# Thermal Remediation Services, Inc.

## *Electrical Resistance Heating for In-Situ Remediation of Soil & Groundwater*

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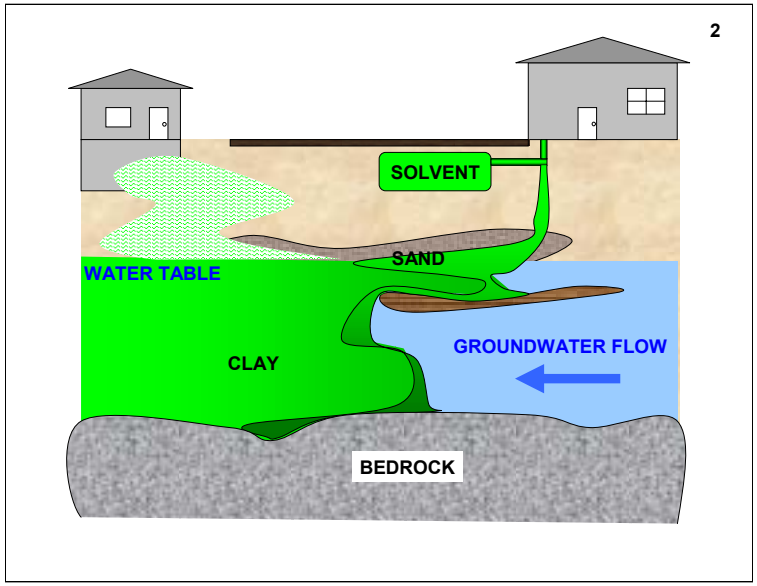
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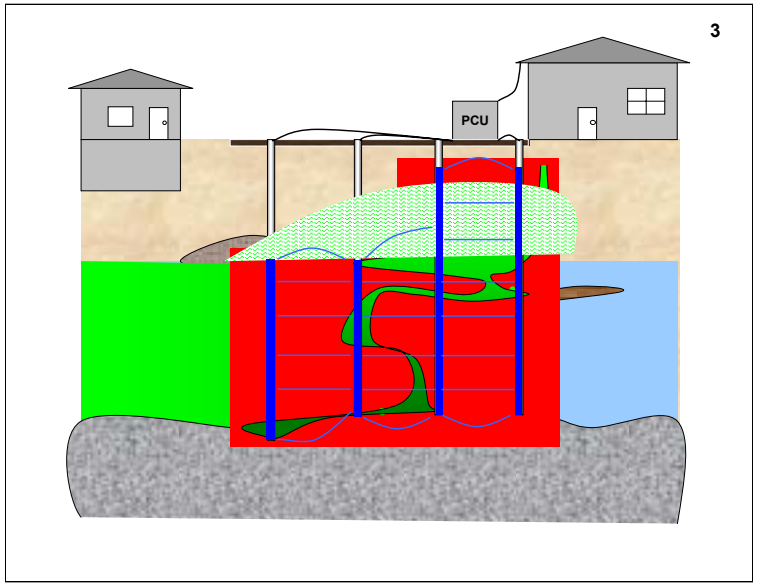
SOLVENT
SAND
WATER TABLE
GROUNDWATER FLOW
CLAY
BEDROCK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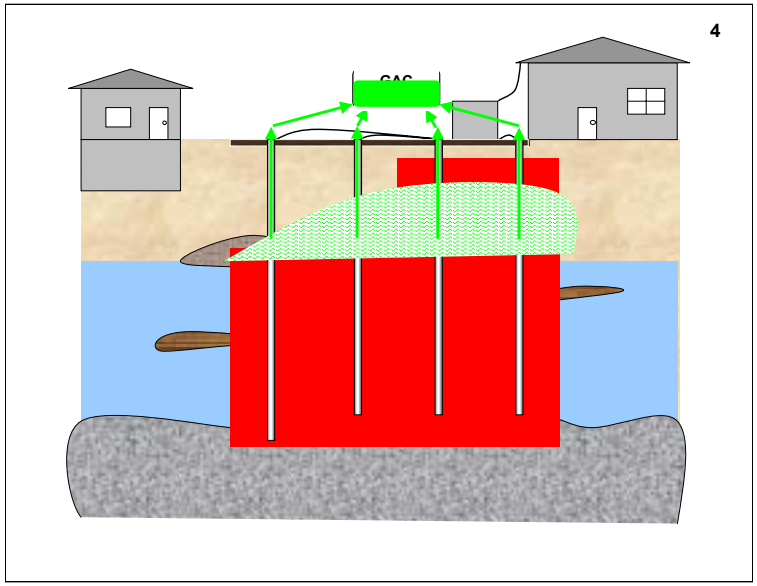
PCU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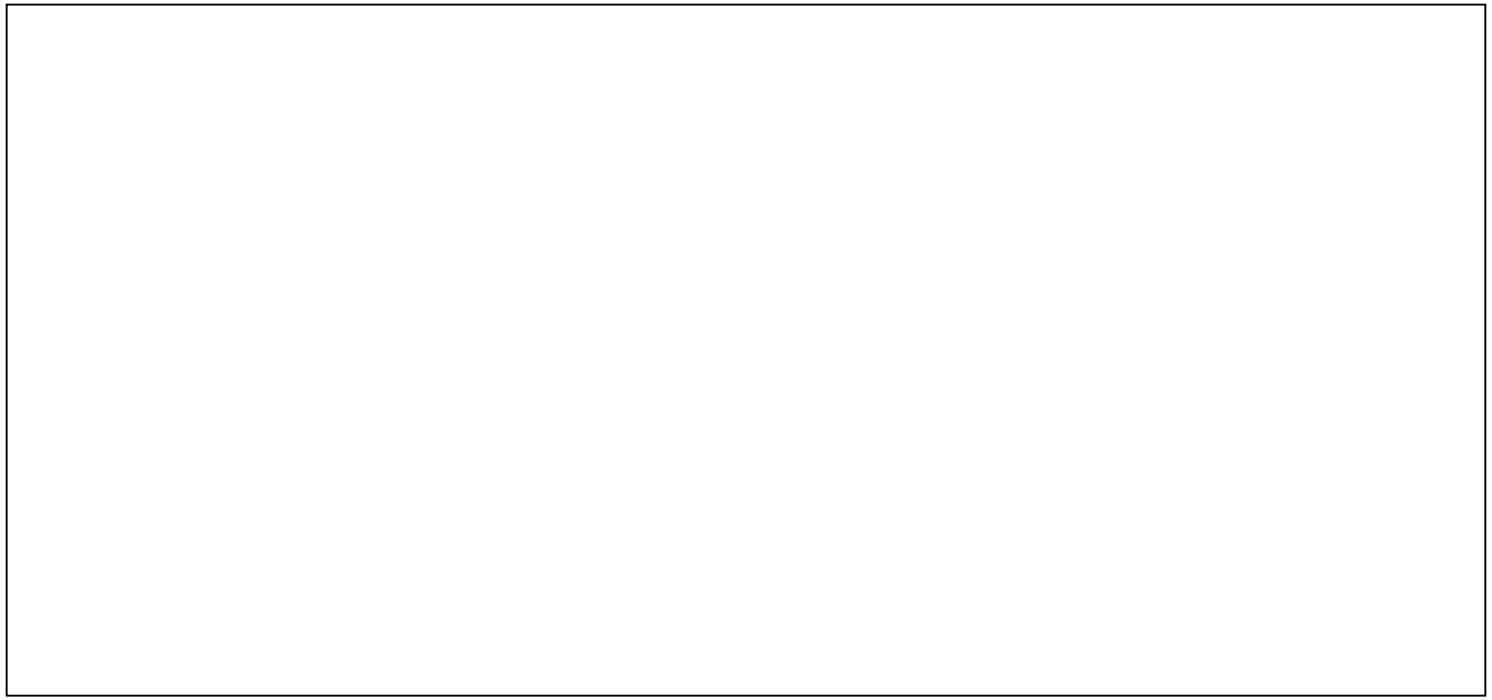
# Why Electrical Resistance Heating?

- Heating is uniform with no bypassed regions
- Heating is rapid – months vs. years
- Steam is produced *in-situ*
- Preferentially heats tight soil lenses and DNAPL hot spots
- Cost effective: most commercial, full-scale sites range from $40-$100 per $yds^3$



# Applications

- Low permeability & heterogeneous lithologies
- DNAPL & LNAPL cleanups by aquifer and smear zone heating
- Heavy hydrocarbon mobilization
- Degradation enhancement (hydrolysis, bio)
- Remediation underneath operating facilities, in the presence of buried utilities and hazardous waste drums

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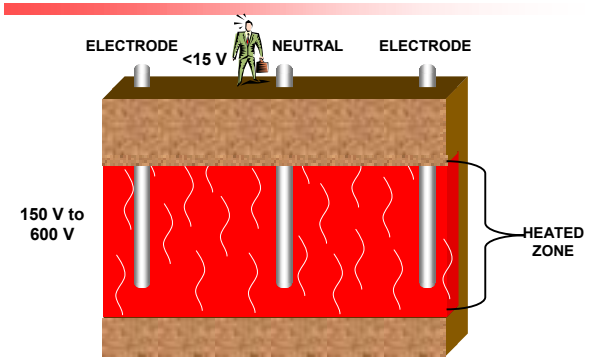
# In-Situ Steam Generation

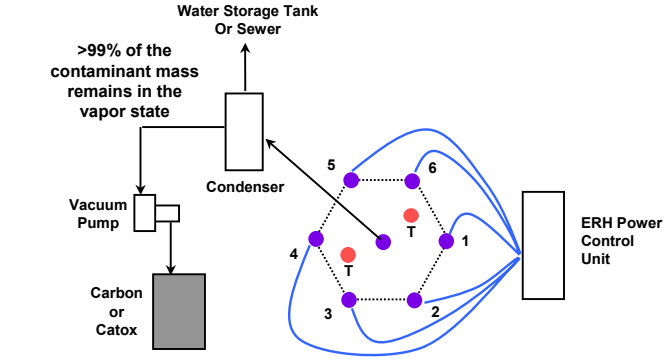



1. Soil grains act as electrical resistors
2. Steam generation is uniform through the heated zone
3. Discrete intervals can be heated

# Surface Equipment


Photo Courtesy of Brown and Caldwell

# Vapor Recovery System



# ERH Equipment Staging

# Full-Scale DNAPL Cleanup the Problem*

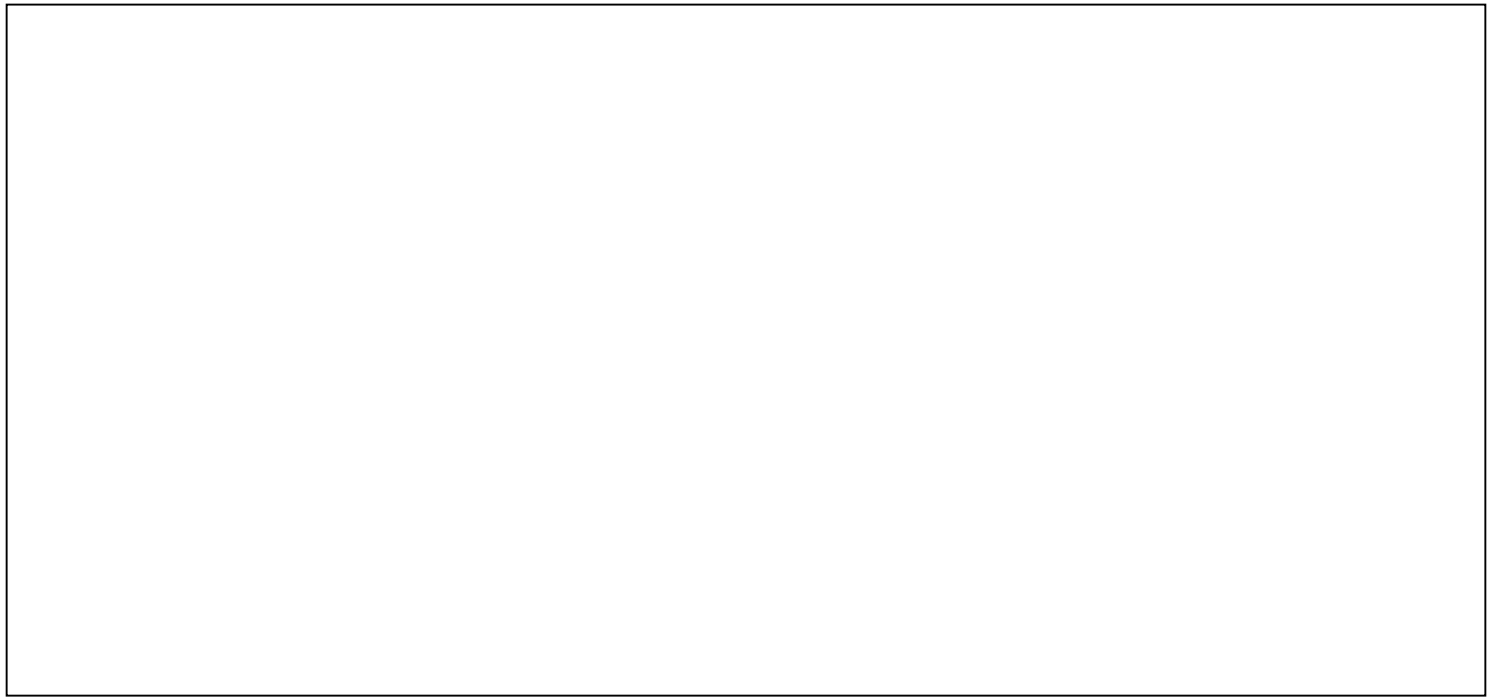
DNAPL (TCE & TCA) covering about 1 acre of an industrial site

ENSR performed remediation for about 5 years and removed 30,000 pounds of TCE & TCA

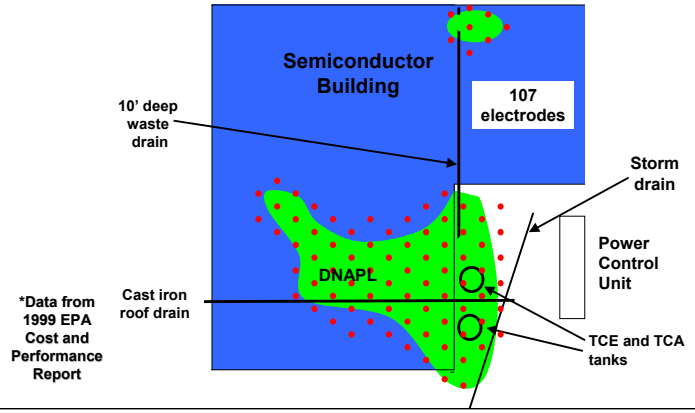
DNAPL remained in four areas, mostly under a large warehouse building

Goal: Reach Tier III RBCA Cleanup Levels over entire site

*Data from the 1999 EPA Cost and Performance Report



# Full-Scale DNAPL Cleanup Site Map*




*Data from 1999 EPA Cost and Performance Report

# ERH Remediation Beneath a Building

Limited overhead access

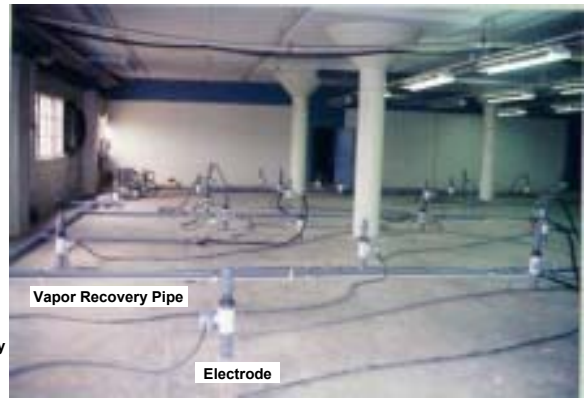
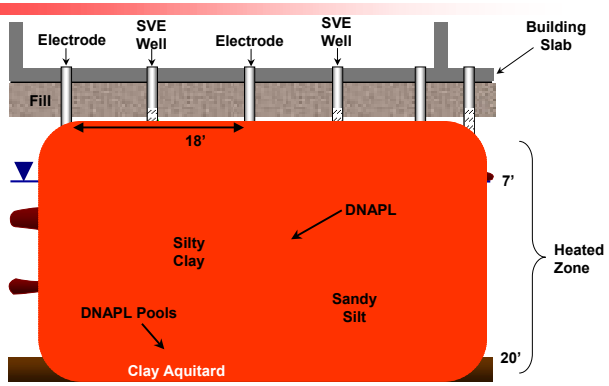



Photo Courtesy of Brown and Caldwell

# Full-Scale DNAPL Cleanup Subsurface Cross-Section



# Full-Scale DNAPL Cleanup Operations & Results*

## Operations

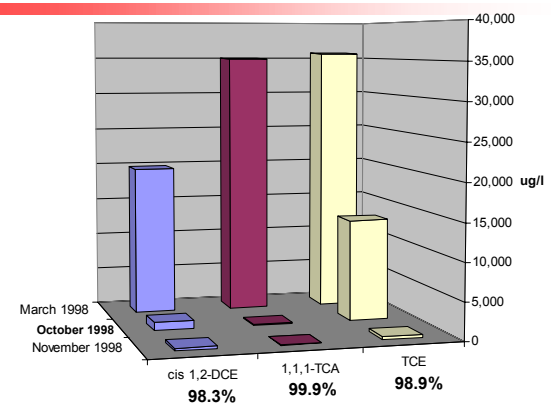
- Heating (107 electrodes) started June 4, 1998
- Aquifer reached boiling in 60 days
- Maintained above the boiling point of TCE (73ºC) for the next 3 months

## Results

- Tier III levels by late November 1998; the site is now closed
- >15,000 pounds of VOCs removed

*Data from 1999 EPA Cost and Performance Report

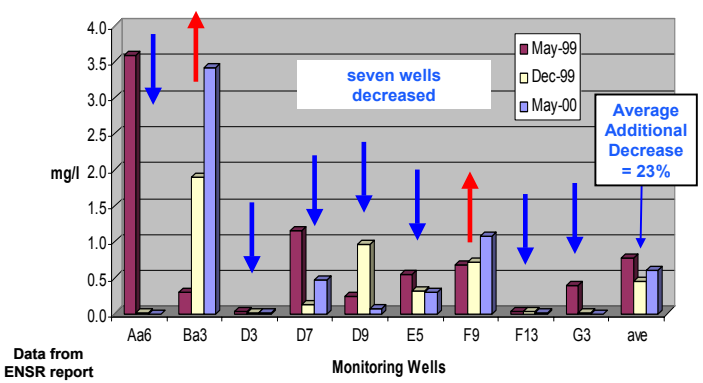
## Average Groundwater Concentrations Seven Most Contaminated Wells*




*Data from 1999 EPA Cost and Performance Report

## Do Groundwater Concentrations Rebound after ERH Remediation?





# Polishing Mechanisms

## Hydrolysis of Halogenated Alkanes

Compounds such as TCA have a hydrolysis half-life of less than one day at steam temperatures.

## Iron Reductive Dehalogenation

Steel shot used as electrode backfill provides an iron source for reductive dehalogenation (iron filing wall)

## Temperature Accelerates Reactions

The above reaction rates are increased by factor of thousands at 100°C (Arrhenius Equation)

## Bioremediation by Thermophiles

Thermophilic bacteria are the most effective solvent dehalogenators and prefer 40-70°C

# Full Scale DNAPL Cleanup Cost & Performance Data*

## Effectiveness

- Total operations took 18 weeks, five days
- Treated approximately 30,000 cubic yards
- Since completing, average groundwater VOC concentrations have continued to decrease

## Costs

- Total project costs were $32/cubic yard
- The total includes electrical costs of $6.50/cubic yard
- Vapor treatment was not required. If vapor treatment had been required, the cost would have been about $41 per cubic yard.

*Data from the 1999 EPA Cost and Performance Report

# TCE DNAPL Remediation
# Air Force Plant Four
# Fort Worth, Texas

Photo Courtesy of URS

# ERH Remediation Beneath Air Force Plant Four

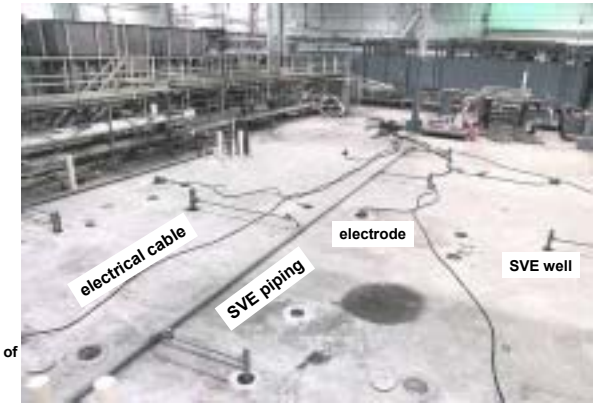



Photo Courtesy of URS

# Lowry Landfill System Layout