

COST AND PERFORMANCE
REPORT

Electrical Resistive Heating at
Former Pumphouse #2
Hunter Army Airfield, Georgia

June 2005

SITE INFORMATION

IDENTIFYING INFORMATION [6]

Site Name: Hunter Army Airfield (Hunter AAF), Former Pumphouse #2

Location: Savannah, Georgia

Regulatory Context: Georgia Environmental Protection Division, Underground Storage Tank (UST) Management Program

Technology: Electrical Resistive Heating (ERH)

Scale: Full-Scale

TECHNOLOGY APPLICATION [6, 10]

Period of Operation: ERH system operation occurred over 4 months from April 5 to August 5, 2002.

Type/Quantity of Material Treated During Application:

Approximately 35,000 cubic yards of media was treated.

BACKGROUND [6, 7]

Hunter AAF contains a former aviation-gas fuel island identified as Former Pumphouse #2 in Figure 1. The pumphouse was used from about 1953 to the early 1970s and consisted of ten 25,000-gallon (gal.) USTs. The pumphouse was inactive from the early 1970s to 1995. In 1995, eight of the ten 25,000-gal. USTs were removed from the ground.

A Corrective Action Plan (CAP)–Part A investigation was performed in 1996 followed by a CAP–Part B investigation occurring in 1997 and 1999 to determine the extent of petroleum contamination at the site. In 1998, the two remaining USTs, as well as the pumphouse structure were removed from the site. During the CAP–Part B investigation, the petroleum contaminants identified in soil and groundwater included benzene, toluene, ethylbenzene, and xylenes (BTEX), as well as polycyclic aromatic hydrocarbon (PAH) constituents. The investigation identified a dissolved groundwater plume as covering an area of approximately 85,800 square feet (ft²).

During the CAP–Part B investigation in 1997, light nonaqueous-phase liquid (LNAPL) was discovered in one of the wells. The free product was removed from the well with absorbent socks from 1997 to 1999. In 2000, the thickness of the free product was found to have increased, and free product was observed in one additional well. The product was removed with absorbent socks. It was determined that the product covered an area of approximately 3,825 ft².

A consulting firm was contracted to implement the approved CAP–Part B remedial alternative, the ERH system. Operation of the remedial system was initiated in April 2002 and continued for 4 months. The results of baseline sampling, the system startup activities, and the final results are documented in semiannual progress reports and are summarized in this report.

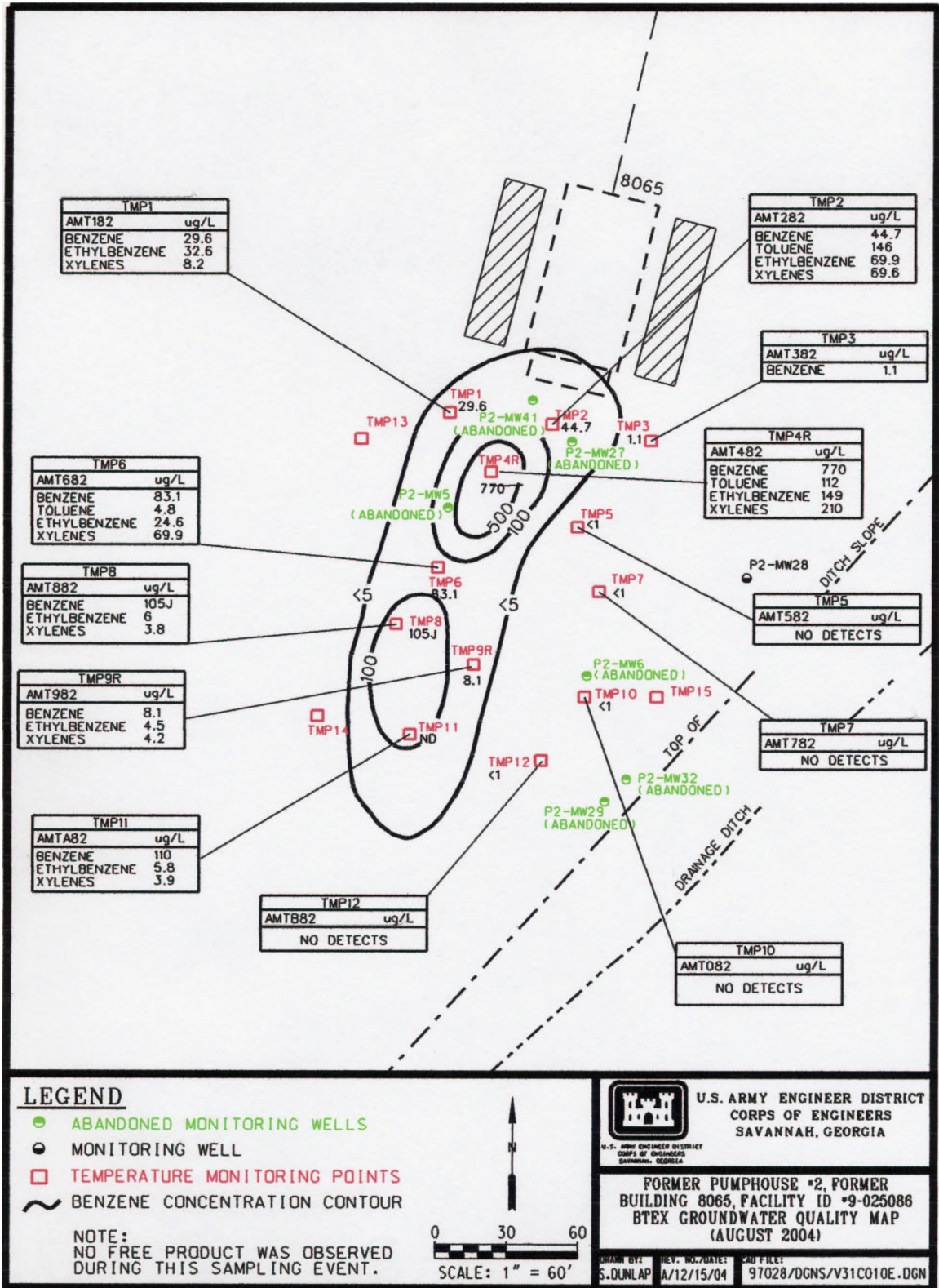


Figure 1. BTEX Groundwater Quality Map (August 2004)
At the Former Pumphouse #2 Site, Facility ID #9-025086

CONTACTS [5, 6]

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MATRIX DESCRIPTION

MATRIX AND CONTAMINATION IDENTIFICATION [6]

Type of Media Treated with Technology System: Soil, groundwater, and LNAPL

Primary Contaminant Groups: BTEX and PAHs

SITE HYDROGEOLOGY AND EXTENT OF CONTAMINATION [1, 3, 4, 6]

The hydrogeology in the vicinity of Hunter AAF is mostly influenced by two aquifer systems, the principal artesian aquifer (Floridan) and the surficial aquifer. The Floridan aquifer is approximately 800 feet (ft) in total thickness and is confined by a layer of phosphatic clay of the Hawthorn Group. Groundwater drawn from the Floridan aquifer is used primarily for drinking water.

The groundwater encountered at Hunter AAF is part of the surficial aquifer system. The surficial aquifer overlies the Hawthorn confining unit and supplies water primarily for domestic lawn and agricultural irrigation. The top of the water table ranges from approximately 12 to 16 (specifically at Former Pumphouse #2) ft below ground surface (bgs). Groundwater in the surficial aquifer system is typically under unconfined, or water table, conditions; however, locally, thin clay beds create confined or semiconfined conditions. This is the case at Hunter AAF, where thin, surficial clay beds are present. Matrix characteristics for the site are described in Table 1.

Table 1. Matrix Characteristics [5, 6]

Parameter	Value
Soil Classification	Very fine to medium-grained sand
Clay Content and/or Particle Size Distribution	97% sand, 3% clay or silt
Depth to Groundwater	Average of 13.5 ft bgs
Hydraulic Conductivity	0.0121 centimeter per second (cm/sec)
Air Permeability	Not measured
Porosity	Average of 0.41
Presence of Nonaqueous-Phase Liquid	LNAPL
Moisture Content	Average of 0.43 (volumetric)
Total Organic Carbon	Ranging from 540 to 43,000 milligrams per kilogram (mg/kg)
Electrical Resistivity of Soil	Not measured

TECHNOLOGY SYSTEM DESCRIPTION

TREATMENT TECHNOLOGY [6]

ERH: Six-Phase Heating™ (SPH™)

TREATMENT SYSTEM DESCRIPTION AND OPERATION [6]

At Hunter AAF, a total of 111 ERH electrodes were installed at spacings of 18 ft and to a depth of 16 ft bgs. The electrodes were spaced to treat an area of about 30,000 ft². The steel conductive interval was from 8 to 16 ft bgs, with each actual steel electrode extending from 9 to 16 ft bgs. Each 2-inch-diameter electrode was placed in a 12-inch-diameter borehole that was backfilled with an Epsom salt (magnesium sulfate) solution and granular graphite in the annular space around the electrode. An electrically insulating polyvinyl chloride (PVC) oversleeve was placed on the nonconductive upper region of the electrode from 0 to 7 ft bgs. Two water tubes, one extending to 9 ft bgs and the other to 13 ft bgs, were installed in the annular space alongside the electrode to add water in order to prevent the power coupling from drying out and degrading.

In the area where free product (LNAPL) was located, 18 of the electrodes were installed in a combination of electrode and dual vapor extraction (DVE) wells. The conductive interval was 9 to 16 ft bgs for these wells. The electrode and DVE wells served as heating elements and as contingency product extraction points.

A total of 23 vapor recovery wells (VRW) were installed at a spacing of 40 ft with a radius of influence of 25 ft each. Two types of VRWs were installed in 8-inch-diameter boreholes: DVE and soil vapor extraction (SVE) wells. Five DVE wells constructed with 2-inch-diameter steel casings were placed in locations where free product was observed. Steam hoses were inserted into the DVE wells to recover product and water as well as air and steam from the vadose zone. The 18 SVE wells, which were also constructed with 2-inch-diameter steel casings, were located outside the free product area.

An infiltration gallery was installed for subsurface discharge of treated water generated by the ERH system. The design of the infiltration gallery was adapted from methodologies used in septic system leaching fields and was based on an estimated volume of 43,200 gallons per day. Three 50-ft-long trenches were located 6 ft apart; each trench contained 1 ft of gravel and a 4-inch-diameter slotted pipe located in the center of the gravel.

To monitor the internal temperature of the treatment area, 15 temperature monitoring points (TMP) constructed with 0.5-inch-inside diameter, PVC casings were installed with thermocouples located at 8, 12, and 16 ft bgs. Temporary piezometers constructed with 1-inch-inside diameter, stainless steel casings were installed within 12 of the TMPs to collect groundwater samples. These 12 monitoring points, identified as TMP-01 through TMP-12, were used to determine the effectiveness of the treatment system. Figure 2 shows the locations of abandoned monitoring wells, current monitoring wells, electrode and DVE wells, DVE and SVE wells, and TMPs located south of Former Pumphouse #2.

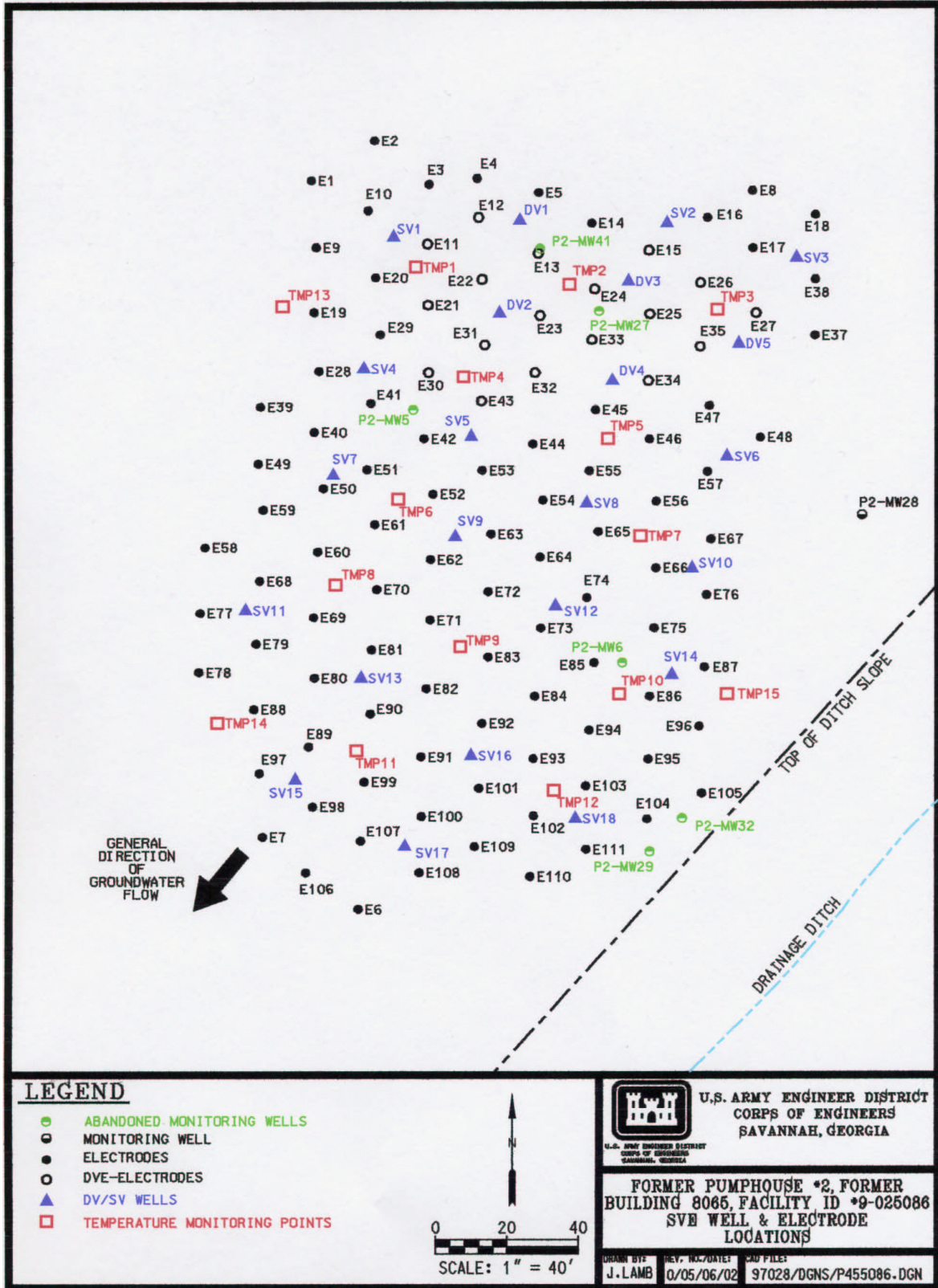


Figure 2. SVE Well and Electrode Locations

The subsurface components of the ERH system – electrodes, wells, and TMPs – were installed over a 9-day period (November 28 to December 6, 2001). The piping from the surface components to the subsurface components in the treatment area was installed over a 10-day period (December 11 to 20, 2001). Baseline groundwater sampling at 11 of the 12 TMPs occurred on January 19, 2002. TMP-09 was not sampled because free product was present in the well.

The startup period for the system was initiated on March 18, 2002. The system exhibited an automatic shutdown of the vacuum extraction unit because of a lower explosive limit (LEL) exceedance in the exhaust gas. This exceedance was caused by the amount of free product in the DVE wells. A “slow start” was performed to maintain low explosive control. Over a period of 5 days (March 18 to 22), the extraction tube was lowered to the product and water table interface, which allowed the system operator to control the amount of volatile organic compounds (VOC) being extracted over a period of time.

In March 2002, a power converter unit (PCU) owned by the U.S. Department of Energy (DOE) was delivered to the site. The PCU was loaned to the U.S. Department of Defense (DOD) for the project. The PCU had a capacity of 950 kilovolt-amperes (kVA) and was capable of using 12,400 or 13,800 volts of alternating current (VAC) power directly from a municipal power grid. The PCU contained an internal, 480-VAC, main stepdown transformer. Power was applied to the treatment area using six output transformers. The operational data is provided in Table 2.

Table 2. Operational Data [6]

Parameter	Value
Average Daily Power Input	510 kWh
Total Power Input	1,678,000 kWh
Average Subsurface Temperature	>90 °C

Note:
kWh – Kilowatt-hour

The startup period officially ended on April 5, 2002, when the heating and extraction systems were placed online. However, because of a problem with the fine voltage adjustment controller on one of the transformers, only half of the power supply could be applied. Only the northern half of the treatment area was heated until this problem was resolved. On April 11, 2002, the problem was resolved, and power was provided to the entire treatment area through use of all six transformers. The average rate of power input during the first weeks of system operation was approximately 500 kilowatts (kW). The voltage of the power supply output was subsequently increased, resulting in an increased power input of 780 kW.

Subsurface temperatures were measured at the TMPs three times a week. The peak average temperature (>90 °C) in the northern half of the treatment area was reached in early

June 2002. The southern half of the treatment area reached boiling temperatures in early July 2002.

Over the 4 months of ERH system operation, nearly 1,678,000 kWh of energy was input into the subsurface. On average, the daily rate of power input varied from 0 to 928 kW. The average daily rate of power input over the 4-month period was 510 kW.

The extracted vapor flow was calculated using a self-averaging pitot tube. The calculated flows ranged from 296 to 593 standard cubic feet per minute (scfm). Vapor extraction rates were considered fairly linear until June 2002, when operations were limited by the LEL. After June 2002, the vapor extraction rates declined because the bulk of the mass of contamination had been removed. The LEL was recorded to estimate the contaminant mass removed over time.

Approximately 470,700 gal. of water was recovered during operation of the ERH system. Of the recovered water, approximately 23,200 gal. was lost to evaporation in the cooling tower used to condense the recovered steam; 223,300 gal. was recirculated to the electrodes; and 224,200 gal. was discharged to the treatment system. Typically, the water addition rate per electrode ranged from 0.5 to 4.5 gallons per hour.

TIMELINE [6, 7]

- November 2001: construction of ERH system
- January 2002: baseline sampling
- March 18, 2002: ERH system startup period initiated
- April 5, 2002: ERH system placed online
- May 2002: first ERH system online sampling event
- June 2002: second ERH system online sampling event
- July 2002: third ERH system online sampling event
- August 5, 2002: ERH system shutdown
- February 2003: confirmation soil sampling/first post-ERH system shutdown sampling event
- September 2003: second post-ERH system shutdown sampling event
- March 2004: third post-ERH system shutdown sampling event
- August 2004: fourth post-ERH system shutdown sampling event

TECHNOLOGY SYSTEM PERFORMANCE

PERFORMANCE OBJECTIVES [2, 5, 6]

The objectives of the corrective action were to remove free product (LNAPL) from the site and to reduce concentrations of chemicals of potential concern (COPC) to less than their cleanup criteria, which are shown in Table 3. Site-specific alternate concentration limits (ACL) and alternate threshold levels (ATL) were developed for COPCs using the results of fate and transport modeling and identified receptor locations. The ACLs and ATLs were developed based on available regulatory screening levels. When regulatory screening levels were not available, ACLs were developed based on risk-based levels.

Table 3. Cleanup Criteria for Hunter AAF [2, 5, 6]

Contaminant	Alternate Concentration Limit for Groundwater (µg/L)	Alternate Threshold Level for Soil (mg/kg)
Benzene	469	0.44
Benzo(a)pyrene	2.0	6.8
Benzo(b)fluoranthene	2.0	27.0
Chrysene	2.0	10.0
Ethylbenzene	Not calculated	389
Indeno(1,2,3-cd)pyrene	Not calculated	0.66
Naphthalene	428	Not calculated
Toluene	1,316,000	2,050
Total Xylenes	Not calculated	700

Notes:

ACLs and ATLs were calculated only for contaminants identified as COPCs in the CAP-Part B report.

µg/L – Microgram per liter

mg/kg – Milligram per kilogram

TREATMENT PERFORMANCE [6]

The treatment performance of the ERH system at Hunter AAF was measured based on the amount of free product found at the site as well as the concentrations of COPCs relative to their cleanup criteria. Over the 4-month period of system operation, an estimated 44,000 pounds of VOCs was removed. Table 4 shows that the amount of free product was reduced from a maximum of 11,500 ft² measured in May 2002 to no free product beginning in June 2002.

A total of four confirmation soil samples were collected in February 2003. These samples indicated that none of the BTEX or PAH compounds were present at concentrations exceeding their ATLS. No additional soil sampling was conducted during the treatment phase or subsequent performance monitoring at the site.

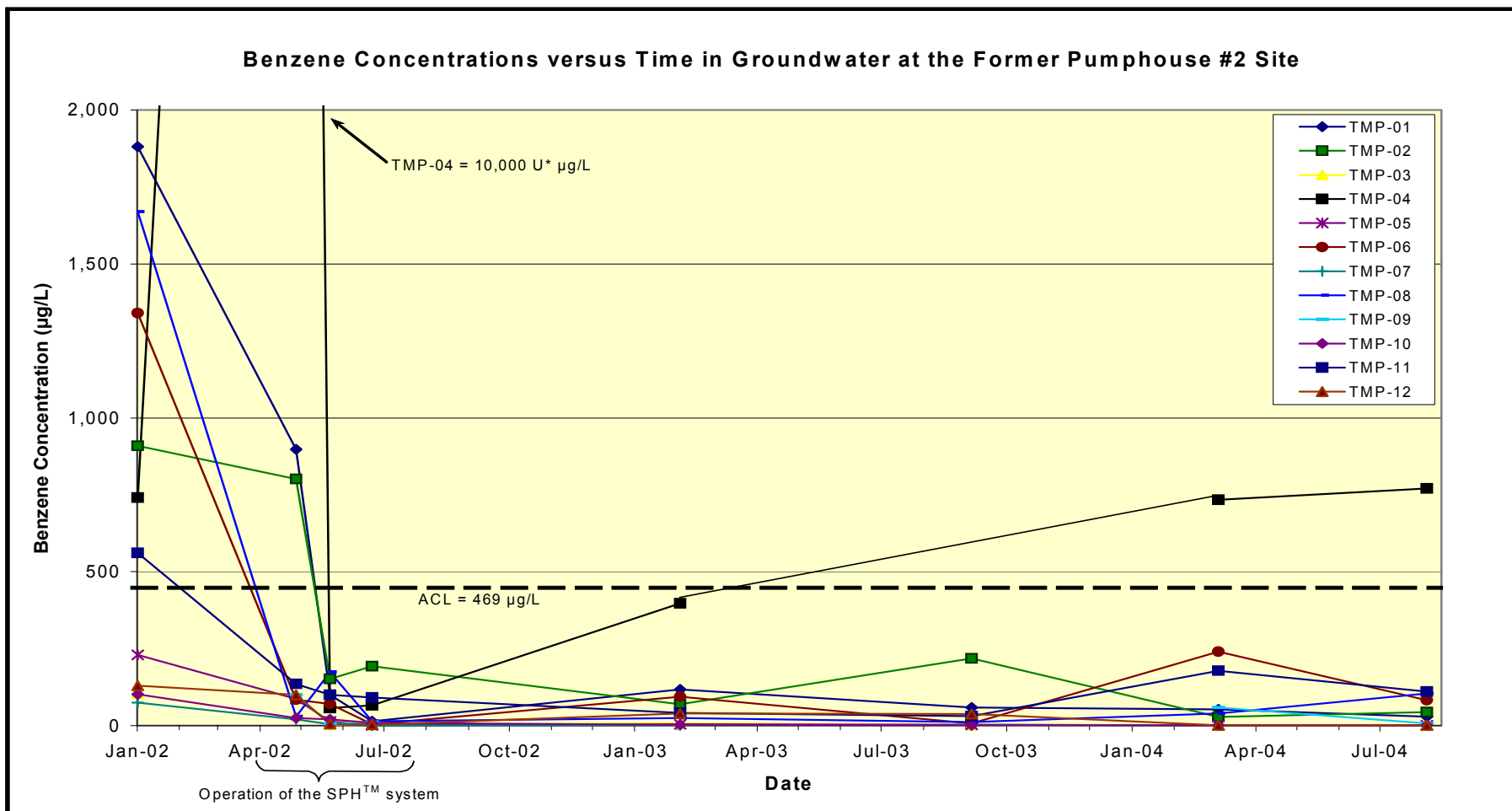
Post-treatment concentrations of benzene and PAHs were measured in groundwater during sampling events in February 2003, September 2003, March 2004, and August 2004. Figure 3 summarizes the changes in benzene concentrations in groundwater by well from January 2002 through March 2004. The dissolved-phase benzene concentrations were reduced to concentrations below the benzene ACL except for one exceedance (733 µg/L) in March 2004 at TMP-04. In February 2003 (6 months after treatment), the concentrations of two PAHs exceeded their ACLs: benzo(a)pyrene in TMP-08 (2.8 µg/L) and naphthalene in TMP-02 (459 µg/L). However, as of March 2004, none of the PAH concentrations in groundwater exceeded ACLs.

The main portions of the benzene plume and free product area were located south (downgradient) of the former tank pit, and this downgradient area is where the ERH system was applied. The former tank pit area may have contained additional contamination that was not remediated and is now impacting TMP-04. Also, there may be some rebound in the groundwater contamination because of flushing of contaminants. Because of DOE needs, the PCU had to be returned after 4 months; thus, the length of system operation had to be limited.

The "Fourth Semiannual Progress Report" [6] recommended that groundwater sampling of TMPs continue semiannually. If the constituent concentrations are below ACLs following a year of semiannual sampling, then "no further action required" status will be requested for the site.

The site remains in a semiannual monitoring-only program. In April 2005, several injection wells were installed around TMP-04 for the injection of Petrox™. Petrox™ is provided by CL-Solutions and is a form of specialized bacteria that promotes active, rapid, aerobic bioremediation of environmental contamination caused by petroleum hydrocarbons, organic solvents, and semivolatiles hydrocarbons. The product contains highly concentrated solutions of live, patented strains of lyophilized (freeze-dried) microscopic organisms (microbes) that occur naturally in the earth's ecosystem. Extracted from a once-contaminated site and isolated under controlled laboratory conditions, these bacteria destroy contamination at its source and then quickly convert it into harmless, naturally recyclable by-products. Petrox™ is available as a freeze-dried powder or as a concentrated liquid and comes in three standard blends or is custom-formulated to meet specific needs. Petrox™ was formulated to remediate gasoline, diesel and heating fuels, BTEX compounds, methl ethyl ketone, methylene chloride, and naphthalene. After the injection of Petrox™, semiannual monitoring will continue.

Figure 3. Trend of Benzene Concentrations in Groundwater at the Hunter AAF Former Pumphouse #2 Site [6, 7]



U* = Laboratory qualifiers; indicating that the compound was not detected at the concentration reported

Table 4. Area of Groundwater Plume and Free Product [6, 7]

Sampling Event	Area of Benzene Contamination in Groundwater (ft²)	Area of Free Product (ft²)
November 1999	85,800	—
August 2001	—	4,900
January 2002	55,500	9,800
May 2002	29,100	11,500
June 2002	18,000	0
July 2002	12,400	0
February 2003	16,400	0
September 2003	13,200	0
March 2004	14,600	0
August 2004	14,400	0

Note:

‘—’ indicates unknown area.

COST OF THE TECHNOLOGY SYSTEM

COST DATA [8]

The U.S. Army Corps of Engineers reported that the total cost for the SPH™ application at Hunter AAF was approximately \$1,300,000, including \$1,042,129 for system design, mobilization and demobilization, installation, and operation and maintenance for 4 months and \$259,000 for electrical service. This total cost does not include costs for the PCU, which was provided on loan from DOE.

OBSERVATIONS AND LESSONS LEARNED

OBSERVATIONS AND LESSONS LEARNED [7, 9]

Following 4 months of ERH system operation, the area of free product at the site was removed, and cleanup levels for COPCs, including benzene and PAHs, were generally met. The only exception involved benzene in groundwater at one monitoring location, where the concentration of 733 µg/L exceeded the ACL of 469 µg/L. Site groundwater will continue to be monitored on a semiannual basis, and plans have been made to enhance in situ biodegradation of residual contaminants in the area near the benzene exceedance using an injection of a specialized bacteria product.

The PCU used to provide power for the ERH system was provided on loan by DOE. The process used to obtain the PCU was relatively lengthy. DOE was able to provide the PCU for only a limited amount of time at the site, and this was a limiting factor in the length of time that ERH could be performed at the site.

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