COST AND PERFORMANCE REPORT

Electrical Resistive Heating at the
Former Manufacturing Facility
Skokie, Illinois

June 2003
SITE INFORMATION

IDENTIFYING INFORMATION

Site Name: Former manufacturing facility (confidential commercial client)
Location: Skokie, Illinois (near Chicago, Illinois)
Regulatory Context: State voluntary cleanup
Technology: Electrical Resistive Heating
Scale: Full-scale

TECHNOLOGY APPLICATION

Period of Operation: June 4, 1998 to November 20, 1998 (initial area treated); December 1998 to April 30, 1999 (additional area treated)

Type/Quantity of Material Treated during Application [7,8]: Initial source zone area - approximately 23,100 cubic yards of soil and groundwater, based on a treatment area of 26,000 square feet and a depth of 24 feet below ground surface (bgs). Additional source zone area - 11,500 cubic yards of soil and groundwater

BACKGROUND [2,4,5,7,8,9,13]

The site is a former electronics manufacturing facility located in Skokie, Illinois. Manufacturing at this location began in 1955 and included machining, electroplating, heat treating, silk screening, silicon chip production, and research and development. Trichloroethylene (TCE) and 1,1,1-trichloroethane (TCA) were feedstock chemicals associated with various manufacturing processes. By 1988, all processes had been discontinued, and the facility was sold and redeveloped.

Releases occurred from spill containment systems and underground storage tanks that leaked. Figure 1 shows the areas where soil and groundwater at the site were found to be contaminated with pools of dense nonaqueous phase liquids (DNAPL). The site was remediated under Illinois' voluntary Site Remediation Program. From 1991 to 1998, steam injection combined with groundwater and vapor extraction was used to clean up the site. After seven years of operation, the area of contamination had been reduced from about 115,000 square feet to about 23,000 square feet. As of early 1998, the remaining area to be remediated represented four source locations where manmade subsurface features limited the effectiveness of the previously used steam-based remediation system. These locations consisted of a closed-end catch basin acting as a heat sink, a subsurface void, two areas with very dense soil near a building (believed to be limiting vapor extraction), and an additional area adjacent to a wall with a deep foundation (where foundation backfill was believed to be providing a preferential pathway for injected steam).

To complete the remediation, the site owner selected Electrical Resistive Heating (ERH) technology that combines electrically heating the subsurface with electrodes inserted in the ground, and soil vapor extraction. This report focuses on the use of ERH and not the steam injection previously completed at the site.
Figure 1. Layout of the Skokie Site [7,13]
MATRIX DESCRIPTION

MATRIX AND CONTAMINANT IDENTIFICATION

Type of Media Treated With Technology System: Source zone (saturated and unsaturated)

Primary Contaminant Groups: Chlorinated Solvents (TCE and TCA, as well as degradation products cis- and trans-1,2-dichloroethene, 1,1-dichloroethene, 1,1-dichloroethane, vinyl chloride and chloroethane)

SITE HYDROGEOLOGY AND EXTENT OF CONTAMINATION [3,4,7,13]

The facility overlies heterogeneous silty sands with clay lenses to 18 feet bgs and a hydraulic conductivity ranging from $10^{-4}$ to $10^{-5}$ cm/sec. Below 16 feet bgs, a dense clay till or ground moraine forms an aquitard with a hydraulic conductivity of $10^{-5}$ cm/sec. Groundwater is encountered at 7 feet bgs. The majority of the remaining DNAPL at the site was pooled on top of the clay till at 18 feet bgs.

At the initiation of ERH, aqueous phase concentrations and concentration trends indicated the presence of DNAPL. Sampling indicated that DNAPL resided in proof-rolled clays at depths of 5 to 8 feet bgs, and in the soil pores from the water table (7 feet bgs) to depths of 18 to 20 feet bgs. Concentrations in groundwater at the initiation of SPH for cis-1,2-dichloroethene (DCE) were as high as 160 mg/L, for TCE as high as 130 mg/L, and for TCA as high as 160 mg/L.

Table 1 lists the matrix characteristics affecting treatment cost or performance for this application.

Table 1. Matrix Characteristics [3,4,7,13]

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil Classification</td>
<td>Heterogeneous sandy and silty clays</td>
</tr>
<tr>
<td>Clay Content and/or Particle Size Distribution</td>
<td>Two discrete clay intervals: 1) silty clay from 5 to 18 feet bgs, and 2) denser clay below 18 feet bgs</td>
</tr>
<tr>
<td>Depth to Groundwater</td>
<td>7 feet bgs</td>
</tr>
<tr>
<td>Hydraulic conductivity</td>
<td>Ranges from $10^{-4}$ to $10^{-5}$ centimeters/second (cm/sec) in silty sand and less than $10^{-5}$ cm/sec in the denser clay</td>
</tr>
<tr>
<td>Air permeability</td>
<td>Not available</td>
</tr>
<tr>
<td>Porosity</td>
<td>Not available</td>
</tr>
<tr>
<td>Presence of NAPLs</td>
<td>DNAPL present</td>
</tr>
<tr>
<td>Moisture content</td>
<td>Typical for water saturated clay (quantitative information not available)</td>
</tr>
<tr>
<td>Total organic carbon</td>
<td>0.12%</td>
</tr>
<tr>
<td>Electrical resistivity of soil</td>
<td>3 ohms</td>
</tr>
</tbody>
</table>
TREATMENT TECHNOLOGY

Electrical Resistive Heating (Six-Phase Heating™) and air stripping for extracted groundwater condensate

TREATMENT SYSTEM DESCRIPTION AND OPERATION [1,3,4,5,6,7,8,9,13]

For the Skokie site, a network of 107 electrodes was designed and installed in the initial treatment area, with 85 of the electrodes constructed beneath the floor of a warehouse building. After November 20, 1998, the system was shut down for about a month while 78 more electrodes were installed (185 electrodes total). All electrodes were designed to be electrically conductive throughout a depth interval of 11 to 21 feet bgs and to increase the subsurface temperature in the depth interval of 5 to 24 feet bgs to the boiling point of water. A network of 37 soil vapor extraction wells, screened to 5 feet bgs, were used to capture vapors. The off gas system consisted of a vacuum extraction blower and a steam condenser. Figure 1 shows the location of the electrodes and monitoring wells at the site, while Figure 2 shows typical ERH equipment layout.

The ERH process operated at the Skokie site from June 4, 1998 to November 20, 1998 to remediate the initial estimated 23,000 cubic yards of contaminated soil. Results of sampling conducted in December 1998 indicated there was a potential for vinyl chloride to be produced outside the initial treatment area at levels in excess of the Tier III cleanup levels. As a result, the treatment area was expanded, restarted in December 1998, and operated until April 30, 1999.

During system operation, the ERH process was controlled remotely via software, allowing real-time adjustment of electrode voltage to control power delivered to the soil. According to the vendor, thermocouples placed in the soil were used to monitor the heating pattern as a basis for adjusting the distribution of power and to assist in determining the best electrical configuration for power delivery as the cleanup progressed. The electrical configuration was adjusted in the field by reconnecting electrical jumpers between electrodes to re-focus electrical energy as needed to maintain rapid treatment. During all phases of the operation, the total power, energy delivered, and electrical current, voltage, and power factors were measured and recorded along with soil temperatures using a computer based data acquisition and control system.

During treatment, the source zone was heated to 100°F C, and the system achieved an operating vacuum of 7.5 inches of mercury. Electric power input was 1,775 Mw-hrs from June 4 to November 20, 1998. Information on power input was not provided for December 1998 to May 1999.
Treatment progress was monitored by measuring vapor concentrations in the soil off-gas exiting the condenser and by periodically monitoring in situ concentrations through groundwater samples collected from wells. The off-gas measurements were used to estimate the rate of contaminant removal and total removed mass throughout the site operation. According to the vendor, approximately 99% of the removed mass was found to remain in the vapor phase past the off-gas condenser while the remaining 1% was collected in the condensed phase. This partitioning reflects the relatively high volatility and modest solubility of the contaminants. The condensate was treated with air stripping prior to discharge.

Groundwater monitoring data were available for March 1998, before the ERH was initiated, and from April 1998 through May 1999. During ERH treatment, up to 40 well points (from the previous steam injection system) were sampled on a periodic basis. According to the vendor, all of these well points were abandoned in July 1999 in accordance with Cook County Department of Public Health-approved procedures.
TIMELINE [3,4,5,8,9,13]

- 1991-3/98  Steam injection and soil and groundwater extraction used at site
- 6/4/98    ERH system began operation
- 8/4/98 (approx.)  Temperatures throughout entire soil volume reach boiling point of water
- 10/98     ERH system temporarily shut off
- 12/98     Additional ERH system began operation
- 4/30/99   System shut off and demobilization began
- 7/29/99   Illinois EPA issues a no further remediation letter
- 5/99-12/99 Post-remedial monitoring conducted

TECHNOLOGY SYSTEM PERFORMANCE

PERFORMANCE OBJECTIVES [4,10,13,14]

Table 2 shows the Tier III cleanup criteria for groundwater proposed by the vendor and approved by Illinois EPA as the cleanup goals for the site. According to Illinois EPA’s Site Remediation Program guidelines, Tier III allows conduct of variable-scale risk assessment activities and more complex contaminant fate and transport modeling than is allowed in more stringent cleanup tiers. The more stringent Tier I standards are shown for comparison.

Table 2. Cleanup Criteria for Skokie Site (Tier III) [13,14]

<table>
<thead>
<tr>
<th>Contaminant</th>
<th>Tier III Cleanup Level for Groundwater (μg/L)</th>
<th>Tier I Cleanup Level for Groundwater (μg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>cis 1,2-Dichloroethene (DCE)</td>
<td>35,500</td>
<td>200</td>
</tr>
<tr>
<td>1,1,1-Trichloroethane (TCA)</td>
<td>8,850</td>
<td>1,000</td>
</tr>
<tr>
<td>Trichloroethene (TCE)</td>
<td>17,500</td>
<td>25</td>
</tr>
</tbody>
</table>

TREATMENT PERFORMANCE [4,6,8,9,13]

Performance data are available for the remediation of the initial 23,000 cubic yards of remaining contamination at the site conducted from June to November 1998 (Table 3) and for the remediation of the additional 11,000 cubic yards of contamination at the site conducted from December 1998 to April 1999 (Table 4). Groundwater monitoring continued after system shutdown in April and data are available through May 1999. Figures 3, 4, and 5 show the changes in groundwater contaminant concentrations by well for DCE, TCA, and TCE, respectively, from March 1998 through May 1999.

As shown in Table 3, by November 20, 1998, the Tier III cleanup goals had been achieved for the three constituents of concern in all seven wells. In addition, as of November 1998, contaminant concentrations in a number of wells had been reduced to the more stringent Tier I cleanup levels. For example, the Tier I cleanup level for TCA had been met in all seven wells, for DCE in one well, and for TCE in two wells.

In October 1998, following 18 weeks of ERH operation, elevated levels of TCE (814,000 μg/L) were detected in well Ca6. According to the vendor, the source of the high concentrations of TCE was not known. To address the elevated concentrations: 1) well Ca6 was converted to an electrode to improve heating;
and 2) Fenton's reagent was added in and around the catch basin to oxidize oils which may have potentially leaked from the catch basin. By November 1998, TCE concentrations in the Ca6 well area had decreased to levels ranging from 250 µg/L to 1,600 µg/L.

Table 4 presents a summary of groundwater monitoring data for the remediation of the additional area of contamination, conducted from December 1998 to April 1999. As shown in Table 4, concentrations of DCE and TCE were higher than the Tier III cleanup levels in well Ca6 in January 1999. By February 1999, TCE concentrations in this well had decreased to between the cleanup levels. As of April 1999 contaminant concentrations in all wells were below the cleanup goals and the system was shut down. Groundwater monitoring data for May 1999 showed that contaminant concentrations remained below cleanup levels.

Groundwater samples were collected monthly and analyzed via head space extraction using an HP 5890 gas chromatograph equipped with an electron capture detector (GC/ECD). A subset of the sample population was analyzed using a gas chromatograph with a mass spectrometer (GC/MS) following EPA Method 8240. Contaminant concentrations in the collected condensate were monitored periodically. Off-gas concentrations exiting the condenser were monitored using a flame ionization detector (FID).

The Illinois Environmental Protection Agency issued a letter on July 29, 2002 granting the site's request for a no further action determination and provided several conditions and terms for the determination, including installation of a passive ventilation system (vent wells) to provide a preferential pathway for vapors to migrate.

Two additional rounds of groundwater monitoring sampling were performed following completion of ERH in April 1999. Table 5 shows the concentrations of TCE, TCA, and DCE in groundwater monitoring wells from May 1999 (1 month after completion of the remediation) and December 1999 (2 months after completion of the remediation). During this time, the concentrations of TCE, TCA, and DCE remained below the Tier III groundwater cleanup levels, and contaminant concentrations remained stable or continued to decrease.
(June 1998 to November 1998)

<table>
<thead>
<tr>
<th>Well No.</th>
<th>Constituent</th>
<th>Prior to ERH Remediation (ppb)</th>
<th>During Remediation (ppb)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>06/28/98</td>
<td>07/15/98</td>
</tr>
<tr>
<td>B3</td>
<td>cis, 1,2-DCE</td>
<td>25,500</td>
<td>40,000</td>
</tr>
<tr>
<td></td>
<td>1,1,1-TCA</td>
<td>8,850</td>
<td>82,000</td>
</tr>
<tr>
<td></td>
<td>TCE</td>
<td>17,500</td>
<td>34,000</td>
</tr>
<tr>
<td>Ba6</td>
<td>cis, 1,2-DCE</td>
<td>35,500</td>
<td>9,600</td>
</tr>
<tr>
<td></td>
<td>1,1,1-TCA</td>
<td>8,850</td>
<td>88,000</td>
</tr>
<tr>
<td></td>
<td>TCE</td>
<td>17,500</td>
<td>7,000</td>
</tr>
<tr>
<td>C4</td>
<td>cis, 1,2-DCE</td>
<td>35,500</td>
<td>43,000</td>
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<tr>
<td></td>
<td>1,1,1-TCA</td>
<td>8,850</td>
<td>11,000</td>
</tr>
<tr>
<td></td>
<td>TCE</td>
<td>17,500</td>
<td>20,000</td>
</tr>
<tr>
<td>Ca6</td>
<td>cis, 1,2-DCE</td>
<td>35,500</td>
<td>1,800</td>
</tr>
<tr>
<td></td>
<td>1,1,1-TCA</td>
<td>8,850</td>
<td>10,000</td>
</tr>
<tr>
<td></td>
<td>TCE</td>
<td>17,500</td>
<td>83,000</td>
</tr>
<tr>
<td>Da2</td>
<td>cis, 1,2-DCE</td>
<td>35,500</td>
<td>10,000</td>
</tr>
<tr>
<td></td>
<td>1,1,1-TCA</td>
<td>8,850</td>
<td>20,000</td>
</tr>
<tr>
<td></td>
<td>TCE</td>
<td>17,500</td>
<td>47,000</td>
</tr>
<tr>
<td>F13</td>
<td>cis, 1,2-DCE</td>
<td>35,500</td>
<td>510</td>
</tr>
<tr>
<td></td>
<td>1,1,1-TCA</td>
<td>8,850</td>
<td>16,000</td>
</tr>
<tr>
<td></td>
<td>TCE</td>
<td>17,500</td>
<td>800</td>
</tr>
<tr>
<td>Fa2</td>
<td>cis, 1,2-DCE</td>
<td>35,500</td>
<td>2,400</td>
</tr>
<tr>
<td></td>
<td>1,1,1-TCA</td>
<td>8,850</td>
<td>24,000</td>
</tr>
<tr>
<td></td>
<td>TCE</td>
<td>17,500</td>
<td>22,000</td>
</tr>
<tr>
<td>Average</td>
<td>cis, 1,2-DCE</td>
<td>35,500</td>
<td>17,900</td>
</tr>
<tr>
<td></td>
<td>1,1,1-TCA</td>
<td>8,850</td>
<td>37,000</td>
</tr>
<tr>
<td></td>
<td>TCE</td>
<td>17,500</td>
<td>30,400</td>
</tr>
</tbody>
</table>

U.S. Environmental Protection Agency
Office of Solid Waste and Emergency Responses
Technology Innovation Office
Figure 3. Monthly cis-DCE Concentrations (µg/L) in Groundwater in Initial Area of Contamination (March 1998 to May 1999, log scale) [4]
Figure 4. Monthly 1,1,1-TCA Concentrations (µg/L) in Groundwater in Initial Area of Contamination (March 1998 to May 1999, log-scale) [4]

* Well subject to continuing release average reduction: >99.99% (excluding Ca6)

[Diagram showing trends and data points for 1,1,1-TCA concentrations over time with labels for different wells and SPH remediation ended marker]
Figure 5. Monthly TCE Concentrations (µg/L) in Groundwater in Initial Area of Contamination (March 1998 to May 1999, log-scale) [4]

<table>
<thead>
<tr>
<th>Well No.</th>
<th>Constituent</th>
<th>Tier III Clean-up Level (mg/L)</th>
<th>December-98 (mg/L)</th>
<th>January-99 (mg/L)</th>
<th>February-99 (mg/L)</th>
<th>March-99 (mg/L)</th>
<th>April-99 (mg/L)</th>
<th>May-99 (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>B3</td>
<td>cis-1,2-DCE</td>
<td>36,500</td>
<td>1</td>
<td>NR</td>
<td>NR</td>
<td>7</td>
<td>NR</td>
<td>&lt;1</td>
</tr>
<tr>
<td></td>
<td>1,1,1-TCA</td>
<td>9,850</td>
<td>&lt;1</td>
<td>NR</td>
<td>NR</td>
<td>&lt;1</td>
<td>NR</td>
<td>&lt;1</td>
</tr>
<tr>
<td></td>
<td>TCE</td>
<td>17,500</td>
<td>2</td>
<td>NR</td>
<td>NR</td>
<td>3</td>
<td>NR</td>
<td>2</td>
</tr>
<tr>
<td>Ba6</td>
<td>cis-1,2-DCE</td>
<td>36,500</td>
<td>7,900</td>
<td>17,000</td>
<td>3,600</td>
<td>4,400</td>
<td>52</td>
<td>630</td>
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<td></td>
<td>1,1,1-TCA</td>
<td>8,850</td>
<td>&lt;25</td>
<td>&lt;28</td>
<td>&lt;28</td>
<td>&lt;25</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
<tr>
<td></td>
<td>TCE</td>
<td>17,500</td>
<td>4,900</td>
<td>4,000</td>
<td>2,800</td>
<td>1,300</td>
<td>11</td>
<td>210</td>
</tr>
<tr>
<td>C4</td>
<td>cis-1,2-DCE</td>
<td>35,500</td>
<td>450</td>
<td>NR</td>
<td>NR</td>
<td>890</td>
<td>NR</td>
<td>66</td>
</tr>
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<td>1,1,1-TCA</td>
<td>8,850</td>
<td>15</td>
<td>NR</td>
<td>NR</td>
<td>&lt;10</td>
<td>NR</td>
<td>&lt;1</td>
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<tr>
<td></td>
<td>TCE</td>
<td>17,500</td>
<td>100</td>
<td>NR</td>
<td>NR</td>
<td>270</td>
<td>NR</td>
<td>12</td>
</tr>
<tr>
<td>Ca6</td>
<td>cis-1,2-DCE</td>
<td>35,500</td>
<td>8,100</td>
<td>41,000</td>
<td>530</td>
<td>4,600</td>
<td>40</td>
<td>4,200</td>
</tr>
<tr>
<td></td>
<td>1,1,1-TCA</td>
<td>8,850</td>
<td>&lt;20</td>
<td>&lt;2,000</td>
<td>1,200</td>
<td>&lt;50</td>
<td>&lt;1</td>
<td>&lt;25</td>
</tr>
<tr>
<td></td>
<td>TCE</td>
<td>17,500</td>
<td>22,000</td>
<td>370,000</td>
<td>13,000</td>
<td>1,500</td>
<td>13</td>
<td>1,300</td>
</tr>
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<td>Da2</td>
<td>cis-1,2-DCE</td>
<td>35,500</td>
<td>190</td>
<td>140</td>
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<td>77</td>
<td>410</td>
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<td>8,850</td>
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<td>&lt;20</td>
<td>NR</td>
<td>&lt;20</td>
<td>&lt;1</td>
<td>3</td>
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<tr>
<td></td>
<td>TCE</td>
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<td>2,100</td>
<td>1,400</td>
<td>NR</td>
<td>7,900</td>
<td>500</td>
<td>650</td>
</tr>
<tr>
<td>F13</td>
<td>cis-1,2-DCE</td>
<td>35,500</td>
<td>50</td>
<td>NR</td>
<td>NR</td>
<td>4</td>
<td>NR</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>1,1,1-TCA</td>
<td>8,850</td>
<td>&lt;10</td>
<td>NR</td>
<td>NR</td>
<td>&lt;1</td>
<td>NR</td>
<td>&lt;1</td>
</tr>
<tr>
<td></td>
<td>TCE</td>
<td>17,500</td>
<td>12</td>
<td>NR</td>
<td>NR</td>
<td>&lt;1</td>
<td>NR</td>
<td>1</td>
</tr>
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<td>F102</td>
<td>cis-1,2-DCE</td>
<td>35,500</td>
<td>46</td>
<td>NR</td>
<td>NR</td>
<td>770</td>
<td>NR</td>
<td>300</td>
</tr>
<tr>
<td></td>
<td>1,1,1-TCA</td>
<td>8,850</td>
<td>8</td>
<td>NR</td>
<td>NR</td>
<td>&lt;1</td>
<td>NR</td>
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<tr>
<td></td>
<td>TCE</td>
<td>17,500</td>
<td>26</td>
<td>NR</td>
<td>NR</td>
<td>82</td>
<td>NR</td>
<td>31</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td>cis-1,2-DCE</td>
<td><strong>NR</strong></td>
<td><strong>2,391</strong></td>
<td><strong>8,306</strong></td>
<td><strong>2,085</strong></td>
<td><strong>1,782</strong></td>
<td><strong>58</strong></td>
<td><strong>240</strong></td>
</tr>
<tr>
<td></td>
<td>1,1,1-TCA</td>
<td><strong>NR</strong></td>
<td><strong>14</strong></td>
<td><strong>341</strong></td>
<td><strong>506</strong></td>
<td><strong>8</strong></td>
<td><strong>1</strong></td>
<td><strong>1</strong></td>
</tr>
<tr>
<td></td>
<td>TCE</td>
<td><strong>NR</strong></td>
<td><strong>4,163</strong></td>
<td><strong>125,000</strong></td>
<td><strong>7,900</strong></td>
<td><strong>1,577</strong></td>
<td><strong>196</strong></td>
<td><strong>150</strong></td>
</tr>
</tbody>
</table>

*Not detects (<) were assumed to be present at one-half the detection limit in computing average concentrations.
NR - not reported
Table 5. Groundwater Quality After ERH Remediation [15]

<table>
<thead>
<tr>
<th>Well No.</th>
<th>Constituent</th>
<th>5/99 (µg/L)</th>
<th>12/99 (µg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A6</td>
<td>cis 1,2-DCE</td>
<td>1,100</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>1,1,1-TCA</td>
<td>ND</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>TCE</td>
<td>1,000</td>
<td>ND</td>
</tr>
<tr>
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ND = Not detected. Detection limit not provided.
COST OF THE TECHNOLOGY SYSTEM

COST DATA [5.7.12]

While data about the total cost of remediation efforts to date was confidential, the vendor provided costs on a per unit basis for the full-scale ERH remediation through November 1998 (initial treatment of 23,100 cubic yards). The cost of $32 per cubic yard included the installation and operation of the ERH power system and electrodes, vapor extraction and condensate treatment, project permitting, preparation of work plans, electrical use, waste disposal, interim sampling, and progress reporting. As of November 20, 1998, a total of 1,775 MW-hr of electrical energy had been consumed by the ERH system at a cost of as much as $14,000/month plus $40 per MW-hr for a total cost for electricity of $145,000. This corresponded to $6.40 per cubic yard of treatment volume, or 20% of the total cost of $32 per cubic yard.

In addition, the vendor provided a unit cost for treatment from December 1998 through May 1999 (treatment of 11,500 cubic yards). This unit cost also was $32 per cubic yard.

OBSERVATIONS AND LESSONS LEARNED

OBSERVATIONS AND LESSONS LEARNED

The ERH system used at this site achieved the established Tier III cleanup goals for the remediation of the initial estimated 23,000 cubic yards of remaining contamination at the site in about six months and for the remediation of the additional 11,500 cubic yards of contamination at the site in about five months. In addition, the concentrations of constituents in a number of wells had been reduced to the more stringent Tier 1 standards.

REFERENCES


17. Adams, Tim, ENSR. Personal communication with Mary Sherrill, Tetra Tech EM Inc. September 4, 2002.