COST AND PERFORMANCE REPORT

Contained Recovery of Oily Waste (CROW)^{TM} Process
at the Brodhead Creek Superfund Site
Stroudsburg, Pennsylvania

June 1997

EPA

Prepared by:

U.S. Environmental Protection Agency
Office of Solid Waste and Emergency Response
Technology Innovation Office

SITE INFORMATION

Identifying Information:

Brodhead Creek Site
Stroudsburg, Pennsylvania

CERCLIS #: PAD980691760

ROD Date: 29 March 1991
ESD Date: 19 July 1994

Treatment Application:

Type of Action: Remedial

EPA SITE Program test associated with application? Yes

Period of operation: July 1995 - June 1996

Quantity of material recovered during application: 1,500 gallons of coal tar

Background [1, 7, 8]

Historical Activity That Generated Contamination at the Site: Coal gasification plant

Corresponding SIC: 4925 (Mixed, Manufactured, or Liquefied Petroleum Gas Production and/or Distribution)

Waste Management Practice That Contributed to Contamination: Waste product disposed of in an open pit.

Location: Stroudsburg, Pennsylvania

Operations: Coal gasification plant

Citizen Gas and Electric operated a coal gasification plant from about 1888 until 1944.

A waste product from those operations was a black tar-like liquid (coal tar) with a density greater than water (specific gravity equal to 1.014) and principally composed of polyaromatic hydrocarbons (PAH). Coal tar was disposed of in an open waste pit on site.

In October 1980, during repairs of a flood control levee near the site, material identified as coal tar was observed seeping into Brodhead Creek.

As a result of the contamination, several investigations and removal response actions were initiated, between 1981 and 1984. The actions included:

- Installation of filter fences and underflow dams to intercept coal tar seepage
- Installation of a coal tar recovery pit on the bank of Brodhead Creek
- Construction of a slurry wall to mitigate coal tar migration from the site into Brodhead Creek
- Excavation of a backwater channel area where seepage of coal tar appeared to be significant
- Installation of recovery wells in the main coal tar pool that recovered approximately 8,000 gallons of coal tar

In December 1982, the site was placed on the Comprehensive Environmental Response Compensation and Liability Act (CERCLA) National Priorities List The remedial investigation (RI) was completed in April, 1989, and a feasibility study (FS) was completed in January 1991.

An interim record of decision (ROD) signed on March 29, 1991 called for the use of an enhanced recovery technology to recover free phase coal tar from subsurface soils. On July 19, 1994, an explanation of significant differences (ESD) was approved. The ESD modified the performance standard of the coal tar recovery operations and addressed requirements under the Resource Conservation and Recovery Act (RCRA) for management of coal tar.

SITE INFORMATION (CONT.)

Regulatory Context:

On August 20, 1987, the potentially responsible parties (PRP) for the site entered into an agreement with the Pennsylvania Department of Environmental Protection (DEP) to conduct the RI/FS.

On March 29, 1991, EPA issued a ROD for the site. The ROD called for the use of an enhanced recovery technology to recover free phase coal tar from subsurface soils.

Remedy Selection: The remedy called for enhanced recovery of coal tar in the subsurface soils; separation of the coal tar from the process waters; discharge of the process waters after treatment to Brodhead Creek; incineration of recovered coal tar at a permitted off-site facility; fencing, deed restrictions and monitoring of groundwater; and testing of biota in Brodhead Creek.

Site Logistics/Contacts

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MATRIX DESCRIPTION

Matrix Identification

Type of Matrix Processed Through the Recovery System: Waste product and process water.

Contaminant Characterization [1, 7]

Primary Contaminant Groups: PAHs, nonhalogenated semivolatiles, volatiles, and metals

Coal tar from coal gasification operations has migrated vertically through the unsaturated and saturated portions of the stream gravel units to the interface with the silty sand. The silty sand prevents further downward movement of the coal tar because of the higher capillary pressures within that unit. Further movement of the coal tar has been lateral toward the natural depressions in the silty sand unit where it has accumulated.

As shown in Figure 1, potentially recoverable coal tar is trapped in a portion of the natural stratigraphic depression east of the slurry wall near monitoring well 2 (MW-2) and in the lower portion of the stratigraphic depression west of the slurry wall, as measured in the central recovery well cluster (RCC) which was part of the initial product recovery system. Both of these tar accumulations were considered to be confined from further downward migration as a bulk nonaqueous phase by the top of the silty

MATRIX DESCRIPTION (CONTINUED)

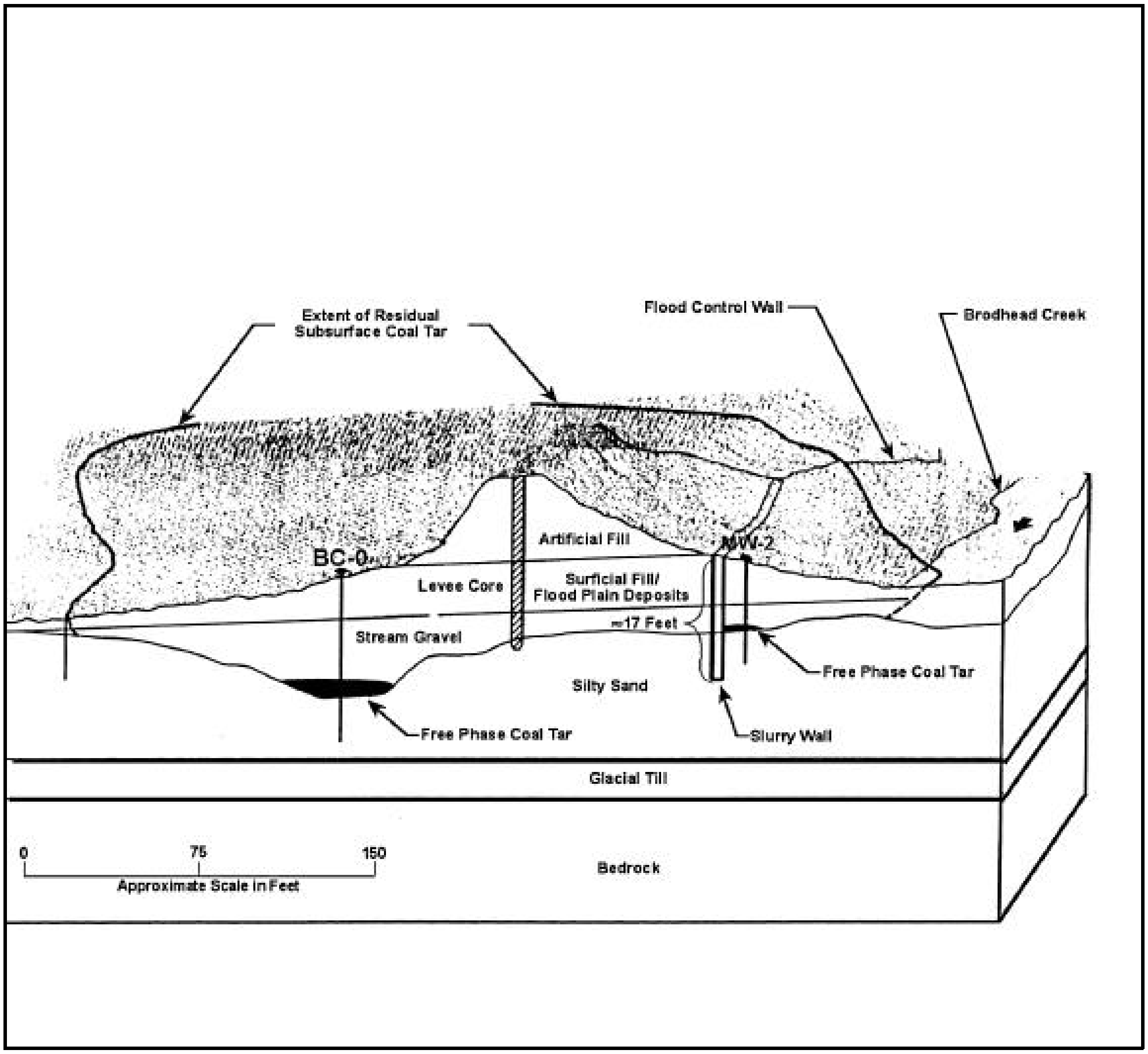

Figure 1. Schematic of Extent of Free and Residual Coal Tar [3]

sand unit. The 1991 ROD estimated the total volume of free phase coal tar associated with these areas to be 9,000 gallons, with 8,715 gallons and 338 gallons of free phase coal tar associated with the RCC and MW-2 areas, respectively.

The primary contaminants at the site were benzo(a)pyrene (representative of carcinogenic PAHs), naphthalene (representative of noncarcinogenic PAHs), benzene, and arsenic. Soil samples from the silty sand unit (monitoring wells 9 and 10) indicated the presence of chloroform at a concentration of 2 μg/kg. Soil samples from the gravel unit (monitoring wells 11 and 12) showed evidence of low VOC concentrations in only MW-11 where traces of coal tar were noted in sampled materials. Semivolatile organic results for the four soil sample locations ranged from non detect in the silty sand to high concentrations in the gravel unit at MW-11. The concentration of SVOCs in

MATRIX DESCRIPTION (CONTINUED)

MW-11 were very high suggesting the presence of residual saturation of coal tar in that area. In MW-11, reported concentrations ranged from 590 μg/kg for indeno(1,2,3-cd)pyrene and up to 54,000 μg/kg for 2-methyl naphthalene. Total PAHs were identified tentatively at concentrations of 450,000 μg/kg.

Contaminants in the groundwater that were detected at concentrations above EPA's maximum contaminant levels (MCL) for groundwater include: benzene (maximum concentration, 1,100 μg/L), arsenic (maximum concentration, 108 μg/L). Several PAHs including benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, and chrysene were detected in groundwater at concentrations ranging from 250 μg/L to 300 μg/L.

Matrix Characteristics Affecting Treatment Costs or Performance [1, 3, 7]

Type of Matrix: Free Phase Coal Tar in soil)

Geology: The site is located within the Valley and Ridge physiographic province of the Appalachian Mountains. As shown in Figure 1, the Brodhead Creek site is underlain by at least 60 feet of unconsolidated sediments of glacial, recent fluvial, and human origin. Four distinct strata make up this unconsolidated interval: surficial fill, flood-plain deposits, stream gravels, and silty sands. The thickness of the stream gravel averages about 10 to 15 feet, but ranges to a maximum of 25 feet in a stratigraphic depression in the center of the site. Bedrock at the site is the Devonian Age Marcellus Shale. Directly underlying the Marcellus Shale is the Devonial Age Buttermilk Falls Formation, which is composed of limestone and is a viable water supply.

DESCRIPTION OF TREATMENT SYSTEM

Primary Treatment Technology

Contained Recovery of Oily Waste (CROW)

Supplemental Treatment Technology

Oil/water separation; carbon adsorption

System Description and Operation [6, 8]

This enhanced recovery process used hot water (approximately 200° F) injected into subsurface areas where free-phase tar had been identified. The heat of the injected water decreased the viscosity of the tar, facilitating recovery. Heating the tar also reversed the difference in density between the oily waste and water. The density of heavy organics is almost equivalent to the density of water at a temperature of about 100°F. At higher temperatures, the oil phase has a lower density than water because water is more polar and resists thermal expansion.

Figure 2 shows a cross section of the subsurface activity associated with the CROW system. Figure 3 presents a plan view of the entire operation at the site and shows the system's well fields.

Downward migration of oily wastes was reduced by thermal expansion and lower density of the oils and floating of coal tar. Balancing the hot-water injection and production rates controlled the upper boundary of the contaminated area, preventing fluid displacement through density induced flotation into the overlying material. Six injection wells were installed in such a manner as to encircle the estimated areal extent of the deposit of tar. The design injection flow rate of approximately 100 gallons per minute (gpm) never was achieved. That failure was the result of iron fouling problems in the well screens and possibly the formation itself. Two production wells were installed near the center of the deposit. Water and tar were extracted from the production wells at approximately 40 gpm, producing a drawdown in the wells that induced a gradient from the injection points to the production points. The induced gradient also

DESCRIPTION OF TREATMENT SYSTEM (CONTINUED)

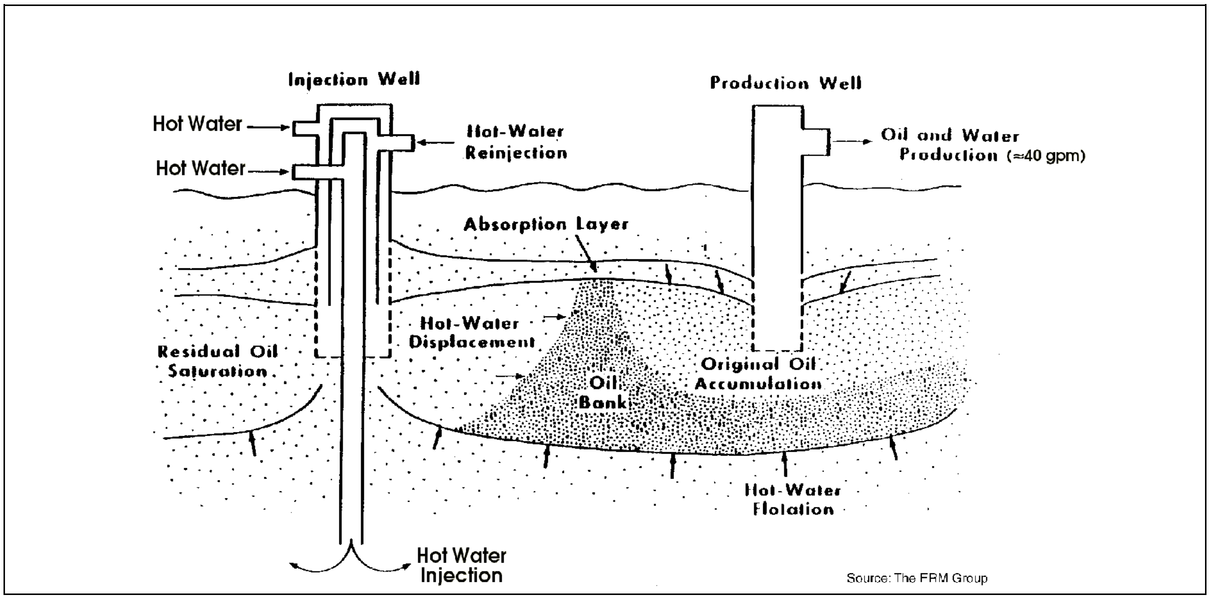

Figure 2. Cross section of subsurface setup of CROW process [6]

limited the heat to levels within the target zone and prevented the release of the mobilized constituents into the surrounding aquifer. After the mixture of tar and water was pumped to the surface, it underwent treatment through a tar-water separator. Approximately 33 gpm of the separated water was recycled through the water heater and discharged into the six injection wells. The remaining 7 gpm was pumped to the FBR unit where the organic constituents were degraded biologically. The treated water then was pumped through two carbon adsorption units to meet limits set by the state under the National Pollutant Discharge Elimination System (NPDES) before it was discharged to Brodhead Creek.

It originally was anticipated that, when the level of recovered coal tar in Oil Storage Tank 4 had reached 50 percent of the tank's capacity (approximately 5,000 gallons), transfer procedures for the coal tar would begin. However, the level in the oil storage tank never reached 50 percent. Therefore, all recovered tar was transferred off site for treatment at the end of the project. The contracted disposal company provided the necessary equipment to transfer the coal tar properly from the settling tanks and the oil storage tank to the truck. The coal tar was dewatered at a facility in Ohio, then transported to a permitted boiler or industrial furnace (BIF) facility in Pennsylvania.

Process water was run through a series of three 20,000 gallon tanks that served as an oil-water separation system, then treated further by the GAC-FBR units, before it was discharged to Brodhead Creek.

Recovered coal tar (deemed a RCRA characteristic waste for toxicity) was dewatered at an off-site facility, then shipped to and burned at another offsite facility permitted as a BIF, in compliance with the off-site rule.

DESCRIPTION OF TREATMENT SYSTEM (CONTINUED)

System Operation

The proposed operating conditions for the CROW system were:

Nominal Pattern Distribution	40 ft x 80 ft
Number of Patterns	2
Number of Wells	
Injection	6
Extraction	2
Interior Monitoring	4
Exterior Monitoring	4
Average Injection/Extraction Well Spacing	28 ft
Average Gross Thickness of Saturated Zone	20 ft
Injection Pressure (at bottom of well)	20 pounds per square inch gauge (psig)
Injection Wellhead Temp.	~170°F
Pattern Injection Rate	
(design)	100 gpm
(actual)	40 gpm
Total Water Injected	13-17 x 10^6 gallons
Water Production (Extraction) Rate/Per Well	35-45 gpm
Total Water Production (Extraction) Rate	70-90 gpm
Total Water Extracted	21 x 10^6 gal
Injection/Production Time	11 months

Nominal pattern distribution refers to how the injection wells and production wells are placed relative to each other to enhance the recovery of the coal tar. There were six injection wells and two production wells in the pattern. The pattern was designed so that four wells were aligned with one production well, with a crossover of injection wells 3 and 4 to the production well. Figure 3 shows the position of the wells at Brodhead Creek.

The CROW process enhances recovery of oily waste by reducing its viscosity and reversing the difference in density between the oil and the water.

Laboratory and pilot work performed indicated that the optimal temperature for flushing of the Brodhead Creek site was 156°F. The average temperature of the targeted area was less than 156°F. The average temperature of the targeted area varied from 150 to 180°F near the injection wells to 110 to 130°F near the production wells. This was the result of the system operating at a lower flow rate than originally designed due to iron fouling of the wells and the formation itself. The lower-than-optimum temperature (156°F) may have resulted in recovery of less tar because the viscosity of the tar had not been reduced as much as had been anticipated.

Suspended solids also caused operational difficulties throughout the system. They interfered with tar settling calculations; fouled the granular activated carbon-fluidized bed reactor (GAC-FBR), carbon drums, and injection wells; and increased the concentrations of dissolved PAHs in the discharge water. Suspended solids occur in the form of silt, iron floc (or other precipitated metals), or biomass. Filters were installed in line at various points in the system to remove the suspended solids.

Modifications to the system included:

- rewiring of heater elements for optimal performance and increased temperature;
- reconfiguring the heater control unit for greater temperature regulation;
- replacing inflatable packers into injection wells (W1, W2, W6);
- utilizing supplementary interior monitoring wells as injection wells.
- repairing and replacing damaged flow meters for increased injection flow control;
- repairing production pumps to increase the capacity and permit increased injection; and
- replacing all four carbon adsorption units with new units.
- modifying the water treatment system to enhance iron flue removal.

DESCRIPTION OF TREATMENT SYSTEM (CONTINUED)

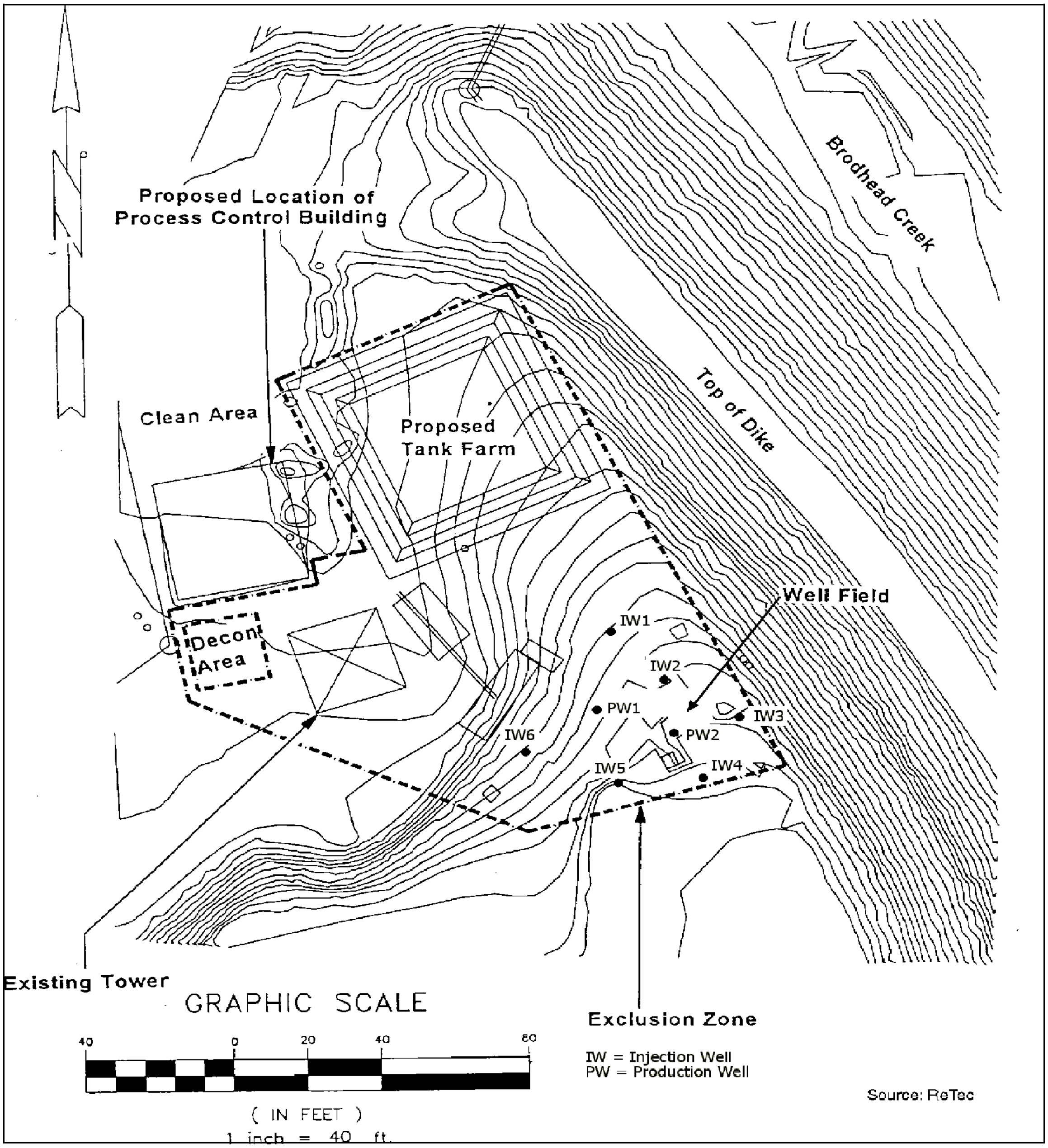

Figure 3. Plan View of CROW System Operations and Positions of Injection and Recovery Wells at Brodhead Creek [6]

TREATMENT SYSTEM PERFORMANCE

Cleanup Goals/Standards [2, 7]

The ROD called for removal of 60 percent of the total free phase coal tar from the subsurface soils. However, the preremedial design investigation revealed that an accurate measurement of the amount of free phase coal tar initially present was not possible, mainly because of the heterogeneity of the subsurface and difficulty experienced with collecting representative samples. During the remedial design, it was learned that, although free phase coal tar was present at both the RCC and MW-2 areas, it was discontinuous, and therefore a direct estimate of the initial volume present could not be made. Consequently, it was not possible to determine when 60 percent of the total free phase coal tar had been removed. The July 1994 ESD revised the standard, requiring the system to be operated until "the incremental change in the amount removed is 0.5% or less of the cumulative coal tar removed per pore volume." Previous laboratory and field data indicate that it is at this point that 98.5 percent of the total recoverable coal tar will have been recovered.

Additional Information on Goals

RCRA hazardous waste regulations were determined to be applicable for the management, storage, treatment, and disposal of the coal tar recovered at the site. The coal tar was RCRA characteristic (toxic) for benzene and arsenic. EPA also determined that the recovered coal tar could be disposed of in an offsite BIF that was in compliance with interim status requirements pursuant to 40 CFR Part 266 Subpart H.

Process water was treated to levels meeting NPDES requirements for Brodhead Creek prior to discharge.

Timeline [5, 6, 8]

Start Date	End Date	Activity
1888	1944	Coal gasification plant operates along the west bank of Brodhead Creek near Stroudsburg, PA.
---	October 1980	Coal tar seepage to Brodhead Creek is discovered during repair of the toe of the flood control levees.
1981	1984	Various investigations and Superfund removal response actions are initiated to mitigate the flow of coal tar into Brodhead Creek.
---	December 1982	The site is placed on the CERCLA National Priorities List.
---	August 1987	Pennsylvania Power and Light (PP&L) Co. and Union Gas enter into a consent agreement with the state of Pennsylvania to conduct an RI/FS for the site.
August 1988	April 1989	Field work for the RI is conducted.
---	January 1991	The FS for the site is completed.
---	March 1991	An interim ROD is approved.
---	September 1992	The consent decree to implement the remedy set forth in the ROD was entered into U.S. District Court for the Eastern District of Pennsylvania.
January 1993	March 1994	The remedial design was completed.
May 1994	October 1994	The remedial construction was completed.
December 1994	June 1996	The remedial action was completed; the performance standard had been met.

TREATMENT SYSTEM PERFORMANCE (CONTINUED)

Treatment Performance Data [6, 8]

Approximately 20 pore volumes of water flushed through the recovery zone resulted inan estimated total volume of coal tar removed from the subsurface of approximately 1,500 gallons. This measure was estimated during each pore volume flushed, but was not verified until the end of the project, when the storage tanks were pumped (see discussion below). Figure 4 shows the estimated cumulative amount of tar recovered over life of the project.

Figure 5 shows the estimate of the percentage increase in cumulative amount recovered, compared with pore volume at the site. For the last three pore volumes (18, 19, and 20) the figure shows an incremental change in the amount removed of less than 0.5 percent of the cumulative amount of coal tar recovered per pore volume of water flushed through the subsurface soils. However, because of problems with the measuring methodology, the accuracy of this estimate cannot be verified directly. The measurement of the amount of tar recovered in the production well during the final pore volume flushes indirectly verified that the performance standard had been achieved. (see discussion below).

Figures 4 and 5 show that the majority of the coal tar recovered occurred in the first three pore volumes. On the measurements made during the process, approximately half the recovered tar was recovered in the first 3 pore volumes, and the other half in the latter 17 pore volumes flushed through the subsurface soils. However, as discussed below, confidence in the measurements was suspect, and the initial recovery cannot be verified.

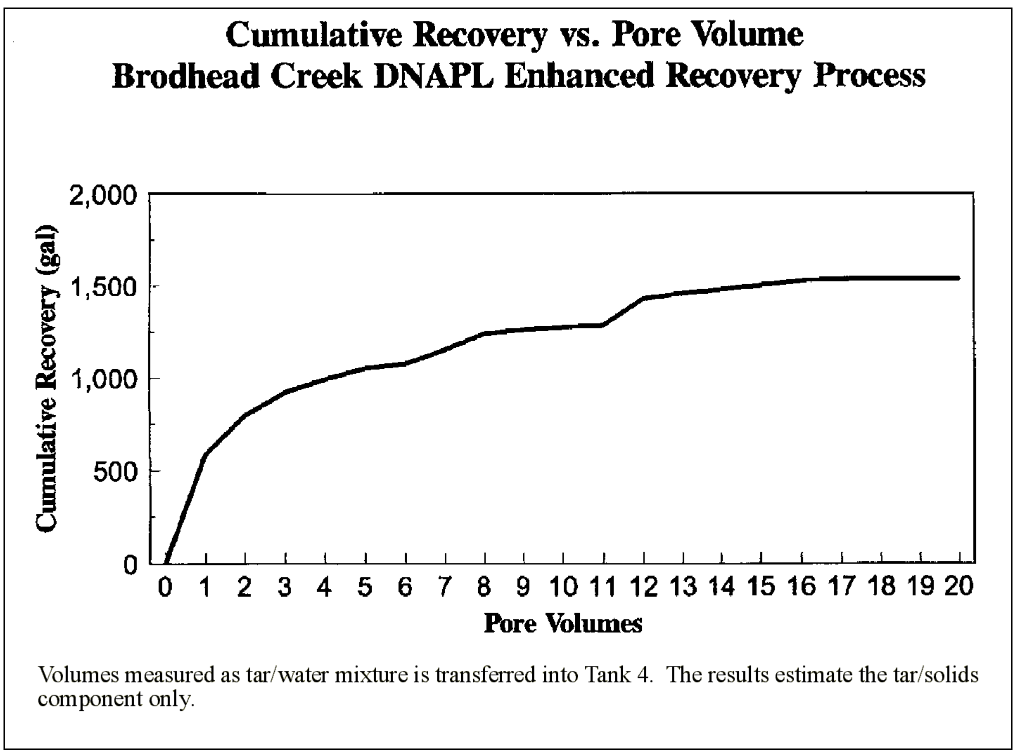

Figure 4. Estimated Cumulative Recovery of Tar Over Life of Project [6, 8]

TREATMENT SYSTEM PERFORMANCE (CONTINUED)

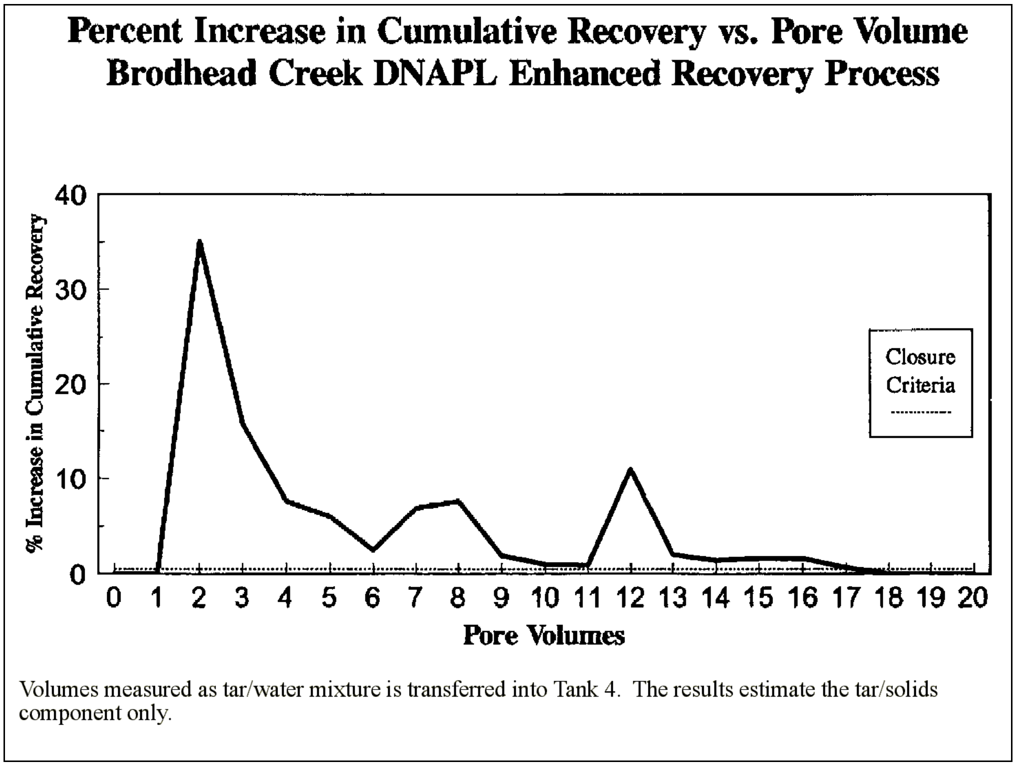

Figure 5. Estimate of the Percent Increase in cumulative Amount Recovered Per Pore Volume [6, 8]

The original design included an automatic tar separation and measuring system that consisted of conductivity meters and a flow meter with a totalizer. In theory, a conductivity meter would sense any dense accumulation of tar at the bottom of the settling tank. The conductivity meter was wired to a tar transfer pump. As long as the meter sensed the presence of tar, the valve would stay open, and the liquid would be pumped from the tank bottom to the oil storage tank. The flow meter and totalizer would measure the transfer of oil. Ideally, at the end of the project, the totalizer would indicate how much tar had been transferred to the oil storage tank. However, viscous tars or oils fouled the conductivity and the flow meters, making accurate readings impossible. This condition caused a problem in determining whether the performance of the system met established standards.

To measure the increase in the cumulative amount of tar recovered, two items of information were needed: the total cumulative amount recovered and the amount recovered in the last pore volume. The initial methods for measuring those quantities were unreliable because of the technical difficulties described above. To estimate the quantities, the site operator checked the bottoms of tanks 1, 2, and 3 each day by collecting a small sample of liquid near the bottom of each tank. If the sample appeared murky, it was allowed to settle overnight.

Generally, the sample would separate by morning into two phases. A light, clear, water phase would rise to the surface, and a dark oily phase would sink to the bottom. This bottom phase, referred to as the “solid mixture,” was a mixture of silt, iron floc, and tar. If the solid

Treatment System Performance (continued)

mixture made up more than 50 percent (by visual inspection) of the sample, a transfer of tar was conducted. A small amount of material at the bottom of that particular tank would be pumped into the oil storage tank. Because the flow meter was not working, it was not possible to measure accurately the flow rate or quantity of tar transferred. Therefore, the operator estimated the quantity. To do so, the operator timed the pump while monitoring the rise in the level of liquid in the oil storage tank. By converting the rise in the level of liquid to a volume, the operator was able to determine the flow rate produced by the oil transfer pump. The flow rate was estimated at 50 gpm. By timing the transfer of tar, the operator could record the total quantity of liquid transferred. To determine the percentage of tar in that liquid, the operator collected a second sample from the same sample port in the tank. That sample also was allowed to settle overnight. The next day, the percentage of solid mixture was observed and recorded. The quantity of tar then was estimated by averaging the before and after percentages of the solid mixture and multiplying by the total volume of liquid transferred.

The results represented the total volume of tar, iron floc, and silt transferred because those materials could not be separated in the solid mixture. As the system was operated, those volumes were recorded. By tracking the pore volumes flushed over the same period of time, an estimate was made that allocated a specific volume of tar transferred to a specific pore volume.

In March 1996, near the end of the project, a sample of recovered solid mixture was collected from the oil storage tank. The sample had an oily aroma and had a murky brownish-orange appearance. The sample was analyzed for its primary components. The results were:

Moisture Content	99.60%
Organic Content	0.27%
Inorganic Content	0.13%
Total	100.00%

The results which indicated that the contents of the oil storage tank were primarily water, prompted concern about the representativeness of the sample. Subsequent sampling showed that a darker phase was present in the bottom few feet of the tank, and that most of the tank was filled with water. However, samples of the darker, denser phase at the bottom of the tank revealed similar results. On the basis of those results, EPA concluded that the modified method of calculating the volume of tar recovered was inaccurate and therefore the results could not be used to certify achievement of the performance standard.

Upon analysis of the contents of the other tank bottoms, it was discovered that much of the dense organic material had accumulated in the primary settling tanks. The material that was transferred into the oil storage tank throughout the operation of the system consisted of a dilute mixture that floated on top of the dense organic material. In addition, pumping from a low point on the tank likely caused a high energy point so that less viscous fluids immediately filled the pipe space. This condition resulted in the transfer of a large amount of water and a small amount of organic material. EPA concluded that it would be necessary to change the performance standard or devise an alternative measure of the performance of the system.

Because no measurable material had been recovered from the production water for three months, the PRPs believed that the performance standard had been met and that it should not be changed. However, EPA required a quantitative measure before it would allow the PRPs to shut down the system. EPA agreed that, if the quantity of tar recovered in the latest pore volume flushing was zero, the total amount of tar recovered could be quantified after the system was shut down. Therefore, EPA required evidence that no measurable separable tar was being recovered from the subsurface as a demonstration of compliance with the performance standard.

Treatment System Performance (continued)

EPA also required that the PRPs monitor the quality of the production water for three additional pore volume flushings at the highest heat possible. To comply with that request, the heater was rewired, additional injection points were installed, using the existing interior monitoring wells and the production pumps were serviced to increase the capacity and permit increased injection of hot water. That maintenance resulted in the hottest three pore volume flushings of the project; injection temperatures averaged about 180°F and production temperatures averaged about 145 °F.

During the final flushing, EPA required that samples of production well water be collected three times per week and analyzed for total PAHs and BTEX. The results were evaluated to determine whether the concentrations of specific constituents were associated with free phase coal tar. Water that is in contact with free phase coal tar tends to have concentrations of constituents near their solubility levels. The analysis showed that most of the constituents analyzed for were present at levels significantly below their individual solubility limits, even before the samples were filtered. This finding indicated that the process water being recovered did not contain free or separable coal tar.

On June 7, 1996, EPA agreed that the performance standard had been met and that injection and production could be halted.

Performance Data Quality

A field sampling plan and groundwater monitoring plan was submitted as part of the final design. The field sampling and groundwater monitoring plan for the Brodhead Creek site covered the sampling objectives, data gathering activities, and groundwater monitoring activities. The sampling objectives covered process monitoring, process water sampling, waste characterization sampling, post-treatment for monitoring, and health and safety concerns. Data gathering activities covered all activities associated with operating and monitoring the CROW process. The groundwater monitoring plan addressed the activities to be conducted for monitoring groundwater responses, such as temperature and water levels, to the CROW process.

Treatment System Costs

Procurement Process

To design and implement the remedy, the PRPs contracted with Remediations Technology, Inc. (RETEC) of Concord, Massachusetts, which holds a licence for the CROW process developed by Western Research Institute.

Cost Analysis [5, 8]

Costs for the Brodhead Creek site began to accumulate in 1980, when EPA responded to the leaking of coal tar into the creek. However, it was not until the consent decree was lodged in 1992 that the remedial action for coal tar recovery began.

As shown in Table 1, the total cost of the project was $1.9 million. Costs were shared by DOE, GRI, and PP&L. The decommissioning work was funded entirely by PP&L. Data on before, during, and after-treatment costs were estimated by the vendor, and are presented in Tables 2, 3, and 4, respectively. The estimated total cost for treatment directly associated with treatment is $1,283,000. The vendor indicated that costs for disposal of residuals and wastes were minimal and that demobilization accounted for most of the cost.

Modifications of the recovery system to meet verification standards increased the cost of the project. Information on the exact increase in cost was not available.

TREATMENT SYSTEM COSTS (CONTINUED)

Quality Of Cost Data

The cost data shown in Tables 2, 3, and 4 represent the vendor's best estimate of the actual costs for each cost element and total about $1.4 million. Table 1 shows a total cost of $1.9 million; the additional elements contributing to the total cost were not provided.

Table 1: Total Costs and Costs Sharing for Implementation of CROW Process at Brodhead Creek Site [8]

Source of Funds	Contractor	Construction and Operation ($)	Decommissioning ($)	Total (1995 $)
DOE	WRI	314,200		314,200
GRI		20,000		20,000
PP&L	WRI	332,400		332,400
	RETEC	1,116,493	92,400	1,208,893
	Direct Payments	41,674		41,093
Total		1,824,767	92,400	1,917,167

Table 2: Treatment Costs[1] [5]

Cost Elements	Cost($)
Solids Preparation and Handling	
Residuals and waste handling and transporting	3,000
Startup Testing and Permits	
Permitting and regulatory	25,000
Startup	40,000
Operation	
Labor	150,000
Supplies and consumables	200,000
Utilities	40,000
Equipment repair and replacement	50,000
Engineering support	30,000
Operation (continued)	

[1] Costs were estimated by the vendor. Costs reflect 1995 dollar values.

TREATMENT SYSTEM COSTS (CONTINUED)

Table 2 (continued): Treatment Costs[1] [5]

Cost Elements	Cost($)
Instrumentation	25,000
Laboratory	50,000
Subcontractors	70,000
Travel and living expenses	70,000
Project management	50,000
Regulatory reporting and coordination	10,000
Miscellaneous/health and safely	10,000
Performance Evaluation	10,000
Treatment Verification	10,000
Remedial Construction	400,000
Cost of Ownership	
Capital equipment	40,000
Total	1,283,000

Table 3: Before-Treatment Costs[1] [5]

Cost Elements	Cost($)
Site preparation	20,000
Equipment transport to the site	10,000
Initial setup	15,000
Installing utilities	5,000
Installing decontamination facilities	2,000
Total	52,000

Table 4: Post-Treatment Costs[1] [5]

Cost Elements	Cost($)
Disposal of residuals and wastes	
Demobilization	80,000
Total	80,000

[1] Costs were estimated by the vendor. Costs reflect 1995 dollar values.

Observations and Lessons Learned

Observations and Lessons Learned

The CROW™ process achieved the cleanup goal for the site within a year. Initial results in the Spring of 1996 indicated that the cleanup goal had been met. However, EPA subsequently determined that the method used to estimate the amount of free coal tar recovered was not accurate and could not be used to demonstrate that the cleanup goal had been met. The method was modified and, based on the results of additional samples, EPA determined in June 1996 that the cleanup goal had been met.

The enhanced recovery process was to remove at least 60 percent of the free phase coal tar from the subsurface soils. However, this performance standard required an accurate determination of initial conditions of either the volume or concentration of free phase coal tar present. Several attempts were made during the remedial design to quantify the amount of free phase coal tar present or determine the concentration of free phase coal tar in the RCC and MW-2 areas. A number of piezometers were installed at the site to determine the lateral extent of the free phase coal tar. EPA learned that, although free phase coal tar was present in both the RCC and MW-2 areas, it was discontinuous (it was not present in a uniform layer at a constant elevation). Therefore, direct estimates of its volume could not be made.

Installation of wells was impeded because of the cobble-filled strata in the subsurface soils. The geology underlying the site consists of the following stratigraphic units in ascending order: bedrock; silty sands; stream gravels; flood plain deposits; and surficial fill. In that type of geology, the drilling method selected should be capable of drilling through large stones. In addition, the boreholes for the injection wells should be oversized and installed by a cased drilling method, rather than by hollow stem auger. This reduces the potential for smearing the borehole sidewall and allows for adequate gravel pack to increase the hydraulic connection to the aquifer, thereby increasing the injection capacity of the wells.

Because of problems with iron fouling of the injection wells, the system operated at a lower injection capacity than expected. To keep the capacity as high as possible, juttering heads were installed on each well. The juttering procedure involved pouring a dilute acid solution into the well, then alternately opening and closing the valves on the juttering head as the air pressure in the well increased. This practice moved water up and down within the well, causing the release of iron particles and biomass from the well screen and gravel pack.

Several attempts were made with split spoon sampling devices to retrieve intact samples from the subsurface soils. However, because of the large size of the gravel present in the subsurface, only partial (disturbed) samples were retrieved. Those samples did not provide reliable information about the concentration of free phase coal tar actually present in the formation. EPA, therefore, determined that accurately measuring the removal of 60 percent of the free phase coal tar would not be possible, EPA then changed the performance standard through an ESD.

The original design called for the CROW process to address the free phase coal tar at the MW-2 area as well. However, because of the expected high cost of treating this area with CROW, EPA decided to allow PP&L to remove the tar by pumping which has been completed.

System failures involving the water heater, fouling of the wells, conductivity and flow within the formation and subsequent changes in the performance standard, as well as in the methods used to measure the performance of the system extended the project by approximately six months. The inability to measure performance as designed required additional time to develop a new measuring system and three additional pore volumes to verify that the performance standard was achieved.

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Preparation of the Analysis

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