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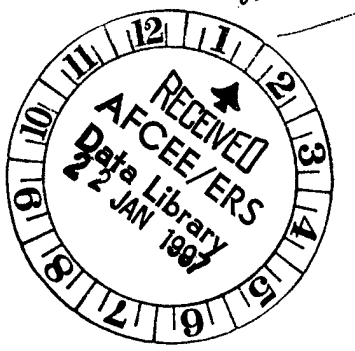

January 20, 1997

Captain Ed Marchand
AFCEE/ERT
3207 North Road, Bldg. 532
Brooks AFB, Texas 78235-5363

Subject: Extended Bioventing Testing Results at the BX Service Station Site, Patrick AFB, Florida (Contract No. F41624-92-8036, Order 17)

Dear Capt Marchand:

Parsons Engineering Science, Inc. (Parsons ES) is pleased to submit the results of the extended bioventing testing at the BX Service Station Site at Patrick Air Force Base (AFB), Florida. Soil gas samples were collected, and *in situ* respiration testing was performed by Parsons ES from 8 to 14 November 1996 to assess the extent of remediation completed during approximately 3 months of soil vapor extraction (SVE), 1.5 years of pilot-scale air injection bioventing, and 1 year of full-scale air injection bioventing. The purpose of this letter is to summarize site and remediation activities to date, present the results of the most recent respiration testing and soil gas sampling, and make recommendations based on site data. A site layout figure and three tables are attached. The as-built bioventing system and sampling/respiration testing locations are illustrated on Figure 1. Table 1 summarizes soil analytical results. Table 2 provides a summary of soil gas sampling results, and Table 3 provides a summary of respiration testing results for the site.

SITE/PROJECT HISTORY

The BX Service Station has been in service since 1954. In 1973, four 5,000-gallon motor gasoline (mogas) underground storage tanks (USTs) and one 4,000-gallon diesel fuel UST were abandoned and filled with sand. The tanks were replaced in 1975 with five 10,000-gallon fiberglass USTs, one of which was removed in 1986 because of leaks. Contaminated soil also was removed along with the leaking UST. Leaking fuel lines found in 1985 were estimated to have released approximately 700 gallons of mogas into site soils (O'Brien & Gere, 1990). During a Phase II assessment conducted in 1990, total petroleum hydrocarbons (TPH) were detected at a maximum concentration of 386 milligrams per kilogram (mg/kg) in soil samples collected at the site (O'Brien & Gere, 1990).

In March 1993, a pilot-scale bioventing system was installed at the BX Service Station by Parsons ES [formerly Engineering-Science, Inc. (ES)] as part of the Air Force Center for Environmental Excellence (AFCEE) Bioventing Pilot Test Initiative

AQM01-03-0518

(Contract No. F33615-90-D-4014, Order 14). The installed pilot-scale bioventing system consisted of one horizontal vent well (HVW-2), five vapor monitoring points (MPA, MPB, MPC, MPD, and MPBG), and a blower unit (see Figure 1). During installation of the pilot-scale system, respiration and air permeability testing and soil and soil gas sampling were performed. A detailed description of pilot-scale bioventing system design and initial site activities are provided in the June 1993 Interim Pilot Test Results report prepared by ES (1993) for this site.

Prior to extended operation of the pilot-scale air injection bioventing system, SVE was performed at the BX Service Station site to reduce the potential for uncontrolled volatile organic compound (VOC) vapor migration and discharge to the atmosphere. Initial soil gas samples collected during pilot-scale bioventing system installation indicated significant concentrations of total volatile hydrocarbons (TVH) in soil gas at the site, and the need for a short period of SVE prior to air injection bioventing. The SVE system utilized a modified internal combustion engine (ICE) for the removal and destruction of hydrocarbon vapors extracted from fuel-contaminated soils at the site (AFCEE, 1994). The SVE system was operated from October 18, 1993 through January 14, 1994, when the blower was reconfigured for air injection bioventing. Startup of the bioventing system immediately followed SVE system shutdown and continued until November 1994. One-year respiration testing and soil gas sampling was performed in December 1994, following 1 month of system shutdown to allow equilibrium conditions to develop in site soils, for comparison to initial results. Following the 1-year testing event, the system was started and reoptimized for continuous air injection.

In March 1994, a soil headspace analyses investigation was conducted by CH2MHill (1994) in the vicinity of the pump islands and USTs (Figure 1). The investigation identified grossly contaminated soil within the immediate area of the pump islands and USTs and outside the effective treatment area of the single HVW pilot-scale bioventing system. CH2MHill performed sampling at 25 locations in accordance with the Florida Department of Environmental Protection (FDEP) soil screening guidelines for the headspace analysis method prescribed in Chapter 17-770.200(2), of the Florida Administrative Code (FAC).

In December 1994, during the collection of 1-year data for the pilot-scale system, Parsons ES performed a soil gas survey in the vicinity of the pump islands and USTs. The results from this survey indicated that the extent of remaining unsaturated soil contamination was localized around the pump islands and USTs, and that soil gas oxygen levels in this area were depleted (less than 5 percent).

Based on favorable 1-year testing results for the pilot-scale bioventing system, and the presence of contaminated soil outside the effective treatment area of HVW-2, the BX Service Station site was added to the AFCEE Extended Bioventing Project (Contract No. F41624-92-D-8036, Order 17) awarded by AFCEE to Parsons ES on 30 September 1994. Under the extended bioventing project, funding was allocated for bioventing system expansion at the site (Option 4); for an additional year of system

operation and testing (Option 1); and for site closure (Option 2), if the results of the additional year of testing demonstrated adequate site remediation.

In preparation for bioventing system expansion, Parsons ES (1995) developed an Initial Remedial Action Plan and performed a supplemental soil headspace survey in May 1995. The survey further delineated the soils to be remediated through bioventing system expansion. Following Patrick AFB, AFCEE, and FDEP approval of the Initial Remedial Action Plan, the expanded full-scale bioventing system was installed in July 1995 by Parsons ES in the area of the pump islands and USTs. The full-scale system consists of two additional HVWs (HVW-1 and HVW-3), five additional MPs (MPE, MPF, MPG, MPH, and MPI), and a new blower system (Figure 1). Full-scale system operation began on July 12, 1995 and continued until October 1996. Soil gas sampling and respiration testing, performed in early November 1996, were conducted following 1 month of system shutdown to allow equilibrium conditions to develop in site soils and allow comparison to initial and 1-year results.

SOIL DATA

Soil sampling by Parsons ES was conducted at the BX Service Station site during installation of the pilot-scale bioventing system (March 1993), after 3 months of SVE and 9 months of pilot-scale air injection bioventing (December 1994), and during installation of the full-scale bioventing system (July 1995). A summary of the soil analytical results is provided in Table 1.

The TPH concentrations in soils sampled from the immediate vicinity of the pilot-scale horizontal vent well decreased 1 to 2 orders of magnitude between March 1993 and December 1994. TPH concentrations at MPA and MPC showed little contamination prior to SVE and pilot-scale bioventing, and remained low at the 1-year sampling event. Benzene, toluene, ethylbenzene, and total xylenes (BTEX) concentrations in soils at the HVW and MPA decreased 3 to 4 orders of magnitude to nondetect levels as a result of SVE and air injection bioventing. Lesser decreases in BTEX soil concentrations were evident at MPC.

Soil samples also were collected from MPE, MPF, and compliance monitoring well CW2 (Figure 1) during full-scale bioventing system expansion. TPH and BTEX concentrations in soils collected from MPE and MPF indicated these areas were moderately impacted by fuel hydrocarbon contamination. Significant contamination was not evident at CW2. Although no soil sampling was performed by Parsons ES following 1 year of full-scale system operation, based on measured reductions in soil gas TVH and BTEX concentrations and decreased *in situ* respiration rates, significant reductions in soil TPH and BTEX concentrations are likely to have occurred as the result of full-scale bioventing system operation.

SOIL GAS CHEMISTRY RESULTS

Field screening and collection of soil gas samples for laboratory analysis were performed on November 11, 1996 following 1 month of system shutdown to allow development of equilibrium conditions. These samples were collected following approximately 3 months of SVE, 1.5 years of pilot-scale bioventing system operation, and 1 year of full-scale bioventing system operation. Soil gas samples were collected from each MP and field-screened to assess soil gas concentrations of oxygen, carbon dioxide, and TVH. As can be seen from the results presented in Table 2, with the exception of MPF, static oxygen concentrations in soil gas have generally increased with continued bioventing at the site. These increases in soil gas oxygen concentrations indicate that aerobic hydrocarbon biodegradation rates have decreased substantially, and suggests that little substrate (fuel hydrocarbon contamination) remains in soils at these locations. Soils at MPF have experienced no measurable increase in soil gas oxygen concentration, which suggests ongoing aerobic activity associated with relatively greater residual hydrocarbon contamination (Table 1). Overall, the amount of aerobic activity and associated hydrocarbon contamination at the site appears to be minimal, as TVH soil gas concentrations measured in the field showed a 1- to 3-order-of-magnitude reduction from initial measurements. Soil gas analytical data collected 1 year and 3 years after bioventing system installation further indicate substantial reductions in soil hydrocarbon contamination.

Initial, 1-year, and 3-year soil gas samples also were collected at selected locations for laboratory analysis (Table 2). For all three sampling events, samples were sent to Air Toxics, Ltd. laboratory in Folsom, California and analyzed for TVH and BTEX using EPA Method TO-3. One-year and 3-year soil gas results show substantial reductions in TVH and BTEX concentrations compared to initial values. With the exception of total xylenes at MPE, BTEX concentrations have been reduced to less than 1.0 part per million, volume per volume (ppmv) at all locations sampled. TVH concentrations were reduced from between 38,000 and 100,000 ppmv to less than 1.0 ppmv in the pilot-scale area (MPB and MPC) during 3 years of soil venting system operation. Soil gas results from MPE and MPF, installed as part of the full-scale bioventing system, showed TVH concentrations were reduced between 1 and 3 orders of magnitude as a result of 1 year of full-scale system operation.

With the exception of results from MPF, located adjacent to the UST source area (Figure 1), field and analytical soil gas results strongly suggest nearly complete remediation of hydrocarbon contaminants at the BX Service Station site. Soil gas TVH field screening and laboratory results for MPF samples indicate that contaminants remaining in the soil at this location may still exceed cleanup criteria.

RESPIRATION TEST RESULTS

In situ respiration (oxygen utilization) testing was performed at the BX Service Station site from November 8 through 14, 1996. Testing was performed according to procedures outlined in the June 1993 Interim Test Results report and followed 1 month

of bioventing system shutdown. Air was injected for approximately 20 hours into MPB, MPE, and MPF using 1 cubic-foot-per-minute (cfm) pumps to locally oxygenate the soils. Following air injection, changes in oxygen, carbon dioxide, and TVH soil gas concentrations were monitored over a 91-hour period. Observed rates of oxygen utilization were then used to estimate aerobic fuel biodegradation rates. Table 3 summarizes initial, 6-month, 1-year, and 3-year respiration and fuel biodegradation rates at the site.

Oxygen utilization and fuel biodegradation rates typically decrease with continued bioventing as the lighter, more readily biodegraded hydrocarbons are preferentially destroyed over the more biologically recalcitrant, higher molecular weight hydrocarbons. As demonstrated by the soil gas results shown in Table 2, the lighter BTEX compounds have been almost completely biodegraded and/or volatilized. Observed *in situ* respiration and fuel biodegradation rates at the BX Service Station have generally decreased as a result of SVE and bioventing system operation at the site. The only significant deviation appears to be the apparent increase in respiration and degradation rates measured at MPB between the 1- and 3-year testing events. This increase is likely the result of an increase in soil moisture content and a decrease in air-filled porosity between the two testing events. Decreased air-filled porosity reduces the volume of oxygen available for aerobic biodegradation, and as a result, oxygen utilization rates appear to be greater. *In situ* respiration rates were not measured during full-scale system installation, but November 1996 rates at MPE appear to be similar to those at MPB. Rates at MPF are somewhat elevated due to the remaining hydrocarbon contamination present at this location.

RECOMMENDATIONS

Based on soil sampling results and soil gas and respiration results obtained following SVE and pilot- and full-scale bioventing system operation, the majority of the soils at the site are likely to have been sufficiently remediated to meet FDEP criteria. The only exception is soils in the vicinity of MPF, where soil gas field screening and laboratory TVH results of 1,020 and 2,200 ppmv, respectively, indicate that some fuel hydrocarbon contamination remains. Although not directly comparable, these TVH results exceed established FDEP headspace sampling criteria for "excessively" contaminated soils (500 ppmv for gasoline-contaminated sites and 50 ppmv for diesel-contaminated sites).

Because of the relatively high TVH concentrations in soil gas at MPF, Parsons ES recommends continued full-scale bioventing system operation at the site for an additional 6 months to 1 year followed by soil gas sampling. Once soil gas TVH concentrations are further reduced at MPF, Parsons ES recommends pursuing closure of the vadose zone soils at this site based on the requirements outlined in Chapter 62-770 (formerly 17-770) of the FAC. A closure sampling plan will be prepared for review and approval by FDEP, AFCEE, and Patrick AFB. Following review and approval of the closure plan, soil sampling will be performed, and a final closure report will be prepared and presented to FDEP, AFCEE, and Patrick AFB.

If you have any questions or require additional information, please contact either Steve Archabal at (602) 852-9110 or me at (303) 831-8100.

Sincerely,

PARSONS ENGINEERING SCIENCE, INC

for
Steven R. Archabal
Site Manager

John W. Ratz, P.E.
Project Manager

cc: Mr. Hugh Houghton, Patrick AFB
S. Archabal (Parsons ES-Phoenix)
J. Hall (Parsons ES-Denver)
R. Brettin (Parsons ES-Austin)
File 727876.27110.E Letter Results Report

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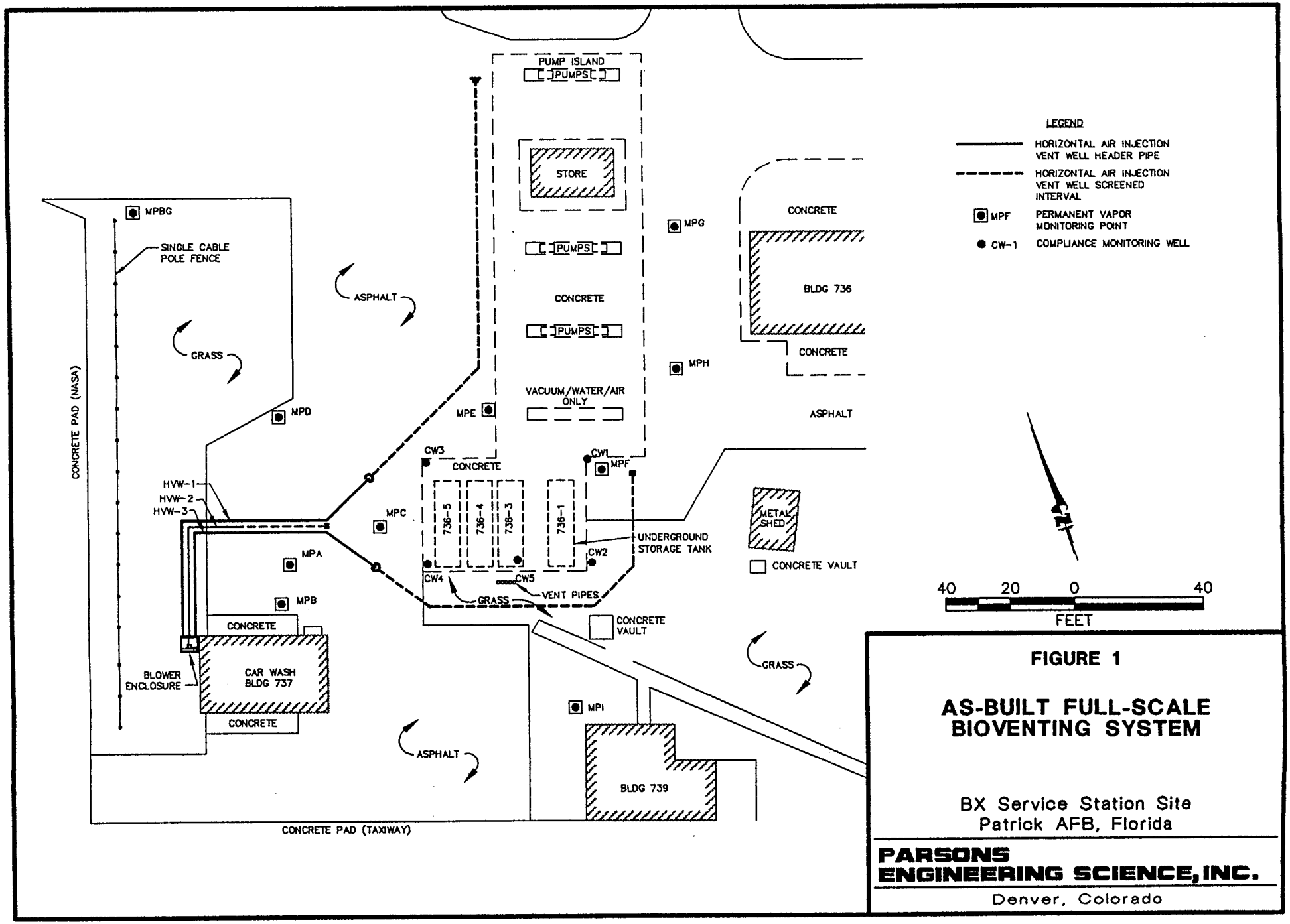

FIGURE 1

AS-BUILT FULL-SCALE BIOVENTING SYSTEM

BX Service Station Site
Patrick AFB, Florida

PARSONS ENGINEERING SCIENCE, INC.

Denver, Colorado

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TABLE 1
SOIL ANALYTICAL RESULTS
BX SERVICE STATION SITE
PATRICK AFB, FLORIDA

Sampling Location-Depth[c/]	Analyte[a/] TPH (mg/kg)[b/]	Benzene (mg/kg)	Toluene (mg/kg)	Ethylbenzene (mg/kg)	Xylenes (mg/kg)
March 1993[d/]					
HVW-4.5[e/]	2,730	< 14[f/]	54	260	2,600
MPA-3.5	11	< 6.2	23	320	140
MPC-3.5	60	< 0.31	< 0.36	< 0.26	5.7
December 1994[g/]					
HVW-4.5[e/]	81.9	< 0.05	< 0.05	< 0.05	< 0.099
MPA-3.5	50.8	< 0.049	< 0.049	< 0.049	< 0.098
MPC-3.5	57.6	0.13	0.15	0.16	0.49
July 1995[h/]					
MPE-3.5	743	0.075	< 0.05	20	160
MPF-3.5	767	0.47	0.57	7.4	9.0
CW2-3.5	13.3	< 0.05	< 0.05	< 0.05	< 0.13

[a/] TPH = total petroleum hydrocarbons analyzed by EPA Method 418.1; benzene, toluene, ethylbenzene, and total xylenes analyzed by EPA Method SW8020.

[b/] mg/kg = milligrams per kilogram.

[c/] Sampling location gives borehole designation and sampled depth in feet below ground surface.

[d/] Soil samples collected by ES, prior to pilot-scale bioventing system startup.

[e/] The pilot-scale horizontal vent well is designated HVW-2 on Figure 1.

[f/] < = analyte concentration in sample was less than the method detection limit shown.

[g/] Soil samples collected by Parsons ES following approximately 3 months of SVE and 9 months of pilot-scale bioventing system opera

[h/] Soil samples collected by Parsons ES during full-scale bioventing system installation.

TABLE 2
SOIL GAS FIELD AND ANALYTICAL RESULTS
BX SERVICE STATION SITE
PATRICK AFB, FLORIDA

Sampling Location[a]	Sampling Event	Field Screening Data: Oxygen (percent)	Field Screening Data: Carbon Dioxide (percent)	Field Screening Data: Field TVH[b,c] (ppmv)	Analytical Data[d]: Laboratory TVH (ppmv)	Analytical Data[d]: Benzene (ppmv)	Analytical Data[d]: Toluene (ppmv)	Analytical Data[d]: Ethylbenzene (ppmv)	Analytical Data[d]: Xylenes (ppmv)
PILOT-SCALE BIOVENTING SYSTEM AREA									
HVW-4[e]	Initial (3/93)	0.0	15.0	> 20,000[f]	47,000	< 2.2[g]	15	14	200
	1-Year (12/94)	---[h]	---	---	---	---	---	---	---
	3-Year (11/96)	---	---	---	---	---	---	---	---
MPA-3.5	Initial (3/93)	0.0	14.3	> 20,000	100,000	< 5.3	110	46	310
	1-Year (12/94)	11.8	5.0	230	6.9	0.033	0.003	0.008	0.46
	1.5-Year (7/95)	11.0	4.8	50	---	---	---	---	---
	3-Year (11/96)	10.7	5.1	156	---	---	---	---	---
MPB-3.5	Initial (3/93)	0.0	13.6	> 20,000	---	---	---	---	---
	1-Year (12/94)	3.5	9.8	560	---	---	---	---	---
	1.5-Year (7/95)	4.2	7.8	50	---	---	---	---	---
	3-Year (11/96)	7.5	6.6	340	0.17	< 0.002	< 0.002	< 0.002	< 0.002
MPC-3.5	Initial (3/93)	0.0	15.2	> 20,000	38,000	< 2.1	8.3	12	83
	1-Year (12/94)	14.2	4.2	200	1.7	0.02	< 0.002	< 0.002	< 0.002
	1.5-Year (7/95)	11.3	6.0	40	---	---	---	---	---
	3-Year (11/96)	12.5	5.0	164	0.13	< 0.002	< 0.002	< 0.002	< 0.002
MPD-3.5	Initial (3/93)	15.9	2.8	260	---	---	---	---	---
	1-Year (12/94)	---	---	---	---	---	---	---	---
	1.5-Year (7/95)	19.1	1.1	20	---	---	---	---	---
	3-Year (11/96)	19.0	1.7	92	---	---	---	---	---
FULL-SCALE BIOVENTING SYSTEM AREA									
MPE-3.5	Initial (7/95)	0.0	18.0	19,000	27,140	88	130	240	1,200
	1-Year (11/96)	8.2	6.0	196	9.9	< 0.005	0.11M[i]	0.24	1.6
MPF-3.5	Initial (7/95)	0.0	17.5	>20,000	27,500	98	67	300	210
	1-Year (11/96)	0.0	10.4	1,020	2,200	0.16	0.53	0.39	0.65
MPG-3.5	Initial (7/95)	15.8	4.0	10	---	---	---	---	---
	1-Year (11/96)	18.9	1.6	80	---	---	---	---	---
MPH-3.5	Initial (7/95)	9.8	8.0	20	---	---	---	---	---
	1-Year (11/96)	17.6	2.0	88	1.0	< 0.002	< 0.002	< 0.002	< 0.002
MPI-3.5	Initial (7/95)	19.5	0.8	10	---	---	---	---	---
	1-Year (11/96)	20.0	0.7	36	---	---	---	---	---
CW2-4[j]	Initial (7/95)	---	---	---	2.29	< 0.002	0.070	< 0.002	< 0.002
	1-Year (11/96)	---	---	---	---	---	---	---	---

[a] Sampling location identifies the sampled monitoring point and depth in feet below ground surface.

[b] TVH = total volatile hydrocarbons.

[c] ppmv = parts per million, volume per volume.

[d] Soil gas analyses performed using EPA Method TO-3.

[e] The pilot-scale horizontal vent well is designated HVW-2 on Figure 1.

[f] > = measurement exceeded maximum reading for GasTech® Trace-Techtor Hydrocarbon Analyzer.

[g] < = analyte concentration in sample was less than the method detection limit shown.

[h] --- = not analyzed.

[i] M= laboratory reported value may be biased due to apparent matrix interferences.

[j] Compliance monitoring well 2 (CW2) is screened from approximately 3 to 13 feet below ground surface. The middle of the effective screened interval for soil gas sampling was approximately 4 feet below ground surface during the 7/95 sampling event.

TABLE 3
RESPIRATION AND DEGRADATION RATES
BX SERVICE STATION SITE
PATRICK AFB, FLORIDA

Testing Location-Depth	Initial (March 1993) Respiration Rate (% O_2/hour)	Initial (March 1993) Degradation Rate (mg/kg/year)[b/]	6-Month (May 1994)[a/] Respiration Rate (% O_2/hour)	6-Month (May 1994)[a/] Degradation Rate[c/] (mg/kg/year)	1-Year (Dec. 1994) Respiration Rate (% O_2/hour)	1-Year (Dec. 1994) Degradation Rate (mg/kg/year)	3-Year (Nov. 1996) Respiration Rate (% O_2/hour)	3-Year (Nov. 1996) Degradation Rate[d/] (mg/kg/year)
MPA-3.5	0.17	940	0.19	970	0.029	130	NM[e/]	NC[f/]
MPB-3.5	0.15	840	0.27	1400	0.035	150	0.084	380
MPC-3.5	0.16	970	0.16	850	0.020	92	NM	NC
MPE-3.5	-----[g/]	-----	-----	-----	-----	-----	0.066	290
MPF-3.5	-----	-----	-----	-----	-----	-----	0.12	540

[a/] Initial bioventing pilot test occurred in March 1993, but SVE/air injection bioventing system operation did not begin until October 18, 1993.
[b/] Milligrams of hydrocarbons per kilogram of soil per year.
[c/] 6-month degradation rates based on average soil moisture results for initial and 1-year soil sampling events.
[d/] 3-year degradation rates based on average soil moisture result from December 1994 soil sampling event.
[e/] NM = not measured.
[f/] NC = not calculated.
[g/] ----- = not analyzed; MPE and MPF were not installed until July 1995.

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