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PARSONS ENGINEERING SCIENCE, INC.

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9 October 1997

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

Subject: Results of Bioventing System Monitoring at Site FC-2, Kelly Air Force Base (AFB), Texas (Contract No. F41624-92-D-8036, Order 17)

Dear Major Marchand:

This letter presents the results of the bioventing system monitoring performed by Parsons Engineering Science, Inc. (Parsons ES) during the week of 24 February 1997 at Site FC-2, located at Kelly AFB, Texas. Soil gas samples were collected and *in situ* respiration testing was performed by Parsons ES to assess the extent of remediation completed during approximately 1 year of expanded-scale bioventing system operation. The purpose of this letter is to summarize site and bioventing activities to date, present the results of the most recent respiration testing and soil gas sampling event, and make recommendations based on site data. A site layout and three tables are attached.

SITE/PROJECT HISTORY

Site FC-2 consists of a circular area approximately 150 feet in diameter located northwest of the Industrial Waste Sludge Lagoon (Site SA-2) and approximately 100 feet north of Leon Creek (Figure 1). The area was used from the 1950's to 1981 for fire control training exercises. Approximately two to four times per year, waste petroleum, oils, and lubricants (POLs) were set on fire near the simulated airplane at the center of the site. The fires were extinguished with a water/protein mixture or an aqueous, film-forming-foam. No collection facility or oil/water separator was used to stop direct infiltration of the waste fuel into the ground. Before any field investigations were performed, the site was regraded with fill material consisting of soils collected from various locations around the base.

As part of the Air Force Center for Environmental Excellence (AFCEE) Bioventing Initiative Project, a 1-year bioventing pilot test was performed at the site starting in December 1992. The purpose of this project was to determine if *in situ* bioventing would be a feasible cleanup technology for the source area fuel-contaminated soils within the unsaturated zone. The pilot-scale system installed by Parsons ES (formerly Engineering-Science, Inc.,[ES]) included one vent well (VW1), four vapor monitoring points (MPA, MPB, and MPC, and a background MP designated MPBG located approximately 300 feet northwest of the site near monitoring well TC-03), and a regenerative blower unit configured for air injection into VW1. During the installation

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of the pilot-scale system, soil and soil gas sampling and respiration and air permeability testing were performed. During system startup, a radius of oxygen influence of at least 35 feet was observed at 4-, 9-, and 13.5-foot soil depths, at an average flow rate of 48 cubic feet per minute (cfm). Based on system monitoring results following 6 and 12 months of pilot-scale bioventing system operation, the actual radius of oxygen influence was estimated to be at least 50 feet. Further detail on the pilot test procedure and results can be found in the Interim Bioventing Pilot Test Results Report (ES, 1993), and the memorandum regarding completion of the 1-year pilot test (AFCEE, 1994).

The 1-year pilot test demonstrated that bioventing is an effective treatment technology for petroleum-contaminated soils present within the unsaturated zone at Site FC-2; and as a result, the site was included in the AFCEE Extended Bioventing Project. Under the Extended Bioventing Project, Site FC-2 was funded for system expansion (Option 4) and 1 year of extended bioventing system operation followed by soil gas sampling and *in situ* respiration testing (Option 1). In anticipation that extended bioventing system operation would sufficiently remediate petroleum-contaminated site soils, Site FC-2 also was funded for confirmation soil sampling (Option 2) under the AFCEE Extended Bioventing Project.

The expanded bioventing system was installed by Parsons ES in January 1996 in accordance with the Final Remedial Action Plan (RAP) and expanded system design package (Parsons ES, 1996). The expanded system, as installed and shown in Figure 1, includes five additional VWs (VW2, VW3, VW4, VW5, and VW6) and three additional MPs (MPD, MPE, and MPF). During the week of 20 January 1997, following 1 year of expanded bioventing system operation, Parsons ES was onsite to shut down the blower system in preparation for Option 1 testing. Blower shutdown occurred approximately 1 month prior to testing to allow soil and soil gas at Site FC-2 to return to equilibrium conditions in order to allow comparison of 1-year expanded system monitoring results with previous monitoring results. Option 1 soil gas sampling and respiration testing was performed by Parsons ES the week of 24 February 1997.

Groundwater at Site FC-2 has been impacted by historic waste fuel disposal activities and free product has been observed at site monitoring well F202. Approximately 1 foot of free product was observed in this well in August 1995. In January 1996, 0.5 inch of free product was observed in the well. A free product sample collected from the well indicates fuel hydrocarbon concentrations typical of a weathered jet fuel. No polynuclear aromatic hydrocarbons (PAHs) were detected in the free product sample, but 1,240 milligrams per liter (mg/L) of benzene and 1,510 mg/L of total benzene, toluene, ethylbenzene, and xylenes (BTEX) were detected. In February 1997, following 1 year of expanded bioventing system operation, no free product was observed in the well.

EXISTING SOIL DATA AND STATE OF TEXAS CRITERIA

In January 1996, five soil samples were collected by Parsons ES during the installation of the expanded bioventing system. Soil samples were analyzed for BTEX by U.S. Environmental Protection Agency (USEPA) Method SW8020, and for total petroleum hydrocarbons (TPH) by USEPA Method SW8015 (Modified). Table 1

summarizes the soil analytical results from the January 1996 sampling event and compares these results to the Texas Natural Resource Conservation Commission's (TNRCC) levels published in risk reduction rules standard number 2 for residential groundwater protection (30 Texas Administrative Code 335, Subchapter S).

The TNRCC risk reduction standard depicted in Table 1 represents maximum BTEX soil concentration values for residential groundwater protection. In a sample collected from VW6 during the installation of the expanded bioventing system, benzene was the only aromatic hydrocarbon exceeding residential groundwater protection standards. However, TPH concentrations exceeding 1,000 milligrams per kilogram (mg/kg) were detected in three of the five soil samples collected, indicating the presence of fuel contamination in the site soils.

SOIL GAS CHEMISTRY RESULTS

Field screening and collection of soil gas samples for laboratory analysis were performed on 17 January 1996 (prior to startup of the expanded bioventing system), and on 24 February 1997 (following 1 year of operation and 1 month of system shutdown). Soil gas samples were collected and field-screened to assess soil gas concentrations of oxygen, carbon dioxide, and total volatile hydrocarbons (TVH). Table 2 summarizes the field and laboratory soil gas results from the January 1996 (initial) and February 1997 (1-year) sampling events. Static oxygen concentrations in soil gas have increased slightly at MPB-13.5, MPC-13.5, MPD-13.5, and MPE-4 with expanded bioventing system operation at the site, and more significantly at MPD-13.5, MPE-9, and MPE-13.5. One-year oxygen levels at MPA-9, MPA-13.5, MPB-4, MPB-9, MPC-4, MPD-4, MPF-4, MPF-9, VW3, VW4, VW5, and VW6 were lower than the initial (January 1996) levels. Soil gas samples collected from MPA-13.5, MPB-9, MPC-9, and VW2 in February 1997 contained no oxygen.

The increases in soil gas oxygen are indicative of reduced microbial aerobic hydrocarbon biodegradation activity at these sample locations. Decreased oxygen levels at some points indicate the continued presence of fuel contamination, and that aerobic fuel biodegradation is still occurring at significant rates. The continued microbial activity has likely been induced by seasonal fluctuations in site groundwater, resulting in the smearing and adsorption of dissolved-phase contaminants onto site soils. It is interesting to note that the field-measured total volatile hydrocarbons (TVH) has been significantly reduced in all of the screened points, and has decreased to 0 parts per million, volume per volume (ppmv) in several of the soil gas sampling points. This trend may imply that the majority of the fuel contamination remaining in site soils is fairly recalcitrant, and composed primarily of longer-chained, non-volatile hydrocarbons.

Soil gas samples were collected in January 1996 from at MPD-4, MPD-13.5, MPE-4, MPE-9, and MPE-13.5 for laboratory analysis. After 1 year of expanded bioventing system operation, soil gas samples were collected from MPC-13.5, MPD-13.5, MPE-13.5, and VW6 for laboratory analysis. All samples were sent to Air Toxics, Ltd. laboratory in Folsom, California, and analyzed for TPH and BTEX by USEPA Method TO-3. The soil gas analytical results are presented in Table 2.

Following one year of extended bioventing system operation, benzene concentrations at MPD-13.5 and MPE-13.5 decreased to non-detect levels. Concentrations of toluene, ethylbenzene, xylenes, and TVH decreased slightly in MPE-13.5, but increased in MPD-13.5 over the same time period. Prior to startup of the pilot-scale bioventing system in December 1992, laboratory TVH and total BTEX soil gas concentrations at MPC-13.5 were 17,000 ppmv and 107 ppmv, respectively (ES, 1993). As a result of pilot-scale bioventing system operation and an additional 1 year of expanded bioventing system operation, soil gas TVH and total BTEX concentrations at MPC-13.5 have been reduced by 2 orders of magnitude and are now at non-detected or very low levels. Soil gas concentrations of BTEX and TVH at VW6 were reported at non-detect or near non-detect levels following 1 year of expanded bioventing system treatment. These results may be notable considering the elevated benzene concentration detected in the soil sample from VW6 (Table 1) prior to expanded system operation.

RESPIRATION TEST RESULTS

A one-year *in situ* respiration test was performed at Site FC-2 between 25 and 28 February 1997. The test was performed according to protocol procedures (Hinchee, *et al.*, 1992) outlined in the Remedial Action Plan (Parsons ES, 1996) for Site FC-2. Prior to this test, air was injected for 16 hours into four MPs (MPB-9, MPC-13.5, MPD-9, and MPD-13.5) and one VW (VW2) using 1 cfm pumps to locally oxygenate soils in the vicinity of these points. Following air injection, changes in oxygen, carbon dioxide, and TVH soil gas concentrations were monitored over a 70-hour period. Observed rates of oxygen utilization were then used to estimate aerobic fuel biodegradation rates at Site FC-2. Biodegradation rates were calculated using a soil moisture content of approximately 24 percent which is an average of the soil moisture content detected in samples from MPB-13.5 and MPC-13.5 during installation of the pilot-scale bioventing system. Table 3 summarizes the respiration and fuel biodegradation rates determined during the pilot-scale bioventing system operation and after 1 year of operation of the expanded bioventing system.

Observed oxygen utilization rates from the most recent respiration test can be compared with rates from previous respiration tests at MPB-9 and MPC-13.5. At MPB-9, oxygen utilization rates and the corresponding fuel biodegradation rates decreased steadily during operation and monitoring of the pilot-scale bioventing system (December 1992 to January 1994), although respiration testing performed in February 1997 indicates rates have increased slightly after one year of expanded system operation. Oxygen utilization and fuel biodegradation rates have steadily decreased at MPC-13.5 since bioventing system operation began in December 1992.

With the exception of VW2, oxygen utilization rates remained relatively high during the February 1997 respiration testing event, indicating that aerobic biodegradation of petroleum hydrocarbons in vadose zone soils continues to be enhanced by the introduction of oxygen. Oxygen utilization and fuel biodegradation rates typically decrease with continued bioventing as the lighter, more readily biodegraded hydrocarbons are preferentially destroyed over more biologically recalcitrant, higher molecular weight hydrocarbons. Respiration testing results following 1 year of expanded bioventing system operation indicate that significant levels of fuel

hydrocarbons remain in subsurface soils at Site FC-2. However, the soil gas analytical data suggests that more easily biodegraded BTEX compounds have been reduced to relatively insignificant concentrations in site soils.

RECOMMENDATIONS

Results of soil gas sampling and respiration testing indicate that soils return to anoxic conditions following system shutdown and hydrocarbon biodegradation rates in contaminated soils range from 780 to 1,600 mg/kg/yr.. These results indicate that significant amounts of aerobically biodegradable fuel components remain in soils at Site FC-2. Based on these results, it is recommended that the bioventing system remain in operation until May 1998. The blower system will then be shut down for a 1-month period to allow soil gas concentrations to return to equilibrium conditions with site soils. Following this system shutdown period, Parsons ES will return to the site to perform Option 2 confirmation soil sampling.

Sincerely,
PARSONS ENGINEERING SCIENCE, INC.

JVR for BRV

Brian Vanderglas
Site Manager

John Ratz
Project Manager

cc: Luis Medina (Kelly AFB)
File 726876.19110.E Letter Results Report

Attachments

REFERENCES

Air Force Center for Environmental Excellence (AFCEE). 1994. Memorandum for SA-ALC/EMR regarding completion of the One-Year Bioventing Pilot Test, Site FC-2 and Site S-4. 25 July.

Engineering-Science, Inc. (ES). 1993. Draft Interim Pilot Test Results Report for Site S-4 and Site FC-2, Kelly AFB, Texas. Denver, Colorado. February.

Hinchee, R.E., S.K. Ong, R.N. Miller, D.C. Downey, and R. Frendt. 1992. Test Plan and Technical Protocol for a Field Treatability Test for Bioventing. January.

Parsons Engineering Science, Inc. (Parsons ES). 1996. Remedial Action Plan for Expanded Bioventing System at Site FC-2, Kelly AFB, Texas. Denver, Colorado. January.

30 Texas Administrative Code 335, Subchapter S.

TABLE 1
SUMMARY OF PETROLEUM HYDROCARBON CONCENTRATIONS IN SOIL
SITE FC-2
KELLY AFB, TEXAS

		Sample Location[c/]				
Analyte[a/]	GWP - Res[b/]	VW2 (14-15)	VW6 (13)	MPE (12-14)	MPF (11-12)	MPD (8-9)
Benzene (mg/kg)[d/]	0.5	0.0481	8.72 [e/]	<2.0[f/]	<2.0	0.28
Toluene (mg/kg)	100	<10	<200	<2.0	<2.0	0.341
Ethylbenzene (mg/kg)	70	<10	0.74	<2.0	<2.0	<100
Xylenes (mg/kg)	1,000	<10	1.36	<2.0	<2.0	0.773
TPH (mg/kg)	NA[g/]	1,022	321	1,550	111	2,391

[a/] BTEX analyzed by EPA Method SW8020; total petroleum hydrocarbons (TPH) analyzed by EPA Method 8015 (modified).

[b/] TNRCC groundwater protection standard for residential use (30 Texas Administrative Code 335, Subchapter S).

[c/] Sample location gives location of boring and sample depth interval (in parentheses) in feet below ground surface.

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

[e/] Box indicates sample result exceeding TNRCC standard.

[f/] < = compound analyzed for, but not detected. Number shown represents the laboratory method detection limit.

[g/] NA = Not applicable.

TABLE 2
INITIAL AND 1-YEAR FIELD AND ANALYTICAL SOIL GAS RESULTS
SITE FC-2
KELLY AFB, TEXAS

Sample Location[a]	Sampling Event[b]	Field-Screening Data			Laboratory Data[e]				
		Oxygen (percent)	Carbon Dioxide (percent)	TVH[c] (ppmv)[d]	TVH (ppmv)	Benzene (ppmv)	Toluene (ppmv)	Ethyl-benzene (ppmv)	Xylenes (ppmv)
MPA-4	Initial	15	4	200	--[f]	--	--	--	--
	1-Year	14	0.25	0	--	--	--	--	--
MPA-9	Initial	9	9	200	--	--	--	--	--
	1-Year	5	1.4	0	--	--	--	--	--
MPA-13.5	Initial	10	3	450	--	--	--	--	--
	1-Year	0	3.5	0	--	--	--	--	--
MPB-4	Initial	16	4.5	150	--	--	--	--	--
	1-Year	4	3	0	--	--	--	--	--
MPB-9	Initial	1	12	300	--	--	--	--	--
	1-Year	0	3	1.4	--	--	--	--	--
MPB-13.5	Initial	18	1	150	--	--	--	--	--
	1-Year	21	0	0	--	--	--	--	--
MPC-4	Initial	17.5	2.5	100	--	--	--	--	--
	1-Year	10	4.5	0	--	--	--	--	--
MPC-9	Initial	0	15	5,000	--	--	--	--	--
	1-Year	0	10.5	7.2	--	--	--	--	--
MPC-13.5	Initial	0	15	> 10,000[g]	--	--	--	--	--
	1-Year	1	12.5	0	130	< 0.003[h]	0.66	0.13M[i]	0.24M
MPD-4	Initial	17	2.5	1,000	97	0.3	0.14	0.036	0.58
	1-Year	9	8	32.9	--	--	--	--	--
MPD-9	Initial	4	5	1,100	--	--	--	--	--
	1-Year	6.5	10.5	29.8	--	--	--	--	--
MPD-13.5	Initial	0	15	5,000	6,300	37	5.2	1.4	3.2
	1-Year	6	10.5	596	7,600	< 0.33	30	1.6	3.8M
MPE-4	Initial	15	5	20	14	0.005	0.009	0.003	0.12
	1-Year	16	3	10.1	--	--	--	--	--
MPE-9	Initial	4	8.5	40	170	0.21	0.22	< 0.18	0.43
	1-Year	15	3.5	3.5	--	--	--	--	--
MPE-13.5	Initial	1	14	8	110	0.067	0.13	< 0.022	1.1
	1-Year	15	6	3	4.1	< 0.002	0.010M	< 0.002	< 0.002
MPF-4	Initial	19	1.5	40	--	--	--	--	--
	1-Year	13	0.75	0	--	--	--	--	--
MPF-9	Initial	5	8.5	100	--	--	--	--	--
	1-Year	2.5	7	0.4	--	--	--	--	--
MPF-13.5	Initial	NS	NS	NS [j]	--	--	--	--	--
	1-Year	16	3	13.5	--	--	--	--	--
VW1	Initial	6.5	10	450	--	--	--	--	--
	1-Year	NS	NS	NS	--	--	--	--	--
VW2	Initial	0	13	400	--	--	--	--	--
	1-Year	0	0.5	208	--	--	--	--	--
VW3	Initial	5.5	11	400	--	--	--	--	--
	1-Year	1	0.05	12.2	--	--	--	--	--
VW4	Initial	14	11	900	--	--	--	--	--
	1-Year	9	0.8	0	--	--	--	--	--
VW5	Initial	16	4	300	--	--	--	--	--
	1-Year	7	0.05	0	--	--	--	--	--
VW6	Initial	13	7	500	--	--	--	--	--
	1-Year	10.5	9.25	3.4	5.4	< 0.002	0.024	0.002	0.004
F204	Initial	15.5	4.5	300	--	--	--	--	--
	1-Year	NS	NS	NS	--	--	--	--	--
F202	Initial	1.5	16	6,000	--	--	--	--	--
	1-Year	NS	NS	NS	--	--	--	--	--
F203	Initial	0	13	500	--	--	--	--	--
	1-Year	NS	NS	NS	--	--	--	--	--

a/ Monitoring point sample depth in feet below ground surface provided as appropriate.
b/ Soil gas sampling performed in January 1996 prior to startup of the expanded bioventing system (Initial), and in February 1997 following 1 year of extended system operation (1-Year).
c/ TVH = Total volatile hydrocarbons.
d/ ppmv = Parts per million, volume per volume.
e/ Laboratory analysis of soil gas performed using EPA Method TO-3.
f/ -- Not analyzed.
g/ > = Concentration greater than maximum reading on Gas-Tech® Trace Techtor hydrocarbon analyzer.
h/ < = Compound analyzed for, but not detected. Number shown represents the laboratory method detection limit.
i/ M = Report value may be biased due to apparent laboratory matrix interferences.
j/ NS = Not sampled.

TABLE 3
RESPIRATION AND BIODEGRADATION RATES
SITE FC-2
KELLY AFB, TEXAS

Location-Depth	Initial (December 1992)[a/]		6-Month (June 1993)[b/]		1-Year (January 1994)[c/]		Expanded System Operation[d/]	
	Respiration Rate (% O_2/min)[e/]	Degradation Rate (mg/kg/year)[f/]	Respiration Rate (% O_2/min)	Degradation Rate (mg/kg/year)	Respiration Rate (% O_2/min)	Degradation Rate (mg/kg/year)	Respiration Rate (% O_2/min)	Degradation Rate (mg/kg/year)
MPA-4	NM[g/]	NM	NM	NM	NM	NM	NM	NM
MPA-13.5	0.04	8,100	0.013	2,600	0.0058	1,200	NM	NM
MPB-9	0.021	3,500	0.0039	480	0.0023	180	0.0074	780
MPB-13.5	0.025	4,200	0.0019	230	0.0083	650	NM	NM
MPC-13.5	0.04	6,700	0.029	3,600	0.022	1,700	0.0073	790
MPD-9	NM	NM	NM	NM	NM	NM	0.013	1,270
MPD-13.5	NM	NM	NM	NM	NM	NM	0.012	1,560
VW2	NA[h/]	NA	NA	NA	NA	NA	0.0064	90

[a/] Rates prior to startup of the pilot-scale bioventing system.

[b/] Rates following 6 months of pilot-scale bioventing system operation.

[c/] Rates following 1 year of pilot-scale bioventing system operation.

[d/] Test performed in February 1997 after 1 year of expanded bioventing system operation.

[e/] % O2/min = Percent oxygen per minute.

[f/] Milligrams of hydrocarbons per kilogram of soil per year.

[g/] NM = Not measured.

[h/] NA = Not applicable. VW2 was not installed until January 1996.

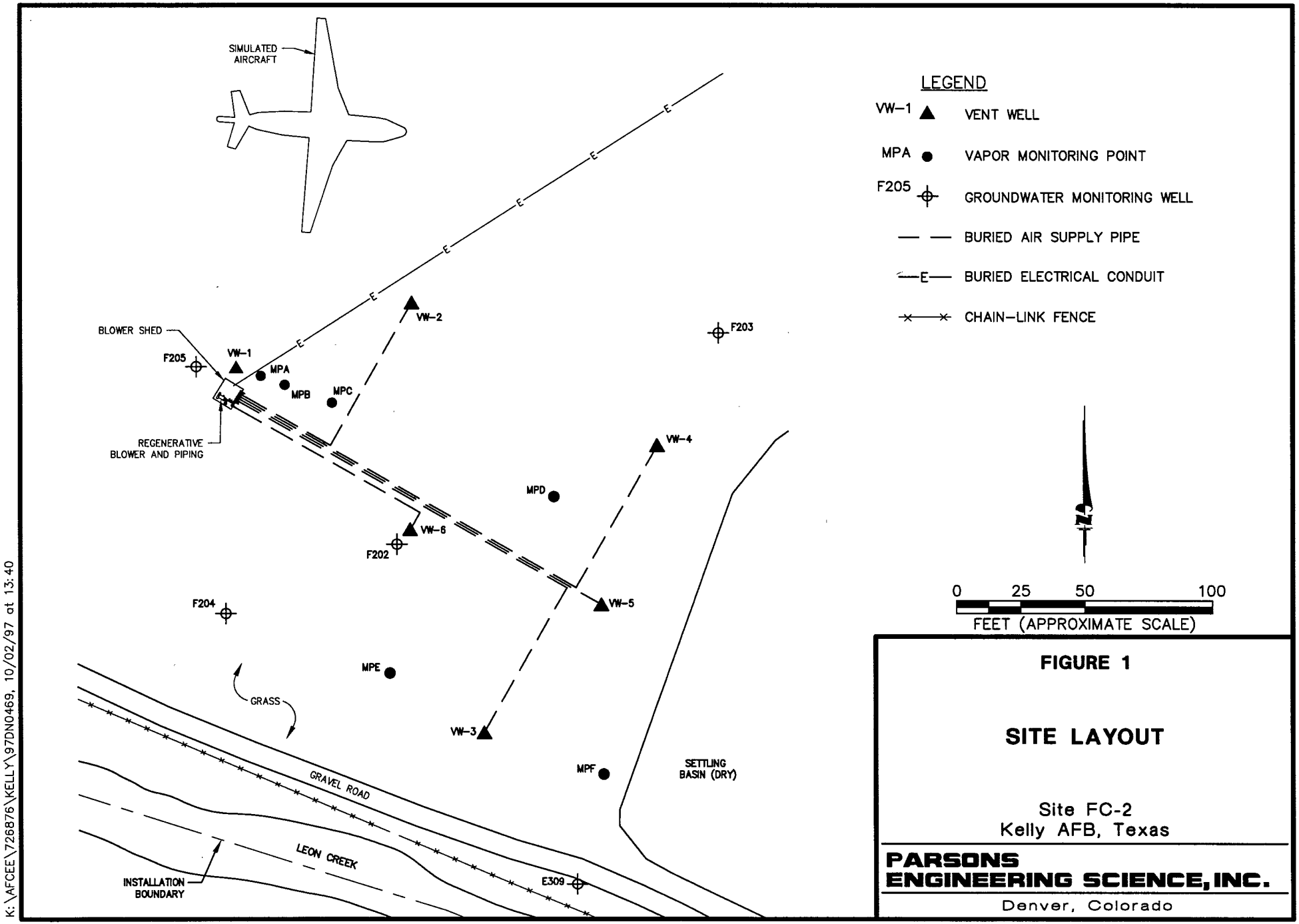

FIGURE 1

SITE LAYOUT

Site FC-2
Kelly AFB, Texas

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Denver, Colorado

K:\AFCEE\726876\KELLY\97DN0469, 10/02/97 at 13:40