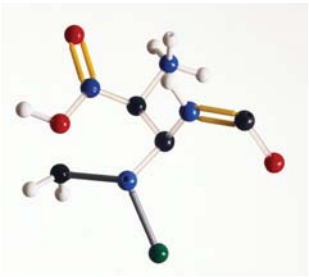
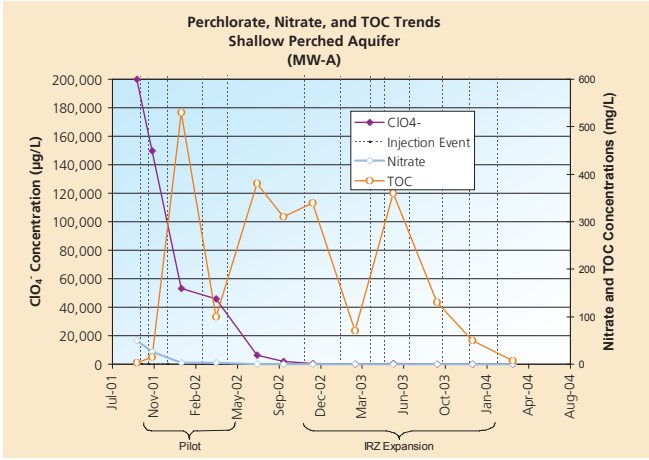
# PERCHLORATE



*Above:*
Perchlorate molecule




- **Project goal:**
  To Develop a comprehensive strategy for site remediation, utilizing innovative and cost-effective technologies.
- **ARCADIS strategy:**
  Reduce source area soil and shallow groundwater impacts, implement interim measures in deep aquifer to contain plume on-site, resolve data gaps and finalize site-wide remedial program.
- **Project Accomplishments:**
  Successful anaerobic IRZ pilot test for perchlorate treatment, expanded to full-scale implementation (99% reduction of perchlorate concentrations in 1 year).

  Successful anaerobic IRZ pilot test for concurrent remediation of perchlorate, $Cr^{6+}$ and TCE.

  Field test currently underway to treat unsaturated soils for perchlorate using anaerobic IRZ technology.

**Scope of Services**
Environmental monitoring
Site strategy development
Pilot study design / implementation
Full-scale design / implementation
Operation and maintenance
Regulatory negotiations

**Performance Period**
November 2000 to present

**Contaminants:**
CVOCs (primarily TCE and daughter products), hexavalent chromium

*ARCADIS was contracted in 2000 to lead the development, evaluation and selection of a final groundwater remedy for this 94-acre site in California. As part of this work, ARCADIS is also participating in the evaluation of innovative technologies with the potential to treat soil impacts in the multiple source areas across the site.*

*Specifically, the project is focused on the remediation of seven source areas and their associated groundwater plumes, some of which are commingled and are comprised of multiple contaminant types. The complexity of the contaminant distribution and the need to avoid the disruption of site operations has presented a significant remedial challenge.*

**Background**

The site has produced small explosives and vehicular safety products since 1957. As a result of the historic operations, soil and groundwater at the site has been impacted by perchlorate, trichloroethene (TCE) primarily, and hexavalent chromium ($Cr^{6+}$).

The site is underlain by

alluvial/colluvial deposits consisting of interbedded sand, silt, and clay. There are three water bearing zones at the site; a shallow unconfined aquifer, and two deeper confined aquifers. Groundwater in the shallow aquifer is encountered at approximately 40 feet below land surface (bls) with perched conditions present in some areas. The most significant impacts to groundwater are present in the shallow aquifer. Consequently, much of the remedial effort completed to date has focused on this aquifer. A strategy is currently being developed to address impacts in the deeper aquifers, which extend up to 400 feet bls.

Source area soils have been found to contain perchlorate concentrations as high as 1,500 milligrams per kilogram (mg/kg), TCE as high as 6.5 mg/kg, and $Cr^{6+}$ as high as 0.084 mg/kg. Concentrations of these same contaminants in shallow groundwater have been detected up to 500 milligrams per liter (mg/L), 90 mg/L, and 0.25 mg/L, respectively.

Previous groundwater remediation efforts have been limited in scope with modest results. A two-well shallow groundwater pump-and-treat system was installed in 1994. Performance data indicates this system is providing marginal mass removal and only localized hydraulic containment. In addition, a bioremediation pilot test was conducted using hydrogen release compound (HRC®) to treat TCE. The HRC® failed to remediate TCE within the test area, but resulted in significant reduction of perchlorate and $Cr^{6+}$.

### The ARCADIS Approach

Since November 2000, ARCADIS has designed, pilot-tested, and implemented a series of innovative interim corrective actions utilizing both in-situ chemical oxidation and anaerobic IRZ technology. The interim corrective actions were designed to reduce contaminant mass while ARCADIS developed a long-term comprehensive remedial strategy for groundwater consisting of the following steps:

1) Reduce source area soil and shallow groundwater impacts and associated mass loading to deeper aquifers to improve groundwater quality and reduce offsite migration.

2) Implement interim deep aquifer measures to reduce COC mass in on-site source areas and contain the existing off-site plume.

3) Resolve groundwater data gaps and produce a comprehensive hydrogeologic model to evaluate and select the most cost effective COC mass remediation and containment approach.

In keeping with this strategy, ARCADIS has worked diligently with the client and regulatory agency to provide guidance toward managing risk associated with continued use of regional groundwater for domestic and agricultural irrigation purposes.

### Project Accomplishments: Groundwater

Based on IRZ pilot test results for shallow groundwater, the technology has been specified as a corrective action for three additional source areas. Additionally, IRZ technology is being used to create a reactive barrier to mitigate the offsite migration of impacted groundwater. Details regarding these efforts are provided below.

- IRZ Pilot Test for Perchlorate

  In September 2001, ARCADIS began an in-situ reactive zone (IRZ) pilot study to demonstrate anaerobic bioremediation of perchlorate in perched groundwater. The area selected for the test contains the highest perchlorate concentrations site-wide.

Nitrate-reducing conditions were established within 30 days using an injection solution consisting of corn syrup and water. Within 1 year the IRZ was expanded to a full-scale implementation addressing the core of the perchlorate plume in this area. Pre-treatment perchlorate concentrations ranged as high as 200,000 to 500,000 µg/L. Following the initial injection of diluted corn syrup in the demonstration area, perchlorate concentrations were reduced by 99 percent within one year. *(See data trend for MW-A.)*

## ■ IRZ Pilot Test for Perchlorate, TCE and $Cr^{6+}$

In August 2002, ARCADIS implemented the IRZ technology for the concurrent reduction of perchlorate, TCE, and $Cr^{6+}$ in shallow groundwater. Baseline contaminant concentrations in this area ranged as high as 7,500 µg/L for perchlorate, 6,000 µg/L for TCE, and 20 µg/L for $Cr^{6+}$.

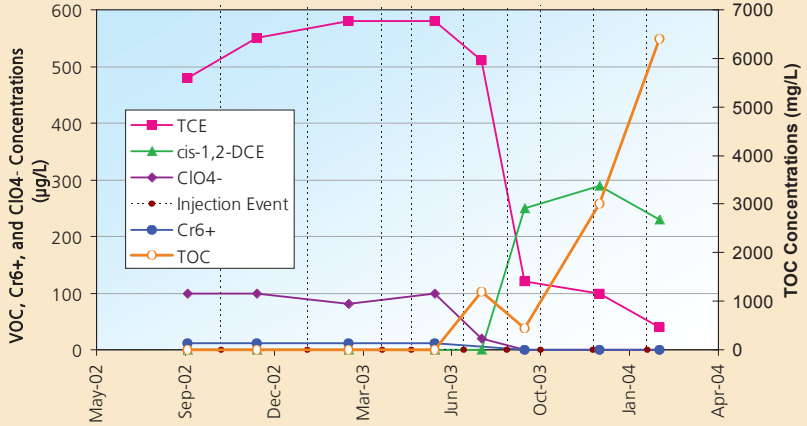
Perchlorate concentrations were reduced by as much as 90 percent within the first 18 months following initiation of the pilot test. Concurrently, hexavalent chromium was reduced to concentrations below the laboratory limits of detection (<0.5 µg/L) throughout most of the treatment area. Increased carbon loading has now begun the process of enhanced reductive dechlorination of TCE. TCE concentrations have dropped by 92 percent with a corresponding increase in cis-1,2-dichloroethene (cis-1,2-DCE), which is also beginning to decline in concentration. *(See data trend chart for MW-B.)*

## ■ Ozone Sparging Pilot Test for TCE

In January 2002, ARCADIS installed an ozone sparging system to address TCE-impacted groundwater underlying a former septic tank where the highest site-wide VOC concentrations are detected. An air and ozone blend is delivered through vertical injection points to the shallow and deeper aquifers. Ozone is sparged into the impacted areas to enhance the sparging process by promoting chemical oxidation via the direct subsurface contact of ozone and VOCs. A soil vapor extraction system managed by another consultant works in tandem with the ozone system to capture VOC laden vapors generated by the sparging process.

Pre-treatment TCE concentrations within the pilot study area ranged as high as

**TCE, c-DCE, Perchlorate, $Cr^{6+}$, and TOC Trends**
**Shallow Perched Aquifer**
**(MW-B)**



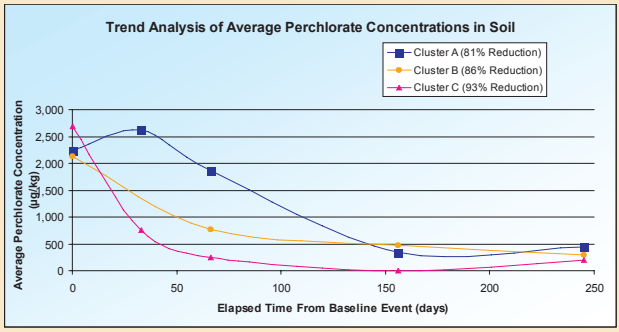
30,000 µg/L in groundwater. Within two years of operation, TCE concentrations have decreased by as much as 97 percent within certain portions of the treatment area. System optimization is ongoing. *(See data trend chart for MW-C.)*

## Project Accomplishments: Soil

In December 2003, ARCADIS initiated an IRZ pilot study to demonstrate anaerobic treatment of perchlorate-impacted vadose zone soils. During a one-time event, dilute corn syrup and ethanol solutions were injected in two separate areas, saturating the uppermost 40 feet of soil in an area measuring 40-feet x 30-feet. The dilute solutions delivered organic carbon to promote the microbial reduction of perchlorate.

- Preliminary results indicate that perchlorate concentrations dropped by nearly 50-percent within the first 2 months following the injection event. This study is still in progress. ARCADIS expects the results of this pilot study to qualify IRZ technology as a viable low-cost strategy for consideration during the remedy selection process.

*Above* In-situ anaerobic soil field demonstration.




*Above*: Overall average perchlorate concetrations with Clusters A, B and C decreased by 81percent, 86 percent and 93 percent, respectively, within 8 months following the injection event.