

Case Study Abstract

Land Treatment at the Scott Lumber Company Superfund Site Alton, Missouri

Site Name: Scott Lumber Company Superfund Site	Contaminants: Polynuclear Aromatic Hydrocarbons (PAHs) - PAH concentrations were measured as high as 0.326 mg/kg in lagoon water, 12,400 mg/kg in sludge, and 63,000 mg/kg in soils - Benzo(a)pyrene ranged from 16 to 23 mg/kg at initiation of treatment	Period of Operation: December 1989 to September 1991
Location: Alton, Missouri		Cleanup Type: Full-scale cleanup
Vendor: Christina Consentini Remediation Technologies, Inc. (ReTeC) 1001 S. 24th Street, W., Suite 105 Billings, MT 59102 (406) 652-7481	Technology: Land Treatment - Construction of land treatment area included a clay liner and berms, run-on swales, and subsurface drainage system - Retention pond and irrigation system - Treatment performed using two lifts of soil - Indigenous microorganisms used to support biodegradation - Nutrients added to Lift No. 1; none added to Lift No. 2 - Cultivated once every two weeks	Cleanup Authority: CERCLA (removal action) - Action memorandum date: 7/10/87 - Fund Lead
SIC Code: 2491B (Wood Preserving - using Creosote)		Point of Contact: Bruce A. Morrison Remedial Project Manager U.S. EPA - Region 7 Emergency Planning and Response Branch 25 Funston Road Kansas City, KS 66115 (913) 551-7755
Waste Source: Surface Impoundment/Lagoon: Spill	Type/Quantity of Media Treated: Soil - 15,961 tons of soil treated in two lifts - Classified as sand per USDA system - Approximately 4% of soil passes a No. 200 sieve	
Purpose/Significance of Application: This was one of the early applications of land treatment at a Superfund site contaminated with creosote compounds.		
Regulatory Requirements/Cleanup Goals: - Action levels in soil were established for total PAHs at 500 mg/kg and for benzo(a)pyrene at 14 mg/kg - Total PAHs was defined as the sum of 16 specific PAH constituents		
Results: - Land treatment achieved specified action levels for PAHs and benzo(a)pyrene - Lift No. 1 - Total PAHs reduced from 560 to 130 mg/kg, and BAP from 16 to 8 mg/kg, in 6 months of treatment - Lift No. 2 - Total PAHs reduced from 700 to 155 mg/kg and BAP from 23 to 10 mg/kg, in 3 months of treatment		
Cost Factors: - Total Costs for Removal Action - approximately \$4,047,000 (including \$1,292,000 for the land treatment contractor (over 3 years), \$254,000 for laboratory analyses, EPA contractors and EPA oversight)		

Case Study Abstract

Land Treatment at the Scott Lumber Company Superfund Site, Alton, Missouri (Continued)

Description:

From 1973 to 1985, the Scott Lumber Company, located near Alton, Missouri, operated a wood treating facility used to preserve railroad ties with a creosote/diesel fuel mixture. As a result of these operations, soil at the site was found to have been contaminated with polynuclear aromatic hydrocarbons (PAHs) at concentrations as high as 63,000 mg/kg. An Action Memorandum was signed in July 1987, which specified the construction and operation of a land treatment unit (LTU) as a removal action for treatment of PAH-contaminated soils at the site. Cleanup activities were performed in three phases. The first two phases involved decontamination and removal of surface debris and sludge at the site and excavation and stockpiling of contaminated soil at the site. Phase III involved on-site land treatment of the contaminated stockpiled soil.

Land treatment was performed from December 1989 through September 1991, and 15,961 tons of soil were treated during this application. Stockpiled soil was placed in the LTU in two lifts. Approximately 200 lbs per acre of ammonium phosphate fertilizer were added to the first lift to adjust the nutrients in the soil. No nutrient adjustments were made to the second lift. Each lift was cultivated once or twice a week and irrigated, as necessary, to maintain a moisture content between 1% and 4%.

Action levels for the soil at the site, established by EPA, were 14 mg/kg for benzo(a)pyrene (BAP) and 500 mg/kg for total PAHs. Land treatment at the Scott Lumber site reduced levels of BAP and total PAHs to below action levels. In Lift 1, BAP concentrations were reduced from 16 mg/kg to 8 mg/kg and total PAH concentrations were reduced from 560 mg/kg to 130 mg/kg within 6 months. In Lift 2, concentrations were reduced from 23 mg/kg to 10 mg/kg for BAP and from 700 mg/kg to 155 mg/kg for total PAHs within 3 months. The total costs for this removal action were \$4,047,000, including \$1,292,000 for the land treatment contractor and \$254,000 for laboratory analyses. Site demobilization was completed in September 1991.

COST AND PERFORMANCE REPORT

EXECUTIVE SUMMARY

This report presents cost and performance data for a land treatment application of contaminated soil at the Scott Lumber Company Superfund site (Scott Lumber), located near Alton, Missouri. From 1973 to 1985, this company operated a wood treating facility that preserved railroad ties with a creosote/diesel fuel mixture. As a result of these operations, soil at the site was contaminated with polynuclear aromatic hydrocarbons (PAHs), which were major components of the creosote/diesel mixture used at Scott Lumber.

An Action Memorandum was signed on July 10, 1987, which specified the construction and operation of a land treatment unit (LTU) as a removal action for treatment of PAH-contaminated soils at the site. Contaminated soil was excavated and stockpiled on site. Land treatment was performed from December 1989 through September 1991, and approximately 15,960 tons of soil were treated in the LTU. The soil in the LTU was cultivated and irrigated on a weekly or bi-weekly basis. Ammonium phosphate fertilizer was added to the first lift to adjust the nutri-

ents in the soil. No nutrient adjustments were made to the second lift. Site demobilization was completed in September 1991.

Action levels established by EPA for soil at the site were 14 mg/kg for benzo-a-pyrene (BAP) and 500 mg/kg for total PAHs.

Land treatment at the Scott Lumber site reduced levels of both BAP and total PAHs to below the soil action levels. In Lift 1, BAP concentrations were reduced from 16 to 8 mg/kg, and total PAH concentrations were reduced from 560 to 130 mg/kg. The most rapid decreases in total PAH concentrations in Lift 1 occurred within the first 6 weeks of treatment. In Lift 2, concentrations were reduced from 23 to 10 mg/kg for BAP and from 700 to 155 mg/kg for total PAHs. The land treatment system was operated for 6 months for Lift 1 and 3 months for Lift 2.

The total removal action costs were approximately \$4,047,000, including approximately \$1,292,000 in costs incurred by the land treatment contractor.

SITE INFORMATION

Identifying Information

Scott Lumber Company Superfund Site
Alton, Missouri

CERCLIS #: MOD068531003

Action Memorandum Date: 7/10/87

Treatment Application

Type of Action: Removal Action

Treatability Study Associated with Application? Yes (see Appendix A)

EPA SITE Program Test Associated with Application? No

Operating Period: 12/89 - 9/91

Quantity of Soil Treated During Application: 15,961 tons

Background

Historical Activity That Generated Contamination at the Site: Creosote wood treating

Corresponding SIC Code: 2491B
(Wood Preserving Using Cresote)

Waste Management Practices That Contributed to Contamination: Surface Impoundment/Lagoon; Spill



SITE INFORMATION (CONT.)

Background (cont.)

Site History: The Scott Lumber Company Superfund (Scott Lumber) site is located within Oregon County in south-central Missouri, approximately one mile east of the town of Alton, Missouri, as shown in Figure 1. From 1973 until 1985, Scott Lumber operated a wood treating facility that preserved railroad ties with a creosote/diesel fuel mixture. A plan view of the site is shown in Figure 2. The process consisted of treating wood using several retort tanks. Waste management practices at the site included discharging creosote contaminated sludge generated during the wood treatment process to an unlined storage lagoon located on site. In addition, an estimated 300 or more gallons of preservative were released during one spill incident, and the direct discharge of creosote waste into the soil was suspected. The creosote sludge was classified as a K001-listed waste by EPA. [1]

Site investigations conducted by EPA indicated that the site was principally contaminated with polynuclear aromatic hydrocarbons (PAHs),



Figure 1. Site Location

which are the major components of the creosote/diesel mixture used in the wood preserving operations. Most of this contamination was located within or near the wood treatment area of the site. [1]

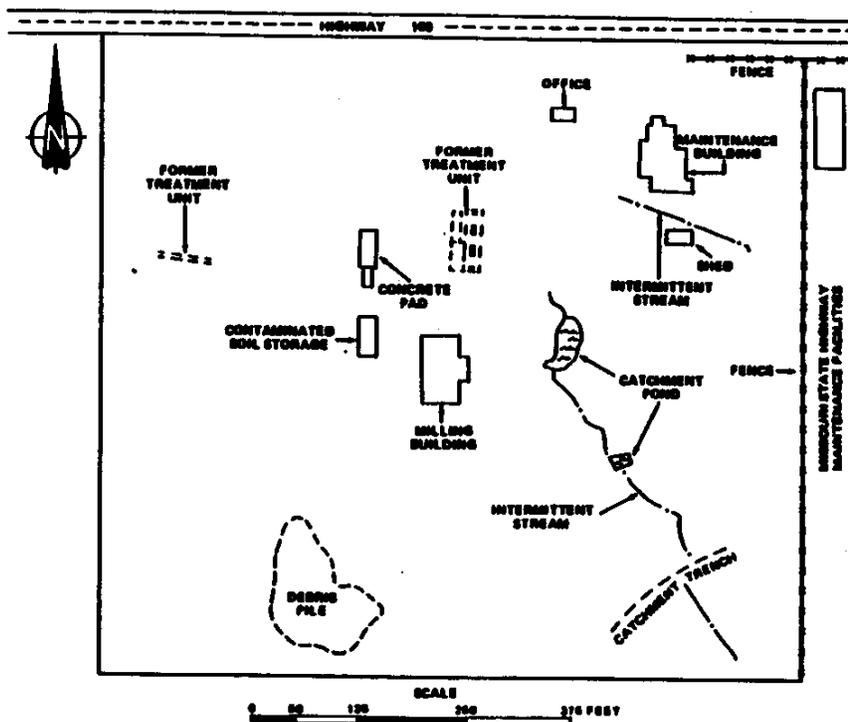


Figure 2. Plan View of SLC Site [4]



SITE INFORMATION (CONT.)

Background (cont.)

Three phases of cleanup activities were conducted at Scott Lumber in response to a July 10, 1987 Action Memorandum. Phase I occurred in 1987 and involved the decontamination and removal of surface debris and sludge at the site. Phase II occurred from July to September 1988 and involved the excavation and stockpiling of contaminated soil identified at the site. Phase III occurred from 1989 to 1991 and involved the on-site land treatment of contaminated soil. [1] This report focuses on Phase III of the cleanup activities.

Regulatory Context: Action levels for the soil at the site were established by EPA and approved by the Agency for Toxic Substances and Disease Registry in 1987. The action

levels were 14 mg/kg for benzo-a-pyrene (BAP) and 500 mg/kg for total PAHs. [1,2]

Total PAHs refer to the 16 constituents listed in Appendix B of this report.

Remedy Selection: Three methods were considered for remediation of PAH contamination at the site: 1) excavation and off-site disposal; 2) encapsulation with on-site disposal; and 3) land treatment. On-site land treatment was determined to be the best alternative because it was the most cost-effective method for permanently eliminating the identified contaminants at the site, and it was an innovative treatment technology. [2,4]

Site Logistics/Contacts

Site Management: Fund Lead

Oversight: EPA

On-Scene Coordinator:

Bruce A. Morrison
U.S. EPA - Region 7
Emergency Planning and Response Branch
25 Funston Road
Kansas City, Kansas 66115
(913) 551-7755

Treatment System Vendor:

Christina Cosentini
Remediation Technologies, Inc. (ReTeC)
1001 S. 24th Street W., Suite 105
Billings, Montana 59102
(406) 652-7481

MATRIX DESCRIPTION

Matrix Identification

Type of Matrix Processed Through the Treatment System:

Soil (ex situ)

Contaminant Characterization

Primary Contaminant Group: Polynuclear Aromatic Hydrocarbons (PAHs)

PAHs were found in the water and sludges of the unlined storage lagoon and soil at the site. PAH concentrations were measured as high as

0.326 mg/kg in lagoon water, 12,400 mg/kg in sludge, and 63,000 mg/kg in soils. [4]

Concentrations for individual PAHs in untreated soils, prior to excavation, are shown in Table 1.



MATRIX DESCRIPTION (CONT.)

Contaminant Characterization (cont.)

Table 1. Contaminant Characterization [4]

PAH Constituent	Soils	
	Average (mg/kg)	Range (mg/kg)
Naphthalene	173	0.15 to 2,000
Acenaphthylene	43	0.34 to 440
Acenaphthene	780	0.051 to 7,500
Fluorene	893	0.47 to 10,000
Phenanthrene	1,700	0.48 to 31,000
Anthracene	163	0.45 to 14,000
Fluoranthene	836	0.31 to 17,000
Pyrene	755	0.19 to 13,000
Benzo(a)anthracene	243	0.23 to 4,300
Chrysene	262	0.61 to 4,900
Benzo(b)/(k)fluoranthene	236	0.62 to 3,200
Benzo(a)pyrene	130	0.74 to 1,600
Indeno(1,2,3-cd)pyrene	75	0.47 to 770
Dibenzo(a,h)anthracene	16	0.37 to 180
Benzo(ghi)perylene	90	0.35 to 830

Matrix Characteristics Affecting Treatment Cost or Performance

The major matrix characteristics affecting cost or performance for this technology and the values measured for each are presented in

Table 2. A particle size distribution of soils at Scott Lumber, using U.S. standard sieves, is shown in Table 3.

Table 2. Matrix Characteristics [9]

Parameter	Value	Measurement Method
Soil Classification	Sand (Gravel and sand with minor silt fractions)	USDA
Clay Content and/or Particle Size Distribution	See below	—
pH	6.8 to 8	—
Field Capacity	Not available	—

Table 3. Particle Size Distribution [9]

Sieve No.	% Finer
10	54.89
20	27.92
40	17.07
60	10.35
100	6.22
200	4.14
Pan	0.00

Site Geology/Stratigraphy

Unconsolidated soils near the ground surface primarily consist of a cherty clay interspersed with dense clay. Chert is a biochemical rock that consists of fibrous chalcedony, quartz,

and silica. The total thickness of the unconsolidated soils that overlie the area's porous limestone is not known. [4]



TREATMENT SYSTEM DESCRIPTION

Primary Treatment Technology Type

Land Treatment

Supplemental Treatment Technology Types

None

Land Treatment System Description and Operation

Construction of the land treatment unit at Scott Lumber began in 1989 and involved the following activities:

- Site preparation;
- Construction of a clay liner in the land treatment area;
- Construction of berms, run-on swales, monitoring wells, and lysimeters around the land treatment area;
- Installation of a subsurface drainage system in the land treatment area;
- Construction of a water retention pond;
- Installation of an irrigation system for the land treatment area;
- Construction of a fence around the land treatment area; and
- Placement of contaminated soil in the land treatment area.

The locations of the land treatment area, contaminated soil stockpile area, and water retention pond, as well as the subsurface drainage layout, are shown on Figure 3.

Site preparation activities included removing three buildings from the proposed land treatment area and relocating sawdust and scrap wood debris at the site prior to regrading the surface topography. While regrading, a new area of subsurface creosote-contaminated soil, approximately 100 feet in diameter, was discovered near what was once the retention pond.

Approximately 5,000 tons of contaminated soil were excavated from this area and added to the stockpile of soil to be remediated. The area was backfilled with clean fill material. [1,2]

Construction of a clay liner in the land treatment area involved the compaction of the top 1 foot of in-situ soil and the addition of a compacted 2-foot clay layer. The in-situ and fill clay layers totaled 3 feet. To inhibit fluid permeability within the clay layers, the compacted clay surface was broken up and loosened between placement of 6-inch lifts, and soil moisture was maintained at 1% to 4% greater than the optimum determined by the Modified Proctor Test. Perimeter berms were constructed around the LTU to the same specifications as the clay liner. [1,2]

An underdrain system was constructed above the clay layer to collect and drain water to a retention pond. The system consisted of a 9- to 10-inch thick sand layer containing a

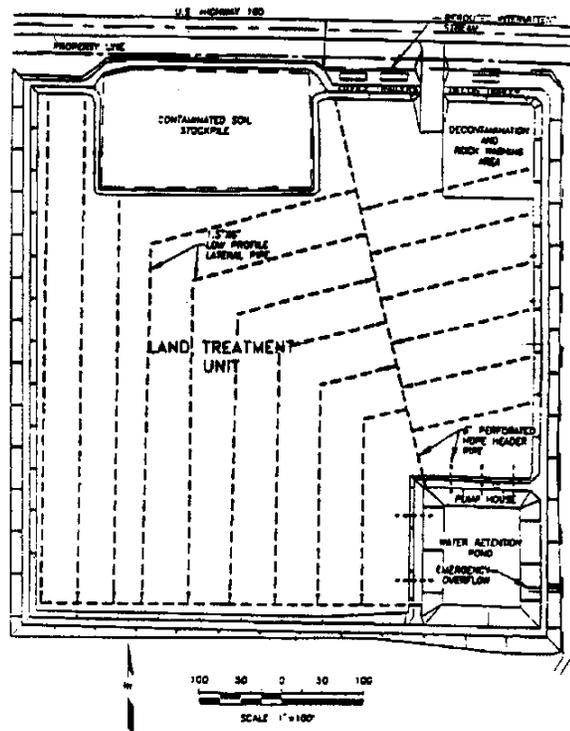


Figure 3. LTU at Scott Lumber [1]



TREATMENT SYSTEM DESCRIPTION (CONT.)

Land Treatment System Description and Operation (cont.)

drainage pipe network consisting of HDPE perforated pipe 1.5 inch thick by 12 inches wide wrapped in a geotextile membrane. The HDPE pipe was connected to 6-inch header pipes placed within the top 6 inches of the clay liner. These header pipes were also perforated and drained to the retention pond. Each header pipe was surrounded by gravel backfill and covered with a geotextile membrane. Figure 3 shows the subsurface drainage network within the LTU. [1 and 2]

A retention pond was constructed in the southeast corner of the LTU to receive the potentially contaminated LTU runoff water collected by the underdrain system. It was lined with a 40-mil HDPE liner that overlay a 3-inch sand cushion, and had a storage capacity of approximately 1 million gallons. When the capacity of the retention pond was exceeded during rainy periods, excess water was discharged to the Alton Wastewater Treatment Plant located adjacent to the site. [2]

A 2- to 4-inch layer of topsoil was placed on top of the underdrain layer to guard against tilling damage and to decrease the leaching potential of contaminated soil. A cross section of the LTU, showing the location and thickness of individual soil layers, is presented in Figure 4. [2]

LTU Operation

Contaminated soil from the stockpile area was placed in the LTU in 2 lifts. The first lift was placed into the treatment area in December 1989, and treatment occurred from May to November 1990 (6 months). This lift consisted of approximately 9,000 tons of soil and averaged 9 inches in thickness. The remaining stockpiled soil was placed on the LTU in December 1990 and May 1991, and treatment of the second lift occurred from May to August 1991 (3 months). The second lift consisted of approximately 7,000 tons of soil and averaged 7 inches in thickness. [1 and 2]

After the first lift of soil was placed in the treatment area, a portable irrigation system was installed. The irrigation system consisted of a 4-inch aluminum pipe placed along the base of the southern LTU berm. Water was pumped from the retention pond, through this line, to a moving wheel lateral line. The lateral line was manually rolled east to west at 40-foot intervals along the southern berm pipe, and water was distributed to the LTU from the lateral line through impulse sprinkler heads spaced every 40 feet. During the summer months, the LTU was irrigated approximately once a week. [2] The irrigation activities for the first lift began during the first week of June 1990, and for the second lift during the third week of May 1991. [8]

Contaminated Soil to be Treated
Zone of Incorporation (Topsoil) 2 to 4 inches
Sand Layer (Including Underdrain Pipe Network) 10 inches
Compacted Clay Liner 2 feet
In-situ Compacted Clay Liner 1 foot

Figure 4. LTU Cross Section [2]



TREATMENT SYSTEM DESCRIPTION (CONT.)

Land Treatment System Description and Operation (cont.)

Following placement of each lift in the LTU, large rocks and debris were removed from the contaminated soil, utilizing an alternating series of cultivating and rock and debris collecting activities. Cultivation broke up the soil and brought rocks, wood, and other debris to the surface, where they were collected with a tractor-mounted Anderson Rock Picker. The rocks and debris collected that were greater than 3 inches in length were placed in a designated stockpiling area for segregation and decontamination. [2] The tilling activities for the first lift began during the first week of June 1990, and for the second lift during the third week of May 1991. [8]

Treatability study results indicated that sufficient indigenous microorganisms existed in the soil at this site to support biodegradation. [4]

Approximately 200 pounds per acre of granular, ammonium phosphate fertilizer was applied to the first lift to obtain a ratio of soil organic content to nitrogen to phosphorus of 100:2:0.4. No nutrient adjustments were necessary for the second lift. [2]

Each lift was cultivated to aid the aerobic bioremediation process. The soil was cultivated using farm equipment (chisel plow, tiller, or subsoil ripper) for specific soil conditions. For example, the subsoil ripper was used to break up thick, compacted, silty clays, and the chisel plow was used for routine soil cultivation. Each lift was cultivated approximately once a week while rock and debris removal was occurring, and twice a week when no rock and debris removal took place. [2]

Soil samples collected in October 1990 indicated that total PAH concentrations were approximately 130 mg/kg and BAP concentra-

tions were approximately 8 mg/kg and treatment of Lift #1 was complete. Treatment of Lift #2 was completed in August 1991, and final concentrations were reported to be 155 mg/kg for total PAH and 10 mg/kg for BAP. Site closure was completed in the autumn of 1991; activities included the disposal of debris at the Butler County landfill, regrading portions of the site, seeding and fertilizing the site, and demobilizing office trailers and equipment. [1]

Health and safety requirements for this operation included compliance with the permissible exposure limit for PAHs set by the Occupational Safety and Health Administration.

Groundwater Monitoring

Groundwater monitoring was conducted throughout operation of the LTU. The groundwater monitoring program was conducted to detect any migration of PAHs from the LTU to the groundwater. Four shallow groundwater monitoring wells screened between 30 and 35 feet below ground surface were installed in each corner of the LTU. Two deep monitoring wells screened between 95 and 100 feet below ground surface were installed in the northwest (upgradient) and southeast (down-gradient) corners of the site. Shallow wells were based on the depth to the groundwater, while deep wells were based on depths of nearby private wells. [8]

Before placement of the compacted 2-foot clay layer, four groundwater lysimeters were installed inside the perimeter berms to monitor contaminant migration through the clay liner. To minimize the development of a migration route, the lysimeter collection tubes were laterally trenched to locations outside the LTU. [2]



TREATMENT SYSTEM DESCRIPTION (CONT.)

Operating Parameters Affecting Treatment Cost or Performance [1,2]

The major operating parameters affecting cost or performance for this technology and the values measured for each during this treatment application are listed in Table 4.

Table 4. Operating Parameters [1,2, 9]

Parameter	Value	Measurement Method
Mixing Rate/Frequency	Once a week during rock removal, twice a week otherwise	—
Moisture Content	10 to 20%	—
pH	6.8 to 8	—
Residence Time (for treatment)	Lift #1 - 6 months Lift #2 - 3 months	—
Temperature	No data available	—
Hydrocarbon Degradation	72 mg/kg/mo. for Lift #1 182 mg/kg/mo. for Lift #2	Calculated
Nutrients and Other Soil Amendments	Soil organic content:nitrogen:phosphorus adjusted to 100:2:0.4 for Lift #1 No nutrient adjustment for Lift #2	Not known

Timeline [1,2,6]

The timeline for this application is presented in Table 5.

Table 5. Timeline [1,2,6]

Start Date	End Date	Activity
1973	1985	Scott Lumber Co. operated
July 10, 1987	—	Action Memorandum signed
August 1987	November 1987	Phase I of removal action - decontamination and removal of surface debris
July 1988	September 1988	Phase II of removal action - excavation and stockpiling of contaminated soil
1989	1991	Phase III of removal action - land treatment of contaminated soil
December 1989	—	First lift - soil placed in LTU
May 1990	November 1990	Treatment process (filling, rock removal/washing, nutrient adjustment, irrigation) of first lift
December 1990	—	Second lift - first load placed in LTU
May 1991	—	Second lift - second load placed in LTU
May 1991	August 1991	Treatment process (no nutrient adjustment) of second lift
September 1991	—	Site demobilization complete



TREATMENT SYSTEM PERFORMANCE

Cleanup Goals/Standards

Action levels for the soil at the site were established by EPA. The action levels were 14 mg/kg for benzo-a-pyrene (BAP) and

500 mg/kg for total PAHs. [1 and 2] Total PAHs refers to the 16 PAH constituents listed in Appendix B to this report.

Additional Information on Goals

Action levels for soil at the site were based on McClanahan's relative carcinogenic risk of BAP compared to 2,3,7,8-tetrachlorodibenzo-p-dioxin, as well as action levels previously

approved by the Agency for Toxic Substances and Disease Registry for cleanup of soil at similar sites. [2]

Treatment Performance Data

Between April and November 1990, EPA collected soil samples from a 5,000-square foot subplot within Sampling Area F shown on Figure 5. This subplot measured 50 feet north/south by 100 feet east/west and was located on the east side of Sampling Area F. Three 50-ml aliquot samples were collected every two weeks during treatment of the first lift from quadrants north, south, and east. These samples were analyzed for total PAHs by GC/MS analytical Method 3230.2A, an EPA Region 7 modification of a CLP analytical method for extraction and analysis of water and solids for semivolatile organic compounds. [7] Samples were collected within Sampling Area F because it was conveniently located near the decontamination and office areas, was out of the way of most facility operations, and the marker flags placed within the subplot could be lined up with permanent markers on the adjoining berm. [2 and 5]

The individual PAH analytical results by sample date for Lift #1 are presented in Appendix B by subplot location. Average concentrations were calculated for each PAH constituent measured in the three Subplot F quadrants, as shown in Appendix B, by sample date. Total PAHs were calculated for each sample date by summing the analytical results for all 16 PAH constituents shown in

Appendix B. The averages of the total PAH concentrations were calculated and plotted against each sample date, as shown in Figure 6, and average BAP concentrations were plotted against each sample date, as shown in Figure 7.

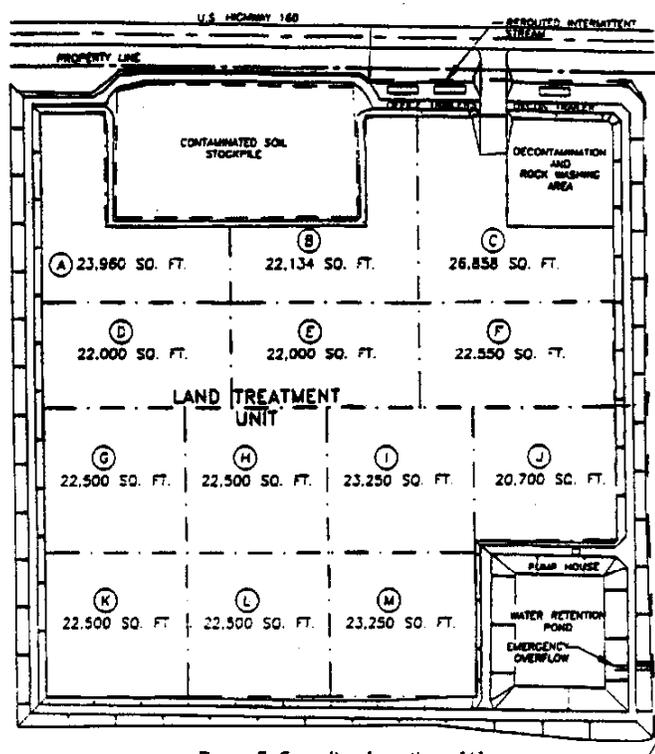


Figure 5. Sampling Locations [1]

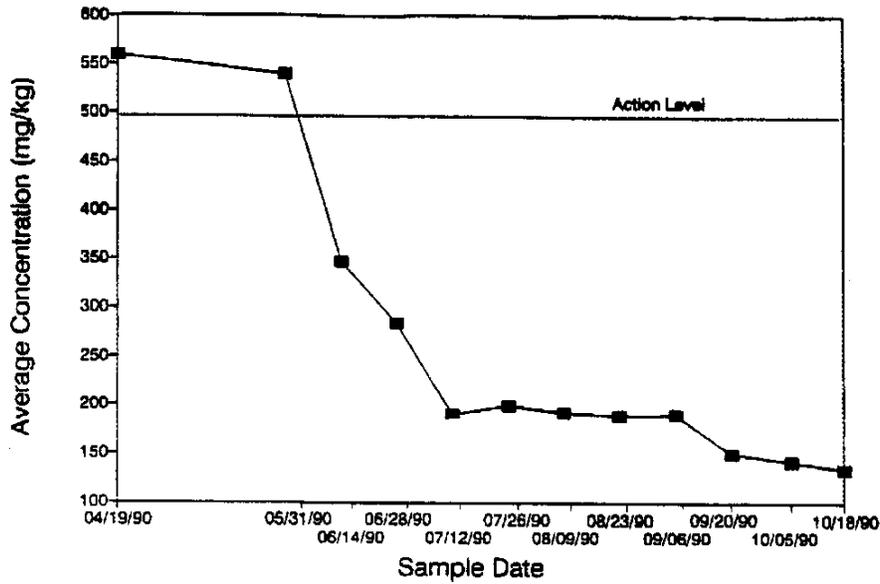


TREATMENT SYSTEM PERFORMANCE (CONT.)

Treatment Performance Data (cont.)

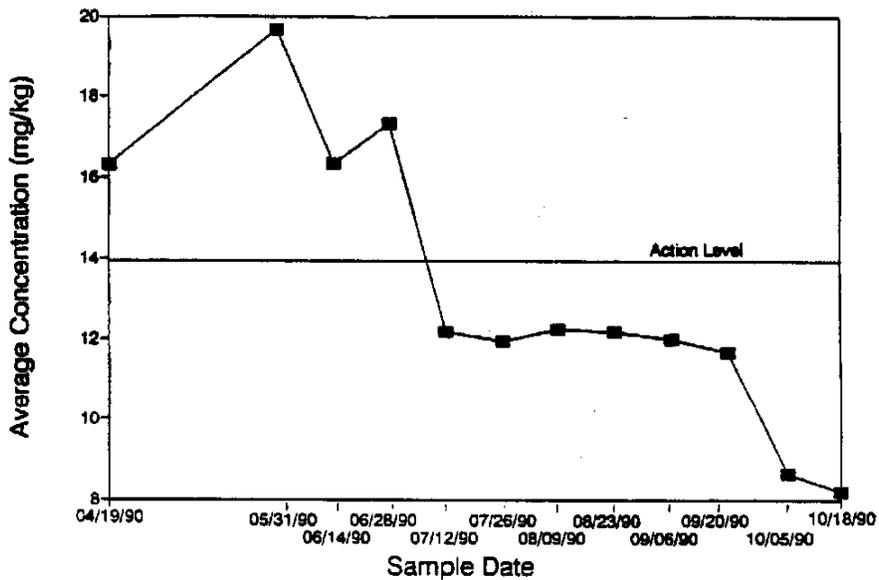
In Lift #2, concentrations were reduced from 23 to 10 mg/kg for BAP and from 700 to 155 mg/kg for total PAH. Initial BAP and total

PAH concentrations for Lift #2 were collected in May 1991. [1]



NOTE: Treatment began in May 1990.

Figure 6. Total PAH Concentrations During Treatment of Lift No. 1 (based on Appendix B)



NOTE: Treatment began in May 1990.

Figure 7. BAP Concentrations During Treatment of Lift No. 1 (based on Appendix B)



TREATMENT SYSTEM PERFORMANCE (CONT.)

Treatment Performance Data (cont.)

Groundwater monitoring was conducted on a quarterly basis during operation of the LTU. No data are available on the results of groundwater monitoring.

During initial soil loading and LTU system start-up, air monitoring of PAHs was con-

ducted using NIOSH Method 5515. Gillian pump monitors placed on equipment used during the cultivating and loading operations detected airborne PAHs at concentrations as high as 6.8 $\mu\text{g}/\text{m}^3$ during an 8-hour sampling period. [2]

Performance Data Assessment

A review of analytical data for treatment of soil in Subplot F of Lift No. 1 indicated that average total PAH concentrations decreased from 560 to approximately 130 mg/kg within 6 months of treatment, and the average BAP concentration decreased from 16 to approximately 8 mg/kg in the same time frame. A rapid decrease in average total PAH and BAP concentrations occurred within the first six weeks of the treatment, when the average total PAH concentration decreased from approximately 560 to 190 mg/kg, and the average BAP concentration decreased from approximately 20 to 12 mg/kg. The action level for total PAH was reached after a few days of treatment, and, for BAP, within the first 6 weeks of treatment.

A review of the analytical data for a 3-ring PAH (phenanthrene) shows a reduction from 65 to 5 mg/kg (92%) over a 6-month time frame, while data for a 5-ring PAH (indeno(1,2,3-cd)pyrene) shows a reduction from 19 to 6 mg/kg (68%) over the same period. These data show that biodegradation is faster for PAH constituents with fewer benzene rings (in this case, biodegradation for phenanthrene was faster than for indeno(1,2,3-cd)pyrene).

A review of air monitoring data for PAHs indicated that the maximum concentration measured was less than the permissible exposure limit set by the Occupational Safety and Health Administration.

Performance Data Completeness

Soil samples were collected during treatment of a small area that represented slightly greater than 1% of the total LTU area.

Subplot F was sampled on a 2-week basis during treatment of the first lift to monitor treatment performance. Soils in Lift No. 1 were assumed to be homogeneous with respect to PAH concentrations. Subplot F was

selected for sampling because of ease of accessibility, proximity to the decontamination area, and the ability to leave marker flags on the subplot.

Constituent-specific analytical data for the 16 PAHs of interest during this cleanup are only available for treatment of the first lift.

Performance Data Quality

Laboratory analytical data are accompanied by statements certifying that the data have met all quality assurance requirements unless

otherwise indicated in the data packages. Duplicate samples were collected from each quadrant and are included in each data package. [6]

TREATMENT SYSTEM COST

Procurement Process

The removal activities at Scott Lumber were financed by EPA. EPA contracted Remediation

Technologies, Inc. to conduct the land treatment activities at the site. [1]



TREATMENT SYSTEM COST (CONT.)

Treatment System Cost [1]

Total removal action costs at Scott Lumber were approximately \$4,047,000. Because little information was provided on the specific elements included in these costs, a breakdown of these costs into the elements of an interagency Work Breakdown Structure (WBS) was not completed at this time. Actual costs for treatment activities (i.e., those incurred by the land treatment contractor) are shown below by year:

1989	\$690,000
1990	\$352,000
1991	\$250,000
TOTAL	\$1,292,000

The \$1,292,000 in total costs for treatment activities corresponds to approximately \$81/ton of soil treated, for the 15,961 tons of soil treated in this application.

Additional costs at Scott Lumber were incurred by the ERCS contractor (\$1,666,000); TAT (\$207,000); EPA Direct (\$187,000); EPA Indirect (\$395,000); laboratory analyses - CLP (\$254,000); and ERT/ERU (\$46,000).

Cost Data Quality

Total cost information was provided by the EPA On-Scene Coordinator (OSC) for this project, and includes cost for several activities. The specific cost elements included in each activity are not available at this time.

Vendor Input

Costs for similar operations were estimated by the treatment vendor to range from \$50 to \$100 per cubic yard of soil treated for quantities in excess of 3,000 cubic yards.[21]

OBSERVATIONS AND LESSONS LEARNED

Cost Observations and Lessons Learned

- Total removal action costs were approximately \$4,047,000, including approximately \$1,292,000 in costs incurred by the land treatment contractor.
- The discovery during construction of the LTU and resulting excavation and treatment of an additional 5,000 tons of contaminated soil added approximately \$65,000 to the contractor costs and delayed the construction of the LTU by one month.
- The OSC indicated that contract expenditures were minimized during this remediation because the ERCS contractor project manager was not required to be present on site during routine bioremediation activities.
- The OSC identified calculating volume, rather than mass, as a preferred method to quantify the amount of soil to be treated in the LTU. Weighing truckloads of soil was more costly than surveying soil stockpiles or using overflights to determine volume.
- The treatment at Scott Lumber was completed using 2 lifts; the system was constructed using a clay liner and underdrain system.



OBSERVATIONS AND LESSONS LEARNED (CONT.)

Performance Observations and Lessons Learned

- The cleanup goal for total PAHs at Scott Lumber was established in terms of the sum of the concentrations for 16 specific polynuclear aromatic hydrocarbons. Cleanup goals for this application were specified as 500 mg/kg for total PAHs and 14 mg/kg for benzo(a)pyrene, one of the 16 specified PAHs.
- The cleanup goals were achieved within 6 months for Lift #1 and 3 months for Lift #2.
- Land treatment at the Scott Lumber site reduced total PAH concentrations from 560 to 130 mg/kg, and BAP from 16 to 8 mg/kg, in Lift #1. In Lift #2, concentrations were reduced from 700 to 155 mg/kg for total PAH and from 23 to 10 mg/kg for BAP.
- The most rapid decreases in PAH concentrations in Lift 1 occurred within the first 6 weeks of treatment.

Other Observations and Lessons Learned

- This was one of the early applications of land treatment of creosote-contaminated soil at a Superfund site.
- A laboratory/demo-scale treatability study conducted using site soils demonstrated the feasibility of bioremediation for treatment of creosote-contaminated soils at Scott Lumber.
- Additional information provided by the OSC and Contracting Officer concerning the procurement and contracting processes at the Scott Lumber site (and other removal action sites) is provided in Reference 10. Reference 10 is available from the U.S. EPA National Center for Environmental Publications and Information (NCEPI), P.O. Box 42419, Cincinnati, OH 45242; (fax orders only - (513) 489-8695).

REFERENCES

1. Federal On-Scene Coordinator's Report, Scott Lumber Company Site, non-NPL, Alton, MO, July 10, 1987 - October 1, 1991. Bruce A. Morrison, U.S. Environmental Protection Agency, January 15, 1993.
2. On-Site Bioreclamation of Creosote-Contaminated Soil at the Scott Lumber Site. Bruce A. Morrison, U.S. Environmental Protection Agency. Paper 92-27.04, from the Air and Waste Management Association Conference, 85th Annual Meeting and Exposition, June 1992.
3. Memorandum Request for Exemption from the \$2 Million Limitation at the Scott Lumber Company Site, Alton, MO. Morris Kay to J. Winston Porter, U.S. Environmental Protection Agency, 15 July 1988.
4. Final Report, Feasibility of Biological Remedial Action at Scott Lumber Company Site, Alton, MO. Ecology and Environment, Inc., March 1988.
5. Personal communication, Bruce A. Morrison, U.S. Environmental Protection Agency, 11 April 1994.
6. Analytical data reports: 4/19/90, 5/31/90, 6/14/90, 6/28/90, 7/12/90, 7/26/90, 8/9/90, 8/23/90, 9/6/90, 9/20/90, 10/5/90, 10/18/90; provided by Bruce A. Morrison.
7. Standard Operating Procedure; Extraction and Analysis of Water and Soils for Semivolatile Organic Compounds, September 21, 1989.



REFERENCES (CONT.)

8. Memorandum; Response to Information Request for Scott Lumber Site, Bruce Morrison to Linda Fiedler, U.S. EPA, January 5, 1995.
9. Letter from Christina Cosentini to Linda Fiedler, Scott Lumber information request, February 3, 1995.
10. Procuring Innovative Treatment Technologies at Removal Sites: Regional Experiences and Process Improvements, U.S. EPA, Publication 542/R-92/003, August 1992.

Analysis Preparation

This case study was prepared for the U.S. Environmental Protection Agency's Office of Solid Waste and Emergency Response, Technology Innovation Office. Assistance was provided by Radian Corporation under EPA Contract No. 68-W3-0001.



APPENDIX A—TREATABILITY STUDY RESULTS

Identifying Information

Site Identifying Information

Site Name: Scott Lumber Company
 Site Location: Alton, Missouri
 CERCLIS #: MODO68531003
 Action Memorandum Date: 7/10/87

Type of Treatability Study

Laboratory/Demo-Scale of Soil Bioremediation

Treatability Study Strategy

The purpose of this treatability study was to assess the feasibility of bioremediation for creosote-contaminated soil by: (a) growing a microbial culture capable of degrading PAHs; (b) demonstrating that the site soil was not toxic to the microbes; and (c) evaluating the relative biodegradability of PAH constituents.

Three test runs were completed during this study. The overall philosophy of conducting the three runs was to measure system performance under differing conditions of soil and creosote loadings and reloadings. As shown in Table 1, Run No. 1 received an initial creosote loading of 1% and no additional loadings. The purpose of this run was to observe the biodegradation of PAH constituents with no soil

present. In addition, after microbes were killed (Week 4), Run No. 1 was used as a control run to assess the potential for PAH removal by processes other than biodegradation. Run No. 2 received an initial creosote loading of 0.5% and then was reloaded with 0.5% creosote at 2 and 4 weeks. The purpose of this run was to investigate the potential enhancement of biodegradation of higher-molecular-weight PAHs by the addition of more easily degraded, lower-molecular-weight PAHs. Run No. 3 received the same creosote loadings as Run No. 2 but was also loaded and reloaded (at times of creosote loading) with 10% clean soil. The purpose of this run was to investigate the potential inhibition of biodegradation due to possible soil toxicity. [4]

Table A-1. Schedule for Loadings and Reloadings Used in Treatability Study [4]

Week	Creosote and Soil Loading (%)*		
	Run #1	Run #2	Run #3
0 (start)	1% creosote 0% soil	0.5% creosote 0% soil	0.5% creosote 10% soil
1	No loading	No loading	No loading
2	No loading	0.5% creosote reloading	0.5% creosote 10% soil reloading
3	No loading	No loading	No loading
4	Microbes killed	0.5% creosote reloading	0.5% creosote reloading 10% soil reloading
5	0.5% creosote loading	No loading	No loading
6	Run terminated	Run terminated	Run terminated

*All loadings are in weight/volume percentages.

Treatment System Description

Bioremediation System

Description and Operation

The bioremediation system consisted of three aqueous bioreactors and related equipment. The bioreactors used were 10-20 liter

plexiglass vessels, which were aerated and mixed using humidified air. The three bioreactors were placed in a walk-in environmental chamber which was kept at a constant temperature of 30°C. [4]



APPENDIX A—TREATABILITY STUDY RESULTS (CONT.)

Treatment System Description (cont.)

Microbial cultures used in this study were grown using sludge from the site and a nearby publicly owned treatment works (POTW). System operation involved loading the bioreactors with an aqueous slurry of clean soil from the site, creosote, inorganic nutrients, and microbial cultures. The three bioreactors were loaded and reloaded with varying quantities of soil and creosote. Bioreactors were maintained at a pH of 7.0

using sulfuric acid, and operated for approximately 6 weeks. [4]

Procurement Process

Ecology & Environment, Inc. was tasked by EPA Region VII through a Technical Assistance Team (TAT) Zone II contract to perform the treatability study as a Technical Assistance Project (TDD No. TPM-8801-001).

Treatment Performance Results

Treatment Performance Data

Treatment performance data were collected for oxygen uptake rate, PAH constituent content, solids content, and organic carbon content. Oxygen uptake was measured to indicate microbial activity levels. Microbial respiration was the only mechanism for consuming dissolved oxygen in the bioreactors. A gas chromatograph coupled with flame-ionization detector (EPA Method 610) was used to measure the concentrations of PAH constituents. Solids content was analyzed by measuring the concentrations of dissolved solids (DS) and volatile suspended solids (VSS). DS measurements indicated the amount of inorganic nutrients and creosote present in the bioreactors, and VSS measurements were used as a rough estimate of the microbial community size. Results from organic carbon analyses yielded values for both soluble organic carbon (SOC) and total organic carbon (TOC). These measurements indicated the amounts of dissolved and total creosote, respectively, in each bioreactor. Samples for each of these parameters were collected from the bioreactors by dipping a beaker into the solution and collecting liquid free of froth and organic sheen.

Data on the oxygen uptake rate for the 3 runs, as a function of time, are presented in Table 2. Data on the concentrations for both individual and total PAH constituents for the 3 runs, as a function of time, are presented in Table 3. The DS, VSS, SOC, and TOC concentrations for the 3 runs, as a function of time, are presented in Figures 1-4, respectively [note - Bioreactor 1 shown on the figures

corresponds with Run No. 1, Bioreactor 2 with Run No. 2, and Bioreactor 3 with Run No. 3]. [4]

Performance Data Assessment

The oxygen uptake data indicate that a microbial culture capable of degrading PAHs was grown during this study. Oxygen was actively consumed in each of the bioreactors, and rates of oxygen consumption increased significantly after reloadings in response to substrate addition. Run Nos. 2 and 3, which were reloaded during the run, experienced the greatest increases in oxygen consumption rates. Since creosote was the only organic substrate present and no physical or chemical mechanism was identified for oxygen consumption, the uptake of oxygen in the bioreactors was attributed to biodegradation of PAHs. VSS results show that the size of the microbial community (biomass) increased over the course of the study in proportion to creosote reloading, indicating that a microbial community capable of degrading PAHs had been established.

In addition, the oxygen uptake data, which showed comparable results for Run No. 3 (which included loading and reloadings with 10% soil) as for Run Nos. 1 and 2, indicate that site soils were not toxic to the microbial community.

However, with respect to the biodegradation of PAHs, the results of the treatability study did not establish the relative biodegradability of PAH constituents. PAH analytical data from the 3 runs are not consistent with data for the



APPENDIX A—TREATABILITY STUDY RESULTS (CONT.)

Treatment Performance Results (cont.)

Table A-2. Oxygen Uptake Rate (mg/L/min) [4]

Day	Run No. 1	Run No. 2	Run No. 3	Loadings
9	0.078	0.067	0.178	Creosote loaded in all 3 runs on Day 1
15	0.131	0.24	0.291	Creosote loaded in Run Nos. 2 and 3 on Day 14; also, soil loaded in Run No. 3 on Day 14
19	0.049	0.202	0.218	No additional loadings between Days 15 and 19

creosote loadings and reloadings. For example, Run No. 1 (the 1% creosote loaded on Day 0, containing 90% PAHs) corresponds with an expected PAH concentration of 9,000 mg/L, while only 855 mg/L of PAHs were measured. However, the data indicate that PAHs are biodegraded using the microbial

cultures in this study, and that bioremediation appears to be feasible for creosote-containing soils at Scott Lumber.

Performance Data Quality

The PAH analyses included matrix spike test quality control efforts. [4]

Table A-3. PAH Data [4]

Days/ Comment	PAH Concentrations (mg/L)												TOTAL
	Acenaph- thene	Fluoran- thene	Naphtha- lene	Benz(a)- anthracene	Benz(a)- pyrene	Benz(b)- fluoran- thene	Benz(k)- fluoran- thene	Chryso- ene	Anthra- cene	Fluorene	Phenan- thene	Pyrene	
<i>Run No. 1</i>													
0	65	134	226	33	13	12	14	24	21	55	164	92	855
7	BDL	53	BDL	13	BDL	BDL	BDL	9	8	13	50	36	193
14	BDL	65	BDL	16	BDL	BDL	BDL	12	BDL	BDL	6	48	147
21	BDL	75	BDL	18	BDL	BDL	BDL	13	BDL	BDL	BDL	56	162
26	BDL	36	BDL	9	BDL	BDL	BDL	10	BDL	BDL	BDL	32	87
<i>Control Run</i>													
Before	BDL	20	BDL	6	BDL	BDL	BDL	BDL	BDL	BDL	BDL	18	44
5 min	7	49	34	14	BDL	BDL	BDL	11	22	6	20	41	204
15 min	BDL	38	30	11	BDL	BDL	BDL	BDL	BDL	BDL	10	33	122
30 min	7	63	35	19	BDL	BDL	BDL	13	BDL	5	13	53	208
1 hour	8	63	37	19	BDL	BDL	BDL	14	BDL	6	16	53	216
6 hour	9	48	29	20	BDL	BDL	BDL	15	BDL	8	22	43	194
6 hour dup.	7	41	25	17	BDL	BDL	BDL	12	BDL	6	19	36	162
<i>Run No. 2</i>													
0	75	322	208	80	33	30	33	62	35	65	192	234	1,369
7	19	173	BDL	40	16	14	17	29	19	19	87	120	553
14 before	BDL	167	BDL	48	20	18	20	34	BDL	BDL	BDL	118	442
14 after	15	134	79	33	14	12	14	23	11	26	BDL	93	454
26 before	6	130	BDL	31	16	13	16	34	BDL	BDL	6	94	346
26 after	19	131	100	28	13	11	14	27	BDL	13	31	95	482
39	18	208	BDL	68	20	26	27	67	BDL	BDL	31	246	794
39 froth	13	229	BDL	51	23	21	24	53	BDL	BDL	20	189	623

Key:

before: Before creosote reloading.

after: After creosote reloading.

dup.: Duplicate analysis of previous sample.

froth: Analysis of froth above bioreactor medium.

BDL: Below the detection limit (detection limit ranged from 5 to 20 ppm, depending on PAH constituent).

**Sample extraction difficulties.*



APPENDIX A—TREATABILITY STUDY RESULTS (CONT.)

Table A-3 (cont.). PAH Data [4]

Day/ Comment	PAH Concentrations (ng/L)												TOTAL
	Acenaph- thene	Fluoran- thene	Naphtha- lene	Benzo(a)- anthracene	Benzo(a)- pyrene	Benzo(b)- fluoran- thene	Benzo(k)- fluoran- thene	Chryseno	Anthra- cene	Fluorene	Phenan- threne	Pyrene	
Run No. 3													
0	510	1,020	1,910	269	108	94	109	224	BDL	467	1,610	706	7,024
7	8	262	67	30	28	30	36	BDL	BDL	BDL	BDL	193	674
14 before	BDL	100	BDL	39	23	22	24	43	BDL	BDL	BDL	146	397
14 after	35	172	163	64	36	35	36	65	16	30	101	217	970
14 dup.	30	135	157	40	22	20	22	41	13	26	82	164	585
26 before	BDL	113	BDL	23	14	12	16	33	BDL	BDL	BDL	113	324
26 after	19	131	100	28	13	11	14	27	BDL	13	31	95	482
39	*	*	*	*	*	*	*	*	*	*	*	137	137
39 dup.	*	*	*	*	*	*	*	*	*	*	*	146	146
39 froth	*	*	*	*	*	*	*	*	*	*	*	129	129

Key:

- before: Before creosote reloading.
- after: After creosote reloading.
- dup.: Duplicate analysis of previous sample.
- froth: Analysis of froth above bioreactor medium.

BDL: Below the detection limit (detection limit ranged from 5 to 20 ppm, depending on PAH constituent).

*Sample extraction difficulties.

Observations and Lessons Learned

Performance Observations and Lessons Learned

- A microbial culture capable of degrading PAHs was grown during this study, as shown by data for oxygen uptake rate and VSS.
- Soils from the Scott Lumber site were shown to be not toxic to the microbial community.
- While the treatability study did not establish the relative biodegradability of PAH constituents, the study showed that PAHs are biodegraded using the microbial cultures in this study and that bioremediation appears feasible for creosote-containing soils at Scott Lumber.

- The treatment vendor indicated that results for DS, SOC, and TOC analyses were inconclusive with respect to microbial activity in the 3 runs.

Other Observations and Lessons Learned

- This technology was selected as the full-scale remedy and successfully implemented at the Scott Lumber Company site. The full-scale treatment application met the established cleanup levels.



APPENDIX A—TREATABILITY STUDY RESULTS (CONT.)

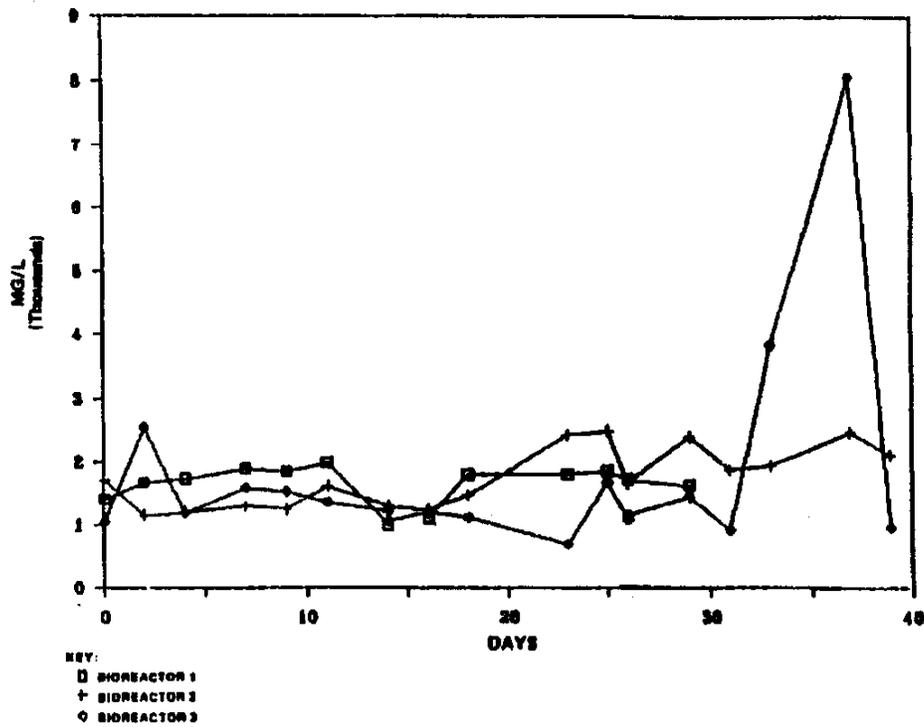


Figure A-1. Dissolved Solids Data [4]

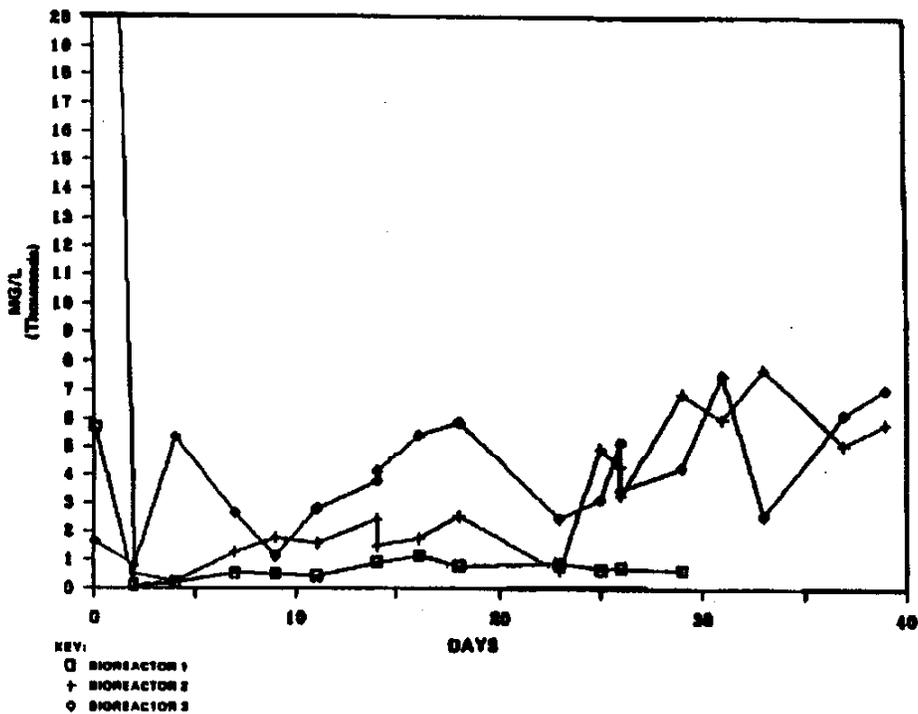


Figure A-2. Volatile Suspended Solids Data [4]

APPENDIX A—TREATABILITY STUDY RESULTS (CONT.)

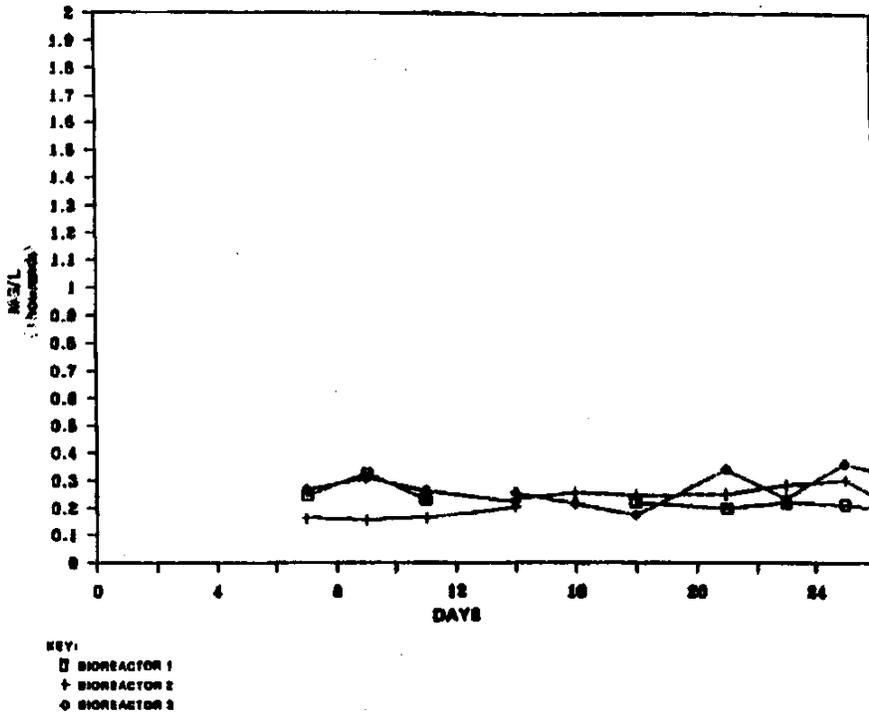


Figure A-3. Soluble Organic Carbon Data [4]

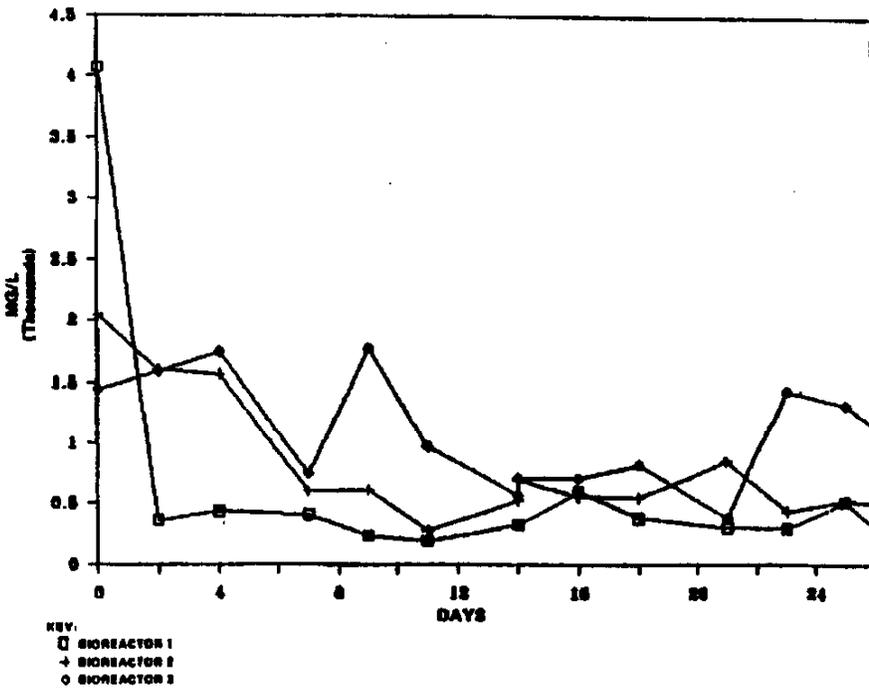


Figure A-4. Total Organic Carbon Data [4]



APPENDIX B—PAH ANALYTICAL RESULTS FOR LIFT ONE

PAH Analytical Results for Lift One (6)
(ug/kg)

Date	Constituent	SUBPLOT F QUADRANTS						Average
		North	North Duplicate	South	South Duplicate	East	East Duplicate	
04/19/90	NAPHTHALENE	6600 LV	6600 LV	8300 V	110000 V	6500 LV	12000 V	25000
04/19/90	ACENAPHTHYLENE	12000 LV	12000 LV	12000 LV	24000 LV	12000 LV	12000 LV	14000
04/19/90	ACENAPHTHENE	27000 V	12000 V	8700 V	12000 LV	24000 V	23000 V	17783
04/19/90	FLUORENE	15000 V	9100 V	10000 V	110000 V	17000 V	20000 V	30183
04/19/90	PHENANTHRENE	31000 V	26000 V	25000 V	210000 V	40000 V	56000 V	64667
04/19/90	ANTHRACENE	150000 V	36000 V	39000 V	93000 V	55000 V	50000 V	70500
04/19/90	FLUORANTHENE	81000 V	57000 V	54000 V	230000 V	92000 V	88000 V	100333
04/19/90	PYRENE	130000 V	60000 V	58000 JV	150000 V	72000 V	73000 V	90500
04/19/90	ANTHRACENE, BENZO(A)	22000 V	12000 V	11000 V	52000 V	23000 V	21000 V	23500
04/19/90	CHRYSENE	39000 V	22000 V	24000 V	68000 V	40000 V	40000 V	38833
04/19/90	FLUORANTHENE, BENZO(B)	19000 V	11000 V	10000 V	33000 V	19000 V	16000 V	18000
04/19/90	FLUORANTHENE, BENZO(K)	15000 V	8300 V	7900 V	26000 V	15000 V	12000 V	14033
04/19/90	PYRENE, BENZO(A)	16000 V	9200 V	8700 V	34000 V	16000 V	14000 V	16317
04/19/90	PYRENE, INDENO(1,2,3-CD)	18000 V	9400 V	4000 V	48000 V	18000 V	15000 V	18733
04/19/90	ANTHRACENE, DIBENZO(A,H)	2600 V	1900 V	1500 LV	7600 V	1500 V	1500 LV	2767
04/19/90	PERYLENE, BENZO(G,H,I)	14000 V	7400 V	7100 V	30000 V	14000 V	12000 V	14083
04/19/90	TOTAL PAHs	598200	299900	289200	1237600	465000	465500	559233
05/31/90	NAPHTHALENE	N/A	N/A	N/A	3700 JV	18000 V	11000 V	10900
05/31/90	ACENAPHTHYLENE	N/A	N/A	N/A	1000 LV	2300 V	2600 V	1967
05/31/90	ACENAPHTHENE	N/A	N/A	N/A	11000 V	27000 V	25000 V	21000
05/31/90	FLUORENE	N/A	N/A	N/A	18000 JV	38000 V	38000 V	31333
05/31/90	PHENANTHRENE	N/A	N/A	N/A	59000 JV	100000 V	100000 V	86333
05/31/90	ANTHRACENE	N/A	N/A	N/A	75000 JV	120000 V	140000 V	111667
05/31/90	FLUORANTHENE	N/A	N/A	N/A	66000 JV	90000 V	94000 V	83333
05/31/90	PYRENE	N/A	N/A	N/A	39000 JV	56000 V	58000 V	51000
05/31/90	ANTHRACENE, BENZO(A)	N/A	N/A	N/A	20000 V	28000 V	29000 V	25667
05/31/90	CHRYSENE	40000 V	49000 V	51000 V	24000 V	31000 V	34000 V	38167
05/31/90	FLUORANTHENE, BENZO(B)	24000 V	24000 V	24000 V	14000 V	17000 V	20000	20500
05/31/90	FLUORANTHENE, BENZO(K)	24000 V	24000 V	24000 V	14000 V	17000 V	29999 V	20500
05/31/90	PYRENE, BENZO(A)	23000 V	24000 V	24000 V	12000 V	16000 V	19000 V	19667



APPENDIX B—PAH ANALYTICAL RESULTS FOR LIFT ONE (CONT.)

PAH Analytical Results for Lift One (Continued)
(ug/kg)

Date	Constituent	SUBPLOT F QUADRANTS								Average
		North	North Duplicate	South	South Duplicate	East	East Duplicate	South	South Duplicate	
05/31/90	PYRENE, INDENO(1,2,3-CD)	11000 V	12000 V	11000 V	6100 V	7100 V	8100 V	1000 LV	1000 LV	9217
05/31/90	ANTHRACENE, DIBENZO(A,H)	1000 LV	3100 V	1000 LV	1000 LV	1000 LV	1000 LV	1000 LV	1000 LV	1350
05/31/90	PERYLENE, BENZO(G,H,I)	8300 V	9200 V	8300 V	4700 V	5800 V	6800 V	6800 V	6800 V	7183
05/31/90	TOTAL PAHs	131300	145300	143300	368500	574200	606500	606500	606500	539783
06/14/90	NAPHTHALENE	13000 V	16000 V	3800 V	7000 V	2500 V	3900 V	3900 V	3900 V	7700
06/14/90	ACENAPHTHYLENE	2500 V	1800 V	1400 V	1800 V	1600 V	1700 V	1700 V	1700 V	1800
06/14/90	ACENAPHTHENE	11000 V	5300 V	3500 V	8400 V	3600 V	4700 V	4700 V	4700 V	6083
06/14/90	FLUORENE	18000 V	14000 V	10000 V	14000 V	6600 V	7800 V	7800 V	7800 V	11733
06/14/90	PHENANTHRENE	53000 V	35000 V	23000 V	40000 V	24000 V	24000 V	24000 V	24000 V	33167
06/14/90	ANTHRACENE	99000 V	99000 V	87000 V	64000 V	51000 V	59000 V	59000 V	59000 V	76500
06/14/90	FLUORANTHENE	110000 V	67000 V	43000 V	62000 V	52000 V	65000 V	65000 V	65000 V	66500
06/14/90	PYRENE	54000 V	36000 V	22000 V	29000 V	27000 V	33000 V	33000 V	33000 V	33500
06/14/90	ANTHRACENE, BENZO(A)	37000 V	25000 V	15000 V	19000 V	18000 V	22000 V	22000 V	22000 V	22667
06/14/90	CHRYSENE	44000 V	30000 V	19000 V	22000 V	23000 V	25000 V	25000 V	25000 V	27167
06/14/90	FLUORANTHENE, BENZO(B)	1000 LV	1000 LV	13000 V	15000 V	15000 V	18000 V	18000 V	18000 V	10500
06/14/90	FLUORANTHENE, BENZO(K)	1000 LV	1000 LV	13000 V	15000 V	14000 V	18000 V	18000 V	18000 V	10333
06/14/90	PYRENE, BENZO(A)	23000 V	18000 V	12000 V	15000 V	14000 V	16000 V	16000 V	16000 V	16333
06/14/90	PYRENE, INDENO(1,2,3-CD)	14000 V	12000 V	7800 V	9100 V	9000 V	10000 V	10000 V	10000 V	10317
06/14/90	ANTHRACENE, DIBENZO(A,H)	7000 V	4100 V	2700 V	3400 V	3800 V	3600 V	3600 V	3600 V	4100
06/14/90	PERYLENE, BENZO(G,H,I)	12000 V	9600 V	6700 V	7500 V	7600 V	8600 V	8600 V	8600 V	8667
06/14/90	TOTAL PAHs	499500	374800	281900	332200	272700	320300	320300	320300	347067
06/28/90	NAPHTHALENE	1400 V	1900 V	3700 V	3800 V	1900 V	1500 V	1500 V	1500 V	2367
06/28/90	ACENAPHTHYLENE	1000 LV	1000 LV	1000 LV	1000 LV	1000 LV	1000 LV	1000 LV	1000 LV	1000
06/28/90	ACENAPHTHENE	1900 V	2200 V	3300 V	3200 V	2600 V	2500 V	2500 V	2500 V	2617
06/28/90	FLUORENE	5700 V	5900 V	5500 V	7900 V	6900 V	6500 V	6500 V	6500 V	6400
06/28/90	PHENANTHRENE	19000 V	20000 V	20000 V	23000 V	26000 V	33000 V	33000 V	33000 V	23500
06/28/90	ANTHRACENE	46000 V	51000 V	41000 V	64000 V	71000 V	47000 V	47000 V	47000 V	53333
06/28/90	FLUORANTHENE	25000 V	24000 V	35000 V	22000 V	36000 V	42000 V	42000 V	42000 V	30667
06/28/90	PYRENE	35000 V	36000 V	51000 V	31000 V	51000 V	55000 V	55000 V	55000 V	43167
06/28/90	ANTHRACENE, BENZO(A)	20000 V	22000 V	23000 V	18000 V	26000 V	26000 V	26000 V	26000 V	22500



APPENDIX B—PAH ANALYTICAL RESULTS FOR LIFT ONE (CONT.)

PAH Analytical Results for Lift One (Continued)
(ug/kg)

Date	Constituent	SUBPLOT F QUADRANTS								Average
		North	North Duplicate	South	South Duplicate	East	East Duplicate	West	West Duplicate	
06/28/90	CHRYSENE	29000 V	28000 V	31000 V	23000 V	36000 JV	33000 V	30000		
06/28/90	FLUORANTHENE, BENZO(B)	16000 V	17000 V	18000 V	15000 V	17000 V	19000 V	17000		
06/28/90	FLUORANTHENE, BENZO(K)	16000 V	17000 V	17000 V	14000 V	17000 V	19000 V	16667		
06/28/90	PYRENE, BENZO(A)	16000 V	18000 V	19000 V	15000 V	17000 V	19000 V	17333		
06/28/90	PYRENE, INDENO(1,2,3-CD)	16000 V	16000 V	16000 LV	14000 V	15000 V	17000 V	15667		
06/28/90	ANTHRACENE, DIBENZO(A,H)	1000 LV	1000 LV	1000 LV	1000 LV	1000 LV	1000 LV	1000		
06/28/90	PERYLENE, BENZO(G,H,I)	1000 LV	1000 LV	1000 LV	1000 LV	1000 LV	1000 LV	1000		
06/28/90	TOTAL PAHs	250000	262000	286500	256900	326400	323500	284217		
07/12/90	NAPHTHALENE	2000 LV	2000 LV	2000 LV	2000 LV	2000 LV	2000 LV	2000		
07/12/90	ACENAPHTHYLENE	2000 LV	2000 LV	2000 LV	2000 LV	2000 LV	2000 LV	2000		
07/12/90	ACENAPHTHENE	2000 LV	2000 LV	2000 LV	2000 LV	2000 LV	2000 LV	2000		
07/12/90	FLUORENE	5800 V	5400 V	2300 V	3600 V	5300 V	2000 LV	4067		
07/12/90	PHENANTHRENE	12000 V	10000 V	6900 V	9900 V	16000 V	5700 V	10083		
07/12/90	ANTHRACENE	60000 V	45000 V	16000 V	40000 V	73000 V	17000 V	41833		
07/12/90	FLUORANTHENE	22000 V	19000 V	19000 V	27000 V	32000 V	42000 V	26833		
07/12/90	PYRENE	16000 V	10000 V	11000 V	24000 V	20000 V	37000 V	19667		
07/12/90	ANTHRACENE, BENZO(A)	9600 V	10000 V	8300 V	13000 V	14000 V	17000 V	11983		
07/12/90	CHRYSENE	13000 V	16000 V	12000 V	20000 V	21000 V	22000 V	17333		
07/12/90	FLUORANTHENE, BENZO(B)	11000 V	9000 V	10000 V	11000 V	17000 V	12000 V	11667		
07/12/90	FLUORANTHENE, BENZO(K)	11000 V	9000 V	10000 V	11000 V	17000 V	12000 V	11667		
07/12/90	PYRENE, BENZO(A)	9100 V	10000 V	8800 V	15000 V	14000 V	16000 V	12150		
07/12/90	PYRENE, INDENO(1,2,3-CD)	5800 V	9100 V	5500 V	9200 V	11000 V	10000 V	8433		
07/12/90	ANTHRACENE, DIBENZO(A,H)	2000 LV	2600 V	2000 LV	2800 V	2000 LV	2300 V	2283		
07/12/90	PERYLENE, BENZO(G,H,I)	4500 V	7000 V	4200 V	7500 V	8400 V	7300 V	6483		
07/12/90	TOTAL PAHs	187800	168100	122000	200000	256700	208300	190483		
07/26/90	NAPHTHALENE	5000 LV	5000 LV	5000 LV	5000 LV	5000 LV	5000 LV	5000		
07/26/90	ACENAPHTHYLENE	5000 LV	5000 LV	5000 LV	5000 LV	5000 LV	5000 LV	5000		
07/26/90	ACENAPHTHENE	5000 LV	5000 LV	5000 LV	5000 LV	5000 LV	5000 LV	5000		
07/26/90	FLUORENE	5000 LV	5000 LV	5000 LV	17000 V	5000 LV	5000 LV	7000		
07/26/90	PHENANTHRENE	8500 V	8100 V	6000 V	29000 V	11000 V	9000 V	11933		



APPENDIX B—PAH ANALYTICAL RESULTS FOR LIFT ONE (CONT.)

PAH Analytical Results for Lift One (Continued)
(ug/kg)

Date	Constituent	SUBPLOT F QUADRANTS				Average
		North	South	South Duplicate	East Duplicate	
07/26/90	ANTHRACENE	27000 V	18000 V	5000 V	36000 V	22333
07/26/90	FLUORANTHENE	15000 V	14000 V	22000 V	17000 V	19000
07/26/90	PYRENE	26000 V	21000 V	54000 V	32000 V	36500
07/26/90	ANTHRACENE, BENZO(A)	12000 V	10000 V	15000 V	12000 V	13500
07/26/90	CHRYSENE	19000 V	15000 V	27000 V	17000 V	19833
07/26/90	FLUORANTHENE, BENZO(B)	10000 V	7500 V	17000 V	14000 V	12417
07/26/90	FLUORANTHENE, BENZO(K)	10000 V	7500 V	17000 V	14000 V	12417
07/26/90	PYRENE, BENZO(A)	11000 V	9600 V	14000 V	11000 V	11933
07/26/90	PYRENE, INDENO(1,2,3-CD)	5000 LV	5700 V	7400 V	5600 V	6600
07/26/90	ANTHRACENE, DIBENZO(A,H)	5000 LV	5000 LV	5000 LV	5000 LV	5000
07/26/90	PERYLENE, BENZO(G,H,I)	5000 LV	4800 V	7000 V	5600 V	6017
07/26/90	TOTAL PAHs	173500	144100	251400	200200	199483
08/09/90	NAPHTHALENE	5000 LV	5000 LV	5000 LV	5000 LV	5000
08/09/90	ACENAPHTHYLENE	5000 LV	5000 LV	5000 LV	5000 LV	5000
08/09/90	ACENAPHTHENE	5000 LV	5000 LV	5000 LV	5000 LV	5000
08/09/90	FLUIORENE	5000 LV	5000 LV	5000 LV	5000 LV	5000
08/09/90	PHENANTHRENE	5000 LV	6500 V	5000 LV	5700 V	6833
08/09/90	ANTHRACENE	13000 V	33000 V	27000 V	22000 V	31500
08/09/90	FLUORANTHENE	9100 V	21000 V	13000 V	17000 V	19017
08/09/90	PYRENE	9800 V	24000 V	14000 V	18000 V	18967
08/09/90	ANTHRACENE, BENZO(A)	5500 V	12000 V	9400 V	11000 V	11150
08/09/90	CHRYSENE	10000 V	22000 V	19000 V	20000 V	21000
08/09/90	FLUORANTHENE, BENZO(B)	7800 V	20000 V	17000 V	29000 V	18800
08/09/90	FLUORANTHENE, BENZO(K)	7500 V	13000 V	13000 V	13000 V	12750
08/09/90	PYRENE, BENZO(A)	5400 V	14000 V	12000 V	13000 V	12233
08/09/90	PYRENE, INDENO(1,2,3-CD)	5000 LV	8000 V	8300 V	7900 V	8100
08/09/90	ANTHRACENE, DIBENZO(A,H)	5000 LV	5000 LV	5000 LV	5000 LV	5550
08/09/90	PERYLENE, BENZO(G,H,I)	5000 LV	7000 V	7000 V	6600 V	6450
08/09/90	TOTAL PAHs	108100	205500	169700	188200	192350
08/23/90	NAPHTHALENE	5000 LV	5000 LV	5000 LV	5000 LV	5000



APPENDIX B—PAH ANALYTICAL RESULTS FOR LIFT ONE (CONT.)

PAH Analytical Results for Lift One (Continued)
(ug/kg)

Date	Constituent	SUBPLOT F QUADRANTS								Average
		North	North Duplicate	South	South Duplicate	East	East Duplicate			
08/23/90	ACENAPHTHYLENE	5000 UV	5000 UV	5000 UV	5000 UV	5000 UV	5000 UV	5000 UV	5000 UV	5000
08/23/90	ACENAPHTHENE	5000 UV	5000 UV	5000 UV	5000 UV	5000 UV	5000 UV	5000 UV	5000 UV	5000
08/23/90	FLUORENE	5000 UV	5000 UV	5000 UV	5000 UV	5100 V	5000 UV	5000 UV	5000 UV	5017
08/23/90	PHENANTHRENE	5500 V	11000 V	5000 UV	5400 V	13000 V	5000 UV	6100 V	5000 UV	7667
08/23/90	ANTHRACENE	27000 V	46000 V	21000 V	22000 V	50000 V	50000 V	44000 V	50000 V	35000
08/23/90	FLUORANTHENE	15000 V	20000 V	20000 V	23000 V	15000 V	13000 V	13000 V	13000 V	17667
08/23/90	PYRENE	13000 V	17000 V	20000 V	21000 V	14000 V	13000 V	13000 V	13000 V	16333
08/23/90	ANTHRACENE, BENZO(A)	5000 UV	5000 UV	10000 V	12000 V	9000 V	8500 V	8500 V	8500 V	8250
08/23/90	CHRYSENE	20000 V	20000 V	19000 V	20000 V	17000 V	15000 V	15000 V	15000 V	18500
08/23/90	FLUORANTHENE, BENZO(B)	30000 V	30000 V	30000 V	30000 V	27000 V	26000 V	26000 V	26000 V	28833
08/23/90	FLUORANTHENE, BENZO(K)	5000 UV	5000 UV	5000 UV	5000 UV	5000 UV	5000 UV	5000 UV	5000 UV	5000
08/23/90	PYRENE, BENZO(A)	12000 V	13000 V	12000 V	13000 V	12000 V	11000 V	11000 V	11000 V	12167
08/23/90	PYRENE, INDENO(1,2,3-CD)	8000 V	8000 V	7500 V	7700 V	6900 V	7000 V	7000 V	7000 V	7517
08/23/90	ANTHRACENE, DIBENZO(A,H)	5000 UV	5000 UV	5000 UV	5000 UV	5000 UV	5000 UV	5000 UV	5000 UV	5000
08/23/90	PERYLENE, BENZO(G,H,I)	8000 V	7000 V	7500 V	7100 V	6800 V	6800 V	6800 V	6800 V	7200
08/23/90	TOTAL PAHs	173500	207000	182000	191200	200800	180400	180400	180400	189150
09/06/90	NAPHTHALENE	5000 UV	5000 UV	5000 UV	5000 UV	5000 UV	5000 UV	5000 UV	5000 UV	5000
09/06/90	ACENAPHTHYLENE	5000 UV	5000 UV	5000 UV	5000 UV	5000 UV	5000 UV	5000 UV	5000 UV	5000
09/06/90	ACENAPHTHENE	5000 UV	5000 UV	5000 UV	5000 UV	5000 UV	5000 UV	5000 UV	5000 UV	5000
09/06/90	FLUORENE	5000 UV	5000 UV	5000 UV	7000 V	5000 UV	5000 UV	5000 UV	5000 UV	5333
09/06/90	PHENANTHRENE	15000 V	6000 V	5000 UV	13000 V	5000 UV	7000 V	7000 V	7000 V	8500
09/06/90	ANTHRACENE	75000 V	29000 V	32000 V	74000 V	27000 V	38000 V	38000 V	38000 V	45833
09/06/90	FLUORANTHENE	20000 V	15000 V	11000 V	13000 V	14000 V	11000 V	11000 V	11000 V	14000
09/06/90	PYRENE	18000 V	15000 V	12000 V	13000 V	16000 V	13000 V	13000 V	13000 V	14500
09/06/90	ANTHRACENE, BENZO(A)	14000 V	12000 V	10000 V	10000 V	12000 V	11000 V	11000 V	11000 V	11500
09/06/90	CHRYSENE	20000 V	17000 V	14000 V	15000 V	20000 V	17000 V	17000 V	17000 V	17167
09/06/90	FLUORANTHENE, BENZO(B)	18000 V	16000 V	13000 V	16000 V	16000 V	15000 V	15000 V	15000 V	15667
09/06/90	FLUORANTHENE, BENZO(K)	14000 V	13000 V	11000 V	10000 V	15000 V	14000 V	14000 V	14000 V	12833
09/06/90	PYRENE, BENZO(A)	14000 V	13000 V	11000 V	9000 V	13000 V	12000 V	12000 V	12000 V	12000
09/06/90	PYRENE, INDENO(1,2,3-CD)	9000 V	8000 V	6000 V	6000 V	5000 UV	6000 V	6000 V	6000 V	6667



APPENDIX B—PAH ANALYTICAL RESULTS FOR LIFT ONE (CONT.)

PAH Analytical Results for Lift One (Continued)
(ug/kg)

Date	Constituent	SUBPLOT F QUADRANTS								Average
		North	North Duplicate	South	South Duplicate	East	East Duplicate	South Duplicate	East Duplicate	
09/06/90	ANTHRACENE, DIBENZO(A,H)	5000 LV	5000 LV	5000 LV	5000 LV	5000 LV	5000 LV	5000 LV	5000 LV	5000
09/06/90	PERYLENE, BENZO(G,H,I)	9000 V	8000 V	5000 LV	5000 LV	5000 LV	5000 LV	5000 LV	5000 LV	6167
09/06/90	TOTAL PAHs	251000	177000	155000	211000	173000	174000	173000	174000	190167
09/20/90	NAPHTHALENE	1300 V	1100 V	1400 V	1500 V	1900 V	2600 V	1900 V	2600 V	1633
09/20/90	ACENAPHTHYLENE	1000 LV	1000 LV	1000 LV	1000 LV	1000 LV	1000 LV	1000 LV	1000 LV	1000
09/20/90	ACENAPHTHENE	1000 LV	1000 LV	1000 LV	1000 LV	1000 LV	1000 LV	1000 LV	1000 LV	1000
09/20/90	FLUORENE	2400 V	1800 V	2600 V	2200 V	3200 V	4400 V	3200 V	4400 V	2767
09/20/90	PHENANTHRENE	7800 V	5500 V	7100 V	7100 V	7700 V	9000 V	7700 V	9000 V	7367
09/20/90	ANTHRACENE	25000 V	21000 V	28000 V	25000 V	34000 V	51000 V	34000 V	51000 V	30667
09/20/90	FLUORANTHENE	9000 V	6900 V	7700 V	8400 V	8400 V	7000 V	8400 V	7000 V	7900
09/20/90	ANTHRACENE, BENZO(A)	29000 V	19000 V	20000 V	26000 V	26000 V	18000 V	26000 V	18000 V	23000
09/20/90	CHRYSENE	11000 V	8600 V	8800 V	9600 V	9000 V	8300 V	9000 V	8300 V	9217
09/20/90	FLUORANTHENE, BENZO(B)	18000 V	13000 V	14000 V	16000 V	15000 V	14000 V	15000 V	14000 V	15000
09/20/90	FLUORANTHENE, BENZO(K)	16000 V	14000 V	20000 V	8200 V	13000 V	14000 V	13000 V	14000 V	14200
09/20/90	PYRENE, BENZO(A)	12000 V	7600 V	8000 V	12000 V	11000 V	7000 V	11000 V	7000 V	9600
09/20/90	PYRENE, INDENO(1,2,3-CD)	14000 V	11000 V	11000 V	12000 V	11000 V	11000 V	11000 V	11000 V	11667
09/20/90	ANTHRACENE, DIBENZO(A,H)	12000 V	1000 LV	10000 V	10000 V	1000 LV	1000 LV	1000 LV	1000 LV	5833
09/20/90	PERYLENE, BENZO(G,H,I)	1000 LV	1000 LV	1000 LV	1000 LV	1000 LV	1000 LV	1000 LV	1000 LV	1000
09/20/90	TOTAL PAHs	170500	121200	149900	149600	152200	158300	152200	158300	150283
10/05/90	NAPHTHALENE	2500 LV	2500 LV	2500 LV	2500 LV	2500 LV	2500 LV	2500 LV	2500 LV	2500
10/05/90	ACENAPHTHYLENE	2500 LV	2500 LV	2500 LV	2500 LV	2500 LV	2500 LV	2500 LV	2500 LV	2500
10/05/90	ACENAPHTHENE	2500 LV	2500 LV	2500 LV	2500 LV	2500 LV	2500 LV	2500 LV	2500 LV	2500
10/05/90	FLUORENE	3000 V	2500 LV	2500 LV	2500 LV	2700 V	2500 LV	2700 V	2500 LV	2617
10/05/90	PHENANTHRENE	6500 V	4700 V	6100 V	4200 V	6400 V	7300 V	6400 V	7300 V	5867
10/05/90	ANTHRACENE	37000 V	24000 V	26000 V	25000 V	32000 V	28000 V	32000 V	28000 V	28667
10/05/90	FLUORANTHENE	10000 V	13000 V	21000 V	8200 V	11000 V	13000 V	11000 V	13000 V	12700
10/05/90	PYRENE	10000 V	14000 V	22000 V	11000 V	12000 V	12000 V	12000 V	12000 V	13500
10/05/90	ANTHRACENE, BENZO(A)	7400 V	8100 V	11000 V	7400 V	7800 V	8000 V	7800 V	8000 V	8283
10/05/90	CHRYSENE	12000 V	12000 V	16000 V	14000 V	13000 V	13000 V	13000 V	13000 V	13333



APPENDIX B—PAH ANALYTICAL RESULTS FOR LIFT ONE (CONT.)

PAH Analytical Results for Lift One (Continued)
(ug/kg)

Date	Constituent	SUBPLOT F QUADRANTS						Average
		North	North Duplicate	South	South Duplicate	East	East Duplicate	
10/05/90	FLUORANTHENE, BENZO(B)	12000 V	12000 V	17000 V	14000 V	10000 V	13000 V	13000
10/05/90	FLUORANTHENE, BENZO(K)	9000 V	11000 V	12000 V	8200 V	6100 V	9800 V	9350
10/05/90	PYRENE, BENZO(A)	9400 V	1000 V	13000 V	10000 V	8900 V	9600 V	8650
10/05/90	PYRENE, INDENO(1,2,3-CD)	8100 V	7200 V	10000 V	9000 V	7800 V	9000 V	8517
10/05/90	ANTHRACENE, DIBENZO(A,H)	2600 V	2500 LV	3300 V	2500 LV	2500 LV	2500 LV	2650
10/05/90	PERYLENE, BENZO(G,H,I)	6900 V	8500 V	8600 V	6900 V	6500 V	7300 V	7450
10/05/90	TOTAL PAHs	141400	128000	176000	130400	134200	142500	142083
10/18/90	NAPHTHALENE	2000	1000 U	1000 U	1000 U	1000 U	1000	1167
10/18/90	ACENAPHTHYLENE	1000 U	1000 U	1000 U	1000 U	1000 U	1000 U	1000
10/18/90	ACENAPHTHENE	1000 U	1000 U	1000 U	1000 U	1000 U	1000 U	1000
10/18/90	FLUORENE	4800	1100	1400	1000 U	1000 U	3100	2067
10/18/90	PHENANTHRENE	8200	4400	3300	3300	3800	6700	4950
10/18/90	ANTHRACENE	41000	12000	16000	7800	8200	17000	17000
10/18/90	FLUORANTHENE	6900	11000	5200	8600	8600	14000	9050
10/18/90	PYRENE	5800	8100	4600	6300	6500	9900	6867
10/18/90	ANTHRACENE, BENZO(A)	5300	6200	3600	4200	5000	6200	5083
10/18/90	CHRYSENE	9100	13000	8400	8500	11000	12000	10333
10/18/90	FLUORANTHENE, BENZO(B)	24000	31000	23000	20000	33000	34000	27500
10/18/90	FLUORANTHENE, BENZO(K)	24000	31000	23000	20000	33000	34000	27500
10/18/90	PYRENE, BENZO(A)	8000	9700	7800	6000	8900	8900	8217
10/18/90	PYRENE, INDENO(1,2,3-CD)	5200	9700	5000	3900	7100	6200	6183
10/18/90	ANTHRACENE, DIBENZO(A,H)	1000 U	1000 U	1000 U	1000 U	1000 U	1000 U	1000
10/18/90	PERYLENE, BENZO(G,H,I)	5700	6800	5000	3200	6100	6100	5483
10/18/90	TOTAL PAHs	153000	148000	110300	96800	136200	162100	134400

