APPENDIX A

Summary of SVE System Operation, Maintenance, Repair, and Hydrocarbon Recovery Calculations

A-1. SVE and Treatment System Maintenance and Repair Summary

A-2. SVE and Treatment System Hydrocarbon Recovery Calculations

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ACRONYMS AND ABBREVIATIONS

C	vapor concentration
kg	kilogram
lb	pound
m^3/hr	cubic meter per hour
O_2	oxygen
ppmv	part per million by volume
SVE	soil-vapor extraction

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A-1. SVE AND TREATMENT SYSTEM MAINTENANCE AND REPAIR SUMMARY

Shakedown testing and radius of influence tests were performed on the new soil-vapor extraction (SVE) System from January 22, 2013 to March 15, 2013. Scheduled maintenance is currently being evaluated and will be included in the next quarterly report.

1.1 Scheduled Maintenance

There was no scheduled maintenance on the SVE System from the beginning of January 2013 through the end of March 2013. Scheduled maintenance will be included in the next quarterly report.

1.2 Non-Scheduled Maintenance and Repairs

There was no non-scheduled maintenance on the SVE System from the beginning of January 2013 through the end of March 2013.

A-2. SVE AND TREATMENT SYSTEM HYDROCARBON RECOVERY CALCULATIONS

As part of the ongoing Stage 2 abatement action for ST-106 and the interim remedial actions for SS-111, vapor samples from the SVE System inlet and exhaust are regularly analyzed on site using a Horiba Mexa 554J emissions analyzer for petroleum hydrocarbon concentration in parts per million by volume (ppmv) and for percent oxygen (O_2), carbon monoxide, and carbon dioxide. This section describes the basic equations and constants that are used to calculate total hydrocarbon recovery volumes.

The measured well gas inlet flow rate (cubic meters per hour [m^3/hr]) and hours of operation are used to calculate recovered mass. Mass removal is estimated using the following conversion:

$$M = CQT$$

where:

M	=	mass removed (kilogram [kg])
C	=	vapor concentration (kg/m^3)
Q	=	extraction flow rate (m^3/hr)
T	=	operational period (hour)

The hydrocarbon recovery is calculated and cumulatively summed over the operational period.

As an example, the mass (kg) of recovered hydrocarbons during a given period can be calculated using the measured influent vapor concentration from a measurement date in that period (such as 32,400 ppmv), the well-gas inlet flow rate (such as 74.8 m^3/hr), the operational hours during the period (539.9 hours), and the constants defined above as follows:

$$C = ((32{,}400 \times 10\text{^} - 6) \times 120)/(0.08205 \times 293.15) = 0.1616\ kg/m\text{^}3$$

$$M = (0.1616) \cdot (74.8) \cdot (539.9) = 6{,}527.9\ kg = 14{,}394\ lbs$$

To be consistent with historical reporting, the mass of petroleum hydrocarbon biodegradation is estimated by using the following equation published by the Air Force Center for Engineering and the Environment guidance to account for the attenuation of petroleum hydrocarbons by bioventing (Leeson and Hinchee, 1996a and b):

$$HC_{Bio} = (C_{V,bkgd} - C_{V,O2})/100 \times Q \times C_r \times \rho_{O2} \times MW_{O2} \times (28.3\ \text{liter/cubic feet}) \times (\text{kg}/1{,}000\ \text{grams}) \times (1{,}440\ \text{minutes/day}) \times (2.2\ \text{pound [lb]/kg}) \times D \times (1/6.2\ \text{gallon/lb})$$

Where:

HC_{Bio}	=	Mass of hydrocarbons biodegraded (gallon)
$C_{V,bkgd}$	=	Concentration of oxygen in background, uncontaminated area (%)
$C_{V,O2}$	=	Concentration of oxygen in extracted off-gas (%)
Q	=	Flow rate (standard cubic feet per minute)
C_r	=	Mass ratio of hydrocarbon to oxygen degraded based on stoichiometry (1/3.5)
ρ_{O2}	=	Density of oxygen (moles/liter), 0.0346 mol/L for Albuquerque, New Mexico and 25º Celsius
MW_{O2}	=	Molecular weight of oxygen (grams/mole), 32 grams/mole for O_2
D	=	Days in operation during quarter

Based on this equation and an average oxygen deficit in the internal combustion engine influent vapor, the amount of biodegradation to date was estimated and is presented in Table A-1.

References

Leeson, A., and R. Hinchee. 1996a. *Principles and Practices of Bioventing, Volume I: Bioventing Principles*. Prepared by Battelle Memorial Institute, Columbus, Ohio, for Catherine M. Vogel, Environics Directorate of the Armstrong Laboratory, Tyndall AFB, Florida Protection Agency; Gregory D. Sayles, National Risk Management Research Laboratory, U.S. Environmental, Brooks AFB, Texas; and Lt. Colonel Ross N. Miller, AFCEE, Technology Transfer Division. September 29.

Leeson, A., and R. Hinchee. 1996b. *Principles and Practices of Bioventing, Volume II: Bioventing Design*. Prepared by Battelle Memorial Institute, Columbus, Ohio, for Catherine M. Vogel, Environics Directorate of the Armstrong Laboratory, Tyndall AFB, Florida Protection Agency; Gregory D. Sayles, National Risk Management Research Laboratory, U.S. Environmental, Brooks AFB, Texas; and Lt. Colonel Ross N. Miller, AFCEE, Technology Transfer Division. September 29.

TABLE A-1

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Table A-1

Calculation of NAPL Mass Degraded by Bioventing

January 2011 through March 2013[a]

Kirtland Air Force Base, New Mexico

		Unit 249 (ST-106)			Unit 335 (Well KAFB-106149)			Unit 345 (Well KAFB-106160)			Unit 344 (Well KAFB-106161)			SVE System (Wells KAFB-106160 and KAFB-106161)			All Units
Date	Background Oxygen (%)	Oxygen Inlet[b] (%)	Mass Degraded (lbs/period)	Mass Degraded (gal/period)	Oxygen Inlet[b] (%)	Mass Degraded (lbs/period)	Mass Degraded (gal/period)	Oxygen Inlet[b] (%)	Mass Degraded (lbs/period)	Mass Degraded (gal/period)	Oxygen Inlet[b] (%)	Mass Degraded (lbs/period)	Mass Degraded (gal/period)	Oxygen Inlet[b] (%)	Mass Degraded (lbs/period)	Mass Degraded (gal/period)	Total Mass Degraded (gal/period)
1/31/2011	18.02	12.3	3,926	633	14.3	1,198	193	16.0	1,255	202	16.8	1,038	167				1,196
2/28/2011	18.02	12.3	4,180	674	14.3	889	143	16.0	1,617	261	16.8	1,048	169				1,247
3/31/2011	18.02	12.3	4,896	790	14.3	988	159	16.0	1,202	194	16.8	885	143				1,286
4/30/2011	18.9	19.9	0	0	14.3	1,137	183	20.3	0	0	15.3	2,750	444				627
5/31/2011	18.7	11.0	7,007	1,130	15.4	538	87	20.2	0	0	15.9	2,549	411				1,628
6/30/2011	17.2	11.0	5,457	880	11.9	1,027	166	14.4	1,079	174	15.6	692	112				1,332
7/31/2011	19.7	12.1	6,356	1,025	14.3	1,134	183	19.4	172	28	16.9	2,212	357				1,593
8/31/2011	19.8	12.1	7,077	1,141	14.2	1,401	226	16.6	1,150	186	16.8	2,152	347				1,900
9/30/2011	17.8	15.8	1,857	300	14.8	413	67	15.9	675	109	17.1	309	50				525
10/31/2011 [c]		System was not in operation			System was not in operation			System was not in operation			System was not in operation						
11/30/2011 [c]		System was not in operation			System was not in operation			System was not in operation			System was not in operation						
12/31/2011 [c]		System was not in operation			System was not in operation			System was not in operation			System was not in operation						
1/31/2012 [c]		System was not in operation			System was not in operation			System was not in operation			System was not in operation						
2/28/2012 [c]		System was not in operation			System was not in operation			System was not in operation			System was not in operation						
3/31/2012 [c]		System was not in operation			System was not in operation			System was not in operation			System was not in operation						
Apr 2012 - Jun 2012	21.0	15.2	6,226.0	1,004.0	15.5	39,988.0	6,450.0	17.4	15,192.0	2,450.0	15.9	6,955.0	1,122.0				11,026
7/31/2012	21.0	17.1	7,074.0	1,141.0	15.7	7,082.0	1,142.0	15.5	7,244.0	1,168.0	16.8	7,790.0	1,256.0				4,707
8/31/2012	21.0	17.1	8,259.0	1,332.0	15.7	4,403.0	710.0	15.5	6,340.0	1,023.0	16.8	7,462.0	1,204.0				4,269
9/30/2012	21.0	17.1	2,873.0	463.0	15.7	2,072.0	334.0	15.5	6,048.0	806.0	16.8	4,018.0	648.0				2,251
10/31/2012	21.0	16.6	2,830.0	456.0	17.7	6,663.0	1,074.0	16.2	4,805.0	775.0	16.2	5,827.0	940.0				3,245
11/30/2012	21.0	16.6	7,989.0	1,289.0	17.7	3,953.0	638.0	16.2	5,338.0	861.0	16.2	3,186.0	514.0				3,302
12/31/2012	21.0	16.6	7,635.0	1,232.0	17.7	2,356.0	380.0	16.2	1,209.0	193.0	16.2	1,330.0	210.0				2,015
3/31/2012	21.0													18.2	19,259.0	3,106.0	3,106
Total 1/2011 to 3/2011			13,002	2,097		3,076	496		4,074	657		2,970	479		0	0	3,729
Total 4/2011 to 6/2011			12,464	2,010		2,703	436		1,079	174		5,991	966		0	0	3,587
Total 7/2011 to 9/2011			15,290	2,466		2,948	476		1,998	322		4,673	754		0	0	4,018
Total 10/2011 to 3/2012			0	0		0	0		0	0		0	0		0	0	0
Total 4/2012 to 6/2012			0	0		0	0		0	0		0	0		0	0	0
Total 7/2012 to 9/2012			6,226	1,004		39,988	6,450		15,192	2,450		6,955	1,122		0	0	11,026
Total 10/2012 to 12/2012			18,206	2,936		13,557	2,186		19,632	2,997		19,270	3,108		0	0	11,227
Total 1/2013 to 3/2013			0	0		0	0		0	0		0	0		19,259	3,106	8,562
Total 1/2011 to 3/2013			83,642	13,491		75,244	12,136		53,327	8,429		50,202	8,093		19,259	3,106	45,255

Notes:

a. Calculations are based on equation described in the appendix text.

b. Oxygen concentrations are based on field measurements during the March 2011 through March 2013 sampling events.

c. All systems were shut down in October 2011 through March 2012 for the radius of influence (ROI) tests and pneulog tests.

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