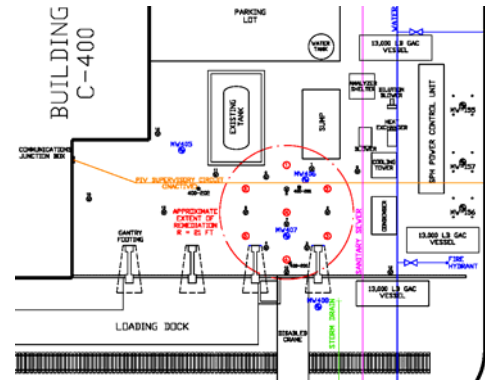


*“TRS guarantees excellence and remediation certainty without cost overruns. Our word is who we are.”*

**U.S. DOE Paducah Gaseous Diffusion Plant in Kevil, Kentucky  
Pilot Scale Remediation of TCE DNAPL at 100 Feet Below Ground Surface**

*This is the deepest ERH application in the world.*

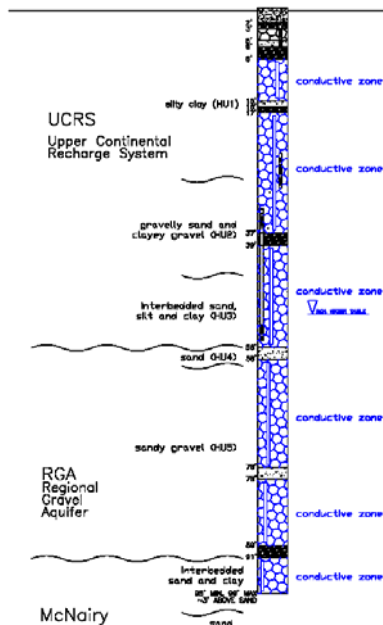
**Contracting Terms:** Fixed Price Per Task  
**Contaminants Treated:** Trichloroethene (TCE)  
**Technology Applied:** Electrical Resistance Heating  
**Geology:** Heterogeneous silt, clay, gravel and sand  
**Hydrology:** Groundwater at 50 ft bgs  
**Treatment Interval:** 5 to 97 feet bgs  
**Beginning Contaminant Levels:** 1,000,000 µg/L  
**Cleanup Levels Achieved:** 10,000 µg/L or 99% reduction  
**Remediation Time Period:** Spring - Fall 2003  
**Project Reference:** Mr. John Farrell, Bechtel Jacobs LLC, Kevil, KY (270) 441-5261



**Figure 1.** Electrode Layout

The objective of the pilot test was to demonstrate the ability of Electrical Resistance Heating (ERH) to reduce TCE concentrations in the unsaturated and saturated zones of the Upper Continental Recharge System (UCRS) and in the groundwater of the Regional Gravel Aquifer (RGA) at the U.S. DOE Paducah Gaseous Diffusion Plant.

The pilot test included the installation and operation of a single Six Phase ERH array at Building C-400. As shown in Figure 1, the single array consisted of six power electrodes, a center neutral electrode, an electrical Power Control Unit (PCU), a steam and vapor recovery (VR) system, pressure and temperature monitoring systems, and contaminant vapor and water treatment systems.



**Figure 2.** Electrode Design

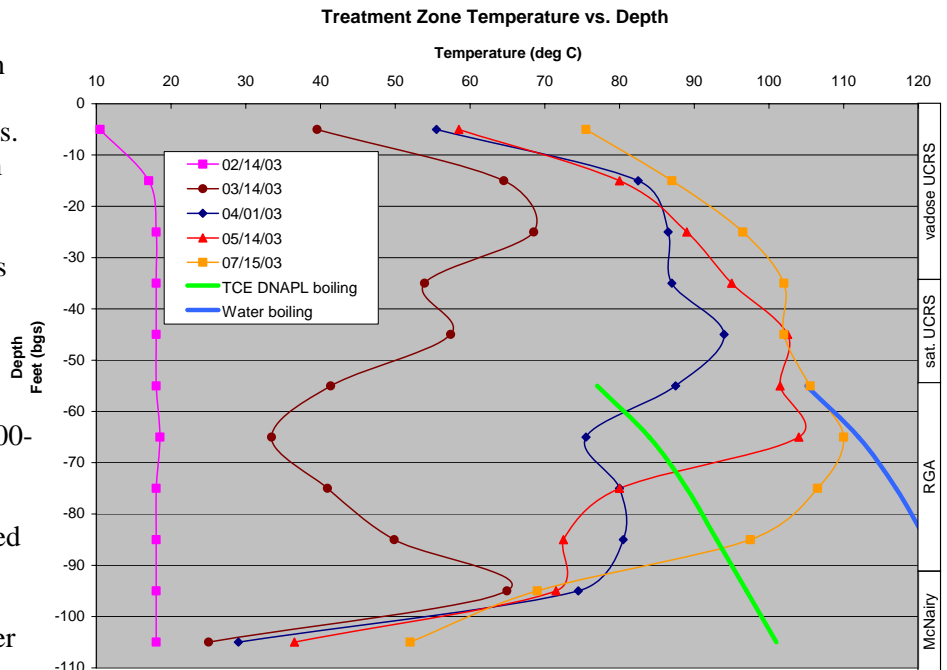
Electrodes were constructed to a final depth of approximately 97 feet bgs, and each electrode consisted of six depth-discrete electrical intervals covering the UCRS, the RGA, and the upper layer of the McNairy Formation. This electrode design (see Fig. 2) underscores the pilot study nature of the project. One of the goals of the pilot study was to attempt to quantify the effects of ERH on the separate geological layers beneath Building C-400. A full-scale application of ERH at this site would utilize a significantly less complex electrode design.

**Combining Technologies for Increased Contaminant Reduction at Reduced Price**

*TRS has patents pending for heat-enhanced biodegradation.*

*ERH electrodes are used not only to increase the temperature in the treatment zone, but also to introduce biological or chemical amendments to enhance the degradation of contaminant source areas and dissolved contaminant plumes. The combination of electrical resistance heating and enhanced in-situ bioremediation technologies can achieve lower cleanup goals at reduced cost.*

In operation, an electrical connection between the conductive intervals developed in several of the electrodes. This prevented these electrodes from heating in discrete intervals as originally designed. However, the overall performance of the electrodes was excellent as the entire subsurface treatment interval was heated to the boiling point of TCE and water. Captured TCE vapors were successfully treated using 20,000-pound granular activated carbon (GAC) vessels and treated air was released to the atmosphere. Recovered steam was condensed and treated condensate was recycled within the aboveground system as makeup water for the ERH processes.



**Figure 3.** Subsurface Temperatures

Once the design temperatures were achieved in the subsurface, approximately 350 – 400 pounds of TCE were recovered each day of operations and more than 30,000 pounds of TCE were removed from the subsurface over the course of the pilot study. Confirmatory sampling showed that concentrations of TCE inside the treatment area were reduced by 98% and 99% in soil and groundwater, respectively.

*TRS provides financial certainty and assurance that your subsurface environmental liability will be remediated.*

*Our reputation is built through hard work and trust because in the end our word is who we are. We provide our customers with certainty that their projects will be completed to the performance and budgetary assurances presented in our proposals.*

*Site owners and consultants select TRS as the preferred ERH provider based on several factors. Please click this link to learn more.*

<http://thermalrs.com/TRSPages/CompanyMain.html>

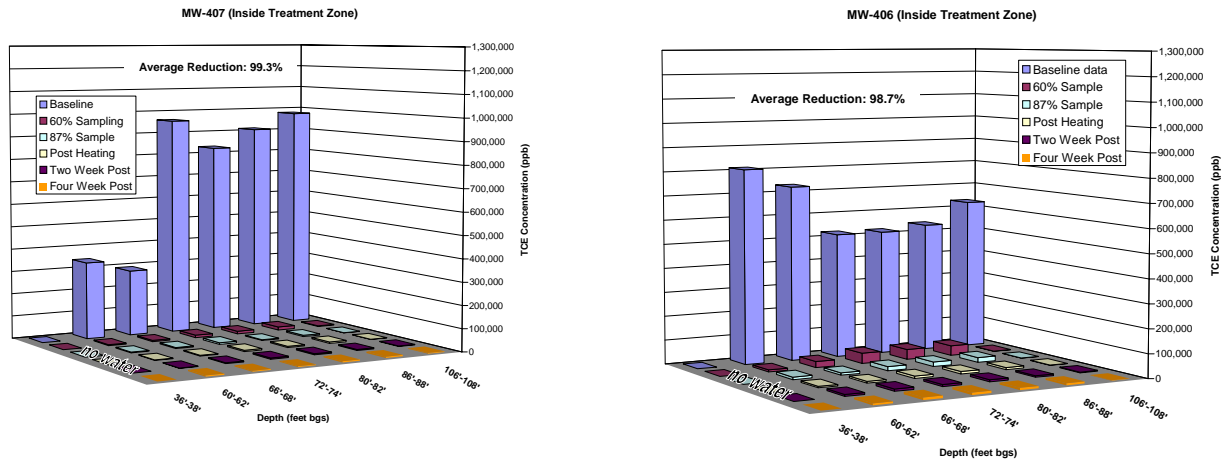
The depth-discrete conductive zones in several of the electrodes became electrically connected during operations of the ERH array. This meant that discrete electrical intervals had to be operated simultaneously rather than sequentially. Because the PCU was properly sized to heat the entire treatment volume, the only effect on the project was the loss of the ability to gather data on the application of ERH at separate depths below the subsurface. This loss of data gathering ability did not effect the evaluation of ERH as a treatment option at the site. Had the design used a smaller PCU, or a series of small PCUs, sized to heat the treatment volume depth interval by depth interval, it would have been impossible to complete the pilot study without mobilizing additional equipment to the site. Adding equipment to the project after the start of operations would have been detrimental to the project schedule and budget.

During operations, a subsurface problem occurred at one electrode that prevented TRS from imputing power to the ground at that location. TRS was able to locate the problem point and design a repair plan that did not require electrode replacement or additional drilling. The ability to repair the electrode without drilling was significant because accommodating a drill rig at the electrode

location would have required the removal of portions the above grade system. Additionally, the project would have been further delayed while the subsurface was allowed to cool so that drilling could be performed.

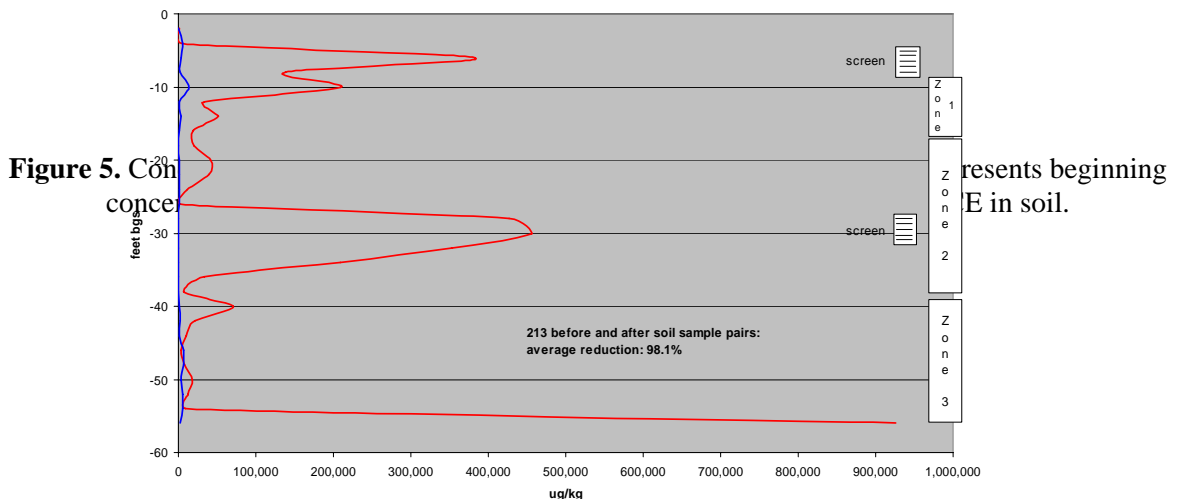
During storm events, silt began to enter the VR system through the extraction wells. TRS determined that the silt was being carried into the wells as rainwater passed through the shallow vadose zone. By adding a simple plastic-sheet cap to the site, TRS was able to eliminate silt buildup in the vapor recovery system. This fix was applied without interruption to the operations schedule.

Figure 3 describes the subsurface temperatures with depth over time. ERH began in February 2003 and was completed in the Fall of 2003. The system was recovering such large quantities of TCE mass that the customer requested continued operations of the ERH pilot system.



**Figure 4.** Concentrations of TCE in Groundwater Before and After ERH at Monitoring Wells Inside the ERH Pilot Test Area.

Figures 4 and 5 describe the TCE concentrations in groundwater and soil before and after ERH. The pilot test performed beyond expectation and the TCE cleanup objectives in soil and groundwater were exceeded. Based on the success of the project the U.S. DOE is planning to expand ERH to full-scale in three areas at the Paducah Gaseous Diffusion Plant.



**Figure 5.** Concentration of TCE in soil. The graph shows a significant peak in concentration between -20 and -30 feet bgs, representing beginning TCE in soil.