APPENDIX A

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

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

A-2. SVE and Treatment System Hydrocarbon Recovery Calculations

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ACRONYMS AND ABBREVIATIONS

C	vapor concentration
CO	carbon monoxide
CO_2	carbon dioxide
K	Kelvin
KAFB	Kirtland Air Force Base
kg	kilogram
kg/m^3	kilograms per cubic meter
m^3/hr	cubic meters per hour
O_2	oxygen
ppmv	parts per million by volume
SVE	soil-vapor extraction

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

The primary maintenance interval for the soil-vapor extraction (SVE) and treatment units 249, 335, 344, and 345 is every 360 hours (approximately 2 weeks), as recommended by the system manufacturer. Routine biweekly maintenance includes checking and changing the oil, filters, spark plugs and spark plug wires; checking the coolant level and adding coolant as needed; cleaning the air filter; and checking all belts, hose connections, battery connections and emergency contact switches. Monthly maintenance includes all bi-weekly maintenance, and includes replacing distributer caps, rotors, polyvinyl chloride valves and cleaning the radiators. All bi-weekly and monthly maintenance requires each unit being serviced, to be shut down for approximately 4 hours.

1.1 Scheduled Maintenence

During the reporting period, biweekly maintenance was performed on the SVE and treatment systems on the following dates:

- July 5, 2011
- July 6, 2011
- July 18, 2011
- July 19, 2011
- August 1, 2011
- August 2, 2011
- August 15, 2011
- August 16, 2011
- August 29, 2011
- August 30, 2011
- September 12, 2011
- September 13, 2011
- September 29, 2011
- September 30, 2011

1.2 Non-scheduled Maintenance and Repairs

During this reporting period, in addition to the standard biweekly and monthly planned maintenance activities, the following maintenance or repairs were performed on the SVE units.

ST-106 Unit 249:

- July through September 2011: Repair work was not required for Unit 249 during this operation period.

KAFB-1065 Unit 335:

- September 13, 2011 – Replaced the carburetor on engine 1 of Unit 335.

KAFB-1066 Unit 345:

- August 29, 2011 – Replaced the controller on engine 2 of Unit 345. Replaced all Goyne coils in the fuel controller.
- September 29, 2011 – Replaced the catalytic converter on engine 2 of Unit 345.

KAFB-1068 Unit 344:

- August 30, 2011 – Flushed the radiator on engine E1 of Unit 344.

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 and treatment systems' inlets and exhausts 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 (CO), and carbon dioxide (CO_2). The hydrocarbon concentrations from the SVE system influent as measured in the field with the Horiba instrument are listed in Table 2-3. For consistency with historical reporting, the cumulative mass recovery values reported in Section 2 are those calculated by the PLC. Described below are the basic equations and constants that are used, along with the PLC field measurements, to calculate total hydrocarbon recovery volumes.

For the SVE and treatment system associated with the Stage 2 abatement action at ST-106, the PLC estimated hydrocarbon vapor concentration is used along with the molecular weight of the influent vapor stream, the gas constant, and the standard temperature to calculate the vapor concentration (C) in kilogram per cubic meter (kg/m^3). Vapor stream concentrations are estimated by the PLC in parts per million by volume (ppmv), which can be converted into kg/m^3 for use in the following equation:

$$C = \frac{(Conc)(MW)}{\mathrm{RT}}$$

where:

Conc	=	vapor concentration (Horiba ppmv reading x 10^{-6})
MW	=	molecular weight of the vapor (120)
R	=	gas constant (0.0821) (L·atm/mol·K)
T	=	temperature (Kelvin [K]) (290)

The measured well gas inlet flow rate (cubic meters per hour [m^3/hr]) and hours of operation are then 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 recovered mass is then converted to equivalent gallons.

The hydrocarbon recovery is calculated for each engine, and cumulatively summed over the operational period.

As an example, the mass (kg) of recovered hydrocarbons for engine E1 during a given period can be calculated using the measured influent vapor concentration from a measurement date in that period (such as 32,400 ppm_v), the well-gas inlet flow rate (such as 74.8 m^3/hr), the engine E1 operational hours during the period (539.9 hours), and the constants defined above as follows:

$$C = \frac{(32{,}400 \times 10^{-6}) \times 120\ )/\ (\ 0.0821 \times 290)}{} = 0.163\ {}^{kg}/_{m^3}$$

$$M = (0.163) \cdot (74.8) \cdot (539.9) = 6{,}594.8\ kg = 14{,}541\ lbs$$

The NAPL-equivalent gallons of hydrocarbon recovery are calculated by multiplying the recovery mass in pounds (lbs) time a density of 6.2 lbs/gallon NAPL.

$$Volume\ (gal.) = 6{,}594.8\ kg \cdot \frac{(2.205\ \text{lbs})}{1\ \text{kg}} \cdot \frac{1\ \text{gal}}{6.2\ \text{lbs}} = 2{,}345\ gal.$$

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 (AFCEE) guidance to account for the attenuation of petroleum hydrocarbons by bioventing (Leeson et al., 1996a,b):

$$HC_{Bio} = (C_{V,bkgd} - C_{V,O2})/100 \times Q \times C \times \rho_{O2} \times MW_{O2} \times (kg/1{,}000g) \times (1{,}440\ min/day)$$

Where:

HC_{Bio}	=	Mass of hydrocarbons biodegraded (kilograms per day)
$C_{V,bkgd}$	=	Concentration of oxygen in background, uncontaminated area (%)
$C_{V,O2}$	=	Concentration of oxygen in extracted off-gas (%)
Q	=	Flowrate (cubic feet per minute [cfm])
C	=	Mass ratio of hydrocarbon to oxygen degraded based on stoichiometry[2] (1/3.5)
ρ_{O2}	=	density of oxygen (moles/liter)
MW_{O2}	=	Molecular weight of oxygen (grams/mole)

Based on this equation and an average oxygen deficit in the ICE influent vapor, the amount of biodegradation occurring at ST-106 (unit 249) and SS-111 (Units 335, 345, and 344 at wells KAFB-1065, 1066, and 1068, respectively) were estimated and included in Table A-1.

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APPENDIX A

Tables

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Table A-1

Calculation of NAPL Mass Degraded by Bioventing

January 2011 through September 2011[a, c]

Kirtland Air Force Base, Bernalillo County, New Mexico

		Unit 249 (ST-106)			Unit 335 (Well KAFB-1065)			Unit 345 (Well KAFB-1066)			Unit 344 (Well KAFB-1068)			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)	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
Total 1/11 to 3/2011			13,002	2,097		3,076	496		4,074	657		2,970	479	3,729
Total 4/11 to 6/2011			12,464	2,010		2,703	436		1,079	174		5,991	966	3,587
Total 7/11 to 9/2011			15,290	2,466		2,948	476		1,998	322		4,673	754	4,018
Total 1/11 to 9/2011			40,756	6,574		8,727	1,408		7,151	1,153		13,634	2,199	11,334

Notes:

a. All operating values are based on RSI-ICE System PLC (computer program) technical data.

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

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

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