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EVALUATION OF REMEDIAL TECHNOLOGY OPTIONS CENTER SOIL AREA

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VAC AIR ALLOYS DIVISION
FREWSBURG, NEW YORK

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EVALUATION OF REMEDIAL TECHNOLOGY OPTIONS CENTER SOIL AREA

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Worldwide Engineering, Environmental, Construction, and IT Services

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1.0 INTRODUCTION

Operation of a combined groundwater extraction and soil vapor extraction (SVE) system for remediation of the area previously described as the "Center Hot Spot Remediation Area" or "Center Soil Area" of the Keywell (Keywell), VacAir Division Site (Site) began in late 1997 following completion of a Feasibility Study and Pre-Design Investigation. The area designated as the Center Soil Area is shown on the Site plan presented on Figure 1.1.

In January 2002, following nearly 5 years of system operation, the New York State Department of Environmental Conservation (NYSDEC) requested that Keywell consider implementation of an alternative treatment to SVE to accelerate progress toward cleanup in the Center Soil Area. Keywell immediately initiated activities for the evaluation of remedial technology options for the Center Soil Area. The field data collection activities were conducted between April and December 2002 and the resultant data were presented in the "Quarterly Monitoring Data Report, October 1, 2002 through December 31, 2002 and 2002 System Performance Evaluation Report" (Annual Report) submitted to NYSDEC January 24, 2003.

Following the compilation of the investigatory data, Keywell began an evaluation of technology options and presented the preliminary results to NYSDEC in a meeting held February 19, 2003. The purpose of this report is to summarize the work performed, resultant data, and the results of the evaluation of the technology options.

The report is organized as follows:

- Section 1.0 Introduction. The Introduction presents an overview of the technology evaluation program for the Center Soil Area;
- Section 2.0 Work Performed. Section 2 describes the work performed, including the initial screening of potential remedial options;
- Section 3.0 Investigative Data and Site Characterization. The data collected during the remedial technology evaluation and resultant updated Site characterization are presented in Section 3.0; and
- Section 4.0 Evaluation of Retained Technology Options. An evaluation of the retained remedial technology options for the Center Soil Area and the recommended option are presented in Section 4.0.

2.0 WORK PERFORMED

The work associated with the evaluation of remedial technology options included:

i) collection of supplemental Site characterization data;
ii) identification of potential remedial technology options;
iii) update of the Center Soil Area characterization;
iv) evaluation of the identified potential technology options; and
v) selection of the preferred remedial technology option.

Summaries of the supplemental data collection activities and identified potential remedial technologies are presented in the following subsections. Descriptions of the other work are presented in other sections of this report.

2.1 DATA COLLECTION

Field data collection activities associated with the technology evaluation consisted of:

i) Soil Vapor Analyses. To define concentrations of volatile organic compounds (VOCs) in soil vapor, samples of the vapor extracted by the SVE wells were collected as near the wellheads as possible. Samples were collected from each of the two well branches as well as from the combined vapor stream. Samples were collected using evacuated canisters and sent to a contract laboratory for TO-14 analyses.

ii) Analyses of Groundwater for VOCs. To determine whether "hotspots" of VOC presence occur in groundwater in the Center Soil Area, groundwater samples were collected from the individual Center Soil Area groundwater extraction wells. The samples were analyzed for the Target Compound List VOCs.

iii) Analyses of Groundwater for General and Geochemical Parameters. To evaluate and potentially design the in situ treatment options, the existing geochemical conditions in the Center Soil Area required characterization. Therefore, groundwater samples were collected from existing wells and the samples were analyzed for general parameters. The monitoring points are shown on Figure 1.1. The geochemical monitoring parameters are listed in Table 2.1. The in situ conditions evaluated using the data from each parameter are also listed in Table 2.1.

Operation of the SVE system draws air into the soils, thereby altering natural geochemical conditions. Therefore, with prior approval by NYSDEC, the SVE system was shut down for 4 to 6 months prior to the sampling for geochemical monitoring. The groundwater extraction system in the Center Soil Area continued to operate during the SVE shutdown period.

2.2 POTENTIAL TECHNOLOGY OPTIONS

Based on the characterization of the Center Soil Area prior to conducting the data collection activities described in Section 2.1, the following treatment technologies were considered potentially feasible for use in groundwater remediation in the Center Soil Area:

i) continued operation of the dual groundwater/SVE system;
ii) elimination of soil vapor extraction and operation of only the groundwater extraction system;
iii) in situ chemical oxidation; and
iv) in situ enhanced anaerobic biodegradation.

Air or steam sparging with associated soil vapor extraction were also considered; however, pilot testing conducted in 1995 during the Pre-Design Investigation demonstrated that air sparging was not a cost effective alternative for this Site.

The general remedial goals and objectives for the Center Soil Area are to reduce the concentrations of Compounds of Concern (COC) in soil and groundwater to comply with standards, criteria, and guidelines (SCGs) to the maximum extent possible. Specific RAOs for the Site are detailed in the Record of Decision.

The potential for a technology to achieve the remedial goals and objectives was the first consideration in the evaluation of options. Based on that preliminary consideration, it was determined that there was no potential for a reactive barrier wall to achieve the RAOs. Therefore, the construction of a reactive barrier wall in the Center Soil Area was eliminated from further consideration.

Detailed evaluations of the retained potential technologies are presented in Section 4.

3.0 INVESTIGATIVE DATA AND SITE CHARACTERIZATION

As stated in Section 1, the data collected during the field activities associated with the technology evaluation as well as the associated quality assurance reviews were presented previously in the Annual Report. The data are also presented in Tables 3.1 through 3.4 of this report. The Site characterization has been updated based on these and other historic data and is summarized as follows.

1. VOCs, particularly trichloroethene (TCE), were identified at concentrations which exceeded the NYSDEC Recommended Soil Cleanup Objective of 700 milligrams per kilogram (µg/Kg) in saturated shallow soils overlying the clay confining layer. The concentrations of TCE detected in soil samples collected from below the water table in this area ranged from 25 to 65,000 µg/Kg with an approximate average concentration of 20,000 µg/Kg. TCE was not detected in unsaturated soils in this area of the Site at any concentration exceeding the cleanup objective.
2. The Site COCs consist of TCE and its degradation products, cis-1,2-dichloroethene (1,2-DCE) and vinyl chloride.
3. The Center Soil Area is estimated to be 100' (L) x 100' (W) x 18' (D). With a static water level estimated to be 8 feet below ground surface (BGS) and an average total concentration of the COCs in groundwater of 37,000 micrograms per liter (µg/L), the estimated aqueous phase chemical mass in the area under static conditions is 65 pounds. Using these same data, it is estimated that an additional 75 pounds of TCE is sorbed to soil in the area.
4. The permeability of Site soils are low. This was demonstrated by the permeability (to air) data presented in the Pre-Design Study report (10^{-7} to 10^{-9} cm^2). The low permeability of soil in the Center Soil Area is further substantiated by the low groundwater extraction rate (estimated 4 gallons per minute [GPM]) required to maintain the dewatered state of the extraction well screens.
5. Based on the estimated extraction rate (4 GPM), 2002 operating time (7,980 hours), and VOC concentration in the extraction well effluent stream (average 27,800 µg/L), approximately 400 pounds of COCs were removed through groundwater extraction in the Center Soil Area in 2002. This chemical mass is approximately six times higher than the estimated aqueous chemical mass in the area and is evidence of a continuing source of COCs to groundwater, e.g., dense non-aqueous phase liquid (DNAPL).
6. The concentration of TCE in soil vapor effluent from the SVE wells is between 21 to 340 parts per million (ppm).

7. The presence of 1,2-DCE, vinyl chloride, ethene, and ethane in groundwater in the Center Soil Area demonstrates that anaerobic degradation of TCE is occurring.

4.0 EVALUATION OF RETAINED TECHNOLOGY OPTIONS

The evaluations of each of the retained technology options are presented in detail in the following subsections.

4.1 ENHANCED BIODEGRADATION

The degradation pathway of TCE is shown on Figure 4.1. Anaerobic biodegradation of TCE proceeds through cis-1,2-DCE to vinyl chloride and then to ethene and ethane. TCE typically does not biodegrade under aerobic conditions except when methane is present. With methane present, biodegradation by a methanogenic co-metabolic pathway can occur. The analytical data presented in Tables 3.2 and 3.3 demonstrate that 1,2-DCE and vinyl chloride are present in groundwater in the Center Soil Area. The presence of these compounds confirms that anaerobic biodegradation of TCE is occurring or has occurred.

The geochemical data presented in Table 3.4, show dissolved oxygen concentrations greater than 8 ppm and oxidation/reduction (redox) potentials greater than 250 in the measurements collected from monitoring points in the Center Soil Area. These data are representative of aerobic conditions. The aerobic conditions in the Central Soil Area result from the operation of the SVE and groundwater extraction wells, which lowers the groundwater table and introduces air into the exposed soils. The data presented in Table 3.1 also show that anaerobic redox conditions are present at background well MW-10 located hydraulically upgradient of the Center Soil Area.

The analytical data also show that dissolved organic carbon (DOC) in the Center Soil Area is limited. DOC acts as the substrate to support anaerobic biodegradation; therefore, due to the limited DOC present, substrate would need to be added to enhance in situ biodegradation.

In order to implement a successful program of enhanced biodegradation, anaerobic conditions such as those seen in background well MW-10 would need to be reestablished. The first step in restoring the Center Soil Area to background conditions would be to cease operation of the SVE and groundwater extraction wells. Ceasing operation would allow the natural water level to recover and oxygen levels in the groundwater would decrease when air was no longer forced into the formation. Addition of an organic substrate such as corn oil, molasses or hydrogen release compound (HRC) and nutrients would be added to enhance the anaerobic biodegradation of the TCE. The organic substrate and nutrients would be injected through a series of wells installed in the area. To treat the aqueous phase TCE present in the Center Soil Area to compliance levels, injections made semi-annually over a minimum of 5 years would be required. However, due to the apparent presence of undissolved TCE, either as NAPL or adsorbed on the soil matrix, the treatment time could be extended three to four times, to 15 to 20 years.

The estimated present worth cost to implement an enhanced biodegradation in situ treatment in the Center Soil Area is $116,000 to $183,000, excluding costs associated with groundwater monitoring. A summary of the costs associated with this alternative is presented in Table 4.1.

4.2 IN SITU CHEMICAL OXIDATION

Potassium permanganate ($KMnO_4$) oxidizes TCE to carbon dioxide, water, and chlorides as shown by the following equation:

$$C_2HCl_3 + 2KMnO_4 \rightarrow 2MnO_2 + 2CO_2 + 2KCl + HCl \text{ (TCE)}$$

The empirical amount of $KMnO_4$ required to oxidize TCE is 2.4 times the mass of TCE and other chlorinated solvents present in the groundwater. However, in addition to TCE, $KMnO_4$ oxidizes other organic material and metals present in the soil and groundwater matrices into which it is introduced. Therefore, an excess of 5 to 10 times the empirical amount of $KMnO_4$ (12 to 24 times the mass of TCE) is typically required to complete the oxidation of TCE. To accomplish treatment of the estimated 140 pounds of chemical mass in the Center Soil Area, 1,700 to 3,400 pounds of $KMnO_4$ would be required. Given the apparent presence of undissolved TCE as NAPL, the quantity of $KMnO_4$ required to oxidize the TCE present would be increased at least two times. Based on the information available it is not possible to calculate the quantity of $KMnO_4$ which would be consumed in treatment but it is estimated to be 3,500 to 7,000 pounds.

To accomplish treatment, a 1 to 3 percent (w/w) $KMnO_4$ solution would be injected into the ground through a series of points installed in the Center Soil Area. Initially, injections would be made at 3-month intervals with monitoring performed between injection events. The frequency of treatments would be adjusted based on the monitoring data. At a concentration of 3 percent, the volume of solution required to introduce 2,000 to 6,000 pounds of $KMnO_4$ would be 14,000 to 28,000 gallons. Given the low permeability of the soils in the Center Soil Area, the injection of this volume of solution would require significant effort. For the purpose of this estimate, it is assumed that injections would be made quarterly for a period of 5 years.

It is estimated that the cost to implement an in situ chemical oxidation treatment in the Center Soil Area would be $146,000, excluding costs associated with groundwater monitoring. A summary of the costs associated with this alternative is presented in Table 4.2.

4.3 DUAL GROUNDWATER/SVE

The existing remediation system in the Center Soil Area consists of a combined groundwater and soil vapor extraction system. The groundwater extraction wells are screened and operated to maintain a dewatered state in the shallow subsurface soils. The SVE system then extracts vapors from the unsaturated soils. These systems are operated concurrently to enhance the mass removal achieved by the separate systems. Analytical data collected from the individual groundwater extraction wells, groundwater effluent stream, and SVE effluent are presented in Tables 3.1 through 3.3. The locations of the remediation wells are shown on Figure 1.1.

Review of the analytical data shows that:

i) the average total concentration of COCs in the groundwater extraction wells (33,000 µg/L) is approximately equal to the concentration in the groundwater effluent (17,200 to 42,900 µg/L). Therefore, the groundwater extraction wells effectively remove the chemical mass present in the area. As described in Section 3, the estimated mass of COCs removed by the groundwater extraction wells in the Center Soil Area during 2002 was 400 pounds; and

ii) TCE is effectively removed from unsaturated soils by the SVE system. Concentrations of TCE in the vapor samples ranged between 21,000 and 340,000 µg/m^3.

Further evidence of the effectiveness of the current systems in achieving progress toward the RAOs is the reduction in concentration of TCE realized to date. Analytical data from monitoring well MW-11 and from the individual extraction wells are representative of groundwater quality in the Center Soil Area. In 1992, prior to the construction of the systems, the concentration of TCE in monitoring well MW-11 was 170,000 µg/L, the average concentration of TCE in the Center Soil Area in late 2002 (represented by the data from the groundwater extraction wells and MW-11) was 37,000 µg/L. The difference in these concentrations represents a reduction in TCE concentration of 80 percent.

The groundwater effluent data presented in Table 3.3 indicate that the operation of the SVE system is effective in reducing the COC concentrations in groundwater. Both the groundwater extraction and SVE systems were operating at the time of sampling in January 2002 and the total COC concentration was approximately 23,000 µg/L. The effluent sampling conducted in December 2002 was performed approximately 4 months following the shut down of the SVE system with only the groundwater extraction system operating, the total COC concentration at that time was approximately 43,000 µg/L, higher than in January. Vapor flow through the SVE system is currently not measured; therefore, the mass removal of the SVE system cannot be calculated. The differing operating conditions at the times of sampling suggest that the SVE reduces the concentration of COCs, particularly TCE, in groundwater in the Center Soil Area. However, the difference in COC concentration between the two sampling events cannot be definitively attributed to the operation of the SVE system without mass calculations.

The evaluation of the existing combined groundwater and SVE systems demonstrates that the operation of these systems is effective in reducing the concentrations of COCs in the Center Soil Area and thus in achieving the RAOs.

The estimated present worth cost to continue to operate the SVE system for 15 years is $159,000, excluding costs associated with groundwater monitoring. A summary of the costs associated with this alternative is presented in Table 4.3.

4.4 GROUNDWATER EXTRACTION ONLY

As discussed previously in this report, the operation of the groundwater extraction system in the Center Soil Area is effective in removing chemical mass and reducing the concentrations of the COCs. As such, the operation of the groundwater extraction wells in the Center Soil Area without the concurrent operation of the SVE system is effective in reducing the concentrations of COCs in the Center Soil Area and thus in achieving the RAOs.

The cost of operating the six groundwater extraction wells in the Center Soil Area is minimal. Twelve groundwater extraction wells operate in the northern portion of the Site and provide the majority of the volume of water pumped and treated. (The locations of all groundwater extraction wells are shown on Figure 1.1.) The incremental increase in operating cost due to the six Center Soil Area wells is limited to the cost of well and forcemain maintenance and is estimated to be $2,000 per year ($26,000 present worth over a 15 year period).

4.5 RECOMMENDATION

The technology evaluations demonstrate that:

i) with the exception of the operation of the groundwater extraction system alone, the estimated costs of the alternatives are similar;

ii) no appreciable benefit would be achieved through the implementation of in situ technologies over the continued operation of the existing combined groundwater and SVE systems; and

iii) due to the apparent presence of non-aqueous TCE, the uncertainty associated with the alternatives is substantial.

The contribution of the operation of the existing SVE system toward achievement of the RAOs cannot be fully evaluated in the absence of mass loading data. It is recommended that the existing systems in the Center Soil Area continue to be operated and that the SVE system be modified to allow the measurement of extracted vapor volume and mass loading calculations. If it is found that the SVE system is removing only negligible mass, a request will be made to shut down the SVE system permanently and continue to operate only the groundwater extraction system in the SVE area.

FIGURES

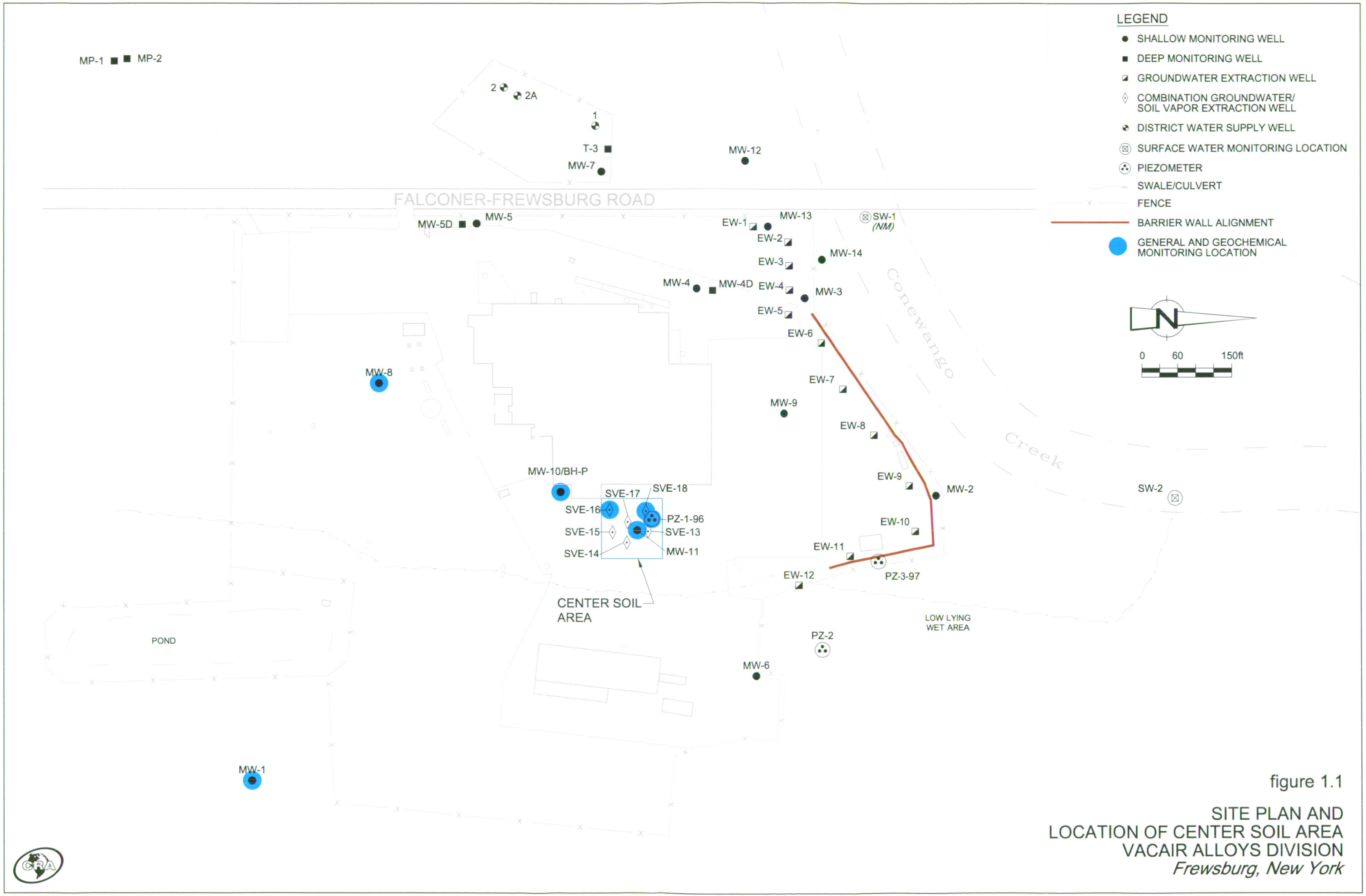

figure 1.1

SITE PLAN AND
LOCATION OF CENTER SOIL AREA
VACAIR ALLOYS DIVISION
Frewsburg, New York

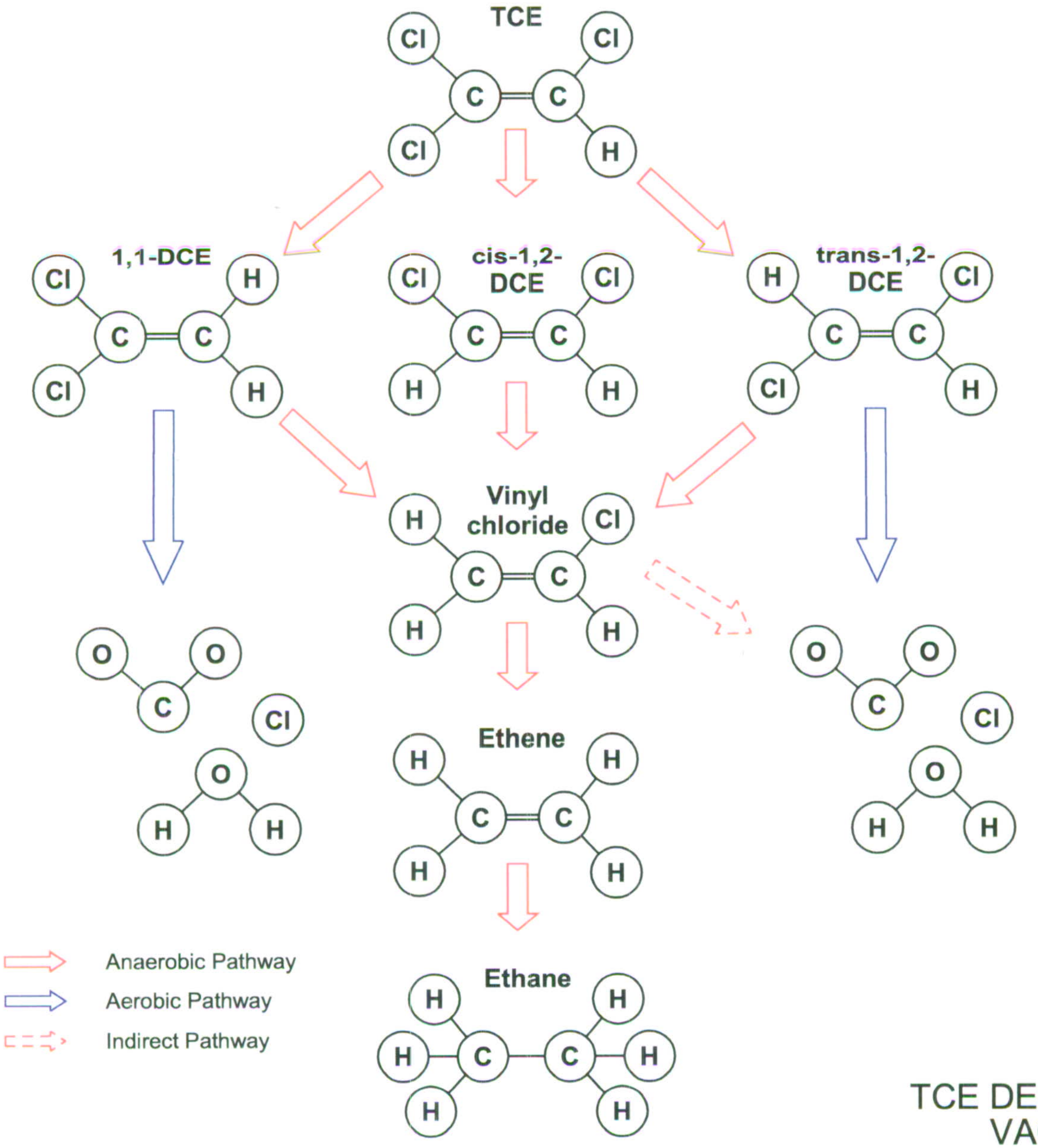

figure 4.1

TCE DEGRADATION PATHWAY
VACAIR ALLOYS DIVISION
Frewsburg, New York

TABLES

TABLE 2.1

GEOCHEMICAL MONITORING PARAMETERS
KEYWELL, L.L.C., VACAIR DIVISION
FREWSBURG, NEW YORK

Parameter	*Condition Evaluated*
Dissolved Oxygen	Redox conditions
pH	Environmental conditions
Temperature	Environmental conditions
Oxidation Reduction Potential	Redox conditions
Alkalinity	Evidence of degradation
Ethene	Evidence of degradation
Ethane	Evidence of degradation
Methane	Evidence of degradation
Chloride	Evidence of degradation
Nitrate	Redox conditions
Nitrite	Redox conditions
TKN	Nutrient availability
Sulfate	Redox conditions
Ammonia	Nutrient availability
Orthophosphate Phosphorus	Nutrient availability
Total Iron	Redox conditions
Dissolved Iron	Redox conditions
Total Manganese	Redox conditions
Dissolved Manganese	Redox conditions
Dissolved Organic Carbon	Presence of substrate

TABLE 3.1

SOIL VAPOR ANALYTICAL RESULTS SUMMARY
VAC AIR ALLOYS
FREWSBURG, NEW YORK

Sample Location:		*Odd-Numbered Branch*		*Even-Numbered Branch*		*Combined Effluent*
	Collection Date:	04/18/02	07/02/02	04/18/02	07/02/02	07/02/02
Parameters	*Units*					
TCL Volatiles						
Chloromethane	$\mu g/m^3$	160 U	770 U	160 U	88 U	31 U
Bromomethane	$\mu g/m^3$	300 U	1400 U	290 U	160 U	58 U
Vinyl chloride	$\mu g/m^3$	200 U	950 U	190 U	110 U	38 U
Chloroethane	$\mu g/m^3$	210 U	980 U	200 U	110 U	39 U
Methylene chloride	$\mu g/m^3$	270 U	1300 U	260 U	150 U	52 U
Acetone	$\mu g/m^3$	750 U	3500 U	720 U	400 U	140 U
Carbon disulfide	$\mu g/m^3$	980 U	4600 U	940 U	530 U	180 U
1,1-Dichloroethene	$\mu g/m^3$	310 U	1500 U	300 U	170 U	59 U
1,1-Dichloroethane	$\mu g/m^3$	320 U	1500 U	310 U	170 U	60 U
trans-1,2-Dichloroethene	$\mu g/m^3$	1200 U	5900 U	1200 U	680 U	240 U
Chloroform	$\mu g/m^3$	380 U	1800 U	370 U	210 U	72 U
1,2-Dichloroethane	$\mu g/m^3$	320 U	1500 U	310 U	170 U	60 U
2-Butanone	$\mu g/m^3$	930 U	4400 U	890 U	500 U	180 U
1,1,1-Trichloroethane	$\mu g/m^3$	430 U	2000 U	410 U	230 U	81 U
Carbon tetrachloride	$\mu g/m^3$	500 U	2300 U	480 U	270 U	93 U
Bromodichloromethane	$\mu g/m^3$	2100 U	10000 U	2000 U	1100 U	400 U
1,2-Dichloropropane	$\mu g/m^3$	360 U	1700 U	350 U	200 U	68 U
cis-1,3-Dichloropropene	$\mu g/m^3$	360 U	1700 U	340 U	190 U	67 U
Trichloroethene	$\mu g/m^3$	100000	340000 J	110000	69000	21000
Dibromochloromethane	$\mu g/m^3$	2700 U	13000 U	2600 U	1400 U	500 U
1,1,2-Trichloroethane	$\mu g/m^3$	430 U	2000 U	410 U	230 U	81 U
Benzene	$\mu g/m^3$	250 U	1200 U	240 U	140 U	47 U
trans-1,3-Dichloropropene	$\mu g/m^3$	360 U	1700 U	340 U	190 U	67 U
Bromoform	$\mu g/m^3$	3200 U	15000 U	3100 U	1800 U	610 U
4-Methyl-2-pentanone	$\mu g/m^3$	1300 U	6100 U	1200 U	700 U	240 U
2-Hexanone	$\mu g/m^3$	1300 U	6100 U	1200 U	700 U	240 U
Tetrachloroethene	$\mu g/m^3$	530 U	2500 U	510 U	290 U	100 U
Toluene	$\mu g/m^3$	300 U	1400 U	280 U	160 U	56 U
1,1,2,2-Tetrachloroethane	$\mu g/m^3$	540 U	2600 U	520 U	290 U	100 U
Chlorobenzene	$\mu g/m^3$	360 U	1700 U	350 U	200 U	68 U
Ethyl benzene	$\mu g/m^3$	340 U	1600 U	330 U	180 U	64 U
Styrene	$\mu g/m^3$	340 U	1600 U	320 U	180 U	63 U
Total Xylenes	$\mu g/m^3$	340 U	1600 U	330 U	180 U	64 U
Vinyl Acetate	$\mu g/m^3$	100 U	5200 U	1100 U	600 U	210 U

Note:

TCL	Target Compound List.
U	Non-detect at associated value.

TABLE 3.2

SUMMARY OF GROUNDWATER EXTRACTION WELL ANALYTICAL DATA
VAC AIR ALLOYS
FREWSBURG, NEW YORK

Parameters	*Units*	*EW-13*	*EW-14*	*EW-15*	*EW-16*	*EW-17*	*EW-18*
Trichloroethene	µg/L	7,500	36,000	35,000	28,000	68,000 J	2,400
1,2-Dichloroethene	µg/L	1,500	1,900	13,000	1,700	3,100	540
Vinyl chloride	µg/L	ND	ND	ND	ND	ND	ND

Note:

J	Estimated.
ND	Non-Detect.

TABLE 3.3

SUMMARY OF CENTER SOIL AREA GROUNDWATER EFFLUENT ANALYTICAL DATA
VAC AIR ALLOYS
FREWSBURG, NEW YORK

Parameters	*Units*	*Jan. 2002* (1)	*Oct. 2002* (2)	*Dec. 2002* (3)
Trichloroethene	µg/L	22,000	8,300	37,000
1,2-Dichloroethene	µg/L	1,400	8,100	5,500
Vinyl chloride	µg/L	ND2000	790	420

Notes:

(1) Both groundwater and vapor extraction operating.

(2) Sample collected within 24 hours of restarting groundwater following a 5-day shut down.

(3) Only groundwater extraction operation.

µg/L Micrograms per Liter.

TABLE 3.4

SUMMARY OF GEOCHEMICAL ANALYTICAL RESULTS
VACAIR ALLOYS
FREWSBURG, NEW YORK

Sample Location:		***MW-1***	***MW-8***		***MW-10***		***MW-11***	***EW-16***	***EW-18***	***PZ-1-96***
Sample Date:		*Oct-02*	*Oct-02*	*Dec-02*	*Oct-02*	*Dec-02*	*Oct-02*	*Oct-02*	*Oct-02*	*Dec-02*
Laboratory Analyses										
Ethane	µg/L	ND0.50	ND0.50	NA	ND0.50/ND0.50	NA	42J	ND0.50	0.68	NA
Ethene	µg/L	ND0.50	ND0.50	NA	ND0.50/ND0.50	NA	5.3	ND0.50	30J	NA
Methane	µg/L	6.7	ND0.50	NA	4.6/4.4	NA	38	13	36	NA
Total Iron	µg/L	1050	873	NA	36400/76600	NA	44900	197000	418	NA
Total Manganese	µg/L	153	588	NA	1980/2570	NA	1570	4810	753	NA
Dissolved Iron	µg/L	134	112	NA	293/261	NA	1310	1490	254	NA
Dissolved Manganese	µg/L	85.7	18.4	NA	135/121	NA	595	768	732	NA
Ammonia Nitrogen	mg/L	ND0.1	ND0.1	NA	ND0.1/ND0.1	NA	0.35	0.17	0.48	NA
Chloride	mg/L	14	20.2	NA	8.2/9.1	NA	16.5	21.7	64.8	NA
Dissolved Organic Carbon	mg/L	ND1.0	ND1.0	NA	ND1.0/ND1.0	NA	2.6	2.5	1.8	NA
Nitrate as N	mg/L	ND0.05	2.3	NA	ND0.50/ND0.50	NA	ND0.05	ND0.05	0.074	NA
Nitrite	mg/L	0.057	ND0.05	NA	ND0.05/0.071	NA	ND0.05	ND0.05	0.14	NA
Phosphate as P, Ortho	mg/L	ND0.05	ND0.05	NA	ND0.05/0.15	NA	ND0.05	ND0.05	ND0.05	NA
Sulfate	mg/L	9.9	21.7	NA	35.9/35.7	NA	21.3	37.4	34.8	NA
Total Alkalinity	mg/L	226	268	NA	122/127	NA	215	198	270	NA
Total Kjeldahl Nigrogen	mg/L	5.4	4.3	NA	ND3.0/5.4	NA	ND3.0	3.8	3.8	NA
Field Analyses										
pH	S.U.	6.29	5.99	6.73	7.49	7.17	7.13	7.31	7.41	6.49
Conductivity	mS/cm	613	793	519	415	249	588	600	922	709
Temperature	°C	10.2	12.6	12.5	12.5	15.0	16.2	14.1	15.5	14.7
Turbidity	NTU	8	4	NM	693	NM	37	364	22	NM
Dissolved oxygen	mg/L	10.89	9.13	140	9.69	0	8.07	8.85	8.62	0
Oxidation/Reduction Potential	mV	300	325	250	245	-151	270	250	280	252

Notes:

°C	Degree Centrigrade.
mg/L	Milligrams per Liter.
mS/cm	Millisemens per centimeter.
mV	Millivolts.
NA	Not Analyzed.
NDx	Not detected at or above x.
NM	Not Measured.
NTU	Nephelometric Turbidity Unit.
S.U.	Standard Unit.

TABLE 4.1

SUMMARY OF ESTIMATED COST - ENHANCED BIODEGRADATION
VACAIR ALLOYS
FREWSBURG, NEW YORK

		Estimated Cost
A.	Pilot Testing	$ 10,000
B.	Design	
	1. Work Plan/Design	$ 5,000
	2. Purchasing/Contracting	$ 2,000
C.	Equipment	$ 3,000
D.	Application System	$ 20,000
	Sub-Total	$ 40,000

		Estimated Annual Cost	***Present Worth*** [(1)] ***(5 Years)***	*(15 Years)*
E.	Substrate and Nutrients	$ 4,000	$ 19,000	$ 52,000
F.	Application of Treatment	$ 7,000	$ 33,000	$ 91,000
G.	Engineering Support	$ 5,000	$ 24,000	$ 65,000
		Sub-Total	$ 76,000	$ 143,000
		Total Estimated Cost	$ 116,000	$ 183,000

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(1) 6 percent discount, 3 percent inflation

TABLE 4.2

SUMMARY OF ESTIMATED COST - IN SITU CHEMICAL OXIDATION
VACAIR ALLOYS
FREWSBURG, NEW YORK

			Estimated Cost
A.	Pilot Testing		$ 10,000
B.	Design		
	1. Work Plan/Design		$ 5,000
	2. Purchasing/Contracting		$ 2,000
C.	Equipment		$ 3,000
D.	Application System		$ 20,000
E.	Potassium Permanganate ($2/pound)		$ 12,000
		Sub-Total	$ 52,000

		Estimated Annual Cost	***Present Worth*** (1)
F.	Application of Treatment (assumes 5 years)	$ 15,000	$ 70,000
G.	Engineering Support (assumes 5 years)	$ 5,000	$ 24,000
		Sub-Total	$ 94,000
		Total Estimated Cost	$ **146,000**

(1) 6 percent discount, 3 percent inflation

TABLE 4.3

SUMMARY OF ESTIMATED COST - CONTINUED OPERATION OF SVE
VACAIR ALLOYS
FREWSBURG, NEW YORK

			Estimated Cost
A.	Equipment		$ 2,500
		Sub-Total	$ 2,500

		Estimated Annual Cost	***Present Worth*** (1)
B.	Operation & Maintenance (assumes 15 years)	$ 7,000	$ 91,000
C.	Engineering Support (assumes 15 years)	$ 5,000	$ 65,000
		Sub-Total	$ 156,000
		Total Estimated Cost	**$ 158,500**

(1) 6 percent discount, 3 percent inflation