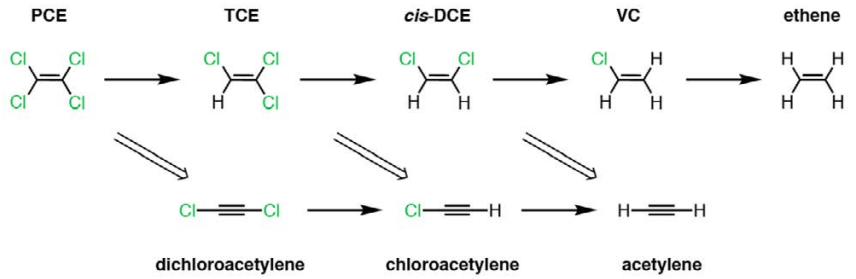
AOC-2 Downgradient Plume at Adjacent Offsite Property	
Media Targeted	Shallow groundwater
Remedial Approach	Halt further CVOC plume migration via sorption-enhanced ISCR by injecting PlumeStop® and S-MicroZVI® to create a permeable reactive barrier (PRB).

S-MicroZVI is a colloidal form of ZVI, less than five microns in size, surface-treated with a reduced sulfur species (i.e., sulfidated) that dramatically improves timelines for ISCR-based remedial pathways to be completed.

Figure 4

Degradation Pathways

Chlorinated ethene degradation pathways and products. The top pathway with single-line arrows represents the reductive dechlorination (hydrogenolysis) pathway. The lower pathway with downward-facing double-line arrows is the beta-elimination pathway.



In the PRB, the co-application of PlumeStop and S-MicroZVI combines a massive surface area for contaminant sorption with the rapid degradation of CVOCs to non-toxic end products such as ethene, ethane, and CO2. These end products, which do not bind to carbon, free up PlumeStop's sorption sites on the aquifer matrix. As PlumeStop is regenerated, the PRB's treatment capacity is further extended.

Aggressively remediating CVOCs in the source zone (AOC-1) eliminates the continuing CVOC mass flux into the near downgradient plume (AOC-2), leaving only the residual contaminants between AOC-1 and AOC-2 for PRB treatment. In this manner, the combined remedy permanently addresses the exposure risk to onsite or potential offsite receptors.

The strategy presented in the FS/RAP was subsequently approved by the Water Board, following completion of the Waste Discharge Requirements (WDR) permitting deliverables and a 6- to 12-month-long approval process. In addition, the approach required City approval prior to implementation, which oversaw site activities throughout the project.

Remedy Implementation

Successful Application Overcomes Challenging Site Conditions

REGENESIS Remediation Services (RRS) implemented the remedies in the shallow groundwater, including design verification testing (DVT), between March 2021 to June 2022. RRS completed the DVT phase in March 2021 and the full-scale application at AOC-1 and AOC-2 in January and May 2022, respectively.

DVT included the installation of Passive Flux Monitor™ (PFM) devices installed at the PRB location to attune mass flux estimates for amendment dosing, injection testing to assess amendment distribution, and soil core collection to confirm the injection interval, along with baseline CVOC and geochemical sampling.

During DVT mobilization, S-MicroZVI was also applied to 20% or 1,000 square feet of AOC-1. The drilling work was completed in an office area with low overhead clearance, requiring a compact hydraulic percussion (i.e., direct push) rig for the injections, operated by Legacy Remediation (Legacy). The work required significant coordination between the tenant, Roux, Legacy, and RRS in order to ensure a safe and healthy work environment for all involved.

During the application, RRS controlled the delivery of amendments to the target injection zone, maintaining low injection pressures averaging less than 20 pounds per square inch (psi), limiting the amendments' surfacing around only a few boreholes.

RRS safely completed the S-MZVI/PlumeStop injections under the time allotted by the project schedule while coordinating the work with the site tenant, achieving the minimal-disruption goal.

To remediate soil vapor CVOCs, Roux installed the SVE system in April 2021, orienting the system to accommodate soil vapor impacts and building occupancy. Roux's innovative design allowed for transitioning to the passive SSDS approach following bulk CVOC vapor removal by the SVE system.

Figure 5 AOC-1 Application Details

Treatment Area	
Treatment Surface Area	5,000 ft²
Target Vertical Interval	7-17 ft bgs
Injection Points	38

S-MicroZVI Injections	
Mass	4,700 lbs
Solution	24,740 gal
Avg. Injection Pressure	15 psi

Application Dates	
March 2021	◉ Initial 20% DVT phase
January 2022	◉ Full-scale 80% phase

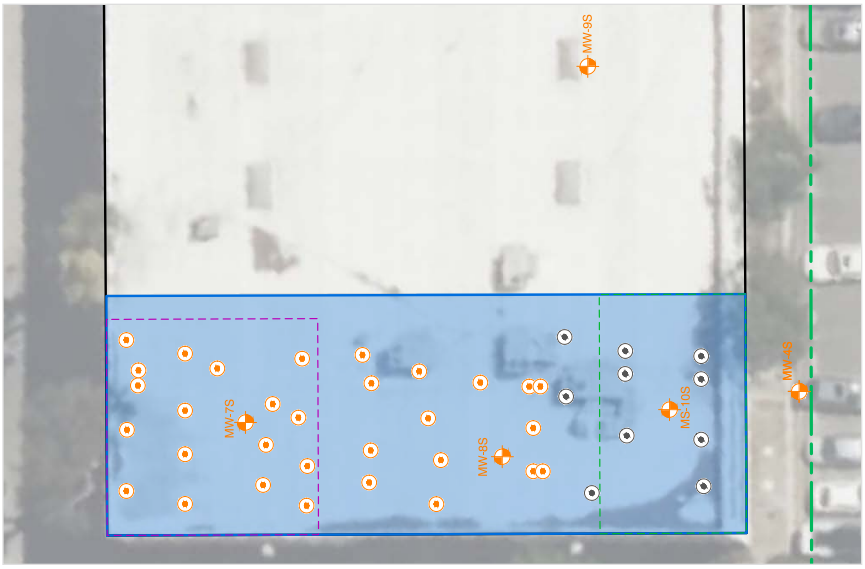
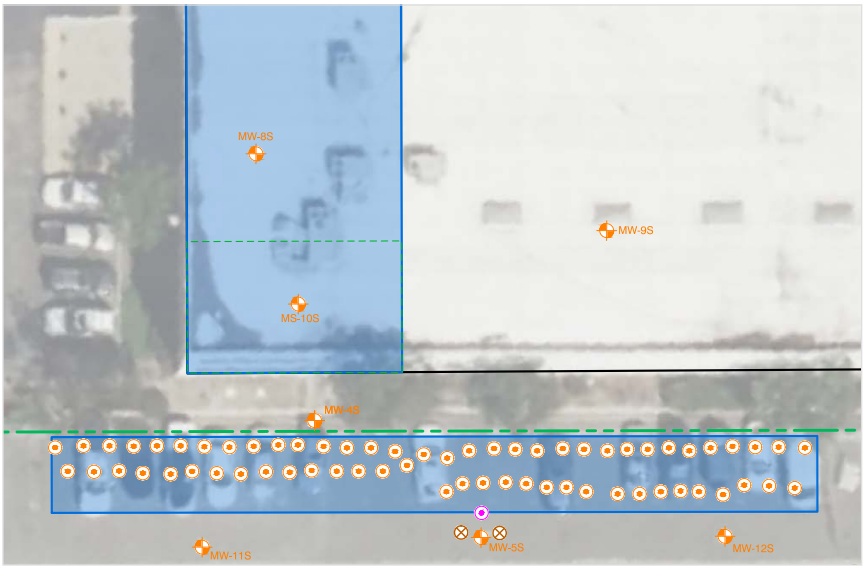


Figure 6 AOC-2 Application Details

Barrier Application	
Barrier Length	200 ft
Target Vertical Interval	8-18 ft bgs
Injection Points	67

Amendments Injected	
PlumeStop	11,200 lbs
S-MicroZVI	4,000 lbs
Avg. Injection Pressure	12 psi
Total Volume	29,480 gal

Application Dates	
March 2021	DVT phase
May 2022	Full-scale phase



Results and Conclusions

Remedy Quickly Reduces CVOC Concentration Below Targets, Priming Site for Future Closure

The groundwater monitoring well network used to measure performance included three wells inside AOC 1 (MW-7s, MW-8s, and MW-10s) and three wells immediately downgradient of the PRB installed at AOC-2 (MW-11s, MW-5s, and MW-12s). Soil vapor sampling has been completed to document changes in CVOC soil vapors. The remediation has resulted in the following results.

96% **Reduction of PCE + TCE**

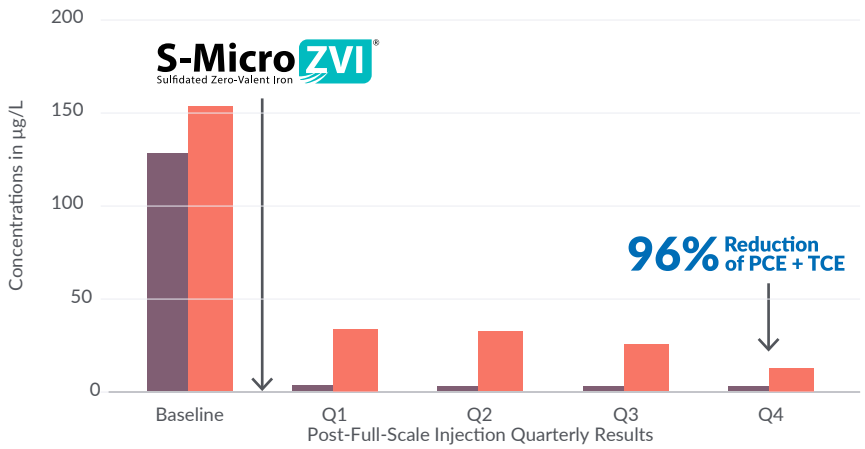
AOC-1 S-MicroZVI Source Area Groundwater Treatment:

PCE and TCE concentrations have been reduced by an average of 99% and 94%, respectively, resulting in a total CVOC reduction of 96% and below area CVOC background levels after four quarters of performance monitoring.

Figure 7

AOC-1 Average PCE and TCE

Average PCE and TCE concentrations in MW-7s, MW-8s, MW-10s



AOC-2 PlumeStop/S-Micro ZVI PRB:

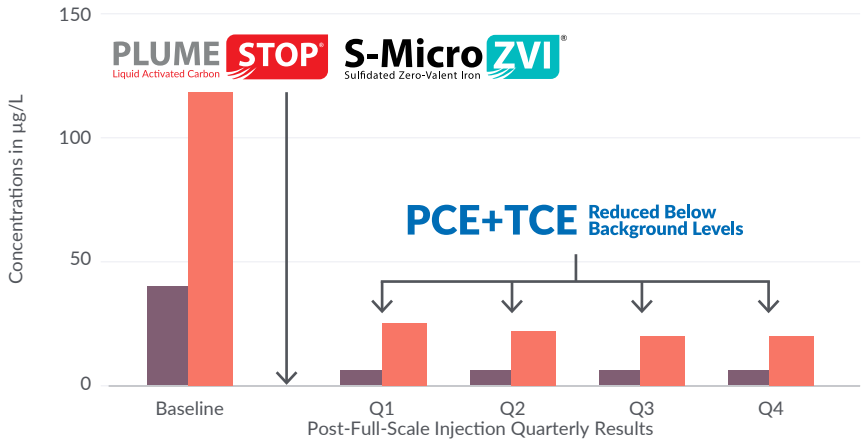
The PlumeStop and S-MicroZVI barrier has reduced PCE and TCE concentrations below the background levels related to the offsite CVOC source(s) through four quarters of monitoring. These results obtained from the near-downgradient performance monitoring wells demonstrate that the barrier is meeting its performance goal, effectively stopping the CVOC contaminant flux from the site.

Consistent with other sites where S-MZVI was used to facilitate ISCR, the rapid and sustained PCE and TCE reductions at AOC-1 and AOC-2 were achieved without forming significant concentrations of daughter products cis-1,2-dichloroethene (cis-DCE) and vinyl chloride (VC).

Figure 8 AOC-2, Average PCE and TCE

Average PCE and TCE concentrations in MW-11s, MW-5s, and MW-12s

- TCE - Average
- PCE - Average



99% **Reduction of PCE + TCE**

AOC-1 SVE Treatment of Soil Vapors

The SVE system installed at AOC-1 has reduced PCE and TCE concentrations by 99% in the sub-slab and vadose zone, eliminating the potential for significant further vapor intrusion.

With the first year of performance monitoring now completed, Roux is petitioning the Water Board to allow permanent SVE system shutdown and removal of the SVE system at AOC-1. The SVE system operated

for less than one year. Moving forward, the SSDS approach (using the same SVE system piping) will continue to mitigate CVOCs passively in the soil gas.

Operations, maintenance, and monitoring (OM&M) activities will continue at AOC-1, concurrent with performance monitoring of the PRB at AOC-2.

The combined remedy has thus far achieved its goals, reducing CVOC concentrations in the treatment areas below the area-wide background levels in the groundwater and soil gas, and setting the site up for future closure. By using the best available technologies to achieve the Client's goals, the project reflects Roux's effectiveness and experience in providing comprehensive remedial solutions for legacy CVOC releases while overcoming challenging site conditions.

About the Consultant

Roux

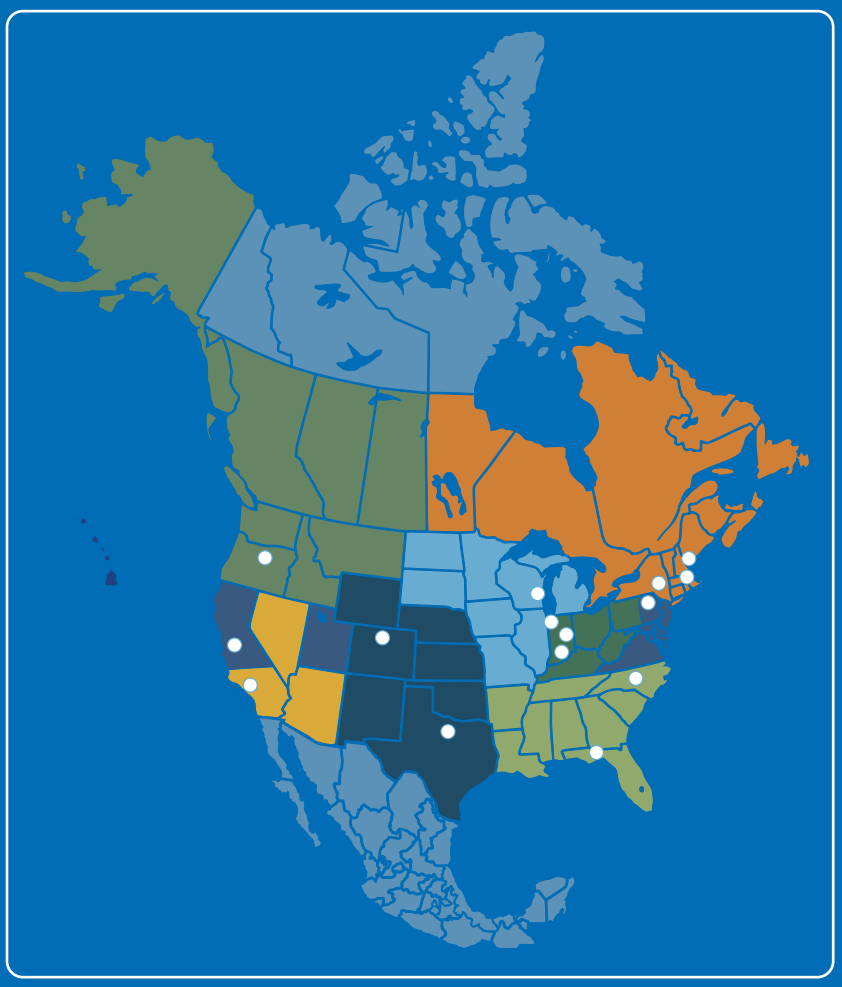
The Roux organization applies sophisticated scientific, technical, and managerial resources to develop and implement effective, efficient, and sustainable solutions to their clients' most challenging environmental and environmentally related health and economic issues. Roux provides their advisory, compliance, and field services to a broad spectrum of both private and public sector clients nationwide, including numerous Fortune 500 companies and their associated law firms.

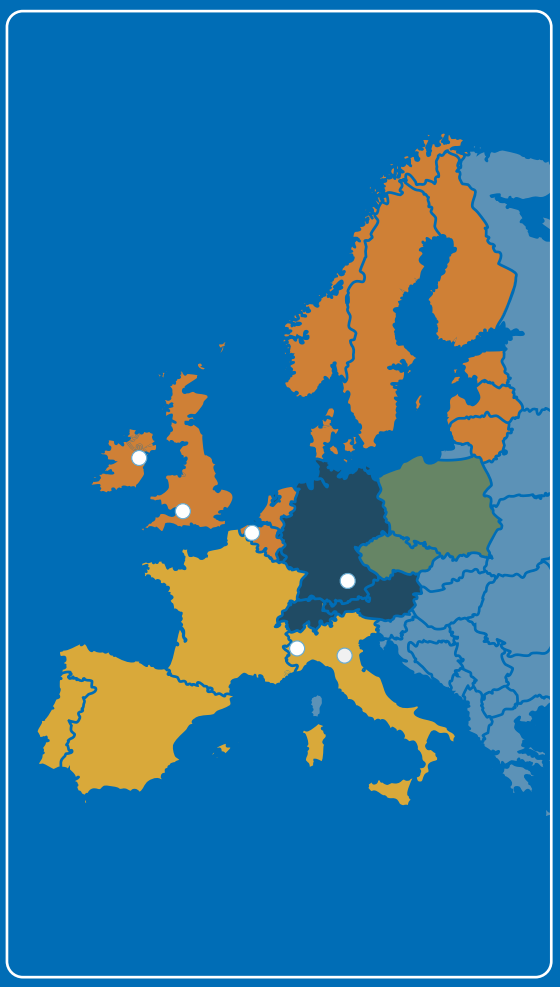
Founded over 40 years ago, Roux was built upon management and cleanup of large, complex environmental remediation projects, including Superfund sites, chemical and manufacturing plants, and petroleum refineries and distribution terminals. Today, Roux offers a much broader array of consulting services as an employee-owned company with over 400 environmental, health & safety, and economic professionals in a variety of science, economic, and engineering disciplines. Roux's clients span sectors in Real Estate; Financial; Manufacturing/Industrial; Energy; Legal; Insurance; Government/Municipal; Environmental, Social, and Governance (ESG); and Water Resources.

April McGuire

April McGuire graduated from UCLA with a B.S. in Chemical Engineering and is based in the Los Angeles area. She is a Senior Engineer at Roux where she manages various types of projects, including remediation, site investigation, vapor intrusion mitigation systems (VIMS) design, and litigation support. She loves the diverse work which always brings new challenges and opportunities for growth, and she prides herself on providing exceptional service to every client she works with.

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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www.REGENESIS.com