

## **COST AND PERFORMANCE REPORT**

### **EXECUTIVE SUMMARY**

This report presents cost and performance data for a land treatment application at the Burlington Northern Superfund site, in Brainerd/Baxter, Minnesota. Land treatment was used at the Burlington Northern site to treat soil and sludge contaminated with polynuclear aromatic hydrocarbons (PAHs) and other non-halogenated semivolatile organic compounds, including naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, benzo(a)anthracene, chrysene, benzo(b and k)fluoranthenes, benzo(a)pyrene, benzo(ghi)perylene, dibenzo(a,h)anthracene, indeno(1,2,3)pyrene, and phenols.

The Burlington Northern site was the location of a railroad tie treating plant that operated from 1907 to 1985. Wood preserving processes operated at the site involved pressure treatment using a heated creosote/coal tar or creosote/fuel oil mixture. Wastewater generated from the wood preserving processes was discharged to two shallow, unlined surface impoundments for disposal. In the 1980's, EPA determined that soil beneath these two surface impoundments, as well as soil in three other areas at the site (the process, drip track, and black dock areas) were contaminated. Total PAH concentrations for visibly-contaminated soils in the surface impoundments were measured as high as 70,633 mg/kg, with individual PAHs measured as high as 21,319 mg/kg (acenaphthene, a two-ring PAH), 7,902 mg/kg (phenanthrene, a three-ring PAH), and 10,053 mg/kg (fluoranthene, a four-ring PAH). Concentrations of benzene-extractable constituents in the surface impoundment soils ranged from 66,100 to 112,500 mg/kg.

In April, 1985, a three-party consent agreement for this site was signed by Burlington Northern, the Minnesota Pollution Control Agency (MPCA), and EPA. Based on the consent agreement, EPA issued an Enforcement Decision Document (a predecessor to a ROD) in June 1986, which required Burlington Northern to treat visibly-contaminated soils and sludges using on-site land treatment. In addition, a RCRA Part B permit was issued for this site which specified that the concentration of methylene chloride extractable (MCE) hydrocarbons (a replacement for benzene extractables) and total PAHs (the sum of 17 specific PAHs) in the treatment zone would not be greater than 21,000 mg/kg and 8,632 mg/kg, respectively. While the permit also specified that the treatment zone would be detoxified to "within Microtox® limits," no quantitative limits were provided in the permit.

The land treatment unit (LTU) used in this application was constructed at Burlington Northern in 1985, with outer dimensions of approximately 300 by 495 feet (150,000 ft<sup>2</sup>) and an area available for treatment of approximately 255 by 450 feet (115,000 ft<sup>2</sup>). The LTU was constructed in layers, over a base of 100 mm thick HDPE, silty sand ballast, gravel, and clean, silty sand. Two-foot wide leachate collection drains were installed in the gravel layer, on 100-foot centers. Each year from 1986 through 1994 (nine years total), between 1,100 and 1,500 cubic yards of contaminated soil and sludge were spread over the LTU to a depth of 6-8 inches. Land treatment was conducted from May through October (the "treatment season"), and included weekly cultivation, irrigation, lime addition, and cow manure application. In July and August, 1995, after completion of LTU operation, Burlington Northern placed a cover over the LTU.

## **EXECUTIVE SUMMARY (CONT.)**

Soil sampling and analysis were performed at the beginning and end of each of the nine treatment seasons, and again throughout the depth of the LTU at the completion of treatment. The yearly analytical data indicate that the average concentrations for MCE hydrocarbons was reduced from 64,000 to 33,000 mg/kg, and for total PAHs from 9,733 to 1,854 mg/kg, over the nine treatment seasons. The analytical data from the LTU at the completion of treatment indicate that MCE hydrocarbons ranged from 24,800 to 26,900 mg/kg, and total PAHs from 608 to 795 mg/kg, throughout the depth of the treated soil and sludge. In addition, at the completion of treatment, Microtox® EC 50 testing (5 minute, 15°C) showed residual toxicity ranging from 4.9 to 15.3. As shown by these data, the LTU met the cleanup goal for total PAHs, but did not meet the cleanup goal for MCE hydrocarbons. According to the Remedial Action Report, the soil was not treated to “within Microtox® limits”; however, as stated previously, these limits were not provided in the available information. In addition, the total PAH cleanup requirement was met for all nine treatment seasons. Because the LTU did not meet the cleanup requirements for MCE hydrocarbons or toxicity, Burlington Northern was required to implement a contingency procedure in their permit and place a cover over the LTU.

The land treatment application at Burlington Northern was PRP-lead, and no information on actual costs incurred (before-treatment, treatment, or after-treatment, as appropriate) is provided in the available references. In addition, no information is provided on unit costs (e.g., costs per cubic yard of soil and sludge treated) for this application.

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## SITE INFORMATION

### Identifying Information:

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Burlington Northern Superfund site

Brainerd/Baxter, Minnesota

CERCLIS # MND000686196

**Enforcement Decision Document Date:** June 4, 1986

### Treatment Application:

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**Type of Action:** Remedial

**Treatability Study Associated with Application?** Yes

(refer to Reference 15 for additional information)

**EPA SITE Program Test Associated with Application?** Yes

A SITE program test of slurry phase biological treatment was conducted on a pilot-scale basis in 1991 using contaminated soil from Burlington Northern. Reference 20 contains additional information on the SITE program test.

**Period of Operation:** May 1986 - October 1994

**Quantity of Material Treated During Application:** 13,000 cubic yards of soil and sludge

This quantity consists of 8,500 cubic yards of soil and sludge excavated from two surface impoundments, 3,500 cubic yards of soil excavated from other areas of interest at the site (process area, drip track area, and black dock area), and 1,000 cubic yards of sand, gravel, and other soil from stockpile closure activities. [1]

### Background

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**Historical Activity that Contributed to Contamination at the Site:** Creosote wood preserving

**Corresponding SIC Code:** 2491B (Wood Preserving Using Creosote)

**Waste Management Practice that Contributed to Contamination:** Manufacturing Process, Surface Impoundments

**Site History:** The Burlington Northern Superfund site (Burlington Northern) is located partly in Baxter and partly in Brainerd, Minnesota, as shown in Figure 1. Burlington Northern Railroad operated a railroad tie treating plant at the site between 1907 and 1985. The wood preserving process used at the site involved pressure treatment using a heated creosote/coal tar or creosote/fuel oil mixture. Wastewater generated from the wood preserving process was discharged to two shallow, unlined surface impoundments for disposal. The first impoundment (referred to as the CERCLA impoundment) was approximately 60,000 square feet in area. This impoundment filled with sludge and was buried under clean fill in the 1930s. A second impoundment (referred to as the RCRA impoundment) was used from the 1930s until October

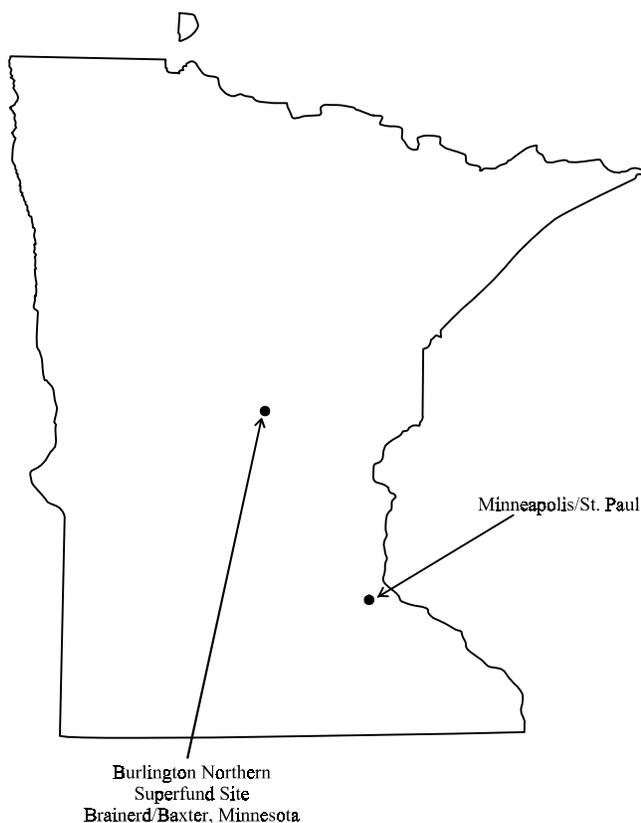
## SITE INFORMATION (CONT.)

### Background (cont.)

1982. EPA determined that the use of these surface impoundments had resulted in contamination of both the soil and groundwater beneath the ponds. Disposal pond soil was classified as RCRA hazardous waste K001, under 40 CFR 261.32. [3, 23]

The soil at three additional areas at Burlington Northern also was determined to be contaminated (the process area, drip track area, and black dock area). These areas are shown on Figure 2. Tie treating operations were completed in the retort building in the process area. Creosote used in the treatment process was also stored in aboveground tanks in this area. Following pressure treatment, the ties were moved to the drip track area for drying. Treated ties were then transported to the black dock area for storage prior to transport off site. [1]

**Regulatory Context:** In April 1985, a three-party consent agreement was signed by Burlington Northern, the Minnesota Pollution Control Agency (MPCA), and EPA. The consent agreement detailed specific actions and studies to be undertaken concerning the two surface impoundments and three additional areas of contaminated soil. Activities included site monitoring, preparing a treatment study, preparing a feasibility study, submitting closure and post-closure plans, and implementing corrective actions. Based on the consent agreement, EPA issued an Enforcement Decision Document (a predecessor to a Record of Decision - ROD) in June 1986, which identified actions to control the source of contamination, including treatment of soils and sludges, and to prevent hazardous substances from migrating away from the contaminated site. The Enforcement Decision Document required Burlington Northern to excavate and treat soils and sludges which were visibly contaminated and which contained free oils that could migrate to groundwater. [3]



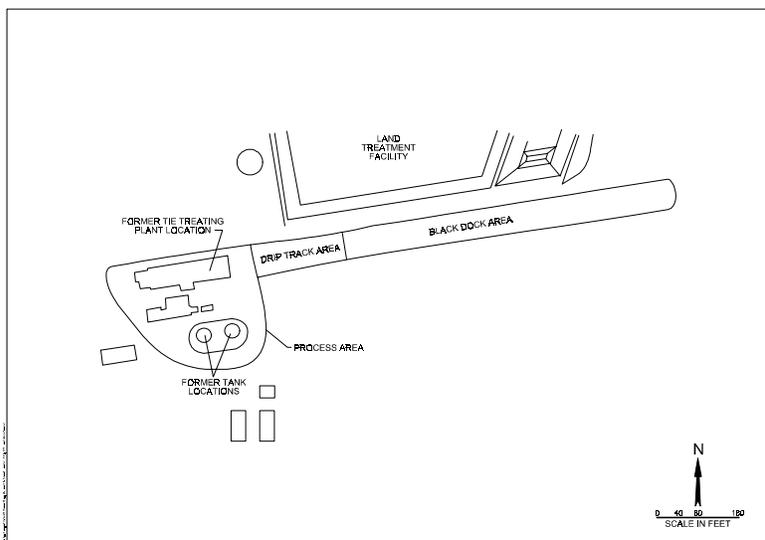
**Figure 1. Site Location**

## SITE INFORMATION (CONT.)

### Background (cont.)

**Remedy Selection:** The following three alternatives for treatment of contaminated soils and sludges were considered for the site:

- On-site land treatment of contaminated soils and sludges;
- On-site incineration of contaminated soils and sludges; and
- On-site land treatment of contaminated soils, and off-site incineration of sludges.



**Figure 2. Additional Areas of Contaminated Soil at Burlington Northern [1]**

On-site land treatment of contaminated soils and sludges was selected for this site because it was identified as protective of human health and the environment, and was the lowest cost alternative. [3]

In 1984, bench- and pilot-scale tests were conducted to evaluate the feasibility of using land treatment for the contaminated soils and sludges from the lagoons. The study consisted of six pilot-scale test plots and six bench-scale reactors which varied in the initial creosote concentration. These tests showed that land treatment was feasible for remediation of these materials. [15]

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## SITE INFORMATION (CONT.)

### Site Logistics/Contacts

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**Site Management:** PRP lead

**Oversight:** EPA/State

**Remedial Project Manager:**

Tony Rutter  
U.S. EPA Region V  
77 W. Jackson Boulevard  
Mail Code HSR-6J  
Chicago, Illinois 60604  
(312) 886-8961

**State Contact:**

Fred M. Jenness  
Minnesota Pollution Control Agency  
Hazardous Waste Division  
Regulatory Compliance Section  
Permit and Review Unit  
530 Lafayette Road North  
St. Paul, Minnesota 55155-4194  
(612) 297-8470

**Treatment Vendor:**

Mindy L. Salisbury  
Remediation Technologies, Inc. (ReTeC)  
413 Waconta St., Suite 400  
St. Paul, MN 55110  
(612) 222-0841

## MATRIX DESCRIPTION

### Matrix Identification

**Type of Matrix Processed Through the Treatment System:** soil and sludge

### Contaminant Characterization

**Primary Contaminant Groups:** Polynuclear Aromatic Hydrocarbons (PAHs), Other Semivolatiles - Nonhalogenated

The Enforcement Decision Document identified visibly contaminated soils as being heavily stained, dark brown to black in color, visibly oily, and usually having a pronounced creosote odor. Table 1 shows the average concentration for PAHs, benzene extractables, and total phenols in visibly contaminated soils in the CERCLA (pre-1930s) and RCRA (post-1930s) surface impoundments. In addition, concentrations ranging from 5 to 30 percent for benzene extractables and 3 to 15 percent for total PAHs were reported for the visibly contaminated soils. [3]

No analytical data were contained in the available references on the concentrations of specific constituents in visibly-contaminated soils in the three additional areas of contaminated soil.

**Table 1. Average Concentrations for Visibly-Contaminated Soils in Surface Impoundments [3]**

Constituent	CERCLA Surface Impoundment (mg/kg)	RCRA Surface Impoundment (mg/kg)
Naphthalene	3,105	6,494
Acenaphthylene	2,280	3,651
Acenaphthene	10,180	21,319
Total 2-Ring PAHs	15,565	31,464
Fluorene	1,505	2,497
Phenanthrene	3,305	7,902
Anthracene	1,085	1,440
Total 3-Ring PAHs	5,895	11,839
Fluoranthene	4,650	10,053
Pyrene	5,015	9,481
Benzo(a)anthracene	722	1,670
Chrysene	889	2,392
Benzo(b)fluoranthene	373	1,756
Benzo(k)fluoranthene	244	461
Benzo(a)pyrene	303	536
Benzo(ghi)perylene	137	671
Dibenz(a,h)anthracene	78	192
Indeno(1,2,3)pyrene	111	120

**MATRIX DESCRIPTION (CONT.)****Contaminant Characterization (cont.)****Table 1 (Continued)**

<b>Constituent</b>	<b>CERCLA Surface Impoundment (mg/kg)</b>	<b>RCRA Surface Impoundment (mg/kg)</b>
Total 4- and 5-Ring PAHs	12,522	27,330
Total PAHs	33,982	70,633
Benzene Extractables	66,100	112,500
Total Phenols	16	65

**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 shown in Table 2.

**Table 2. Matrix Characteristics**

<b>Parameter</b>	<b>Value</b>	<b>Measurement Method</b>
Soil Classification	Information not provided	Information not provided
Clay Content and/or Particle Size Distribution	Information not provided	Information not provided
pH	Information not provided	N/A
Field Capacity	Information not provided	Information not provided

N/A - Measurement method not reported for this parameter because resulting value not expected to vary among measurement procedures.

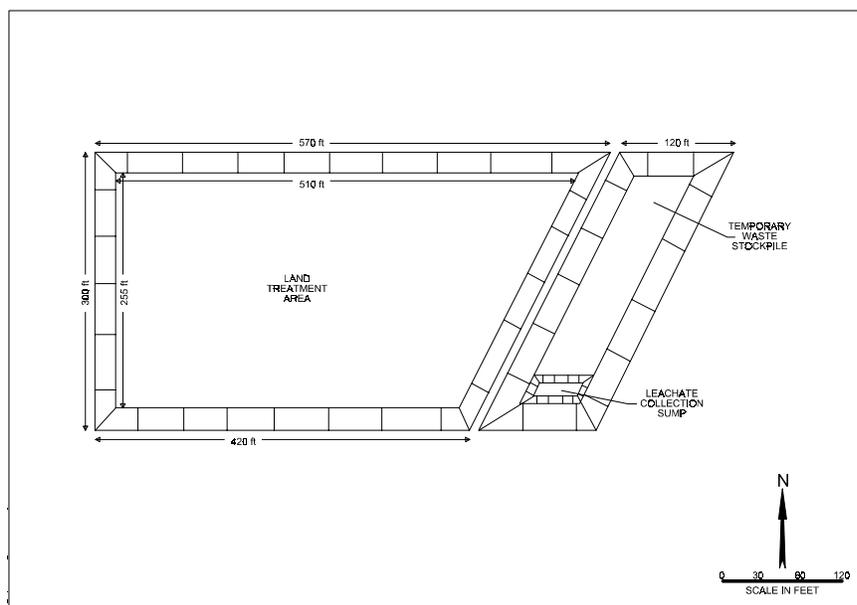
## TREATMENT SYSTEM DESCRIPTION

**Primary Treatment Technology Type:** Land Treatment

**Supplemental Treatment Technology Type:** None

### Soil Vapor Extraction System Description and Operation

In 1985, a land treatment unit (LTU) was constructed at the Burlington Northern site. The LTU had outer dimensions of approximately 300 by 495 feet (about 150,000 ft<sup>2</sup>) and an area available for treatment of approximately 255 by 450 feet (about 115,000 ft<sup>2</sup>). The LTU was constructed over the former RCRA surface impoundment (after the visibly contaminated soils and sludges had been removed). A diagram of the LTU, the leachate collection sump, and the temporary waste stockpile is shown in Figure 3. [1]



**Figure 3. Land Treatment Unit Constructed at Burlington Northern**  
[1]

#### LTU Construction

The LTU was constructed with the following layers, as shown in Figure 4:

- A 100-millimeter thick high density polyethylene (HDPE) membrane;
- An 18-inch layer of silty sand ballast;
- A 6-inch layer of gravel; and
- A 24-inch layer of clean, silty sand.

## TREATMENT SYSTEM DESCRIPTION (CONT.)

### Soil Vapor Extraction System Description and Operation (Cont.)

Depth (Inches Below Surface)	
0	LTU Surface
8	Material Treated in 1994
14	Material Treated in 1993
20	Material Treated in 1992
26	Material Treated in 1991
32	Material Treated in 1990
38	Material Treated in 1989
44	Material Treated in 1988
50	Material Treated in 1987
56	Material Treated in 1986
80	Clean, Silty Sand
86	Gravel
102	Silty Sand Ballast
	100-mm HDPE liner

**Figure 4. LTU Construction Layers [1]**

The HDPE membrane covered the bottom and the side slopes of the LTU. The bottom of the LTU sloped downward 0.5 percent to the south and west. The LTU was surrounded by containment berms (3 to 1 side slopes) to prevent surface run-on from entering the treatment unit.  
[1]

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## TREATMENT SYSTEM DESCRIPTION (CONT.)

### Soil Vapor Extraction System Description and Operation (Cont.)

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The gravel layer operated as a leachate collection system and as a "marking layer" during treatment. Two-foot wide leachate collection drains on 100-foot centers were located in the gravel layer, extending through the gravel layer into the sand ballast to within 1 foot of the liner. The drains were filled with gravel, and perforated pipe wrapped with filter fabric were installed in the drains to collect leachate. The collection system carried leachate to a sump, which was filled with 6-inch rounded cobbles and had a capacity of 50,000 gallons. [1, 2]

#### LTU Operation

Contaminated soil and sludge excavated from the surface impoundments and other areas of interest at the site were stored in a temporary stockpile located adjacent to the LTU. Starting in May 1986, between 1,100 and 1,500 cubic yards of soil and sludge were spread over the LTU to a depth of 6-8 inches each year. Dump trucks were used to transport the contaminated materials from the temporary stockpile to the treatment area. [1]

Land treatment was conducted from May through October each year (referred to as the treatment season), and the system was operated for 9 treatment seasons, between 1986 and 1994. Weather permitting, the treatment area was cultivated weekly to a 12-inch depth with a tractor-mounted rototiller. Thus, some mixing occurred between the current lift and the previous year's lift. One reason for this mixing was to increase the microbial population in the current year's lift. An agricultural disk was used on a periodic basis to level the surface of the LTU. About once every three years, a 24-inch ripper was used to break up the compacted soil layer beneath the 12-inch tilling zone. Irrigation of the LTU was performed periodically to maintain a soil moisture content of approximately 10 percent by weight. Soil pH was maintained between 6.2 and 7.0 with lime addition, and the carbon:nitrogen:phosphorus ratio was maintained near 100:2:1, with cow manure application. [1, 2]

Leachate from the LTU, collected in the sump, was discharged to an on-site equalization tank. Some of the leachate was applied to the LTU as irrigation water, while the remainder was discharged to a local sewer system. [1]

After completion of LTU operation, Burlington Northern placed a cover over the LTU during July and August 1995. EPA reviewed the design documents and approved the design prior to construction. The closure was approved by EPA on January 8, 1996. [22]

## TREATMENT SYSTEM DESCRIPTION (CONT.)

### Operating Parameters Affecting Treatment Cost or Performance

The major operating parameters affecting cost or performance for this technology and the values measured for each are shown in Table 3.

**Table 3. Operating Parameters [1, 5]**

Parameter	Value	Measurement Method
Mixing Rate/Frequency	Cultivated weekly with rototiller (weather permitting)	N/A
Moisture Content	10-12.8% by weight	N/A
pH	6.2 to 7.0	Saturated paste extraction
Residence Time	6 months	N/A
Temperature	Information not provided	N/A
Hydrocarbon Degradation	8-58%	Calculated - see Table 5
Nutrients and Other Soil Amendments	Cow manure C:N:P maintained at 100:2:1	Nitrogen measured using potassium chloride and water extractions
Conductivity	1.76 mmhos/cm	Saturated paste extraction
Sulfur	0.05%	N/A

N/A - Measurement method not reported for this parameter because resulting value not expected to vary among measurement procedures.

### Timeline

A timeline for this application is shown in Table 4.

**Table 4. Timeline [1, 2, 3, 22]**

Start Date	End Date	Activity
1907	1985	Burlington Northern conducted wood preserving operations at the site
December 1982	-	Site placed on NPL
August 1985	October 1985	Construction of land treatment unit
May 1986	October 1994	Land treatment of contaminated soil and sludges
July 1995	August 1995	Cover placed over LTU

## TREATMENT SYSTEM PERFORMANCE

### Cleanup Goals/Standards [1, 23]

A RCRA Part B permit for this site specified the following:

- Treatment of the soil and sludge so that the concentration of methylene chloride extractable (MCE) hydrocarbons and the sum of the concentrations for 17 PAHs in the treatment zone would not be greater than these values for non-visibly-impacted soils; and
- Detoxification of the treatment zone to “within Microtox® limits”. However, no quantitative limits were specified in the permit.

The first specification corresponds to the following cleanup goals for treated soil and sludge:

- MCE Hydrocarbons: 21,000 mg/kg; and
- Total PAHs: 8,632 mg/kg.

Total PAHs were identified in this application as the sum of the concentrations for the following 17 PAHs:

- |                       |                              |
|-----------------------|------------------------------|
| • Naphthalene;        | • Chrysene;                  |
| • Acenaphthylene;     | • Benzo(b)fluoranthene;      |
| • Acenaphthene;       | • Benzo(k)fluoranthene;      |
| • Fluorene;           | • Benzo(e)pyrene;            |
| • Phenanthrene;       | • Benzo(a)pyrene;            |
| • Anthracene;         | • Indeno(123-cd)pyrene;      |
| • Fluoranthene;       | • Dibenzo(ah)anthracene; and |
| • Pyrene;             | • Benzo(ghi)perylene.        |
| • Benzo(a)anthracene; |                              |

In addition, the permit provided for the following contingency procedures if the LTU did not meet these cleanup goals at the end of the treatment period:

- Extend the closure period and continue operations;
- Extend the closure period and modify operations; and
- Place a cover over the treatment area to prevent infiltration of liquid through the treatment zone.

## TREATMENT SYSTEM PERFORMANCE (CONT.)

### Additional Information on Goals [23]

In addition to the cleanup goals described above for treatment of soil and sludge, the following concentration limits were identified in the Consent Order as "action levels" for groundwater at Burlington Northern:

- 30 nanograms per liter (ng/L) for the sum of the following known or suspected carcinogenic PAHs and heterocycles:

-- Benzo(a)anthracene;	-- Indeno(123-c,d)pyrene;
-- Benzo(b)fluoranthene;	-- Dibenzo(a,h)anthracene;
-- Benzo(j)fluoranthene;	-- Dibenzo(a,h)acridine;
-- Benzo(k)fluoranthene;	-- Dibenzo(a,j)acridine;
-- Benzo(a)pyrene;	-- Dibenzo(a,e)pyrene;
-- 7H-Dibenzo(c,g)carbazole;	-- Dibenzo(a,i)pyrene; and
-- 5-Methylchrysene;	-- Dibenzo(a,l)pyrene.

- 300 ng/L for the sum of the following 22 non-carcinogenic PAHs and heterocycles:

-- Indene;	-- Fluoranthene;
-- 2,3-Dihydroindene;	-- Pyrene;
-- Naphthalene;	-- Benzo(h)fluoranthene;
-- 1-Methylnaphthalene;	-- Benzo(e)pyrene;
-- 2-Methylnaphthalene;	-- Perylene;
-- Biphenyl;	-- Acridine;
-- Acenaphthylene;	-- Carbazole;
-- Acenaphthene;	-- 2,3-Benzofuran;
-- Fluorene;	-- Benzo(b)thiophene;
-- Phenanthrene;	-- Dibenzothiophene; and
-- Anthracene;	-- Indole.

The following action levels for individual constituents in groundwater were also specified. However, these action levels were not required cleanup goals:

Acenaphthene	-	4,000 $\mu\text{g/L}$	Phenol (total)	-	4,000 $\mu\text{g/L}$
Anthracene	-	2,000 $\mu\text{g/L}$	2,4-Dimethylphenol	-	100 $\mu\text{g/L}$
Fluoranthene	-	300 $\mu\text{g/L}$	2,4-Dichlorophenol	-	20 $\mu\text{g/L}$
Fluorene	-	300 $\mu\text{g/L}$	2-Methylphenol	-	30 $\mu\text{g/L}$
Naphthalene	-	30 $\mu\text{g/L}$	Biphenyl	-	300 $\mu\text{g/L}$

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## TREATMENT SYSTEM PERFORMANCE (CONT.)

### Treatment Performance Data

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To assess LTU treatment performance, each lift of contaminated soil and sludge was sampled immediately after application and then monthly through the end of the treatment season. To facilitate sampling, the LTU was divided into three areas of approximately equal size. Each month, two sites were sampled in each of the three areas, resulting in six samples. The sample from each site consisted of a composite of at least three subsamples from that area. The samples were analyzed for MCE hydrocarbons and PAHs, and the results for each of these six samples were averaged. Tables 5 through 9 present the before treatment (from the beginning of each treatment season, after the new soil lift was applied in May or June), and after treatment (from the end of each season, in October or November). Analytical results for these samples from the nine treatment seasons are shown in Tables 5 through 9, as described below:

- Table 5 - Treatment Performance Data for MCE Hydrocarbons;
- Table 6 - Treatment Performance Data for Two-Ring PAHs;
- Table 7 - Treatment Performance Data for Three-Ring PAHs;
- Table 8 - Treatment Performance Data for Four- and Five-Ring PAHs; and
- Table 9 - Treatment Performance Data for Total PAHs.

Tables 5 through 9 also show the dates on which samples were collected, where available.

At the completion of the last treatment season (1994), samples were collected at four depths in the LTU to assess residual concentrations of MCE hydrocarbons and PAHs. These samples were also analyzed for Microtox® EC 50. Table 10 presents the results for these samples. For each of the four depths sampled, concentrations of MCE hydrocarbons, specific PAHs, and Microtox® EC 50 are presented for the 1994 treatment season (0-8 inches), 1990-1993 treatment seasons (8-32 inches), 1986-1989 treatment seasons (32-56 inches), and the soil layer immediately below the original layer of contaminated material (55-66 inches).

Table 11 summarizes analytical data for selected parameters in the leachate during treatment. The results are from grab samples collected from the treatment area drain tile leachate. More detailed data on leachate are presented in Appendix A. Data were collected for MCE hydrocarbons, 7 PAHs, and 5 acid extractable constituents in the leachate during the 9 treatment seasons.

## TREATMENT SYSTEM PERFORMANCE (CONT.)

### Treatment Performance Data (cont.)

**Table 5. Treatment Performance Data for MCE Hydrocarbons [1, 2, 5, 6, 7, 8, 9]**

Treatment Season	Before Treatment		After Treatment	
	Concentration (mg/kg)	Date Sample Collected	Concentration (mg/kg)	Date Sample Collected
1986	53,000	N/A	22,000	N/A
1987	67,000	05/20/87	48,000	10/09/87
1988	74,000	05/04/88	36,000	10/19/88
1989	83,000	05/11/89	47,000	10/24/89
1990	26,000	05/21/90	24,000	N/A
1991	53,000	N/A	28,000	10/27/91
1992	69,000	N/A	29,000	11/11/92
1993	89,000	05/07/93	38,000	10/18/93
1994	62,000	06/23/94	27,000	11/03/94
Average	64,000	-	33,000	-

N/A - Date sample collected is not available.

**Table 6. Treatment Performance Data for Two-Ring PAHs [1, 2, 5, 6, 7, 8, 9]**

Treatment Season	Before Treatment		After Treatment	
	Concentration (mg/kg)	Date Sample Collected	Concentration (mg/kg)	Date Sample Collected
1986	2,250	N/A	ND (120)	N/A
1987	2,848	05/20/87	140	10/09/87
1988	1,972	05/04/88	65	10/19/88
1989	2,749	05/11/89	ND (11)	10/24/89
1990	848	05/21/90	92	N/A
1991	1,319	N/A	3	10/27/91
1992	99	N/A	9	11/11/92
1993	3,269	05/07/93	108	10/18/93
1994	691	06/23/94	65	11/03/94
Average	1,783	-	68	-

N/A - Date sample collected is not available.

ND - Not detected; value in parentheses is the reported detection limit.

## TREATMENT SYSTEM PERFORMANCE (CONT.)

### Treatment Performance Data (cont.)

**Table 7. Treatment Performance Data for Three-Ring PAHs [1, 2, 5, 6, 7, 8, 9]**

Treatment Season	Before Treatment		After Treatment	
	Concentration (mg/kg)	Date Sample Collected	Concentration (mg/kg)	Date Sample Collected
1986	9,560	N/A	445	N/A
1987	8,750	05/20/87	774	10/09/87
1988	6,032	05/04/88	191	10/19/88
1989	2,989	05/11/89	448	10/24/89
1990	2,113	05/21/90	411	N/A
1991	2,423	N/A	291	10/27/91
1992	265	N/A	163	11/11/92
1993	5,927	05/07/93	401	10/18/93
1994	1,287	06/23/94	225	11/03/94
Average	4,372	-	372	-

N/A - Date sample collected is not available.

**Table 8. Treatment Performance Data for Four- and Five-Ring PAHs [1, 2, 5, 6, 7, 8, 9]**

Treatment Season	Before Treatment		After Treatment	
	Concentration (mg/kg)	Date Sample Collected	Concentration (mg/kg)	Date Sample Collected
1986	4,350	N/A	1,330	N/A
1987	6,273	05/20/87	3,412	10/09/87
1988	4,927	05/04/88	2,889	10/19/88
1989	5,149	05/11/89	2,059	10/24/89
1990	3,047	05/21/90	772	N/A
1991	2,355	N/A	654	10/27/91
1992	262	N/A	392	11/11/92
1993	4,275	05/07/93	711	10/18/93
1994	1,566	06/23/94	505	11/03/94
Average	3,578	-	1,414	-

N/A - Date sample collected is not available.

## TREATMENT SYSTEM PERFORMANCE (CONT.)

### Treatment Performance Data (cont.)

**Table 9. Treatment Performance Data for Total PAHs [1, 2, 5, 6, 7, 8, 9]**

Treatment Season	Before Treatment		After Treatment	
	Concentration (mg/kg)	Date Sample Collected	Concentration (mg/kg)	Date Sample Collected
1986	16,160	N/A	1,895	N/A
1987	17,871	05/20/87	4,326	10/09/87
1988	12,931	05/04/88	3,145	10/19/88
1989	10,887	05/11/89	2,518	10/24/89
1990	6,008	05/21/90	1,275	N/A
1991	6,097	N/A	948	10/27/91
1992	626	N/A	564	11/11/92
1993	13,471	05/07/93	1,220	10/18/93
1994	3,544	06/23/94	795	11/03/94
Average	9,733	-	1,854	-

N/A - Date sample collected is not available.

**Table 10. Residual Concentrations of MCE Hydrocarbons and PAHs in the LTU at Completion of Treatment (November 3, 1994) [1]**

Parameters	Concentration (mg/kg)				Treatment Goal <sup>f</sup>
	Depth Sampled (Inches)				
	0-8 <sup>1</sup>	8-32 <sup>2</sup>	32-56 <sup>3</sup>	56-66 <sup>4</sup>	
MCE Hydrocarbons	26,900	24,800	25,300	450	21,000
Naphthalene	2.63	2.1	9.2	0	
Acenaphthylene	5.02	6.85	9.3	0.02	
Acenaphthene	57.48	37	31	0	
<b>Total 2-Ring PAH</b>	65.13	45.95	49.5	0.02	
Fluorene	23	22	36	0	
Phenanthrene	105	44	53	0.02	
Anthracene	97	62	110	0.13	
<b>Total 3-Ring PAH</b>	225	128	199	0.15	
Fluoranthene	189	112	95	0.07	
Pyrene	126	77	92	0.1	
Benzo(a)anthracene	32	36	33	0	
Chrysene	35	51	36	0	
<b>Total 4-Ring PAH</b>	382	276	256	0.17	
Benzo(b)fluoranthene	44	66	87	0.04	
Benzo(k)fluoranthene	20	17	32	0	
Benzo(e)pyrene	15.5	20.5	27.5	0.0275	

**Table 10 (Continued)**

Parameters	Concentration (mg/kg)				Treatment Goal <sup>5</sup>
	Depth Sampled (Inches)				
	0-8 <sup>1</sup>	8-32 <sup>2</sup>	32-56 <sup>3</sup>	56-66 <sup>4</sup>	
Benzo(a)pyrene	15.5	20.5	27.5	0.0275	
Indeno(123-cd)pyrene	12	17.6	22.2	0.13	
Dibenzo(ah)anthracene	4.5	5.8	9.3	0	
Benzo(ghi)perylene	12	11	21.2	0	
<b>Total 5-Ring PAH</b>	123.5	158.4	226.7	0.225	
<b>Total PAHs</b>	795.63	608.35	731.2	0.565	8,632
Microtox® EC 50 (5 min, 15°C)	15.3	8.2	4.9	70	-- <sup>6</sup>

<sup>1</sup>The 0"-8" depth corresponds to the 1994 treatment season.

<sup>2</sup>The 8"-32" depth corresponds to the 1990 to 1993 treatment seasons.

<sup>3</sup>The 32"-56" depth corresponds to the 1986 to 1989 treatment seasons.

<sup>4</sup>The 56"-66" depth corresponds to the soil layer immediately below the original layer of contaminated material.

<sup>5</sup>Treatment goal was established for total PAHs only; no treatment goal has been established for individual PAH constituents or groups of constituents (e.g., 2-Ring PAHs) in soils.

<sup>6</sup>No quantitative treatment goal has been established for Microtox®.

**Table 11. Summary of Concentration Data for Selected Parameters in Leachate During Treatment [1]**

Parameter	Units	Groundwater Action Level	Range of Concentrations Measured	Number of Sampling Events
MCE Hydrocarbons	mg/L	Not specified	ND - 600	36
PAHs				
Acenaphthene	µg/L	4,000	ND - 18	36
Acenaphthylene	µg/L	Not specified	ND - 13	36
Anthracene	µg/L	2,000	ND - 52	36
Fluoranthene	µg/L	300	ND - 5.7	36
Fluorene	µg/L	300	ND - 73.28	36
Naphthalene	µg/L	30	ND - 590	36
Phenanthrene	µg/L	Not specified	ND - 18	36
Acid Extractables				
Phenol	µg/L	4,000	ND - 5.3	36
2,4-Dimethylphenol	µg/L	100	ND - 100	36
2,4-Dichlorophenol	µg/L	20	ND - 22	36
2-Methylphenol	µg/L	30	ND - 87	36
4-Methylphenol	µg/L	Not specified	ND - 48	36

ND - Not detected; detection limit not provided in available references.

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## TREATMENT SYSTEM PERFORMANCE (CONT.)

### Performance Data Assessment

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#### Soil/Sludge:

The treatment performance data presented in Tables 5 and 9 show that the cleanup goal for total PAHs was achieved for all 9 treatment seasons. However, the cleanup goal for MCE hydrocarbons was not met in any of the 9 treatment seasons. The concentrations of MCE hydrocarbons in soil before treatment ranged from 26,000 to 89,000 mg/kg, and from 22,000 to 48,000 mg/kg in soil after treatment, all of which are greater than the cleanup goal of 21,000 mg/kg. The median value for MCE hydrocarbons in soil after treatment was 29,000 mg/kg, and the mean (average) value was 33,000 mg/kg. Because the cleanup goal for MCE hydrocarbons was not met at the end of the treatment period, Burlington Northern implemented the contingency procedure of placing a cover over the treatment area to prevent infiltration of liquid through the treatment zone.

Total PAHs in soil before treatment ranged from 626 to 17,871 mg/kg, and from 564 to 4,326 mg/kg in soil after treatment. The concentrations of total PAHs in the soil after treatment was less than the cleanup goal of 8,632 mg/kg for all 9 treatment seasons. The median value for total PAHs in soil after treatment was 1,275 mg/kg, and the mean (average) value was 1,854 mg/kg.

The residual concentrations of MCE hydrocarbons and PAHs (November 1994 samples) did not vary substantially with depth in the LTU among the treatment seasons, as shown in Table 10. The concentrations of MCE hydrocarbons varied less than 10% with depth through the top 56 inches of the LTU. The concentrations of total PAHs varied approximately 26% with depth through the top 56 inches of the LTU.

In addition, data on residual concentrations show that contaminants in the soils treated in the LTU did not migrate to the uncontaminated soil layer below the LTU. After treatment, the concentrations of MCE hydrocarbons, total PAHs, and Microtox® EC 50 in the uncontaminated soil layer in the LTU immediately below the original layer of contaminated material (the 56- to 66-inch layer) were substantially lower than in the layers of treated soil (the 0- to 56-inch layers).

Analytical data on treatment performance for individual PAH constituents show that treatment efficiency (measured as a percent reduction in average concentration from before treatment to after treatment) decreased with increasing number of ring structures in the PAH molecule. For example, as shown in Tables 6, 7, and 8, two-ring PAHs were reduced an average of 96%, three-ring PAHs were reduced an average of 92%, and four- and five-ring PAHs were reduced an average of 60%. Two-ring PAHs were reduced to concentrations below analytical detection limits for two of the nine treatment seasons.

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## TREATMENT SYSTEM PERFORMANCE (CONT.)

### Performance Data Assessment (cont.)

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#### Leachate:

Analytical data for leachate collected during treatment were compared with the groundwater action levels to evaluate the quality of the leachate. These data for the 36 sampling episodes over a 9-year period are presented in Appendix A and summarized in Table 11. With the exception of naphthalene and 2-methylphenol, the range of concentrations measured in the leachate were below the groundwater action levels. Naphthalene was measured as high as 590 µg/L (versus an action level of 30 µg/L) and 2-methylphenol was measured as high as 87 µg/L (versus an action level of 30 µg/L).

### Performance Data Completeness

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Data are available for characterizing specific constituents, groups of constituents, and indicator parameters in the soil before and after treatment for each of 9 treatment seasons in the LTU. In addition, data are available on leachate quality during the 9 treatment seasons, and on general operating conditions during the treatment operation.

### Performance Data Quality

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Limited information is provided in the available references on the types of QA/QC protocols used and the QA/QC data that are available concerning this effort. No exceptions to protocol or limits were identified in this information. In addition, no information is available on the specific steps involved with the MCE hydrocarbon analysis. [5]

During the earlier treatment seasons (1986-1990), total hydrocarbons were analyzed using a benzene extraction procedure. The benzene extractable hydrocarbons procedure was based on a modification of Procedure 503C in Standard Methods for Examination of Water and Wastewaters, 15th edition, for measurement of oil and grease by soxhlet extraction. For this application, benzene was substituted for freon as the extraction solvent. The benzene extraction procedure was replaced with a methylene chloride extraction procedure for the latter treatment seasons (1991-1994). According to Burlington Northern, this revision to the analytical procedure is not expected to have had a significant impact on the quality of the analytical results, and results for total hydrocarbons are identified throughout this report as MCE hydrocarbons. [5, 9]

## **TREATMENT SYSTEM COST**

### **Procurement Process [21]**

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The land treatment application at Burlington Northern was a PRP-lead project, and Burlington Northern selected ReTeC as the treatment vendor for the project. (The PRP point of contact is Dave Seep, (817) 333-1946.) No additional information is provided in the available references on the process used to procure ReTeC for this remediation project, or on the competitive nature of the procurement.

### **Treatment System Cost**

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This is a PRP-lead remediation, and EPA does not have information on the actual costs incurred for this application. No information is provided in the available references on actual treatment system costs, including costs for before-treatment activities (e.g., site work), activities directly attributed to treatment (e.g., system design, construction, and operation), or after-treatment activities, if any. In addition, no information is provided in the available references on actual costs per unit (e.g., ton, cubic yard) of soil treated.

### **Vendor Input**

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No information was provided by the vendor on site-specific factors that affect project costs for similar land treatment applications.

## **OBSERVATIONS AND LESSONS LEARNED**

### **Cost Observations and Lessons Learned**

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- The land treatment application at Burlington Northern was PRP-lead, and no information on actual costs incurred (before-treatment, treatment, or after-treatment) is provided in the available references. In addition, no information is provided on unit costs (e.g., costs per cubic yard of soil and sludge treated) for this application.

### **Performance Observations and Lessons Learned**

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- The cleanup goal for total PAHs was met in this application. The concentrations of total PAHs was reduced in the LTU from before treatment levels ranging from 626 to 17,871 mg/kg to after treatment levels ranging from 564 to 4,326 mg/kg during the 9 treatment seasons. The concentrations in the soil after treatment were less than the cleanup goal of 8,632 mg/kg for all 9 treatment seasons.
- The concentrations of methylene chloride extractable (MCE) hydrocarbons were reduced in the LTU from before treatment levels ranging from 26,000 to 89,000 mg/kg to after treatment levels ranging from 22,000 to 48,000 mg/kg during the 9 treatment seasons. These values are all greater than the cleanup goal for MCE hydrocarbons of 21,000 mg/kg, and because of this, Burlington Northern implemented a contingency procedure of placing a cover over the LTU based on a permit provision.
- Microtox® analysis showed an EC 50 (5 min, 15°C) residual toxicity of 4.9-15.3 in the treated soil at the conclusion of treatment. However, no quantitative cleanup goal was specified for this parameter.
- Residual sampling of the layer immediately below the original layer of contaminated material showed that the soil contaminants did not migrate downward in the soil to below the treated soil during the 9 treatment seasons. The concentrations of MCE hydrocarbons and total PAHs, and the Microtox® EC 50 value, were substantially lower in the soil layer in the LTU immediately below the original layer of contaminated material (the 56- to 66-inch layer) than in the layers of treated soil (the 0- to 56-inch layers) at the conclusion of treatment.
- The residual concentrations of MCE hydrocarbons and PAHs at the completion of treatment did not vary substantially with depth in the LTU among the treatment seasons. The concentrations of MCE hydrocarbons varied less than 10% with depth through the top 56 inches of the LTU. The concentrations of total PAHs varied approximately 26% with depth through the top 56 inches of the LTU.

## **OBSERVATIONS AND LESSONS LEARNED (CONT.)**

### **Performance Observations and Lessons Learned (cont.)**

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- Treatment efficiency (measured as a percent reduction in average concentration from before treatment to after treatment) decreased with increasing number of ring structures in the PAH molecule. Two-ring PAHs were reduced an average of 96%, three-ring PAHs were reduced an average of 92%, and four- and five-ring PAHs were reduced an average of 60%. Two-ring PAHs were reduced to concentrations below analytical detection limits for two of the nine treatment seasons.
- With the exception of naphthalene and 2-methylphenol, the range of concentrations measured in the leachate were below the groundwater action levels. Naphthalene was measured as high as 590 µg/L (versus an action level of 30 µg/L) and 2-methylphenol was measured as high as 87 µg/L (versus an action level of 30 µg/L).

### **Other Observations and Lessons Learned**

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- Burlington Northern placed a cover over the LTU during July and August 1995. EPA reviewed the design documents and approved the design prior to construction. The closure was approved by EPA on January 8, 1996.
- The vendor indicated that the reason MCE hydrocarbons were not treated to below the cleanup level is because a "plateau effect" limited the extent of biodegradation of total extractable hydrocarbons. Although a treatability study indicated otherwise, full-scale performance data indicated that total extractable hydrocarbons (as MCE) were biodegraded only to a level slightly higher than the target treatment goal.
- The vendor indicated that the higher than expected MCE hydrocarbon levels and residual toxicity in the soil at the conclusion of treatment did not reflect a significant threat to human health or the environment, and expressed their belief that the residual creosote constituents in the soil were "biostabilized." The vendor suggested performance standards based on concentrations of specific constituents of interest would be more appropriate at other sites, instead of those based on MCE hydrocarbons or Microtox analyses.
- While this application did not meet the MCE hydrocarbon cleanup goal, MCE hydrocarbons are no longer typically used as a performance measure for land treatment systems.

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**Analysis Preparation**

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**Appendix A. Table A-1. Concentrations of Selected Parameters in Leachate During Treatment [1]**

Parameter	Units	Groundwater Action Level	Sampling Date				
			06/17/86	08/07/86	10/14/86	05/20/87	08/21/87
MCE Hydrocarbons	mg/L	--	3.4	7.9	2.5	1.5	19
PAHs							
Acenaphthene	µg/L	4,000	ND	4	3	ND	4
Acenaphthylene	µg/L	--	ND	ND	ND	ND	3
Anthracene	µg/L	2,000	ND	ND	ND	ND	14
Fluoranthene	µg/L	300	ND	2	1	ND	2
Fluorene	µg/L	300	ND	ND	ND	ND	2
Naphthalene	µg/L	30	ND	ND	ND	ND	2
Phenanthrene	µg/L	--	ND	ND	ND	ND	ND
TOTAL PAH	µg/L		0	6	4	0	27
Acid Extractables							
Phenol	µg/L	4,000	ND	ND	ND	ND	5.3
2,4-Dimethylphenol	µg/L	100	ND	ND	ND	ND	6.5
2,4-Dichlorophenol	µg/L	20	ND	ND	ND	ND	ND
2-Methylphenol	µg/L	30	ND	ND	ND	ND	ND
4-Methylphenol	µg/L	--	ND	ND	ND	ND	ND

Parameter	Units	Groundwater Action Level	Sampling Date						
			North Drain 05/04/88	South Drain 05/04/88	North Drain 10/19/88	South Drain 10/19/88	05/03/89	11/16/89	05/10/90
MCE Hydrocarbons	mg/L	--	9	8	144	144	600	20	10
PAHs									
Acenaphthene	µg/L	4,000	2	3	2	2	ND	ND	ND
Acenaphthylene	µg/L	--	ND	ND	ND	ND	ND	ND	ND
Anthracene	µg/L	2,000	ND	ND	ND	1	ND	ND	ND
Fluoranthene	µg/L	300	1	2	ND	ND	ND	ND	ND
Fluorene	µg/L	300	1	ND	ND	ND	73.28	ND	ND
Naphthalene	µg/L	30	ND	ND	3	5	ND	590	ND
Phenanthrene	µg/L	--	ND	ND	ND	ND	ND	ND	ND
TOTAL PAH	µg/L		4	5	5	8	73.28	590	0
Acid Extractables									
Phenol	µg/L	4,000	ND	ND	ND	ND	ND	ND	ND
2,4-Dimethylphenol	µg/L	100	ND	ND	ND	ND	ND	ND	ND
2,4-Dichlorophenol	µg/L	20	ND	ND	ND	ND	ND	ND	22
2-Methylphenol	µg/L	30	ND	ND	ND	ND	ND	ND	ND
4-Methylphenol	µg/L	--	ND	ND	ND	ND	ND	ND	ND

ND - Not detected; detection limit not provided in available references.

Table A-1 (Continued)

Parameter	Units	Groundwater Action Level	Sampling Date					
			05/21/91	06/26/91	07/25/91	08/20/91	09/19/91	10/27/91
MCE Hydrocarbons	mg/L	--	ND	20	20	20	ND	ND
PAHs								
Acenaphthene	µg/L	4,000	ND	6	7	6	14	18
Acenaphthylene	µg/L	--	ND	ND	ND	ND	5	ND
Anthracene	µg/L	2,000	ND	9	ND	ND	16	13
Fluoranthene	µg/L	300	ND	ND	ND	ND	ND	ND
Fluorene	µg/L	300	ND	ND	ND	ND	6	ND
Naphthalene	µg/L	30	14	11	18	16	29	ND
Phenanthrene	µg/L	--	ND	ND	ND	ND	18	ND
TOTAL PAH	µg/L		14	26	25	22	88	31
Acid Extractables								
Phenol	µg/L	4,000	ND	ND	ND	ND	ND	ND
2,4-Dimethylphenol	µg/L	100	30	ND	24	ND	ND	20
2,4-Dichlorophenol	µg/L	20	ND	ND	ND	ND	ND	ND
2-Methylphenol	µg/L	30	59	12	87	33	57	ND
4-Methylphenol	µg/L	--	ND	ND	9	ND	48	ND
Parameter	Units	Groundwater Action Level	Sampling Date					
			05/21/92	06/29/92	07/21/92	08/20/92	09/17/92	11/11/92
MCE Hydrocarbons	mg/L	--	14	29	ND	ND	116	51
PAHs								
Acenaphthene	µg/L	4,000	ND	ND	ND	ND	ND	ND
Acenaphthylene	µg/L	--	ND	ND	ND	ND	ND	ND
Anthracene	µg/L	2,000	ND	ND	ND	ND	ND	20
Fluoranthene	µg/L	300	ND	ND	ND	ND	ND	ND
Fluorene	µg/L	300	ND	ND	ND	ND	ND	ND
Naphthalene	µg/L	30	ND	ND	ND	ND	ND	ND
Phenanthrene	µg/L	--	ND	ND	ND	ND	ND	ND
TOTAL PAH	µg/L		0	0	0	0	0	20
Acid Extractables								
Phenol	µg/L	4,000	ND	ND	ND	ND	ND	ND
2,4-Dimethylphenol	µg/L	100	ND	25	72	100	62	ND
2,4-Dichlorophenol	µg/L	20	ND	ND	ND	ND	ND	ND
2-Methylphenol	µg/L	30	ND	ND	ND	ND	ND	ND
4-Methylphenol	µg/L	--	ND	ND	ND	ND	ND	ND

ND - Not detected; detection limit not provided in available references.

Table A-1 (Continued)

Parameter	Units	Groundwater Action Level	Sampling Date					
			05/07/93	06/21/93	07/26/93	08/23/93	09/20/93	10/18/93
MCE Hydrocarbons	mg/L	--	110	123	21	96	153	15
PAHs								
Acenaphthene	µg/L	4,000	ND	ND	ND	ND	13	18
Acenaphthylene	µg/L	--	ND	ND	ND	ND	ND	13
Anthracene	µg/L	2,000	ND	ND	ND	ND	13	19
Fluoranthene	µg/L	300	ND	ND	ND	ND	ND	ND
Fluorene	µg/L	300	ND	ND	ND	ND	ND	ND
Naphthalene	µg/L	30	13	ND	ND	43	29	43
Phenanthrene	µg/L	--	ND	ND	ND	ND	ND	8
TOTAL PAH	µg/L		13	0	0	43	55	101
Acid Extractables								
Phenol	µg/L	4,000	ND	ND	ND	ND	ND	ND
2,4-Dimethylphenol	µg/L	100	24	ND	ND	48	50	73
2,4-Dichlorophenol	µg/L	20	ND	ND	ND	ND	ND	ND
2-Methylphenol	µg/L	30	ND	ND	ND	ND	32	ND
4-Methylphenol	µg/L	--	ND	ND	ND	ND	6	ND
Parameter	Units	Groundwater Action Level	Sampling Date					
			06/23/94	07/26/94	08/15/94	09/07/94	10/13/94	11/03/94
MCE Hydrocarbons	mg/L	--	ND	ND	11	ND	1	ND
PAHs								
Acenaphthene	µg/L	4,000	11	ND	8	11	ND	17
Acenaphthylene	µg/L	--	9	ND	3	6	ND	7.8
Anthracene	µg/L	2,000	21	ND	13	18	52	21
Fluoranthene	µg/L	300	ND	ND	ND	ND	ND	5.7
Fluorene	µg/L	300	ND	ND	ND	ND	ND	ND
Naphthalene	µg/L	30	27	15	16	32	52	34
Phenanthrene	µg/L	--	13	ND	5	ND	ND	ND
TOTAL PAH	µg/L		81	15	45	67	104	85.5
Acid Extractables								
Phenol	µg/L	4,000	ND	ND	ND	ND	ND	ND
2,4-Dimethylphenol	µg/L	100	39	27	28	44	64	47
2,4-Dichlorophenol	µg/L	20	ND	ND	ND	ND	ND	ND
2-Methylphenol	µg/L	30	76	ND	ND	ND	ND	34
4-Methylphenol	µg/L	--	ND	ND	ND	ND	ND	10

ND - Not detected; detection limit not provided in available references.