

**Guaranteed Remediation Certainty
Our Word Is Who We Are**

Project Example – In Situ Thermal Remediation of Trichloroethene using Electrical Resistance Heating at an Operating Industrial Facility, Kennedy Jenks Consultants, Inc., Eastern Montana

*This project included a firm fixed price with our **standard guarantee** for remediation of trichloroethene (TCE.)*

Client References: Mr. Galen Davis,
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GalenDavis@KennedyJenks.com

Contract Terms: Standard firm fixed price guarantee.

TRS Price: \$325,000.

Engineer: Mr. Greg Beyke, Vice President of Engineering, TRS, Franklin, TN, (615) 791-5772, gbeyke@thermalrs.com.



Figure 1. ERH Site Layout

Project Superintendent and Construction Manager: Mr. Tom Powell, Project Manager, TRS, Vancouver WA, (360) 693-6301, tpowell@thermalrs.com.

Geology: Finely layered silty and clayey sands to 14 ft bgs with a stiff clay layer to 25 ft bgs.

Hydrology: Water table ranges from approximately 2 ft bgs to 6 ft bgs.

Treatment Area, Depth Interval and Volume: approximately 1,600 square feet; 2 – 22 ft bgs; approximately 1,200 cubic yards.

Beginning Contaminant Concentrations: Average 19 ppm MIP detection TCE in soil and groundwater. Maximum TCE concentration was 85 ppm.

Remedial Goal: Reduce TCE concentrations in soil to 0.1 mg/kg for a reduction of about 99%.

Goal Achieved: Average 99.5% reduction of TCE in soil. 13 out of 14 samples being non-detect.

Date of Project: November 2006 to January 2007.

Problems Encountered and Corrective Actions: The project was conducted in the winter in Eastern Montana and encountered very cold temperatures. Project water lines were successfully protected however some freezing of condensate in the vapor recovery lines was experienced. The vapor recovery lines were also heat traced and insulated to overcome this problem.

Background

As a subcontractor to Kennedy Jenks Consultants, TRS provided a remediation of trichloroethene (TCE) in soil using ERH at an operating facility located in eastern Montana. This project was performed for a firm fixed price based on our standard guarantee that included installing and operating the ERH system until either the remedial goal was achieved or the design energy was applied to the subsurface, whichever occurred first. Figure 1 above shows a photo of the actual treatment site. Figure 2 shows a plot plan of the ERH site.

The ERH design energy was 294,000 kW-Hrs and the remedial goal was to reduce the TCE concentrations in soil to 0.1 mg/kg or less, a reduction of about 99%. Based on a comparison of fourteen pre and post ERH soil samples, TCE in soil was reduced by an **average 99.5%**. The actual energy applied to the subsurface at the time of confirmation sampling was 251,616 kW-hrs.

Site Characteristics

Site lithology in the remediation area principally consists of finely layered silty and clayey sands to 14 ft bgs, with a stiff clay layer from 14 to 25 ft bgs. The depth to shallow groundwater (above the stiff clay layer) ranges from two to six ft bgs, with the highest seasonal levels occurring in June.

The total treatment area is approximately 40 feet by 40 feet or 1,600 square feet. The desired remediation depth interval extends from two to 22 feet below ground surface (ft bgs). The resulting target remediation volume is approximately 1,200 cubic yards.

TCE was the primary contaminant of concern. The maximum beginning concentration of TCE in soil was 85 ppm as measured with a Membrane Interface Probe (MIP).

Diesel LNAPL is also present in soil and groundwater beneath the pad in a heavily smeared fashion. The plume down gradient of the pad flows through a zero valent iron permeable reactive barrier (ZVI PRB) that KJC installed a little over a year ago.

ERH Design Parameters

The ERH pilot system included 12 electrodes in the treatment region as shown on Figure 2. Electrodes were installed using 10-inch outer diameter (o.d.) borings that extend to an average total depth of 23 feet bgs using hollow stem auger or air rotary drilling techniques.

Each electrode provided co-located vapor recovery (VR) to capture steam and vapors generated during the ERH application. TRS also recovered steam and VOC vapors from the dry well to prevent releases to the atmosphere.

The ERH system was controlled and monitored remotely and checked with bi-weekly personnel site visits.

TRS's ERH specialty equipment provided continuous thermal data collection within the subsurface. Temperature data was collected from four TMPs installed next to the confirmatory boring locations. Each TMP was constructed using 3/4-inch chlorinated polyvinyl chloride (CPVC) pipe and each included a TRS-installed thermocouple string that monitored temperatures at 5-foot intervals. All TMPs were completed above ground surface.

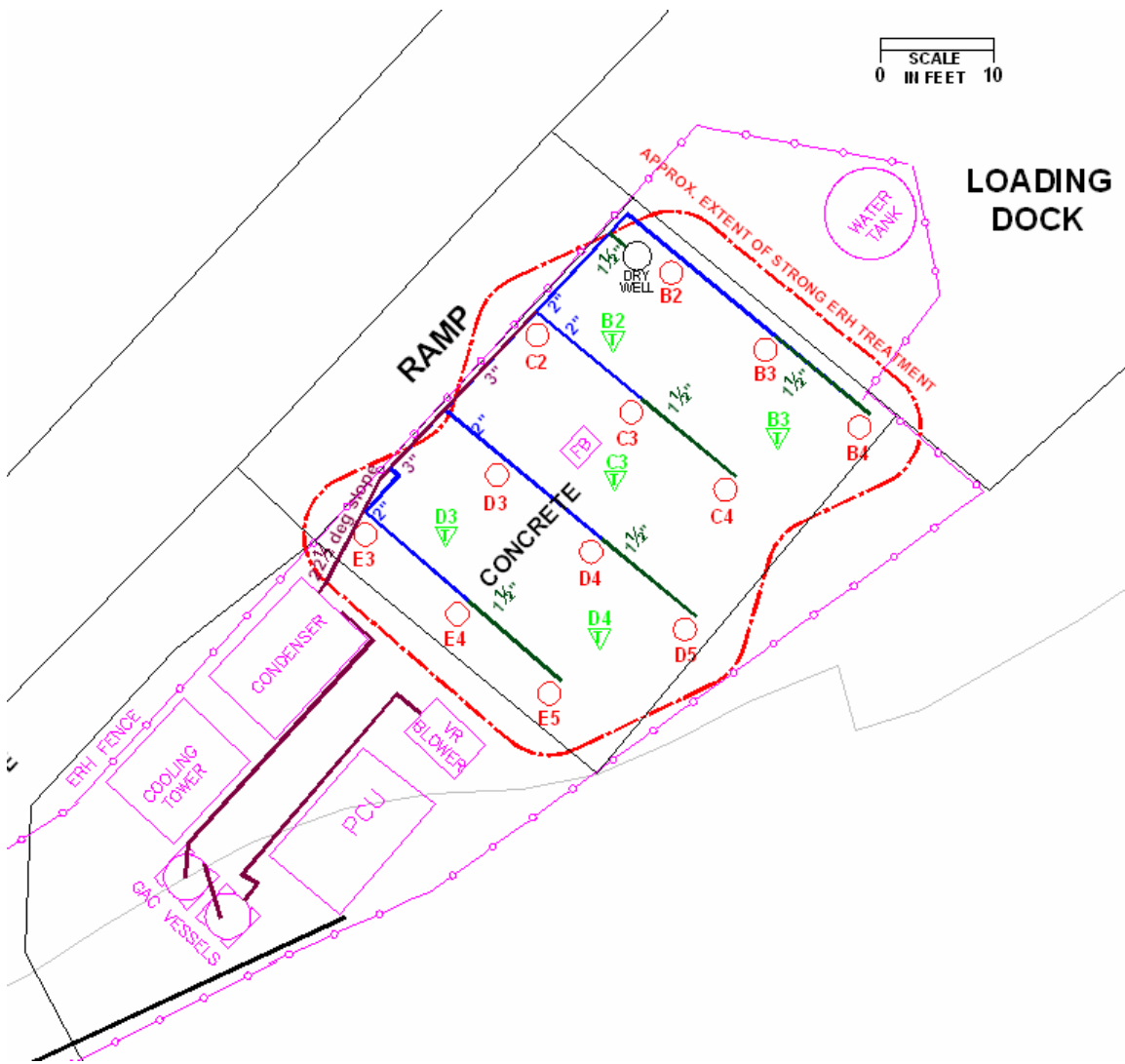


Figure 2. ERH Plot Plan

Results

Power was applied to the subsurface at an average of 148 kilowatts, resulting in a total energy application of 251,616 kW-hrs over the life of the project, between startup on November 4, 2006 and final shutdown on January 26, 2007.

Subsurface temperatures increased to the boiling point of TCE at depth in contact with water (approximately 77°C) within about 25 days. ERH operations continued for another 57 days. Figure 3 illustrates the average subsurface temperature vs. time for the duration of the ERH application.

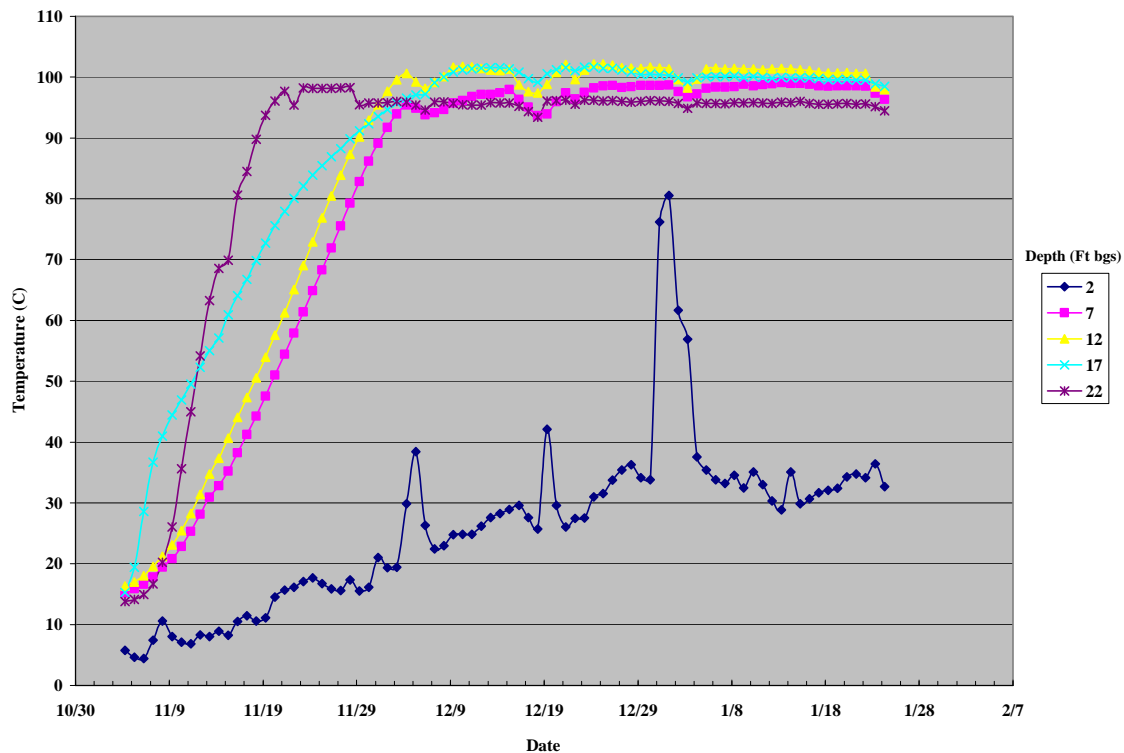


Figure 3. Average Site Temperatures

The temperatures at the two foot bgs depth remained relatively cool during the project. This interval was comprised mostly of gravel and provided a beneficial air sweep for the site. This air sweep resulted in cold air continuously being pulled through this region resulting in cooler temperatures being indicated at two feet bgs. The temperature spikes shown at this two foot interval are the result of the vapor recovery blower being shutdown to remove accumulated ice in the vapor recovery piping. On occasion ice would form on the cool side (after the condenser) of the vapor recovery piping. Eventually, the entire vapor recovery piping after the condenser was heat traced and insulated to reduce the ice formation.

TRS achieved an average 99.5% reduction of TCE concentrations in soil (see Figure 4) during approximately 82 days of ERH operations. Prior to the remediation, the client measured initial concentrations of TCE from 9 locations at four separate depths per location utilizing the MIP technology. The MIP detection method provides a concentration for both soil and groundwater simultaneously. After the remediation was completed, the client selected 14 locations from the pre-test sampling that represented the highest TCE concentrations. The client then took actual soil samples from those 14 locations at the depth where the MIP had indicated the highest concentrations of TCE. Figure 4 illustrates the pre and post ERH sample results.

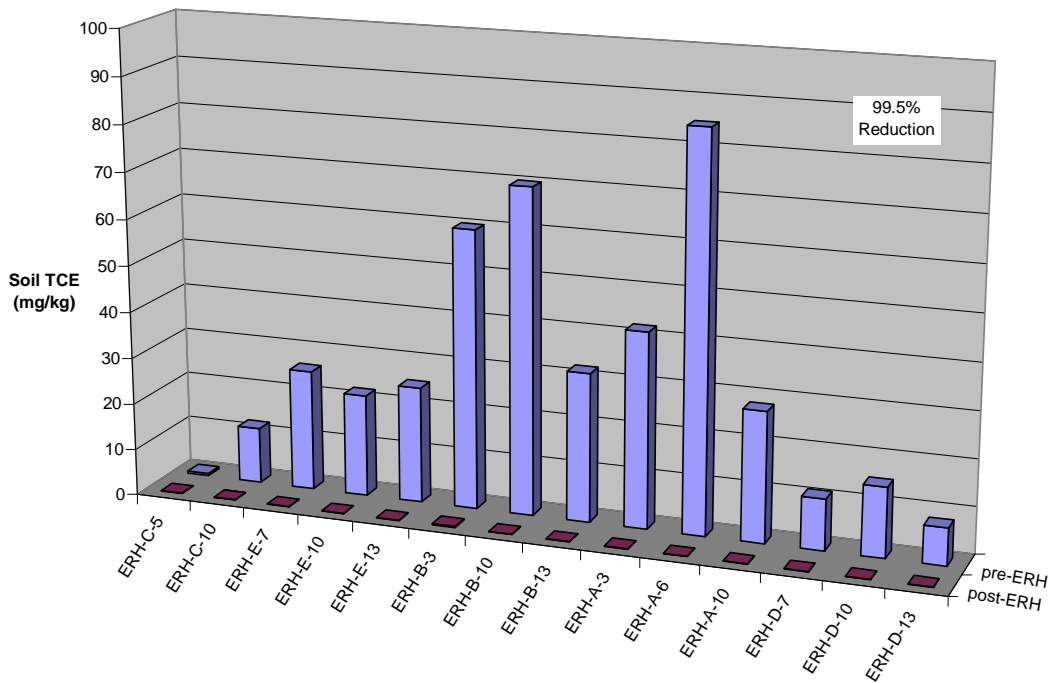


Figure 4. Analytical Results

The pre-ERH MIP results and the laboratory results for TCE from each of the post ERH sampling event are presented in Table 1. Prior to application of the ERH technology, the maximum concentration of TCE in soil and groundwater combined as measured with the MIP was 85 ppm.

Table 1. Pre- and Post-ERH-Treatment TCE Concentrations in Soil

Pre-Treatment MIP ^(a) Concentration			Post-Treatment Concentration ^(b)		
Sample Location	Depth (feet)	TCE (ppm) ^(c)	Sample ID	Depth (feet)	TCE (mg/kg) ^(d)
MIP-23	0-5	ND			
	5-10	0.49	ERH-C-5	5	<0.0892
	10-15	12	ERH-C-10	10	<0.0802
	15-20	2			
MIP-30	0-5	10			
	5-10	ND			
	10-15	3			
	15-20	3			
MIP-31	0-5	ND			
	5-10	26	ERH-E-7	7	<0.0858
	10-15	22	ERH-E-10	10	<0.0838
	15-20	25	ERH-E-13	13	<0.0855
MIP-32	0-5	60	ERH-B-3	3	0.242
	5-10	70	ERH-B-10	10	<0.0940
	10-15	32	ERH-B-13	13	<0.0873
	15-20	9			
MIP-33	0-5	21			
	5-10	26			
	10-15	12			
	15-20	ND			
MIP-34	0-5	3			
	5-10	0.16			
	10-15	8			
	15-20	7			
MIP-35	0-5	42	ERH-A-3	3	<0.0881
	5-10	85	ERH-A-6	6	<0.0827
	10-15	28	ERH-A-10	10	<0.0867
	15-20	17			
MIP-37	0-5	2			
	5-10	11	ERH-D-7	7	<0.0821
	10-15	15	ERH-D-10	10	<0.0912
	15-20	8	ERH-D-13	13	<0.0887
MIP-38	0-5	1			
	5-10	19			
	10-15	14			
	15-20	3			

Notes:

(a) MIP = Membrane interface probe.

(b) Soil samples analyzed for volatile organic compounds using EPA Method 8260.

(c) ppm = parts per million. *In situ* MIP measurement represents a total soil and groundwater concentration.

(d) mg/kg = milligrams per kilogram.

The pre-treatment groundwater depth was approximately 5 feet below ground surface.

No measurable groundwater was encountered in post-treatment soil borings.

At the start of the project, it was estimated that 294,400 kW-hr of energy would be required to reach the original project goal of 99.88% removal of benzene from soil. Only 251,616 kW-hr of energy was applied during the project, 42,384 kW-hr less than calculated to reach the cleanup goals.

Upon review of the analytical results from the final sampling event, Kennedy Jenks Consultants Inc. determined that the majority of the soil samples were below the cleanup goal and the ERH treatment was complete. Thirteen of the 14 post ERH samples were reported as non-detect for TCE. One sample, ERH B-3 (3 feet bgs) was shown to have 0.242 mg/kg of TCE remaining. This location measured 60 ppm during the pre-ERH investigation. When compared to the pre-ERH MIP results, the post-ERH sample ERH-B3 represents a 99.6% reduction of TCE.

Conclusions

Based upon the data collected before and during the project the following conclusions were drawn:

1. Thirteen of the fourteen confirmatory soil samples were well below the cleanup goal of 0.1 mg/kg of TCE in soil.
2. The project was completed on time and before the estimated total energy was applied.
3. The ERH equipment performed satisfactorily in very cold climate conditions without adversely effecting the ongoing operations of the facility.