Technical Memorandum

Operable Unit 2 System Shutdown and Rebound Monitoring
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Jet Propulsion Laboratory, Pasadena, California

Final November 1, 2005

The objective of this technical memorandum is to summarize progress of the soil vapor extraction (SVE) treatment system since implementation of recommendations made in the *SVE Progress Report and Optimization Evaluation* (National Aeronautics and Space Administration [NASA], 2005[1]), and to present a plan for soil vapor rebound monitoring and dismantling of the SVE system. The general approach for site closure was presented in the *Remedial Design/ Remedial Action Workplan for Operable Unit 2* (Geofon, 2002[2]).

INTRODUCTION AND BACKGROUND

JPL was placed on the National Priorities List (NPL) in 1992. The *Remedial Investigation/Feasibility Study (RI/FS) Work Plan*[3] identified the investigative work required to adequately characterize the chemicals in Operable Unit 2 (OU-2), on-facility soil. Investigative work identified in the *RI/FS Work Plan* consisted of installation and sampling of nested soil vapor monitoring wells. The sampling of these wells indicated the presence of volatile organic compound (VOC) vapors, primarily carbon tetrachloride (CCl_4), Freon 113, and trichloroethene (TCE).

An SVE pilot study was initiated at VE-01 in April 1998 and was conducted in five phases through June 2002. The Record of Decision of OU-2 (NASA, 2002[4]) was signed in September 2002, expanding operations to three additional vapor extraction wells as part of the final remedial action. Subsequently, the SVE system then was operated at VE-03 from October 2002 through April 2003, at VE-04 from May 2003 through December 2003, and at VE-02 from April 2004 through October 2004.

In February 2005, the *SVE Progress Report and Optimization Evaluation* (NASA) was completed to evaluate the performance of the SVE system during the first operational period at each well and to provide recommendations for optimizing future system operations. This optimization report concluded that VOC concentrations have been significantly reduced since startup of the system, and identified CCl_4 and TCE as the remaining chemicals of interest based on a comparison of soil vapor monitoring data (August 2003 through November 2004) to the Vapor Screening Levels (VSLs) calculated based on the *Interim Site Assessment & Cleanup Guidebook* (May 1996[5]) prepared by the Los Angeles Regional Water Quality Control Board (RWQCB). The optimization evaluation also concluded that VOC mass loadings at two soil vapor monitoring locations within the area of influence of VE-03 could potentially result in leachate concentrations exceeding maximum contaminant levels (MCLs) in groundwater.

VE-01 demonstrated the highest VOC mass extraction rates during the first operational cycle, 0.83 lb per day compared to 0.10, 0.01, and 0.04 lb per day for VE-02, VE-03, and VE-04, respectively. Cost effectiveness of the SVE system was estimated as part of the optimization

evaluation. The average cost per pound of VOC mass removed by the SVE system during the first operational period at each well was approximately $10,000/lb at VE-01, $12,000/lb at VE-02, $100,000/lb at VE-03, and $37,000 at VE-04.

Based on these conclusions, a second round of SVE operation was recommended at both VE-01 and VE-03. The SVE system was operated again at VE-01 from December 2004 through May 2005, and at VE-03 from June through September 2005.

SVE PERFORMANCE OBJECTIVES

The performance objectives outlined in the ROD for OU-2 (NASA, 2002) include:

- Reduction of overall VOC concentrations at the vapor monitoring points and extraction wells compared to baseline levels and to concentrations protective of chemical leaching to groundwater.
- Asymptotic mass removal achieved after temporary shutdown periods and appropriate optimization of the SVE system.
- Operate only as long as cost-effective.

Each performance objective was evaluated as part of the optimization report for the first operating period. The following is a summary of the performance objective evaluations for the second operating periods at VE-01 and VE-03, including all SVE operating data through the end of VE-03 operation in September 2005.

VOC Concentration Reduction

During the RI and periodic soil vapor monitoring, four VOCs were frequently detected in soil vapor samples at elevated concentrations: CCl_4; 1,1,2-trichloro-1,2,2-trifluoroethane (Freon™ 113); TCE; and 1,1-dichloroethene (1,1-DCE). SVE was initiated in 1998, and full scale system operation continued through September 2005. During this time, approximately 300 pounds of total VOCs were removed from the soil. Table 1 summarizes the historic (1996-1998) range of VOC concentrations and the range of VOC concentrations detected during the first three sampling events in 2005 (February, April, and July). As shown in this table, a 60% to 99% reduction in the soil vapor concentrations has occurred since operation of the SVE system began.

As part of the optimization report, one year of soil vapor monitoring data (August 2004 through November 2004) was compared to the VSLs. Based on this evaluation, CCl_4 and TCE were identified as the remaining chemicals of interest, and a new quarterly monitoring schedule was recommended to target the locations where prior exceedances of the VSLs were identified. The new quarterly monitoring schedule was first conducted in July 2005, and the results indicate that TCE and CCl_4 concentrations remain above the VSL at only 3 of the 14 locations identified in the optimization report: MP-3-29 (CCl_4), MP-3-40 (CCl_4), and MP-4-20 (TCE). Table 2 presents a comparison of all 2005 detected concentrations (February, April, and July) to the VSLs. While there are a few remaining VSL exceedances identified from the most recent sampling in July 2005, these exceedances are associated with relatively low concentrations, 1.3 mg/L CCl_4 and 11 mg/L TCE.

Table 1: Summary of Historic and Recent Soil Vapor Sampling Results

Chemical	1996-1998 Range of Concentrations (mg/L)	2005 Range of Concentrations (mg/L)	% Reduction
CCl_4	ND-402	ND-2.4	99%
1,1,-DCE	ND-9.8	ND-1.3	87%
Freon™ 113	ND-113	ND-3.3	97%
TCE	ND-47	ND-19	60%

Table 2: Comparison of 2005 Detected Concentrations to VSLs

Soil Vapor Monitoring Probe Number	Depth (ft bgs)	Date	Concentration mg/L	Estimated DTW, ft bgs	Leaching Depth	VSL µg/L	C/VSL
Carbon Tetrachloride							
3	29	07/12/05	1.3	48	19	0.19	6.88
3	40	07/12/05	1.3	48	8	0.10	13.49
33	120	02/03/05	2.2	235.4	115.4	2.75	0.80
33	120	02/03/05	2.4	235.4	115.4	2.75	0.87
Trichloroethene							
4	20	02/03/05	19	124.4	104.4	8.52	2.23
4	20	04/19/05	18	124.4	104.4	8.52	2.11
4	20	07/12/05	11	124.4	104.4	8.52	1.29
39	100	04/22/05	3.7	171	71	4.80	0.77
39	100	07/12/05	2.5	171	71	4.80	0.52
1,1-Dichloroethene							
33	120	02/03/05	1.2	235.4	115.4	196.45	0.01
33	120	02/03/05	1.3	235.4	115.4	196.45	0.01
Chloroform							
27	20	04/20/05	92	254.6	234.6	116.00	0.79
27	35	04/20/05	81	254.6	219.6	116.00	0.70
Toluene							
17	24	04/19/05	9.1	201	177	420.00	0.02
Freon 113							
10	35	02/03/05	3.2	262	227	21,177	0.00
39	100	04/22/05	3.3	171	71	7,489	0.00
39	100	07/12/05	2.5	171	71	7,489	0.00

Notes:

Highlighted cells indicate that the concentration exceeds the VSL for that sample location.

bgs = below ground surface

ft = feet

DTW = depth to water

C/VSL = concentration/VSL ratio

VSL = vapor screening level

Data collected during the past year (October/November 2004, February 2005, April 2005, and July 2005) were also used to calculate the remaining mass of VOCs in the soil. The October/November sampling event is the annual event in which samples are collected from all soil vapor monitoring points that are not plugged. Only a selected subset of soil vapor monitoring points was sampled in the quarterly (February and July 2005) and semiannual (April 2005) events. Therefore the mass estimates are based on the site-wide results from October/November 2004, and incorporate more recent data if available from the February, April, and July 2005 sampling events. The VOC mass estimates were calculated using a three-dimensional computer modeling software package, Earth Vision™ Volumetrics program. Table 3 summarizes the historical and recent mass estimates for the two remaining chemicals of concern, TCE and CCl_4. Based on the most recent mass estimate, the SVE system has removed approximately 99% of the CCl_4 mass and 60% of the TCE mass from the soil.

Table 3: Summary of CCl_4 and TCE Mass Estimates

Date	CCl_4 (lb)	TCE (lb)
1996-1998 (before SVE operation)	661.1	76.4
July 2001	10.2	38.4
May 2002	8.8	31.2
August 2003 – July 2004	13.1	35.4
October/November 2004	8.1	38.2
February 2004	8.1	32.7
April 2004	NA	31.7
July 2004	8.0	30.7

NA – CCl_4 not detected at any monitoring location; therefore a mass estimate was not calculated.

Asymptotic Mass Removal

The influent VOC concentrations were combined with flowrate data to calculate mass of VOCs removed from the subsurface. As presented in the optimization report, daily mass removal rates of CCl_4 and TCE during the first operating cycle at each well were higher for VE-01 (maximum of 13 lbs per day) compared to the other vapor extraction wells, which removed less than 0.35 lb per day. In addition, mass extraction rates for the second operational cycles at VE-01 and VE-03 are significantly less than the first operational cycles at each location.

During the initial operational cycle for VE-01 (from April 1998 through June 2002), the maximum and average mass extraction rates were 13.21 and 0.76 lb/day for CCl_4, and 0.70 and 0.07 lb/day for TCE. During the second operation period at VE-01 (December 2004 through May 2005), maximum and average VOC mass extraction rates dropped to 0.11 and 0.02 lb/day for CCl_4, and 0.01 and 0.005 lb/day for TCE.

At VE-03, the average and maximum mass extraction rates for the second operational period were 0.001 and 0.004 lb/day CCl_4, and 0.005 and 0.001 lb/day TCE, which is generally lower than the mass extraction rates achieved during the first operational cycle (average mass extraction rates of 0.004 and 0.006 lb/day for both CCl_4 and TCE). A graph showing cumulative CCl_4 and TCE mass extracted since startup of the SVE system in 1998 is included as Figure 1.

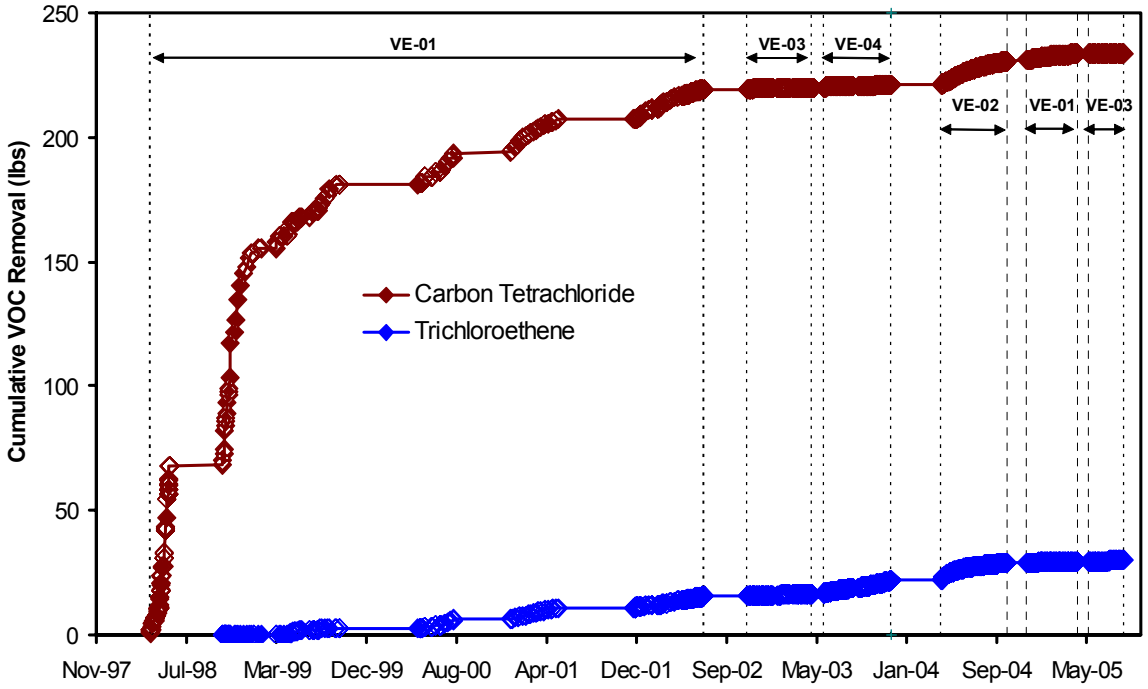

Figure 1: Cumulative CCl_4 and TCE Mass Removal

As demonstrated in this graph, and based on the significant reduction in mass removal rates during the second operation periods, the SVE system reached asymptotic mass removal.

Cost-Effectiveness

Due to the decreasing VOC mass removal rates, the SVE system is becoming less cost-effective to operate. During the first operational cycle at VE-01, the average cost per pound of VOC removed was approximately $9,000; however, during the current operational period the average cost has increased to approximately $85,000 per pound of VOC removed. In addition, the average cost per pound of VOC removed from VE-03 has increased to approximately $600,000 during the last operating period, compared to $100,000 during the previous operating period. Figure 2 shows the average cost per pound of VOC removed by the SVE system since startup in 1998.

Note that adjustments were made during the most recent operating period at VE-03, which decreased the average cost per pound of VOC removed over time at this well. Operation of VE-03 was started using both extraction screens through June, but only Screen A was operated in July and only Screen B was operated in August. The mass removal was negligible throughout, amounting to only 0.03 lb in June, 0.05 lb in July, and 0.09 lb in August.

As discussed in the optimization report, operation of the SVE system has significantly reduced VOC concentrations in the vadose zone, and reduced the potential for adverse impacts to the underlying groundwater. Recent quarterly soil vapor monitoring results indicate that VOC concentrations are currently below the VSLs at all but 2 sample ports at MP-3 and one sample

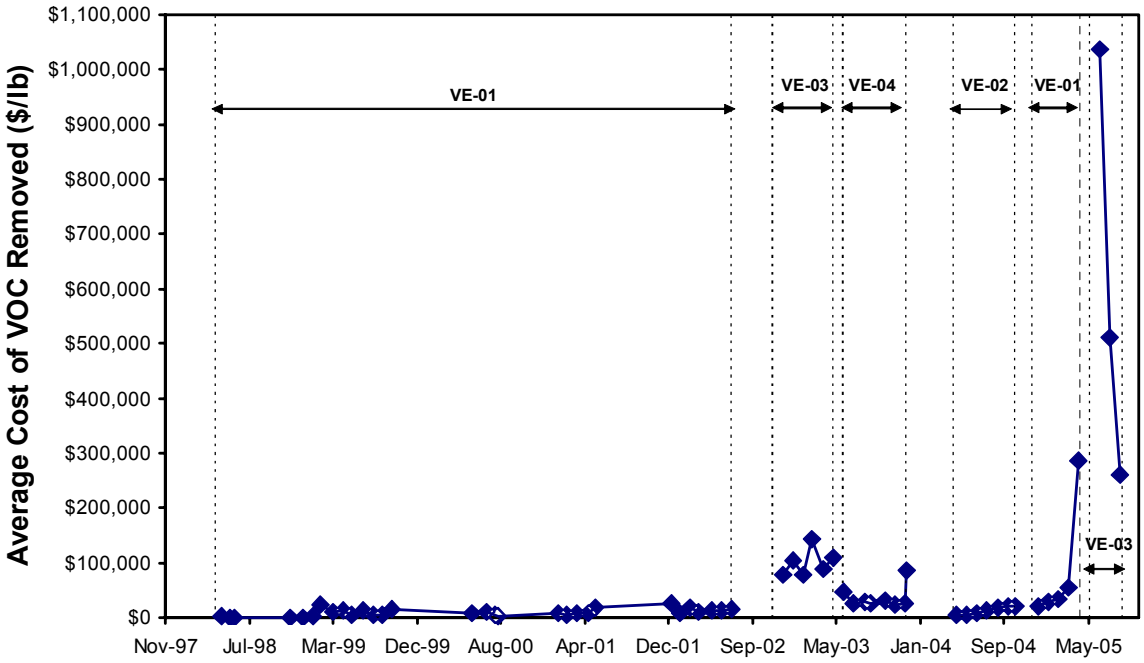

Figure 2: Operational Cost per Pound of VOC Removed

port at MP-4. Continued operation of VE-03 was completed from June through September 2005 to further reduce VOC concentrations at these locations, if possible. TCE and CCl_4 mass removal rates have decreased significantly since start-up of the system in 1998. In addition, due to the decrease in VOC mass extracted, operation of the SVE system has become increasingly cost-ineffective.

PROPOSED APPROACH FOR SITE CLOSURE

Based on the information presented above, the performance objectives were achieved and the SVE system was temporarily shut down on September 9, 2005. Rebound monitoring has been initiated as the first step to site closure. As discussed in the *Remedial Design/Remedial Action Workplan* (Geofon, 2002), the rebound evaluation period shall last for a period of 4-6 months. The annual soil vapor monitoring event that was conducted in October will serve as the first rebound monitoring event after SVE operation. One additional monitoring event will then be conducted in March/April and the degree of rebound will be evaluated. If significant rebound occurs, the SVE system will be reinitiated; otherwise, the SVE system will be permanently shut down and dismantled.

The second step to site closure will include estimating residual impact to groundwater using fate and transport modeling to evaluate leaching to groundwater (using RWQCB VSLs and/or VLEACH™) and groundwater mixing. If the results of the fate and transport modeling indicate that there is little or no impact to groundwater based on the remaining VOC concentrations, then the RAO will be achieved and site closure will be requested. If any minimal impact to groundwater remains, then the residual VOC-impacted soil will be managed under the groundwater remedies for OU-1 and OU-3.

[1] NASA. 2005. *Final Soil Vapor Extraction Progress Report and Optimization Evaluation, Operable Unit 2, National Aeronautics and Space Administration, Jet Propulsion Laboratory, Pasadena, California.* February.
[2] Geofon, Inc. 2002. *Draft Final Remedial Design/Remedial Action Workplan for Operable Unit 2, National Aeronautics and Space Administration, Jet Propulsion Laboratory, Pasadena, California.* December.
[3] Ebasco. 1993. *Final Work Plan for Performing a Remedial Investigation/Feasibility Study at the NASA-Jet Propulsion Laboratory*. December.
[4] NASA. 2002. *Record of Decision and Remedial Action Plan for Operable Unit 2, National Aeronautics and Space Administration, Jet Propulsion Laboratory, Pasadena, California.* September.
[5] California Regional Water Quality Control Board – Los Angeles Region (RWQCB). 1996. *Interim Site Assessment & Cleanup Guidebook*. May.