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TEST RESULTS FOR POTASSIUM PERMANGANATE ADDITIONS – SUMMER 1998
UNION CHEMICAL COMPANY SUPERFUND SITE
SOUTH HOPE, MAINE

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(Revision 2)

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DISCLAIMER STATEMENT

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1.0 INTRODUCTION

IT Corporation (IT), formerly Fluor Daniel GTI, Inc., conducted an expanded field test of potassium permanganate additions to ground water at the Union Chemical Company (UCC) Superfund site in South Hope, Maine. The test was conducted in accordance with the work plan dated March 11, 1998, as submitted to and approved by the Environmental Protection Agency (EPA) and Maine Department of Environmental Protection (MEDEP). This report presents interim and post-test data to evaluate the potential efficacy of potassium permanganate applications at the site.

The expanded field test was conducted from June through August of 1998. Photographic documentation for the test is provided in **Appendix A**. This report also incorporates the results of the periodic ground water sampling performed during April and October of 1998 and post-test sampling from April of 1999. (Note: the April 1999 data was concurrent with the Q25 sampling and the "pre-test" conditions for the 1999 potassium permanganate addition activities).

1.1 Potassium Permanganate ($KMnO_4$) Properties

Potassium permanganate ($KMnO_4$) is widely used in the water treatment industry to oxidize and precipitate dissolved metals and in the sewage treatment industry to treat sulfide odors. $KMnO_4$ will react with and oxidize a wide range of common organic contaminants relatively quickly and completely. In particular, $KMnO_4$ reacts rapidly with the non-conjugated (i.e., non-aromatic) double bonds in chlorinated ethenes such as trichloroethylene (TCE), tetrachloroethylene (PCE), dichloroethylene (DCE) isomers, and vinyl chloride (VC). Potassium permanganate is also effective with benzene, toluene, ethylbenzene, and xylene (BTEX) and simple polycyclic aromatic hydrocarbons (PAHs). The redox potential is a function of oxidant concentration and solution pH. As a general rule, $KMnO_4$ will oxidize anions more readily than neutral molecules, which are, in turn, more readily oxidized than cations.

Recent research at the University of Waterloo[1] has demonstrated that injection of $KMnO_4$ solutions into soils contaminated with chlorinated ethenes results in substantial *in-situ* destruction of the contaminants. Prior to the initiation of 1998 field test at this site, IT had completed three successful field trials of potassium permanganate with the percent reduction of chlorinated ethenes ranging from ~60% to >99%.

Potassium permanganate oxidizes the chlorinated ethenes to carbon dioxide (CO_2) and chloride ion. The balanced chemical equations for potassium permanganate oxidation of chlorinated ethenes are as follows:

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[1] "Laboratory and controlled field experiments using potassium permanganate to remediate trichloroethylene and perchloroethylene DNAPLs in porous media," Schnarr, Truax, Farquhar, Hood, Gonulla and Stickney, Journal of Contaminant Hydrology, 29 (1988) pages 205-224.

PCE: $4KMnO_4 + 3C_2Cl_4 + 4H_2O \text{--->} 6CO_2 + 4MnO_2 + 4K^+ + 12Cl^- + 8H^+$
TCE: $2KMnO_4 + C_2HCl_3 \text{--->} 2CO_2 + 2MnO_2 + 2K^+ + 3Cl^- + H^+$
DCE: $8KMnO_4 + 3C_2H_2Cl_2 \text{--->} 6CO_2 + 8MnO_2 + 8K^+ + 6Cl^- + 2OH^- + 2H_2O$
VCM: $10KMnO_4 + 3C_2H_3Cl \text{--->} 6CO_2 + 10MnO_2 + 10K^+ + 3Cl^- + 7OH^- + H_2O$

Several observations can be made from these equations. The lower the degree of chlorination, the more basic the reaction becomes. The oxidation of PCE and TCE produces acid. The oxidation of DCE and vinyl chloride consumes acid. Also, the lower the degree of chlorination, the more potassium permanganate is required to oxidize the chlorinated ethene.

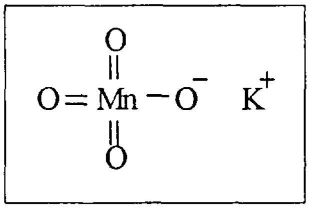
Potassium permanganate is applied as a solution. It is fairly soluble at 20^0 C (64 g/L) and can easily be made up to >1% solutions. Higher concentrations are possible with hot water (solubility is 250g/L or 25% @ 65^0 C). The standard application level that IT has used is 1-3%. Because of its high strength and reactivity, potassium permanganate can be used to treat a wide range of contaminant levels in ground water and soil, including dense non-aqueous phase liquids (DNAPLs). These permanganate solutions are relatively stable and generally spent only through reaction with the contaminant or other reduced species (iron, natural organics). The permanganate ion, MnO_4^- is not thermodynamically stable in water; permanganate tends to (very slowly) oxidize water with the evolution of oxygen:

$$4MnO_4^- + 4H^+ \ \_ \ 4MnO_2 + 2H_2O + O_2$$

This reaction is so slow as to not be a concern for preparation, handling, and short-term storage of the potassium permanganate solutions used.

The physicochemical properties of potassium permanganate are presented below, and the Material Safety Data Sheets for potassium permanganate are located in **Appendix B**.

$KMnO_4$ Material Properties

Parameter	Value	Comments
Chemical Formula	 $KMnO_4$	Dark Purple solid with a metallic luster, odorless, granular crystalline, oxidizer, corrosive, RCRA ignitable waste
CAS Registry Number	7722-64-7	
Density	2.703g/cm^3 (168 lb/ft^3) at 20°C (68°F)	
Solubility	60 g/L (6%) at 68°F % in w/V 42 g/L (4.2%) at 50°F 80 g/L (8.0%) at 80°F	
Specific Gravity	1.039 (6% w/w) at 20°C	
Particle Size	20% retained on #425 U.S. standard sieve 7% retained on #75 U.S. standard sieve	
Purity	98% typical	
Standards	Certified by the National Sanitation Foundation (NSF) to ANSI/NSF Standard 60: Drinking Water Treatment	
Bulk Density	100 lb/ft ^3	
Volatility	Not volatile	
Stability	Stable at ambient conditions	
Standard Electrode Potential	E_o = 1.70 V	

1.2 Reaction Mechanisms

In-situ oxidation is a chemical reaction. The effectiveness of treatment is a function of three things - the kinetics of the reaction between the potassium permanganate and the contaminant, the contact between the oxidant and the contaminant(s), and competitive reactions of potassium permanganate with other reduced/oxidizable species. If the contaminant being targeted for *in-situ* chemical oxidation is reactive (i.e., chlorinated ethenes) and sufficient oxidant has been added to overcome the demand from other reduced species, then oxidation of the contaminants can occur. The limiting factors to the successful application of *in-situ* oxidation are the transport of the oxidant to the areas of contamination and sufficient oxidant to achieve desired contaminant reductions. The oxidation of TCE and DCE by potassium permanganate, compared to the time to transport the potassium permanganate to the treatment zone, is essentially an instantaneous reaction. If the potassium permanganate contacts the contaminant it will react. IT's field experience has demonstrated that significant oxidation can be observed in as little as a few hours after injection. By contrast, travel times for the potassium permanganate to migrate away from the injection point may be on the order of a day to weeks, depending on the distance to be traveled and the permeability of the formation.

The primary limitation to potassium permanganate treatment is the ability to apply the potassium permanganate *in-situ* and to maintain efficient contact between the potassium permanganate and the contaminant. Low permeability soils and highly heterogeneous soils present a challenge and require careful design of the application system. The key to optimizing the economics and efficacy of the application of potassium permanganate is, therefore, choosing the proper application system.

1.3 Synopsis of Site Setting

The UCC Superfund site, a former chemical manufacturing, solvent recovery, and hazardous waste treatment facility, is located in South Hope, Maine. The facility is situated on a 12.5-acre parcel in a rural area along the south side of State Route 17, approximately seven miles west of the town of Rockport, Maine and 32 miles east of Augusta, Maine. A fence encloses the 2.5-acre developed portion of the site. The UCC Facility is shown in **Figure 1**. All the buildings formerly on the site were razed prior to 1995.

The geology of the site consists of a shallow fill/disturbed zone overlying a poorly conductive glacial till, which extends down to bedrock of schist and gneiss. The extent of this fill appears to be limited primarily to the area within the fenced portion of the site and areas disturbed by construction and demolition activities. The depth of original unconsolidated overburden ranges in thickness from 20 feet on the western portion of the site to more than 80 feet in the area of Quiggle Brook. The depth to water is variable, but tends to be 15 to 20 feet across the fenced portion of the site under non-pumping conditions.

In 1995 and 1996, IT implemented the SC/MOM remedy in the source area of the site. Treatment system wells were constructed as shallow (20 to 25 feet) hexagonally arranged hot air injection points surrounding separate soil vapor extraction (SVE) wells and ground water pumping wells. Each of the ground water pumping wells extend approximately five feet into the bedrock. The depths of the soil vapor extraction wells vary across the source area. With the treatment plant in operation, the water table has been depressed greater than 10 feet across the site and greater than 25 feet in the leach field/interceptor trench area. For the period leading up to the initiation of the 1998 field test, all SVE wells were dry, indicating that dewatering has occurred to below the depths of the SVE wells across the site.

1.4 Past $KMnO_4$ Testing Activities

The following potassium permanganate ($KMnO_4$) activities have previously been performed for the UCC site:

- Bench Scale Potassium Permanganate Jar Test, Spring 1997,
- Short Duration Field Pilot Test, Fall 1997.

Together, the results from these activities formed the overall basis for the procedures and activities utilized during the potassium permanganate addition activities performed for the 1998 field test.

1.4.1 Bench Scale Potassium Permanganate Jar Test

A discussion of the procedures used and results generated during the Potassium Permanganate Jar Test, performed during the months of April and May of 1997, is presented in a memo dated July 22, 1997 and is included in the March 1998 Potassium Permanganate Addition Work Plan.

1.4.2 Short Duration Field Pilot Test

A discussion of the procedures used and results generated during the Short Duration Field Potassium Permanganate Field Pilot Test, performed during October and November 1997, is presented in a letter report dated January 13, 1998 and is included in the March 1998 Potassium Permanganate Addition Work Plan.

2.0 DESCRIPTION OF TESTING ACTIVITIES

2.1 Preparation and Storage of Potassium Permanganate Solution

A 1% $KMnO_4$-water solution was used for the addition activities at the Union Chemical site during the summer of 1998. Prior to adding to the testing wells, this solution had to be prepared, mixed and stored to support the addition activities. This section summarizes these activities.

The following equipment and materials were used to prepare, mix and store the potassium permanganate solution for the testing activities:

- 500 gallon plastic mixing tank with mechanical mixer,
- 4,000 gallon polyethylene dilution tank,
- 6,500 gallon polyethylene storage tank,
- 12,000 gallon secondary containment area,
- centrifugal mixing pump,
- centrifugal addition pump,

- 4,000 lbs. of $KMnO_4$ granules (in 55 lb. containers),
- mixing and delivery plumbing, valving and fittings,
- well head connection and control fittings, and
- personal protective equipment (PPE) for handling $KMnO_4$.

The handling, mixing and storage area was constructed south of the water treatment plant (WTP) building just off the southwest corner of the constructed cap, as shown by **Figure 1**. All handling, mixing and storage activities of the $KMnO_4$ solution were completed inside the constructed secondary containment storage area.

2.2 Addition and Monitoring Procedures

The potassium permanganate solution was added to the overburden and upper fractured bedrock through a total of twenty (20) existing site wells, as shown on **Figure 1**. The addition wells utilized were as follows:

- nine (9) soil vapor extraction (SVE) wells, and
- eleven (11) ground water pumping wells.

As discussed in the March 1998 workplan, the SVE wells across the site are "generally" less than 30 feet in depth and extend into the dewatered zone under the cap. Utilization of the SVE wells allows additions of potassium permanganate to the "upper" overburden, and potentially results in treatment of the "lower" overburden through vertical migration of permanganate through de-watered soils. The ground water pumping wells are screened from 35 feet below the surface grade and into the bedrock. Use of the pumping wells for potassium permanganate additions allows for treatment of "lower" overburden and shallow bedrock.

To add $KMnO_4$ to the SVE wells, flexible tubing and well head fixtures were attached directly onto a threaded fitting atop each SVE well casing. Addition of the $KMnO_4$ solution to the pumping wells necessitated removing the ground water pump in the specified addition well(s) and connecting the flexible tubing and well head fixtures to the well head. The ground water pump in the addition well(s) was disconnected and removed immediately prior to initiating addition activities into that specific well. The ground water pumps in the surrounding pumping wells were kept operational throughout the testing activities to maintain proper hydraulic control and provide monitoring information in the addition area. The ground water pumps were re-deployed and activated in each addition well once the $KMnO_4$ solution added to that well had fully dissipated from the area.

2.3 Summary of Addition Schedule and Locations

2.3.1 $KMnO_4$ Addition Testing Schedule

Summary of the Schedule for the $KMnO_4$ Test
Union Chemical Site
Summer 1998

April 1998	Q23 sampling performed (data used as pre-test ground water conditions)
May 1998	$KMnO_4$ equipment installation and testing Pre-Test monitoring and sampling activities performed
June 1998	$KMnO_4$ testing activities started on June 16, 1998 $KMnO_4$ added to Addition Areas[1] 1 and 2 Field Testing for VOCs, iron and manganese
July 1998	$KMnO_4$ added to Addition Areas 3 and 4 Field Testing for VOCs, iron and manganese
August 1998	$KMnO_4$ added to Addition Area 5 $KMnO_4$ addition activities stopped on August 21, 1998[2] Interim Laboratory Testing for VOCs, iron and manganese
September 1998	Post-test field GC analysis and monitoring performed
October 1998	Post-test field GC analysis and monitoring performed Q24 sampling performed and post-test GW sampling and analysis completed

Notes
1 = Addition Areas are shown on Figure 2
2 = The total duration of the $KMnO_4$ testing activities was 67 days.

2.3.2 $KMnO_4$ Addition Locations

A discussed, a total of 20 site wells were used for the addition of $KMnO_4$ into the subsurface at the Union Chemical site (Note: $KMnO_4$ was also added to B-6A-D for a 10-day period in July. While this location was within the area of hydraulic control of the ground water extraction system, there were no nearby monitoring points that could be used. Thus, this well is not included in the evaluation of the expanded field test data). The testing areas are shown on **Figure 2**; the sequence, location and types of applications are summarized in the text box below.

$KMnO_4$ Testing Locations, Sequence and Type of Applications
Union Chemical Site

Addition Area #1	
Location:	hydraulically upgradient portion of the cap
Target Area:	overburden soils and groundwater
No./Type of Addition Points:	3 SVE wells
Well IDs:	V-1, V-36 and V-36a
Addition Area #2	
Location:	hydraulically upgradient portion of the cap
Target Area:	overburden/bedrock ground water
No./Type of Addition Points:	4 pumping wells
Well IDs:	P-3, P-5, P-8, P-13
Addition Area #3	
Location:	hydraulically center portion of the cap
Target Area:	overburden soils and overburden/bedrock ground water
No./Type of Addition Points:	2 pumping wells, 2 SVE wells
Well IDs:	P-10, P-11, V-14, V-19
Addition Area #4	
Location:	hydraulically downgradient portion of the cap
Target Area:	overburden soils and ground water
No./Type of Addition Points:	4 SVE wells
Well IDs:	V-12, V-15, V-20, V-24
Addition Area #5	
Location:	hydraulically downgradient portion of the cap
Target Area:	overburden/bedrock ground water
No./Type of Addition Points:	5 pumping wells
Well IDs:	P-16, P-21, P-22, P-25, P-26

2.4 Data Collection and Analysis

Several types of data were collected to measure performance and impact of the potassium permanganate addition. These methods and their use are summarized in the following sections. Whenever possible, laboratory data was supplemented through the collection of Level I or II data.

2.4.1 Level I Data

Level I data (e.g., water-level measurements, color, ORP and pH measurements) was collected periodically to provide a general indication of the performance and effect of the addition process. Level I data provide screening quality data useful for cursory evaluation and optimization of the field activities. Use and acceptance of level I data is based on professional judgement relative to the consistency and representativeness of the data.

2.4.2 Level II Data

Level II data (e.g., field gas chromatograph (FGC) analysis) is designed to provide quick turnaround information, supplementing more expensive and time consuming Level III data. Level II data is not meant to provide decision-making quality data since continuous and sufficiently detailed quality control (QC) information cannot be provided by the instrumentation. While FGC data typically completes blank and calibration runs to ensure that the instrument is operating within control limits, FGC results do not typically complete minimum detection limit studies to quantify the instrument method detection limit (MDL). As such, the FGC can be used for qualitative and semi-quantitative review only, recognizing the performance and capabilities of the equipment. Acceptance or rejection of Level II data depend upon the judgement of qualified personnel familiar with the data and interpretation.

2.4.3 Level III Data

Collection and off-site laboratory analyses of groundwater samples using EPA and MEDEP approved methodologies generates Level III data, which can be used for decision-making purposes. Only Level III data is used to perform quantitative evaluations of the results of the 1998 potassium permanganate test. Level III data was collected for volatile organic compounds (VOCs), DMF, iron and manganese as part of the baseline, interim and post-test monitoring.

3.0 TEST RESULTS

3.1 Data Quality Objectives

As stated in the March 1998 Potassium Permanganate Addition Work Plan, the use of potassium permanganate in the subsurface is an innovative enhancement of the ground water treatment system at the Union Chemical site. To ensure the safe application and proper evaluation of this technology, and to address specific Agency concerns, IT developed a series of Data Quality Objectives (DQOs). These DQOs were evaluated throughout the testing activities as a means to closely monitor the subsurface response to the addition activities and respond to these changes in a logical and appropriate manner.

DQO #	*Data Quality Objectives*
1	*Maintenance of hydraulic control of the oxidant solution through active pumping.*
2	*Evaluate the potential for fouling, scaling or precipitation in the soil matrix and well screen around the addition well.*
3	*Evaluate impacts of increased strength of $KMnO_4$ solution.*
4	*Evaluate application rates at various locations around the site.*
5	*Evaluate flow and persistence of $KMnO_4$ in the subsurface.*
6	*Evaluate end products of the $KMnO_4$ oxidation.*
7	*Evaluate application points (SVE wells vs. pumping wells) and their effectiveness in distribution of $KMnO_4$.*
8	*Protect Quiggle Brook from accidental spills and/or ground water discharges containing $KMnO_4$.*
9	*Address any health and safety considerations in dealing with an oxidant to preserve a safe work environment for employees.*
10	*Determine applicability of adding oxidant solution into wells as part of a future, larger-scale application.*
11	*Determine potential impacts of site-specific geologic and/or hydrogeologic conditions that may limit application.*
12	*Avoid impacts to soil closure activities also planned for the summer of 1998.*

3.1.1 Maintenance of Hydraulic Control of the Oxidant Solution Through Active Pumping

Actions:

1. Throughout the testing activities, the addition rates of $KMnO_4$ to wells were monitored and adjusted, as needed, to maintain the desired flow rate at each addition well. At no time during the testing activities did the combined addition rates exceed a total of 2 gallons per minute (gpm). As discussed in the Work Plan, a 2 gpm addition rate was determined to be an

acceptable addition rate into the subsurface while still maintaining hydraulic control across the site. **Tables 1 and 2** present the quantities of potassium permanganate added and the individual addition rates for each $KMnO_4$ application.

2. During the testing activities, each addition well used adjacent, fully operational ground water extraction wells to maintain hydraulic control and to act as monitoring wells as the $KMnO_4$ solution was being added into the subsurface. **Table 2** lists each addition well with their respective ground water extraction and/or monitoring points.
3. To confirm that no localized mounding was occurring around the $KMnO_4$ addition wells, depth to water (DTW) was measured in surrounding monitoring and soil vent wells throughout the addition activities.

Results:

1. The addition rates used during the test were within the 2 gpm limits for the test.
2. Monitoring of oxidation reduction potential (ORP) provided a clear indication of the presence of potassium permanganate; and potassium permanganate was not detected in wells outside the network of pumping wells for the site.
3. DTW measurements taken prior to, periodically during, and immediately after each $KMnO_4$ addition activity consistently showed that addition of the $KMnO_4$ solution into site wells was not resulting in significant localized mounding. IT believes that the density of the ground water (GW) extraction wells in the testing area minimized the mounding effect that would normally be observed upon adding water into an aquifer.

3.1.2 Evaluate the Potential for Fouling, Scaling or Precipitation in the Soil Matrix and Well Screen Around the Addition Well

Actions:

1. During the addition activities, daily checks of the $KMnO_4$ addition rates were performed to monitor the potential for decreasing addition rates into the test wells. A decrease in the addition rates would be the result of increased resistance to flow and be indicative of scaling or fouling of the well screen and/or soil matrix.
2. In addition to monitoring the addition rate over time, slug testing of the first addition wells used in the test (V-1, V-36, V-36a and P-13) was completed prior to and after the addition activities. The slug test data is included as **Table 5.**

Results:

1. Throughout the $KMnO_4$ activities, none of the addition wells exhibited significant fluctuations and/or decreases in the addition rates, with the exception of wells P-3, P-8 and P-25, which are discussed in **Section 3.1.4**.

2. Results of the slug testing show no significant indications of scaling and/or fouling of the well screen and soil matrix surrounding the addition wells. [Note: Due to the favorable results of the initial slug testing activities and the on-going addition rate monitoring, the slug testing was discontinued after the first month of testing.]

3.1.3 Evaluate Impacts of Increased Strength of $KMnO_4$ Solution

Action:

1. IT used an increased strength of $KMnO_4$ solution for the 1998 test (approximately a 1% KMO_4 solution -- 10,000 mg/L -- as compared with the 1997 test using a <500 mg/L solution).

Results:

1. Use of the 1% solution presented no adverse effects during the test activities. As discussed above, no significant indications of scaling and/or fouling of the well screen and soil matrix surrounding the addition wells were observed during the testing activities. In addition, no additional problems were encountered in the mixing, handling and delivery of the 1% $KMnO_4$ solution.

2. Given that there were no adverse impacts to using the 1% solution, IT recommends using this concentration (or higher) for future applications since it allows for introduction of a greater mass of oxidant into the subsurface.

3.1.4 Evaluate Application Rates at Various Locations Around the Site

Action:

1. The addition rates were monitored for each application point; the results are provided in **Table 2**.

Results:

1) As shown in **Table 2**, the addition wells, regardless of whether they were SVE or GW

extraction wells, generally demonstrated consistent infiltration rates across the site, averaging 0.3 - 0.5 gpm per well, with a few exceptions. The only wells that exhibited significantly reduced flow were P-3, P-8 and P-25 respectively, as discussed below.

(a) The P-3 and P-8 wells are located 30 feet apart from one another in the upper portion of the cap. Both wells exhibited slow infiltration rates prior to $KMnO_4$ addition activities (0.1-0.3 gpm during slug test activities, refer to **Table 7**). Upon initiating the addition activities, the infiltration rates of both these wells, within the first day of addition, slowed to a point were their rates could not be measured. Upon inspection, it was observed that, when one well was turned off, the other well's infiltration rate would increase. It was determined that these wells were connected hydraulically and were co-located in sufficiently tight silty soils that restricted the infiltration of $KMnO_4$ solution from the addition wells.

(b) P-25 is located in the eastern portion of the site, about 20 feet downgradient from the former leachfield area of the site. P-25 exhibited similar behavior as P-8 in that it exhibited poor infiltration initially which eventually stopped altogether during addition activities, allowing only 234 gallons of $KMnO_4$ solution to be added to the well. Since the infiltration rates for this well were initially very slow, and the surrounding wells all exhibited good infiltration rates, IT believes that the poor infiltration rates at P-25 are most likely due to a pre-existing clogged well screen and/or localized tight soils.

3.1.5 Evaluate Flow and Persistence of $KMnO_4$ in the Subsurface

Action:

1. Wells downgradient of addition wells were monitored for the presence of $KMnO_4$ in the subsurface by periodically collecting oxidation/reduction potential (ORP) measurements, field iron and manganese measurements and visual.

Result:

1. The field ORP measurements are provided in **Appendix C** and turned out to be the best indicator of the presence of $KMnO_4$ in the subsurface. Most ORPs at the site prior to the beginning of the test were negative numbers. As $KMnO_4$ is migrating towards a well, the ORP of the well will increase to a positive number, sometimes with values of 500 or greater. In some instances, purple water was visually identified in downgradient wells due to additions in upgradient wells. There is approximately 25 feet of spacing between pumping and SVE wells. Thus, the field measurements showed that, in some instances, applications in one well resulted in pushing of $KMnO_4$ up to distances of 25 feet. In no instance was $KMnO_4$ detected at distances greater than 25 feet from an addition point.

2. Field measurements showed that, when permanganate additions stopped at a well or appeared at a well via migration, the positive ORP readings did not persist for more than a few days to one week. Thus, the $KMnO_4$ is short-lived in the subsurface, being consumed relatively quickly by contaminants and the subsurface media.

3.1.6 *Evaluate End Products of the $KMnO_4$ Oxidation*

Action:

1. The end products of the $KMnO_4$ oxidation in the subsurface were evaluated by performing inorganic and organic analysis of the ground water in the test area prior to and after the $KMnO_4$ addition activities.

Results:

1. The results of the inorganic and organic laboratory analyses are summarized in **Table 3** and **Table 4** and are further discussed further in **Sections 3.3** and **4.0** of this report. In general, there appeared to be some detectable increases in the concentrations of manganese in the subsurface. In contrast, there were detectable decreases in concentrations of VOCs. Further, there were no significant increases of vinyl chloride, confirming that the $KMnO_4$ reaction with PCE, TCE and DCE bypasses the production of vinyl chloride.

3.1.7 *Evaluate Application Points (SVE wells vs. pumping wells) and Their Effectiveness in Distribution of $KMnO_4$*

Action:

1. Eleven (11) GW pumping wells and nine (9) SVE wells were utilized for $KMnO_4$ addition during the testing activities. As discussed above, only slight differences were observed in the infiltration rates for either SVE or GW pumping wells.

Result:

1. It was generally observed during the field activities that, when adding $KMnO_4$ to the SVE wells, no significant changes in the ORP levels in the surrounding and downstream wells could be measured. (Note: the term significant means impacts not included in the background scatter of anticipated ambient/non-effect measurements). In contrast, when the pumping wells were used as the addition points, significant and consistent changes in the ORP measurements from the surrounding wells were observed. [Note: A significant change in the ORP measurements was characterized by a change from a negative number to a positive

number, with measurements over 200 giving a strong indication for the presence of $KMnO_4$.]

3.1.8 Protect Quiggle Brook from Accidental Spills and/or Ground water Discharges Containing $KMnO_4$

Action:

1. Throughout the testing activities, the secondary containment, piping and wellhead fittings were inspected daily for evidence of leaks and/or spills. Also, as the addition activities moved towards the eastern portion of the site (nearer to Quiggle Brook) only pumping wells, which included secondary containment at the well head via the well boxes were utilized as addition points.

Result:

1. Throughout the addition activities, Quiggle Brook and other surface water bodies (wetlands and standing water adjacent to treatment building) remained unimpacted and protected from accidental spills and/or ground water discharges containing $KMnO_4$. No uncontained spills and or releases to the environment occurred during the addition activities. However, three separate accidental spills did occur within secondary containment systems during the test, as discussed below.

   (a) Accidental spill of 50-100 gallons of $KMnO_4$ solution into the secondary containment "well box" at addition point P-3. This event happened during the second week of addition activities and was the result of a buildup of backpressure in the P-3 well casing. IT believes that the back pressure was caused by the generation of carbon dioxide (CO_2) gas resulting from the $KMnO_4$ reactions taking place in and around the well casing. The build up of CO_2 gas in the well casing resulted in the well head fitting at P-3 to become disconnected and resulted in a spill of 50-100 gallons of $KMnO_4$ solution within the well box. The well box contained the majority of the $KMnO_4$ solution with minor surface staining around the box. The spilled $KMnO_4$ solution was collected and added into the P-3 well. The generation of CO_2 gas from the $KMnO_4$ reaction is discussed further in **Section 4.0** of this report. [Note: This event resulted in the adding of pressure release valves to the addition wellhead fittings. The pressure relief valves work by venting any built up air pressure within the well casing, while preventing any liquid from being released.]

   (b) Accidental overfilling of the 4000 gallon mixing tank with treated water from the WTP resulted in the spilling of approximately 500 gallons (on two occasions) of dilute $KMnO_4$ solution into the secondary containment area of the mixing area. Both times the volume was completely contained in the secondary containment dike around the bulk tanks.

The dilute water- $KMnO_4$ mixture was pumped back into the mixing tanks by use of a bilge pump. The first event happened on 6/29/98 and was the result of a faulty solenoid valve which failed to close upon reaching the high point in the tank. The second event happened on 7/22/98 and was the result of operator error (the fill pump was mistakenly left on manual operation, thereby not turning off when the high level switch in the tank was reached).

3.1.9 Address any Health and Safety Considerations in Dealing with the Oxidant to Preserve a Safe Work Environment for Employees

Action:

1. Prior to initiating the handling and mixing of $KMnO_4$, IT reviewed the Material Safety Data Sheets (MSDS) for $KMnO_4$ and generated a Job Safety Analysis (JSA) form for the handling of solid and liquid $KMnO_4$ (included in the work plan).

Result:

1. During the testing activities, no additional adverse health or work conditions were identified. Therefore, it was determined that, by following the procedures and practices outlined in the JSA and the manufacturer's MSDS, a safe work environment for the handling of $KMnO_4$ can be maintained.

3.1.10 Determine applicability of Adding Oxidant Solution into Wells as Part of a Future, Larger-Scale Application.

Action:

1. Evaluate the overall 1998 test for safety and potential efficacy and the ability to apply this treatment on a larger, site-wide application.

Result:

1. IT believes that the activities performed during $KMnO_4$ testing activities and the results generated from those activities support the logistic, technical and economic feasibility of utilizing $KMnO_4$ addition technology on a larger scale as a means towards enhancing the current ground water extraction and treatment system for the Union Chemical Management of Migration.

3.1.11 *Determine Potential Impacts of Site Specific Geologic and/or Hydrogeologic Conditions that May Limit Application*

Action:

1. Review data generated during the 1998 test to determine whether the low permeability conditions of the clay overburden (or any other site features), effectively prevent the successful use of $KMnO_4$ at the site.

Result:

1. The only site-specific conditions that could limit application of the $KMnO_4$ addition technology at the Union Chemical site would be the potential for exceedingly low permeability in localized areas across the site. This condition may have been observed during addition activities into wells P-3, P-8 and P-25. The result of this condition is that it is difficult to add significant volume of solution into these low yielding wells thereby limiting the amount of mass of $KMnO_4$ that can be added into the subsurface surrounding these wells. Effective treatment of the site as a whole may be achieved without performing addition at these low permeability locations. In contrast, use of sodium permanganate, which can be applied at concentrations as high as 50% (due to its much greater solubility relative to potassium permanganate) may be useful in low permeability areas to apply a greater mass of permanganate to the subsurface with minimal addition volumes.

3.1.12 *Avoid Impacts to Soil Closure Activities also Planned for the summer of 1998*

Action:

1. Coordinate soil closure sampling activities with the 1998 potassium permanganate test, and confirm that potassium permanganate was not added to the areas being sampled.

Result:

1. Approximately 50% of the $KMnO_4$ added to the subsurface was added into site ground water extraction wells, which are screened from 35 to 50 feet beneath the ground surface, well beneath the soil closure zone.

2. The rates of addition to the SVE well locations were intentionally set at a lowered addition rate in order to keep the hydraulic head of $KMnO_4$ solution in the well casing at no more than 5 to 10 feet up from the bottom of the well. The SVE wells are typically 30 feet in depth (well below the soil closure zone). This was done to avoid introducing $KMnO_4$ to the shallower soils.

3. Of the nine (9) SVE addition points used, only two (2) were within 20 feet of the soil closure sample location. **Table 6** presents the relative locations and depths of the $KMnO_4$ SVE addition points and the nearest soil closure sample location.

4. No presence of residual $KMnO_4$ was observed in the shallow zone soils during the soil closure sampling activities.

3.2 Deviations from Work Plan

The following deviations from the March 1998 Work Plan were identified during the $KMnO_4$ Addition activities:

- Modifications to the SVE Addition Well Head Connections, and
- Flushing of the addition wells with treatment plant water after the $KMnO_4$ Addition was completed.

3.2.1 Modifications to the SVE Addition Well Head Connections

In the March 1998 Work Plan, it was described that the addition activities into the SVE wells will be made via a hose which is extended to the bottom of the SVE well, thus avoiding introduction of $KMnO_4$ to the shallower soils.

This addition procedure was performed during the early stages of Addition #1, however, since the drop tube prevented a complete liquid tight connection at the wellhead, it was discontinued over concerns with the possibility of overflowing the well casing. Although the initial addition rates could be set as to avoid backflow up the well casing, it was felt that if well conditions changed during the applications, as in the case of P-3 and P-8, an uncontrolled release of $KMnO_4$ solution could happen.

To ensure against the potential for an uncontrolled $KMnO_4$ release and also to avoid introducing $KMnO_4$ into the shallower soils around the SVE well, the following modifications were made:

- liquid tight connections were constructed to connect directly to the SVE well,
- conservatively low addition rates were used for the SVE wells, to avoid generating a hydraulic head of $KMnO_4$ solution in the addition well.

EPA and MEDEP were apprised of this modification at the time of its implementation through the periodic site update correspondence.

3.2.2 Flushing of the Addition Well with Treatment Plant Water after the $KMnO_4$ Addition was Completed

In the March 1998 Work Plan, it was stated that the addition wells will be flushed with treated water upon completing the $KMnO_4$ addition for that well. Post application, each well used for addition was monitored using a combination of visual and physical observation. Each well was found to rapidly return to a clean color with a neutral ORP indicative of baseline conditions. While the absence of residual color may have resulted from reaction of the oxidant or hydrogeologic conditions (e.g., flow or dissolution), more likely, both conditions occurred to some degree. During the pre-test equipment setup, it was decided that this would not be practical during a larger, multi-well application due to the additional logistical, equipment and time constraints that would be required. Instead of flushing the wells with treated water, the post-addition presence of $KMnO_4$ within the well casing was monitored daily until it had been flushed naturally from the well. Most importantly, the wells rapidly returned to baseline conditions without the need to complete the flushing by water addition.

3.3 Discussion of Results

3.3.1 Field Data

Data collected in the field included depth to ground water, pH, ORP, iron and manganese concentrations from field test kits, and VOC concentrations based on field GC. These results are provided in Appendix C.

Depth to water was measured to evaluate the influence of potassium permanganate additions on groundwater elevations. These measurements were made in wells downgradient of addition points. This data showed that the potassium permanganate additions did not result in wide-scale resaturation of overburden at the site. However, the differences in groundwater elevations measured could be attributed to either natural fluctuations or additions of potassium permanganate. Thus, this data was not useful for evaluating the spread of potassium permanganate through the overburden.

Measurements of pH were made to evaluate whether there were any measurable effects due to the addition of potassium permanganate or as a result of the breakdown process. As discussed earlier, the breakdown of PCE and TCE by potassium permanganate produces acids (resulting in a lower pH), and the breakdown of DCE and vinyl chloride consumes acid (resulting in a higher pH). Since there are higher concentrations of DCE at the site than TCE or PCE, the overall reaction would be expected to result in an elevated pH. However, there are other contaminants at the site as well, and the specific chemical breakdown reactions for all of these contaminants are not known. An examination of the data show that all measured values were within ranges previously detected at the site and do not show a consistent trend of either raising or lowering pH. The potassium permanganate reaction with contaminants is immediate; thus, any changes in pH would be immediate. Following any reaction induced changes in pH, there would be a mixing with surrounding, untreated water which would move the pH back towards natural conditions. IT believes that, if there were any reaction induced changes in pH, that the frequency of pH measurements performed for this test was not sufficient to record these changes accurately.

Measurements of ORP were the most useful field measurements made during the test. Groundwater at the site has overall ORP values that are negative. The presence of potassium permanganate produces a positive ORP. As the potassium permanganate is consumed, the ORP returns to a negative value. Wells showing this relationship include P-2, P-4, P-6, P-9, P-11, P-12, P-13, p_16, P-20, and P-24. In all cases, the ORP measurements returned to negative numbers within two weeks. [Note: some wells experienced a subsequent rise in ORP due to additions from other, nearby locations.]

Concentrations of iron, manganese and VOCs were measured in the field to evaluate the effect of the potassium permanganate additions on the existing groundwater concentrations. Potential impacts included the following:

- Decreases in iron and manganese concentrations due to oxidation and precipitation of these metals.
- Increases in manganese concentrations due to the presence of manganese in the addition solution.
- Decreases in dissolved phase VOCs as a result of oxidation.
- Increases in dissolved phase VOCs due to desorption from the soil matrix and transfer from the soil matrix to groundwater.

The results from the field test kits and field GC did not produce consistent findings. The data show both increases and decreases in iron, manganese and VOCs. While these results may reflect the limitations of the field tests, IT believes that the results are more significantly impacted by the speed of the potassium permanganate reactions relative to the frequency of testing. Similar to the discussion above for pH measurements, following the reactions with potassium permanganate (which are immediate), the treated area begins to mix with surrounding, untreated water. Given that our field measurements for iron, manganese and VOCs were separated by periods of several weeks to a month (or more), any changes due to the potassium permanganate would be expected to be masked by mixing of treated and untreated water in the subsurface.

3.3.2 Laboratory Data and VOC Reductions

Ground water samples were collected and analyzed at an off-site laboratory for iron, manganese, VOCs and DMF. The results of the analyses for VOCs and DMF are provided in **Tables 3A** and **3B**, and the results for iron and manganese are provided in **Table 4**. While the laboratory results for iron and manganese also produced mixed results (similar to the field test results), the data indicate that there was a general decrease in iron concentrations and a general increase in manganese concentrations in treated areas. A more detailed analyses of iron and manganese changes was not considered important for the following reasons:

1. Changes in iron and manganese concentrations may have been important as a predictor for formation clogging; however, formation clogging was not an issue during this test.

2. During the period of this test, the concentrations of iron and manganese in the plant influent did not vary outside the range of previous variability. Thus, any localized changes in iron and manganese concentrations did not have a widespread impact on the site.

In addition, potassium permanganate was not expected to have an impact on DMF concentrations at the site. Therefore, the remainder of the analyses of laboratory data centers on the VOC results.

3.3.2.1 Evaluation of Methodologies

The efficacy of the 1998 potassium permanganate test was evaluated by determining whether there were measurable reductions in VOC concentrations at the site as a result of the potassium permanganate applications. A number of methodologies were considered, as discussed below. In addition, it is reasonable to consider that, over the course of the test, that there may have been VOC reductions that would have occurred due to continued operation of the groundwater pumping system. Reductions potentially attributable to the groundwater pumping system were also evaluated.

<u>VOC Reductions Due to Groundwater Extraction System</u>. For each month of operation, IT collects samples of the treatment plant influent for laboratory analyses. To identify a trend in VOC reductions due to operation of the ground water pumping system, the monthly plant influent was used for the period preceding the 1998 test. Specifically, one year of data was examined – May 1997 through May 1998. [Note: the May 1998 sample was collected prior to the initiation of the potassium permanganate applications.] Data were plotted for cis-1,2-DCE, 1,1-DCA, TCE and total chlorinated VOCs. Then, a best-fit curve was developed to evaluate the concentration trends. [Note: due to the scatter in the data points, it was not possible to develop curves with high statistical correlations.] The results of these curve projections are provided in Appendix D. In general, these curves have relatively steep slopes, indicating relatively high percentages of potential VOC reduction due to continued operation of the ground water pumping system. As a check on these curves, the total chlorinated VOC data were evaluated over a longer period, from system startup (November 1996) through May 1998. These results are also presented in Appendix D and show a curve with a less severe downward slope. All of these curves were used to project potential reductions in VOC concentrations due to operation of the groundwater pumping system for points in time past May 1998 (when potassium permanganate additions were initiated).

<u>Geosoft Contour Maps</u>. The Interim report for the 1998 potassium permanganate test used the construction of Geosoft contour maps to estimate VOC reductions. The majority of the data used to construct these maps was from pumping wells, which are screened in both overburden and bedrock. This data was augmented with data from monitoring wells screened in overburden. However, there was a potential bias in the data since monitor wells in bedrock were not included. The maps could not be appropriately revised to incorporate both overburden and bedrock monitoring well data (since there are different concentrations at the same locations (shallow and deep). Further, there is insufficient data from just the pumping wells to generate representative Geosoft maps. Therefore, the Geosoft contour maps are not used for evaluation of the VOC data.

Periodic Monitoring Data. Periodic groundwater monitoring was performed in April 1998 (Q23), October 1998 (Q24) and April 1999 (Q25). The April 1998 data represents baseline conditions for the 1998 potassium permanganate test. Both the October 1998 and April 1999 data reflect post-test conditions. The monitoring program includes wells that are primarily on the perimeter of the treatment area at the site. Groundwater migration rates at the site have been modeled at approximately 16 feet per year (under non-pumping conditions). The 1998 test included potassium permanganate additions within the source area only. Thus, the monitor wells around the perimeter of the source area would not reflect any VOC reductions that may have occurred within the source area because of their location and the slow rates of groundwater movement. Therefore, a comparison of the isoconcentrations maps from Q23, Q24 and Q25 was not considered a representative evaluation of potential VOC reductions due to potassium permanganate applications in the 1998 test.

Individual Well Comparisons. **Tables 3A** and **3B** present results for VOC analyses by well. A review of this data show that there is not a consistent trend within the data. Some wells show increases in VOCs while other wells show decreases in VOCs. At the beginning of the test, comparisons of VOC concentrations in individual wells over time was viewed as the most likely method for providing data to perform VOC reduction calculations. Thus, wells in the treatment area were identified and sampled in June, August and October. However, as with other measurements, the relatively rapid speed with which the potassium permanganate reactions occur hinder the ability to measure the VOC reductions in a specific well. It is anticipated that the VOC reductions are immediate. Then, once the potassium permanganate is expended, mixing of treated and untreated water from the surrounding formation occurs. Therefore, the samples collected from individual wells (at a frequency of every several months) was not adequate for calculating VOC reductions due to potassium permanganate additions.

Evaluation of Plant Influent. The plant influent data is generated monthly and represents the total concentration (and mass) of contaminants captured within the groundwater treatment system. Since the influent data represents groundwater under the source area as a whole, it would include both treated and untreated areas. While this negates the effects of mixing, which impacts on well-specific data evaluations, it also serves to underestimate the potential efficacy of potassium permanganate because it includes untreated areas. The plant influent data was selected to evaluate VOC reductions as a result of the 1998 potassium permanganate additions because it is most representative of the treatment area as a whole. In addition, the potential VOC reductions due to continued operation of the ground water pumping system were based on the plant influent data. Use of the influent data to calculate VOC reductions due to potassium permanganate lends a consistency to the data evaluation.

3.3.2.2 Estimates of VOC Reductions

The estimates of VOC reductions are provided in **Table 7**. The methodology for this evaluation is as follows:

1. Two points in time were selected for analyses – October 1998 and April 1999. Both of these were compared against April 1998 (pre-test) concentrations.

2. Using the trend graphs in **Appendix D**, the VOC reductions potentially attributable to continued operation of the groundwater pumping system were calculated.

    (a) For October 1998, the estimated concentrations were extrapolated from the trend curves. Then, the estimated concentrations for October 1998 were compared with the actually measured influent concentrations in April 1998 to estimate VOC reductions. These reflect those reductions that may have been anticipated without potassium permanganate additions.

    (b) For April 1999, the estimated concentrations were extrapolated from the trend curves and compared with the actual values for April 1998. VOC reductions potentially attributable to the ground water pumping system were calculated accordingly.

3. Actual VOC reductions were calculated by comparing influent concentrations from October 1998 and April 1999 (post-test data) with April 1998 (pre-test) data.

4. The percent VOC reduction potentially attributable to the groundwater pumping system was subtracted from the actual VOC reductions observed. In this manner, the remaining VOC reductions are above and beyond what could have been attributed to the groundwater pumping system, and are attributed to the potassium permanganate additions.

As shown in **Table 7**, an analysis of the October 1998 data shows that there were no VOC reductions for 1,2-DCE, DCA or TCE that were above those that were projected by the influent trend graphs for the groundwater pumping system. In contrast, there was a 32 to 42% reduction in total chlorinated VOCs that could be attributed to potassium permanganate. An analysis of the April 1999 data showed the following reductions:

• 1,2-DCE	54%
• 1,1-DCA	40%
• TCE	2%
• Total Chlorinated VOCs	38 to 51%

These VOC reduction calculations are considered underestimates of the VOC reductions attributable to potassium permanganate for the following two reasons:

1. The 1998 additions did not treat the entire area of the groundwater pumping system. Therefore, the plant influent would include treated and untreated areas. Actual reductions in the treated areas would be greater than those calculated for the influent as a whole.

2. The trend analyses in Appendix D projected percent reductions for the groundwater pumping system of 25 to 54%. This means that, without any potassium permanganate additions, VOC reductions in this range could have been anticipated. Based on our experience, these percent reductions are too

high for a groundwater pumping system, especially for one that has been in operation for several years. These high projections are a reflection of the scatter in the influent data and the resulting curve fit. Nonetheless, by subtracting these potential VOC reductions from the actual VOC reductions observed, the resulting VOC reductions are felt to underestimate the efficacy of the potassium permanganate additions.

4.0 CONCLUSIONS

1. The $KMnO_4$ addition could be conducted in a manner that was protective of on-site personnel and the environment. Secondary containment features around the mixing area and application points near the stream were important and are recommended for any future applications.

2. There was no formation clogging that was observed during the test.

3. Field measurements for depth to water, pH, iron, manganese and VOCs (using field GC) had limited utility in evaluating the results of the potassium permanganate additions. In contrast, field measurements of ORP provided excellent information regarding the presence and migration of potassium permanganate in the field.

4. Potassium permanganate reacts quickly with the subsurface media. In all cases (based on ORP measurements), potassium permanganate was expended within two weeks from application or from appearing in a well due to migration.

5. The majority of the $KMnO_4$ additions into SVE wells did not show immediate results during the testing activities. IT believes that the majority of the $KMnO_4$ solution added into the SVE wells was retained, or at least held up temporarily, in the unsaturated soils located below the SVE wells and above the surface of the water table (at depths of 30 to 50 feet below grade). IT believes that this $KMnO_4$ solution slowly became available to the overburden ground water as it slowly drained out of the unsaturated soil matrix.

6. $KMnO_4$ addition into ground water pumping wells showed immediate and significant results, as shown by some of the overburden ground water organic compound testing data. IT believes that the groundwater pumping wells provide the best pathway for addressing the dissolved contaminant mass in the overburden and shallow bedrock zones at the Union Chemical site.

5.0 RECOMMENDATIONS

IT believes that the results generated from the $KMnO_4$ Addition Activities performed this past summer, further confirm the beneficial technical and economic potential of utilizing $KMnO_4$ addition technology on a larger scale at the Union Chemical site as a means towards attaining the ultimate closure goals.

TABLES

TABLE 1
Potassium Permanganate Addition Summary

Potassium Permanganate Test (Summer 1998)
Union Chemical Site, Hope, Maine

Area Evaluated	Vent/Pumping Wells	Date Addition Started	Date Addition Ended	Gallons of 1 % $KMnO_4$ Solution Added	Total Pounds of $KMnO_4$ Added	Estimated Pounds of $KMnO_4$ Added to Overburden	Estimated Pounds of $KMnO_4$ Added to Bedrock
Area 1	V-1	6/16/98	6/19/98	1524	111	111	--
	V-36			1624	119	119	--
	V-36A			1717	125	125	--
Area 2	P-3	6/19/98	6/30/98	1400	102	20	82
	P-5		6/26/98	2573	188	38	150
	P-8		7/2/98	373	27	5	22
	P-13	6/25/98		4287	313	63	250
Area 3	P-10	7/7/98	7/20/98	4308	315	63	252
	P-11			3355	245	49	196
	V-14			4012	293	293	--
	V-19			1018	74	74	--
Area 4	V-12	7/21/98	7/31/98	1904	139	139	--
	V-15			2493	182	182	--
	V-24			2542	186	186	--
	V-20			2546	186	186	--
Area 5	P-16	8/4/98	8/21/98	3728	272	54	218
	P-21			3323	243	49	194
	P-22			1952	142	28	114
	P-25			234	17	3	14
	P-26			3205	234	47	187
			TOTALS	*48,118*	*3,513*	*1,834*	*1,679*

Note: A total of 478 gallons of 1% $KMnO_4$ solution (35 lbs. of $KMnO_4$) was added to B-6A-D from July 7 through July 16, 1998.

TABLE 2
Potassium Permanganate Addition Infiltration Rates

Potassium Permanganate Test (Summer 1998)
Union Chemical Site, Hope, Maine

Addition Event	Addition Well ID	Addition Rate per Well (gpm)	Duration of Addition per Well	Gallons of 1 % $KMnO_4$ Solution Added	Adjacent Active Pumping and Monitoring Wells	Comments/Observations:
Addition #1	V-1	0.3	4 days	1524	P-2, P-3, P-5	
	V-36	0.4	4 days	1624	P-3, P-8, P-13	
	V-36A	0.3	4 days	1717	P-3, P-8, P-10, P-13	
Addition #2	P-3	0.25	7 days	1400	P-2, P-5, P-10, P-11	6/21/98, A buildup of vapor pressure in the P-3 well casing resulted in 50-100 gallon spill of $KMnO_4$ solution in the well box.
	P-5	0.5	5 days	2573	P-2, P-6, P-10, P-11	
	P-8	<0.2	7 days	373	P-10, P-11, P-14, P-15, P-19	Infiltration of $KMnO_4$ solution stalled after 3 days of addition.
	P-13	0.5	5 days	4287	P-10, P-14, P-19, P-20	Potentially high yielding well.
Addition #3	P-10	0.4	10 days	4308	P-5, P-15, P-14, P-19, P-20	
	P-11	0.4	10 days	3355	P-4, P-9, P-12, P-15, P-16, P-16A	
	V-14	0.3	10 days	4012	P-10, P-15, P-19, P-20, P-24	Potentially high yielding well.
	V-19	0.3	10 days	1018	P-14, P-15, P-20, P-24, P-26	
Addition #4	V-12	0.3	9 days	1904	P-9, P-16A, P-16, P-17, P-22, P-23	
	V-15	0.3	9 days	2493	P-16A, P-16, P-20, P-21, P-25	
	V-24	0.3	9 days	2542	P-20, P-21, P-25, P-26	
	V-20	0.3	9 days	2546	P-15, -16, P-21, P-25, P-26	

TABLE 2 (continued)
Potassium Permanganate Addition Infiltration Rates

Potassium Permanganate Test (Summer 1998)
Union Chemical Site, Hope, Maine

Addition Event	Addition Well ID	Addition Rate per Well (gpm)	Duration of Addition per Well	Gallons of 1 % $KMnO_4$ Solution Added	Adjacent Active Pumping and Monitoring Wells	Comments/Observations:
Addition #5	P-16	0.4	12 days	3728	P-16A, P-21, P-22, P-23, P-25	
	P-21	0.5	12 days	3323	P-22, P-26, P-24	
	P-22	0.4	12 days	1952	P-23, P-27 P-29	Potentially high yielding well.
	P-25	<0.1	12 days	234	P-27, P-28. P-29	Infiltration of $KMnO_4$ solution stalled after 3 days of addition.
	P-26	0.4	12 days	3205	P-27. P-28, P-29	Potentially high yielding well.
			TOTALS	***48,118***		

TABLE 3A
Summary of Pre- and Post-Test Laboratory Analytical Results - Pumping Wells (all results in ug/L)

Potassium Permanganate Test (Summer 1998)
Union Chemical Site, Hope, Maine

Site Id:	Period	Date	Chlorinated VOCs								Non-Chlorinated VOCs (BTEX)				Total Chlorinated VOCs	Total Non-Chlorinated VOCs	TOTAL VOCs	DMF	Iron
			1,1-DCA	cis-1,2-DCE	2-Butanone	TCE	1,1-DCE	1,1,1-TCA	VC	Other	Total X	E	T	B					
Groundwater Closure Standards			5	70	170	5	7	200	2		10,000	700	2,000					390	
P-01	Post-test 1997	12/2/97	Not sampled															-	-
P-01	Pre-test 1998	6/4/98	Not sampled															-	-
P-01	Interim 1998	8/31/98	24	33	-	72	-	-	-	11	-	-	-	-	140	-	140	-	-
P-01	Q24/Post Test 1998	10/7/98																-	-
P-01	Q25/Pretest 1999	4/23/99	8	<0.5U	<0.5U	72	<0.5U	<0.5U	<0.5U	3	<1.0	<0.5U	<0.5U	<0.5U	83	-	83	-	-
P-02	Post-test 1997	12/2/97	Not sampled															-	-
P-02	Pre-test 1998	6/4/98	Not sampled															-	-
P-02	Interim 1998	9/1/98	5	2	-	1	-	-	-	9	1	-	2	-	17	3	20	-	-
P-02	Q24/Post Test 1998	10/7/98	Not sampled															-	-
P-02	Q25/Pretest 1999	4/23/99	Not sampled															-	-
P-03	Post-test 1997	12/2/97	Not sampled															-	-
P-03	Pre-test 1998	6/4/98	2	*1,300*	<0.5U	*1,800*	3	<0.5U	72	53	*0.9*	1	3	<0.5U	3,230	5	3,235	27	106,000
P-03	*Interim 1998*	9/1/98	*Not sampled*															-	-
P-03	Q24/Post Test 1998	10/7/98	2	1,600	<0.5U	530	3	<0.5U	23	121	3	2	8	<0.5U	2,279	13	2,292	43	2,700
P-03	Q25/Pretest 1999	4/23/99	2	95	<0.5U	2,900	2	<0.5U	25	7	<1.0	<0.5U	1B	<0.5U	3,031	1	3,032	-	-
P-04	Post-test 1997	12/2/97	Not sampled															-	-
P-04	Pre-test 1998	6/4/98	Not sampled															-	-
P-04	Interim 1998	9/1/98	85	15	6	2	3	-	1	34	15	3	2	-	146	20	166	-	-
P-04	Q24/Post Test 1998	10/7/98	Not sampled															-	-
P-04	Q25/Pretest 1999	4/23/99	Not sampled															-	-
P-05	Post-test 1997	12/2/97	Not sampled															-	-
P-05	Pre-test 1998	6/4/98	Not sampled															-	-
P-05	Interim 1998	8/31/98	12	47	-	6	-	-	-	10	-	-	-	-	75	-	75	-	-
P-05	Q24/Post Test 1998	10/7/98	Not sampled															-	-
P-05	Q25/Pretest 1999	4/23/99	Not sampled															-	-
P-06	Post-test 1997	12/2/97	Not sampled															-	-
P-06	Pre-test 1998	6/4/98	Not sampled															-	-
P-06	*Interim 1998*	8/31/98	96	59	-	17	3	8	5	88	13	5	21	-	276	39	315	-	-
P-06	Q24/Post Test 1998	10/7/98	Not sampled															-	-
P-06	Q25/Pretest 1999	4/23/99	Not sampled															-	-
P-08	Post-test 1997	12/2/97	Not sampled															-	-
P-08	Pre-test 1998	6/4/98	13	*2,300*	<0.5U	*6,300*	7	<0.5U	*290*	273	13	9	35	<0.5U	9,183	57	9,240	110	32,600
P-08	Interim 1998	8/31/98	28	1,800	-	2,800	7	-	140	233	6	3	25	-	5,008	34	5,042	54	-
P-08	Q24/Post Test 1998	10/7/98	390	810	12	830	23	2	22	211	330	5	15	<0.5U	2,300	350	2,650	28	986
P-08	Q25/Pretest 1999	4/23/99	96	2,400	80	7,200	6	2	60	12	41	1	4B	<0.5U	9,856	46	9,902	-	-
P-10	Post-test 1997	12/2/97	Not sampled															-	-
P-10	Pre-test 1998	6/4/98	Not sampled															-	-
P-10	Interim 1998	9/3/98	9	360	-	340	1	-	270	68	36	9	24	2	1,048	71	1,119	-	-
P-10	Q24/Post Test 1998	10/7/98	Not sampled															-	-
P-10	Q25/Pretest 1999	4/23/99	7	750	<0.5U	530	1	<0.5U	220	64	3	<0.5U	1B	<0.5U	1,572	4	1,576	-	-
P-11	Post-test 1997	12/2/97	Not sampled															-	-
P-11	Pre-test 1998	6/4/98	Not sampled															-	-
P-11	*Interim 1998*	8/31/98	*580*	*460*	-	*300*	*120*	*320*	*37*	*120*	2	1	3	1	1,937	7	1,944	-	-
P-11	Q24/Post Test 1998	10/7/98	Not sampled															-	-
P-11	Q25/Pretest 1999	4/23/99	Not sampled															-	-

TABLE 3A

Summary of Pre- and Post-Test Laboratory Analytical Results - Pumping Wells (all results in ug/L)

Potassium Permanganate Test (Summer 1998)
Union Chemical Site, Hope, Maine

Site Id:	Period	Date	Chlorinated VOCs								Non-Chlorinated VOCs (BTEX)				Total Chlorinated VOCs	Total Non-Chlorinated VOCs	TOTAL VOCs	DMF	Iron
			1,1-DCA	cis-1,2-DCE	2-Butanone	TCE	1,1-DCE	1,1,1-TCA	VC	Other	Total X	E	T	B					
Groundwater Closure Standards			*5*	*70*	*170*	*5*	*7*	*200*	**2**		*10,000*	*700*	*2,000*					*390*	
P-12	Post-test 1997	12/2/97								Not sampled								-	-
P-12	Pre-test 1998	6/4/98	*2,400*	*1,000*	*220*	*1,600*	*230*	*2,000*	4	293	*130*	42	*270*	2	7,747	444	8,191	140	39,400
P-12	Interim 1998	8/31/98	670	280	41	300	54	470	8	116	123	34	400	1	1,939	558	2,497	460	
P-12	Q24/Post Test 1998	10/7/98	520	170	6	160	22	140	8	96	98	28	430	1	1,122	557	1,679	220	24,300
P-12	*Q25/Pretest 1999*	*4/23/99*								*Not sampled*								-	-
P-13	Post-test 1997	12/2/97								Not sampled								-	-
P-13	Pre-test 1998	6/4/98								Not sampled								-	-
P-13	Interim 1998	9/3/98	-	880	-	1,200	-	-	-	301	<1	-	-	-	2,381	-	2,381	-	-
P-13	Q24/Post Test 1998	10/7/98								Not sampled								-	-
P-13	Q25/Pretest 1999	4/23/99								Not sampled								-	-
P-14	Post-test 1997	12/2/97								*Not sampled*								-	-
P-14	Pre-test 1998	6/4/98								Not sampled								-	-
P-14	Interim 1998	8/31/98	120	1,100	-	560	22	-	90	301	*1.1*	1	2	-	2,193	4	2,197	-	-
P-14	Q24/Post Test 1998	6/4/98								Not sampled								-	-
P-14	Q25/Pretest 1999	6/4/98								Not sampled								-	-
P-16	Post-test 1997	12/2/97	1,900	1,400	280	620	380	66	28	511	1,130	310	670	2	5,185	2,112	7,297	-	2,630
P-16	Pre-test 1998	6/4/98	*3,300*	*2,200*	*320*	*140*	*350*	*110*	93	592	*1,660*	880	*500*	2	7,105	3,042	10,147	1,800	3,280
P-16	*Interim 1998*	*8/31/98*								*Not sampled*								-	-
P-16	Q24/Post Test 1998	10/7/98	2,400	1,800	130	710	210	210	42	537	7,400	760	280	1	6,039	8,441	14,480	540	1,930
P-16	Q25/Pretest 1999	4/23/99	2,000	1,300	31	310	200	160	79	329	910	98	23B	1	4,409	1,032	5,441	-	-
P-16A	Post-test 1997	12/2/97	3,400	3,800	1,700	770	640	66	40	621	9100B	1,500	870	4	11,037	11,474	22,511	-	31,800
P-16A	*Pre-test 1998*	6/4/98								*Not sampled*								-	-
P-16A	Interim 1998	8/31/98	2,100	770	170	29	110	18	280	315	3,170	640	690	2	3,792	4,502	8,294	-	-
P-16A	Q24/Post Test 1998	10/7/98								Not sampled								-	-
P-16A	Q25/Pretest 1999	4/23/99								Not sampled								-	-
P-17	Post-test 1997	12/2/97								Not sampled								-	-
P-17	Pre-test 1998	6/4/98								Not sampled								-	-
P-17	Interim 1998	8/31/98	1,500	1,200	32	120	150	58	19	252	550	63	83	1	3,331	697	4,028	-	-
P-17	*Q24/Post Test 1998*	*10/7/98*								*Not sampled*								-	-
P-17	Q25/Pretest 1999	4/23/99								Not sampled								-	-
P-19	Post-test 1997	12/2/97								Not sampled								-	-
P-19	Pre-test 1998	6/4/98								Not sampled								-	-
P-19	Interim 1998	9/1/98	9	360	-	450	1	-	2	61	-	-	-	-	883	-	883	-	-
P-19	Q24/Post Test 1998	10/7/98	17	430	<0.5U	430	2	<0.5U	2	45	17	1	1	<0.5U	926	19	945	<3.0U	2,270
P-19	Q25/Pretest 1999	4/23/99								**Not sampled**								-	-
P-20	Post-test 1997	12/2/97	200	1,500	3	290	26	<0.5U	110	158	153	17	10	<0.5U	2,287	180	2,467	-	964
P-20	Pre-test 1998	6/4/98								Not sampled								-	-
P-20	Interim 1998	9/1/98	610	890	-	310	38	3	180	233	171	8	14	-	2,264	193	2,457	-	-
P-20	Q24/Post Test 1998	10/7/98								Not sampled								-	-
P-20	Q25/Pretest 1999	4/23/99								*Not sampled*								-	-

TABLE 3A

Summary of Pre- and Post-Test Laboratory Analytical Results - Pumping Wells (all results in ug/L)

Potassium Permanganate Test (Summer 1998)
Union Chemical Site, Hope, Maine

Site Id:	Period	Date	Chlorinated VOCs								Non-Chlorinated VOCs (BTEX)				Total Chlorinated VOCs	Total Non-Chlorinated VOCs	TOTAL VOCs	DMF	Iron
			1,1-DCA	cis-1,2-DCE	2-Butanone	TCE	1,1-DCE	1,1,1-TCA	VC	Other	Total X	E	T	B					
Groundwater Closure Standards			5	70	170	5	7	200	2		10,000	700	2,000					390	
P-21	Post-test 1997	12/2/97	**5,700**	**1,700**	**3,900**	**3,500**	**630**	**2,900**	**16**	2,260	14000B	**1,400**	1,800	3	20,606	17,203	37,809	-	727
P-21	Pre-test 1998	6/4/98	Not sampled															-	-
P-21	Interim 1998	9/1/98	Not sampled															-	-
P-21	Q24/Post Test 1998	10/7/98	Not sampled															-	-
P-21	Q25/Pretest 1999	4/23/99	Not sampled															-	-
P-22	Post-test 1997	12/2/97	**5,800**	**1,800**	**4,300**	**4,000**	**700**	32	**16**	1,328	7400B	**1,500**	1,100	5	17,976	10,005	27,981	-	5,270
P-22	*Pre-test 1998*	6/4/98	***4,600***	***2,200***	***3,700***	***1,400***	***530***	*56*	**55**	813	*2,080*	***1,400***	*740*	4	13,354	*4,224*	17,578	**2,400**	*4,750*
P-22	Interim 1998	9/1/98	Not sampled															-	-
P-22	Q24/Post Test 1998	10/7/98	**3,000**	**960**	**4,100**	**930**	**230**	4	**14**	284	2,350	540	360	3	9,522	3,253	12,775	**1,800**	198
P-22	Q25/Pretest 1999	4/7/99	**3,567**	1	**1,900**	**1,317**	**433**	3	**17**	772	1,433	370	160	4	8,008	1,967	9,975	**1,010**	-
P-22	Q25/Pretest 1999	4/23/99	**2,000**	**960**	**3,800**	**290**	**120**	1	**5**	130	1,620	140	110B	1	7,306	1,871	9,177	-	-
P-23	Post-test 1997	12/2/97	Not sampled															-	-
P-23	Pre-test 1998	6/4/98	Not sampled															-	-
P-23	*Interim 1998*	8/31/98	***2,400***	***920***	***660***	***200***	***100***	*32*	***7***	*241*	*900*	*160*	*390*	2	*4,560*	1,452	6,012	-	-
P-23	Q24/Post Test 1998	10/7/98	**3,100**	**1,100**	**1,200**	**130**	**510**	85	**18**	332	286	61	350	2	6,485	699	7,184	**2,700**	1,980
P-23	Q25/Pretest 1999	4/23/99	Not sampled															-	-
P-24	Post-test 1997	12/2/97	Not sampled															-	-
P-24	Pre-test 1998	6/4/98	Not sampled															-	-
P-24	Interim 1998	9/1/98	**62**	**500**	-	**270**	3	-	**5**	30	3	2	-	-	870	5	875	-	-
P-24	Q24/Post Test 1998	10/7/98	**46**	**420**	<0.5U	**230**	3	<0.5U	**4**	28	8	3	<0.5U	<0.5U	731	11	742	<3.0U	158
P-24	Q25/Pretest 1999	4/7/99	**66**	**160**	6	**115**	6	<0.5U	**4**	7	3	2	1	<0.5U	364	6	370	11	-
P-24	Q25/Pretest 1999	4/9/99	***32***	*4*	<0.5U#		*2*	<0.5U#	**2**		*7*	*2*	*0.8*	<0.5U#	-	10	10	*13*	-
P-25	*Post-test 1997*	12/2/97	***1,900***	***1,900***	*14*	***680***	***160***	*<0.5U*	**53**	117	*2660B*	*480*	*190*	1	4,824	3,331	8,155	-	*407*
P-25	Pre-test 1998	6/4/98	***1,200***	***2,200***	***310***	***290***	***190***	10	***870***	303J	*1,590*	*500*	*230*	1	5,373	2,321	7,694	**430**	3,090
P-25	Interim 1998	9/3/98	**3,200**	**1,900**	**390**	**490**	**160**	6	**34**	362	8,100	460	390	1	6,542	8,951	15,493	**720**	-
P-25	Q24/Post Test 1998	10/7/98	**2,800**	**1,900**	150	**410**	**180**	20	**57**	358	2,000	85	180	0.8	5,875	2,266	8,141	**460**	3,700
P-25	Q25/Pretest 1999	4/23/99	**2,700**	**1,900**	85	**310**	**120**	3	**55**	170	2,940	24	41B	0.6	5,343	3,006	8,349	-	-
P-27	Post-test 1997	12/2/97	Not sampled															-	-
P-27	Pre-test 1998	6/4/98	Not sampled															-	-
P-27	Interim 1998	9/1/98	**1,000**	**1,000**	94	**160**	**89**	5	**260**	294	3,220	**780**	140	1	2,902	4,141	7,043	-	-
P-27	Q24/Post Test 1998	10/7/98	**1,500**	**1,200**	55	**190**	**150**	<0.5U	**190**	288	2,910	**680**	78	1	3,573	3,669	7,242	**1,600**	129
P-27	Q25/Pretest 1999	4/23/99	Not sampled															-	-
P-28	Post-test 1997	12/2/97	Not sampled															-	-
P-28	Pre-test 1998	6/4/98	***3,200***	***4,000***	***2,000***	***330***	***560***	*190*	***51***	451	*2,490*	***1,900***	*660*	3	10,782	5,053	15,835	**4,900**	1,550
P-28	Interim 1998	9/1/98	**2,300**	**3,500**	**1,400**	**220**	**470**	14	**98**	413	8,000	**2,000**	530	2	8,415	10,532	18,947	**4,900**	-
P-28	Q24/Post Test 1998	10/7/98	**2,300**	**3,200**	**630**	**160**	**460**	<0.5U	**110**	205	6,900	**1,500**	460	2	7,065	8,862	15,927	**3,700**	152
P-28	Q25/Pretest 1999	4/23/99	**670**	**1,400**	<0.5U	**37**	**40**	10	**18**	63	12	3	1	<0.5U	2,238	16	2,254	-	-
P-29	Post-test 1997	12/2/97	Not sampled															-	-
P-29	*Pre-test 1998*	6/4/98	*Not sampled*															-	-
P-29	Interim 1998	9/1/98	**3,800**	**1,700**	**510**	**89**	**520**	-	**22**	341	2,990	690	250	2	6,982	3,932	10,914	-	-
P-29	Q24/Post Test 1998	10/7/98	**53,000**	**20,000**	150	**120**	**9,400**	<0.5U	<0.5U	216	23,400	**8,800**	170	2	82,886	32,372	115,258	**2,100**	140
P-29	Q25/Pretest 1999	4/23/99	Not sampled															-	-

Notes:
Values exceeding Groundwater Closure Standards shown in emboldened text
All other analytes are the sum of all other constitutes present at less than 1% of the total VOCs
Data qualified with a D or J been used at their reported concentration, qualified data shown in italicized text
Where multiple sample results were completed on the same day (i.e., duplicates), the results were averaged for use herein.
DMF is not included in this analysis

-	*Indicates no data for this analyte or no analysis was completed*
N/A	*Not analyzed, not available or not calculated*

TABLE 3B
Summary of Pre- and Post-Test Laboratory Analytical Results - Monitoring Wells (all results in ug/L)

Potassium Permanganate Test (Summer 1998)
Union Chemical Site, Hope, Maine

Site Id:	Period	Date	Chlorinated VOCs								Non-Chlorinated VOCs (BTEX)				Total	Total	
			1,1-DCA	cis-1,2-DCE	2-Butanone	TCE	1,1-DCE	1,1,1-TCA	VC	Other	Total X	E	T	B	Chlorinated VOCs	n-Chlorinat VOCs	TOTAL VOCs
Groundwater Closure Standards			5	70	170	5	7	200	2		10,000	700	2,000				
B-Series Monitoring Wells																	
B-1A-D	Q22	10/22/97	<0.5U	<0.5U	2	<0.5U	<0.5U	<0.5U	<0.5U	1	*0.7*	<0.5U	<0.5U	<0.5U	3	*0.7*	3
B-1A-D	Q23	4/29/98	Not Sampled														
B-1A-D	Q24	10/6/98	Not Sampled														
B-1A-D	Q25	4/6/99	Not Sampled														
B-2A-I	Q22	10/22/97	20	1	<0.5U	<0.5U	<0.5U	<0.5U	<0.5U	3	<1U	<0.5U	<0.5U	<0.5U	24	<1	24
B-2A-I	Q23	4/29/98	42	1	3	1	2	<0.5U	<0.5U	5	<1.0U	<0.5U	<0.5U	<0.5U	53	<1.0	53
B-2A-I	Q24	10/6/98	34	1	<0.5U	<0.5U	1	<0.5U	<0.5U	4	<1.0	<0.5U	<0.5U	<0.5U	40	<1.0	40
B-2A-I	Q25	4/6/99	48	1	<0.5U	<0.5U	2	<0.5U	<0.5U	11	<1.0	<0.5U	<0.5U	<0.5U	62	<1.0	62
B-2B-S	Q22	10/22/97	Not Sampled														
B-2B-S	Q23	4/30/98	<0.5U	<0.5U	<0.5U	<0.5U	<0.5U	<0.5U	<0.5U	<5	<1.0U	<0.5U	<0.5U	<0.5U	<5	<1.0	
B-2B-S	Q24	10/6/98	13	<0.5U	<0.5U	<0.5U	1	1	<0.5U	<1	<1.0	<0.5U	<0.5U	<0.5U	14	<1.0	14
B-2B-S	Q25	4/6/99	<0.5U	<0.5U	<0.5U	<0.5U	<0.5U	<0.5U	<0.5U	<1	<1.0	<0.5U	<0.5U	<0.5U	<1	<1.0	
B-4B-D	Q22	10/21/97	280	170	8	88	63	73	1	71	<3U	<1U	<1U	<1U	754	<3	754
B-4B-D	Q23	4/29/98	Not Sampled														
B-4B-D	Q24	10/6/98	Not Sampled														
B-4B-D	Q25	4/6/99	Not Sampled														
B-5A-D	Q22	10/23/97	81	<0.5U	<0.5U	<0.5U	<0.5U	<0.5U	<0.5U	<1	<1.0U	<0.5U	<0.5U	<0.5U	81	<1.0	81
B-5A-D	Q23	4/28/98	70	<0.5U	<0.5U	0.5	1	<0.5U	<0.5U	6	<1.0U	<0.5U	<0.5U	<0.5U	78	<1.0	78
B-5A-D	Q24	10/6/98	280	<0.5U	<0.5U	<0.5U	5	<0.5U	<0.5U	<1	<1.0	<0.5U	<0.5U	<0.5U	285	<1.0	285
B-5A-D	Q25	4/7/99	170	<0.5U	<0.5U	<0.5U	5	<0.5U	<0.5U	3	<1.0	<0.5U	<0.5U	<0.5U	178	<1.0	178
B-5B-I	Q22	10/23/97	600	3	36	*1*	*18*	3	<0.5U	3	*0.6*	<0.5U	<0.5U	<0.5U	664	*0.6*	665
B-5B-I	Q23	4/29/98	690	2	7	<0.8	29	0.8	0.6	2	<1.0U	0.7	<0.5U	<0.5U	731	0.7	732
B-5B-I	Q24	10/6/98	340	3	<0.5U	1	13	1	<0.5U	1	<1.0	<0.5U	<0.5U	<0.5U	359	<1.0	359
B-5B-I	Q25	4/7/99	580	<0.5U	<0.5U	<0.5U	33	<0.5U	0.9	3	<1.0	<0.5U	<0.5U	<0.5U	617	<1.0	617
B-5B-S	Q22	10/23/97	160	20	<0.5U	10	*34*	*19*	<0.5U	10	<1U	<0.5U	<0.5U	<0.5U	253	<1	253
B-5B-S	Q23	4/29/98	2	1	<0.5U	<2	0.9	<0.5U	<0.5U	1	<1.0U	<0.5U	<0.5U	<0.5U	5	<1.0	5
B-5B-S	Q24	10/6/98	Not Sampled														
B-5B-S	Q25	4/7/99	17	<0.5U	<0.5U	0.8	1	<0.5U	<0.5U	1	<1.0	<0.5U	<0.5U	<0.5U	20	<1.0	20
B-6A-D	Q22	10/20/97	*1,700*	*860*	*28*	*25*	*62*	*4*	*6*	*90*	*1,470*	*670*	*190*	*0.8*	*2,775*	*2,331*	*5,106*
B-6A-D	Q23	4/29/98	1,100	540	5	7	41	<0.5U	5	98	940	480	190	0.5	1,796	1,611	3,407
B-6A-D	Q24	10/6/98	Not Sampled														
B-6A-D	Q25	4/5/99	350	190	3	8	7	<0.5U	1	29	15	26	1	<0.5U	588	42	630
B-6A-D	Pretest 1999	4/23/99	Not Sampled														
B-6B-I	Q22	10/20/97	*3,300*	*3,300*	*830*	*650*	*370*	*110*	*5*	*1,378*	*6,000*	*1,000*	*1,000*	*4*	*9,943*	*8,004*	*17,947*
B-6B-I	Q23 *	4/29/98	*60*	*58*	*24*	*27*	*8*	*5*	*<0.5U*	*45*	*117*	*22*	*2*	*<0.5U*	225	156	*381*
B-6B-I	Q24	10/6/98	Not Sampled														
B-6B-I	Q25	4/7/99	*26*	*30*	*7*	*16*	*5*	*5*	*<0.5U*	*19*	*45*	*13*	*3*	*<0.5U*	*106*	*61*	*167*
B-6B-I	Pretest 1999	4/23/99	36	<0.5U	<0.5U	20	5	6	0.5	31	64	19	2	<0.5U	99	85	184

TABLE 3B
Summary of Pre- and Post-Test Laboratory Analytical Results - Monitoring Wells (all results in ug/L)

Potassium Permanganate Test (Summer 1998)
Union Chemical Site, Hope, Maine

Site Id:	Period	Date	Chlorinated VOCs								Non-Chlorinated VOCs (BTEX)				Total Chlorinated VOCs	Total n-Chlorinat VOCs	TOTAL VOCs
			1,1-DCA	cis-1,2-DCE	2-Butanone	TCE	1,1-DCE	1,1,1-TCA	VC	Other	Total X	E	T	B			
Groundwater Closure Standards			5	70	170	5	7	200	2		10,000	700	2,000				
B-8A-D	Q22	10/22/97	800	33	80	26	330	<0.5U	3	20	42	21	50	0.9	1,292	114	1,406
B-8A-D	Q23	4/27/98	780	32	160	23	270	<0.5U	3	26	28	17	43	0.9	1,294	89	1,383
B-8A-D	Interim 1998	8/31/98	710	33	580	24	240	-	3	40	28	15	27	0.9	1,630	71	1,701
B-8A-D	Q24	10/6/98	600	19	99	11	140	<0.5U	2	13	13	4	12	0.5	884	30	914
B-8A-D	Q25	4/5/99	660	32	70	20	240	<0.5U	3	21	31	17	32	0.9	1,046	81	1,127
B-8B-I	Q22	10/22/97	14	2	<0.5U	1	7	0.6	<0.5U	1	0.6	<0.5U	<0.5U	<0.5U	26	0.6	27
B-8B-I	Q23	4/27/98	4	<0.5U	<0.5U	<0.5U	2	<0.5U	<0.5U	2	<1.0U	<0.5U	<0.5U	<0.5U	8	<1.0	8
B-8B-I	Interim 1998	8/31/98	Not Sampled														
B-8B-I	Q24	10/6/98	7	0.6	<0.5U	0.7	3	<0.5U	<0.5U	<1	<1.0	<0.5U	<0.5U	<0.5U	11	<1.0	11
B-8B-I	Q25	4/5/99	3	0.8	<0.5U	1	2	2	<0.5U	3	<1.0	<0.5U	<0.5U	<0.5U	12	<1.0	12
B-8C-S	Q22	10/22/97	<0.5U	<0.5U	<0.5U	<0.5U	<0.5U	<0.5U	<0.5U	<1	<1U	<0.5U	<0.5U	<0.5U	<1	<1	
B-8C-S	Q23	4/27/98	<0.5U	<0.5U	<0.5U	<0.5U	<0.5U	<0.5U	15	<2	<1.0U	<0.5U	<0.5U	<0.5U	15	<1.0	15
B-8C-S	Interim 1998	8/31/98	Not Sampled														
B-8C-S	Q24	10/6/98	3	<0.5U	<0.5U	<0.5U	<0.5U	<0.5U	<0.5U	<1	<1.0	<0.5U	<0.5U	<0.5U	3	<1.0	3
B-8C-S	Q25	4/5/99	<0.5U	<0.5U	<0.5U	<0.5U	<0.5U	<0.5U	<0.5U	3	<1.0	<0.5U	<0.5U	<0.5U	3	<1.0	3
B-9A-I	Q22	10/22/97	Not Sampled														
B-9A-I	Q23	4/30/98	600	330	5	170	52	10	1	82	42	4	8	<0.5U	1,250	54	1,304
B-9A-I	Q24	10/7/98	2,300	1,300	<0.5U	520	240	0.7	6	231	114	64	18	2	4,598	198	4,796
B-9A-I	Q25	4/6/99	910	<5U	63	300	100	5	3	113	17	10	6	0.9	1,494	34	1,528
B-12A-D	Q22	10/21/97	<0.5U	<0.5U	<0.5U	<0.5U	<0.5U	<0.5U	<0.5U	<2		<0.5U	<0.5U	<0.5U	<2		
B-12A-D	Q23	4/30/98	<0.5U	<0.5U	<0.5U	<0.5U	<0.5U	<0.5U	<0.5U	<1	<1.0U	<0.5U	<0.5U	<0.5U	<1	<1.0	
B-12A-D	Q24	10/6/98	<0.5U	<0.5U	<0.5U	<0.5U	<0.5U	<0.5U	<0.5U	<2	<1.0	<0.5U	<0.5U	<0.5U	<2	<1.0	
B-12A-D	Q25	4/7/99	7	5	<0.5U	6	2	7	<0.5U	4	<1.0	<0.5U	<0.5U	<0.5U	31	<1.0	31
B-12B-I	Q22	10/21/97	5,300	4,200	3,800	2,600	1,600	180	33	2,610	12,200	2,800	1,400	5	20,323	16,405	36,728
B-12B-I	Q23	4/30/98	1,300	1,300	1,400	560	420	390	15	773	3,600	810	350	3	6,158	4,763	10,921
B-12B-I	Q24	10/6/98	1,900	1,600	1,300	670	480	4	16	308	5,000	1,200	460	2	6,258	6,662	12,920
B-12B-I	Q25	4/7/99	790	<0.5U	160	430	230	190	9	283	2,140	470	180	1	2,092	2,791	4,883
B-12C-S	Q22	10/21/97	Not Sampled														
B-12C-S	Q23	4/30/98	190	270	19	410	200	1,400	1	635	249	39	25	<0.5U	3,125	313	3,438
B-12C-S	Q24	10/6/98	Not Sampled														
B-12C-S	Q25	4/6/99	290	350	<0.5U	470	120	1,000	1	381	318	57	2	0.6	2,611	377	2,988
B-13A-D	Q22	10/21/97	13	110	<2U	11	9	<0.5U	<0.5U	3	<4U	7	<0.5U	<0.5U	146	7	153
B-13A-D	Q23	4/27/98	5	52	<0.5U	27	3	<0.5U	1	4	<1.0U	3	<0.5U	<0.5U	92	3	95
B-13A-D	Q24	10/7/98	2	41	<0.5U	25	2	<0.5U	<0.5U	4	0.5	2	<0.5U	<0.5U	74	2.5	77
B-13A-D	Q25	4/5/99	9	56	12	4	3	<0.5U	8	32	5	17	<0.5U	<0.5U	124	22	146
B-13B-I	Q22	10/21/97	52	450	<5U	43	35	<0.5U	2	15	24	32	0.8	<0.5U	597	57	654
B-13B-I	Q23	4/27/98	18	230	<0.5U	23	16	<0.5U	4	16	7	14	<0.5U	<0.5U	307	21	328
B-13B-I	Q24	10/7/98	8	170	<0.5U	18	11	<0.5U	0.9	12	5	15	<0.5U	<0.5U	220	20	240
B-13B-I	Q25	4/6/99	18	230	4	20	16	<0.5U	3	19	5	22	<0.5U	<0.5U	310	27	337
B-13C-S	Q22	10/22/97	100	460	20	66	39	<2.5U	39	117	105	70	13	<2.5U	841	188	1,029
B-13C-S	Q23	4/28/98	35	140	7	8	10	<0.5U	16	45	11	14	3	<0.5U	261	28	289
B-13C-S	Q24	10/7/98	12	63	<0.5U	11	4	<0.5U	6	34	7	16	0.7	<0.5U	130	24	154
B-13C-S	Q25	4/5/99	0.9	18	10	23	<0.5U	<0.5U	<0.5U	6	<1.0	0.7	<0.5U	<0.5U	58	0.7	59

TABLE 3B
Summary of Pre- and Post-Test Laboratory Analytical Results - Monitoring Wells (all results in ug/L)

Potassium Permanganate Test (Summer 1998)
Union Chemical Site, Hope, Maine

Site Id:	Period	Date	Chlorinated VOCs								Non-Chlorinated VOCs (BTEX)				Total Chlorinated VOCs	Total n-Chlorinat VOCs	TOTAL VOCs
			1,1-DCA	cis-1,2-DCE	2-Butanone	TCE	1,1-DCE	1,1,1-TCA	VC	Other	Total X	E	T	B			
Groundwater Closure Standards			5	70	170	5	7	200	2		10,000	700	2,000				
Former Extraction wells																	
EW-1	Q22	10/21/97	630	*190*	27	58	250	<0.5U	3	20	*103*	*43*	*11*	1	1,178	*158*	1,336
EW-1	Q23	4/29/98	390	130	41	23	120	<2.5U	3	17	27	24	13	<2.5U	724	64	788
EW-1	Q24	10/9/98	330	110	5	23	100	<0.5U	2	20	26	28	13	0.7	590	68	658
EW-1	Q25	4/6/99	260	100	<0.5U	39	180	<0.5U	3	16	*0.5*	<0.5U	<0.5U	<0.5U	598	*0.5*	599
EW-3	Q22	10/21/97	Not Sampled														
EW-3	Q23	4/29/98	Not Sampled														
EW-3	Q24	10/9/98	Not Sampled														
EW-3	Q25	4/23/99	4	<0.5U	<0.5U	32	0.8	<0.5U	<0.5U	3	<1.0	<0.5U	<0.5U	<0.5U	40	<1.0	40
EW-4	Q22	10/21/97	17	13	<0.5U	9	<0.5U	<0.5U	<0.5U	5	<0.5U	<0.5U	<0.5U	<0.5U	44	<0.5	44
EW-4	Q23	4/29/98	32	21	<0.5U	6	0.9	0.5	6	18	<1.0U	<0.5U	0.6	<0.5U	84	0.6	85
EW-4	Q24	10/7/98	38	16	<0.5U	7	0.6	1	<0.5U	33	0.6	<0.5U	1	<0.5U	96	2	98
EW-4	Q25	4/6/99	25	13	3	4	<0.5U	0.8	<0.5U	9	<1	<0.5U	<0.5U	<0.5U	55	<1	55
MW-series monitoring wells																	
MW-11-S	Q22	10/21/97	<0.5U	<0.5U	<0.5U	<0.5U	<0.5U	<0.5U	<0.5U	2	<1U	<0.5U	<0.5U	<0.5U	2	<1	2
MW-11-S	Q23	4/29/98	Not Sampled														
MW-11-S	Q24	10/7/98	Not Sampled														
MW-11-S	Q25	4/6/99	Not Sampled														
MW-12-S	Q22	10/22/97	<2U	<0.5U	<0.5U	0.5	<0.5U	2	<0.5U	<1	<1U	<0.5U	<0.5U	<0.5U	3	<1	3
MW-12-S	Q23	4/29/98	Not Sampled														
MW-12-S	Q24	10/7/98	Not Sampled														
MW-12-S	Q25	4/6/99	Not Sampled														
MW-13A-D	Q22	10/21/97	9	80	<0.5U	29	6	<0.5U	<0.5U	2	<2U	<4U	<0.5U	<0.5U	126	<4	126
MW-13A-D	Q23	4/29/98	Not Sampled														
MW-13A-D	Q24	10/7/98	Not Sampled														
MW-13A-D	Q25	4/6/99	Not Sampled														
MW-14-S	Q22	10/21/97	*13*	460	350	2,400	6	6	1	2,463	*27*	*6*	<1U	<0.5U	5,699	*33*	5,732
MW-14-S	Q23	4/28/98	*<0.5U*	*4*	*<0.5U*	*54*	*<0.5U*	*0.6*	*<0.5U*	*7*	*<1.0U*	*<0.5U*	*<0.5U*	*<0.5U*	*66*	*<1.0*	*66*
MW-14-S	Q24	10/7/98	*10*	290	<0.5U	1,900	6	<0.5U	2	1,992	3	3	1	<0.5U	4,200	7	4,207
MW-14-S	Q25	4/6/99	<0.5U	1	<0.5U	20	<0.5U	0.8	<0.5U	7	<1.0	<0.5U	<0.5U	<0.5U	29	<1.0	29
MW-15-D	Q22	10/21/97	*18*	*810*	490	61	<5U	<5U	<5U	51	*29*	*9*	67	<5U	1,430	*105*	1,535
MW-15-D	Q23	4/28/98	*2*	*1,300*	460	220	*3*	<0.5U	*5*	50	*7.0U*	2	180	<0.5U	2,040	*189*	2,229
MW-15-D	Q24	10/7/98	1	980	4,100	170	2	<0.5U	3	60	8	2	130	<0.5U	5,316	140	5,456
MW-15-D	Q25	4/6/99	1	700	130	170	1	<0.5U	1	35	3	1	72	<0.5U	1,038	76	1,114

Notes:
Values exceeding Groundwater Closure Standards shown in emboldened text
All other analytes are the sum of all other constituents present at less than 1% of the total VOCs
Data qualified with a D or J been used at their reported concentration, qualified data shown in italicized text
Where multiple sample results were completed on the same day (I.e., duplicates), the results were averaged for use herein.
DMF is not included in this analysis

-	*Indicates no data for this analyte or no analysis was completed*
N/A	*Not analyzed, not available or not calculated*

TABLE 4
Summary of Pre- and Post-Test Laboratory Analytical Results
Total Iron and Manganese Concentrations in Groundwater

Potassium Permanganate Test (Summer 1998)
Union Chemical Site, Hope, Maine

Location / Collection	Sample Date	Iron (mg/l)	Manganese (mg/l)
P-3			
Pre-Test	6/4/98	106	3.51
Post-Test [2]	10/7/98	2.7	0.511
% change		*- 97%*	*- 85%*
P-8			
Pre-Test	6/4/98	32.6	1.62
Post-Test [1]	8/31/98	0.986	4.5
% change		*- 97%*	*+ 178%*
P-12			
Pre-Test	6/4/98	39.4	2.01
Post-Test 1[1]	8/31/98	24.3	2.13
% change		*- 38%*	*+ 6%*
P-16			
Pre-Test	6/4/98	3.28	1.05
Post-Test [2]	10/7/98	1.93	6.5
% change		*- 41%*	*+ 519%*
P-22			
Pre-Test	6/4/98	4.75	0.27
Post-Test [2]	10/7/98	0.198	0.289
% change		- 96%	+ 7%
P-25			
Pre-Test	6/4/98	3.09	0.119
Post-Test [2]	10/7/98	3.7	7.84
% change		+ 20%	+ 6500%

TABLE 4 (continued)
Summary of Pre- and Post-Test Laboratory Analytical Results

Potassium Permanganate Test (Summer 1998)
Union Chemical Site, Hope, Maine

Location / Collection	***Sample Date***	***Iron (mg/l)***	***Manganese (mg/l)***
P-28			
Pre-Test	6/4/98	1.55	0.208
Post-Test [1]	8/31/98	0.152	0.124
% change		*- 90%*	*- 40%*
Average % decrease for all seven wells		*- 63%*	*+1010%*

Notes:
Pre-Test sampling event performed on 6/4/98.
[1] = post sampling event performed on 8/31/98
[2] = post test sampling event performed on 10/7/98

Table 5
Pre and Post Addition Infiltration Rate Testing

Potassium Permanganate Test (Summer 1998)
Union Chemical Site, Hope, Maine

Location	*Date Performed*	*Measured Infiltration Rate (gpm)*	*Comments:*
P-3			
Pre-Addition	6/19/98	<0.2	
Post-Addition	7/02/98	<0.1	
% change		--	
P-8			
Pre-Addition	6/19/98	<0.1	
Post-Addition	--	--	*not performed due to stoppage of infiltration during addition activities (see report section 3.1.4)*
% change		--	
P-13			
Pre-Addition	6/25/98	0.45	
Post-Addition	7/6/98	0.5	
% change		*+11 %*	
V-1			
Pre-Addition	6/16/98	0.25	
Post-Addition	6/19/98	0.3	
% change		*+20 %*	
V-36			
Pre-Addition	6/16/98	0.25	
Post-Addition	6/19/98	0.2	
% change		*-20%*	
V-36A			
Pre-Addition	6/16/98	0.25	
Post-Addition	6/16/98	0.25	
% change		*0 %*	

TABLE 6

Comparison of the Locations and Depths of the $KMnO_4$ SVE Addition Points and the Nearest Soil Closure Sample Location

Potassium Permanganate Test (Summer 1998)
Union Chemical Site, Hope, Maine

$KMnO_4$ Addition Well	$KMnO_4$ Addition Depth	Nearest Soil Closure Point ID	Lateral Distance from $KMnO_4$ Point	Soil Closure Sample Depth
V-1	2-20 ft. bgs	**1-4**	26 ft.	4.9 ft. bgs
V-36	3.5-21.5 ft. bgs	**1-12**	28 ft.	5.6 ft. bgs
V-36a	6-24 ft. bgs	**1-3**	40 ft.	3.4 ft. bgs
V-12	7.3-25.3 ft. bgs	**1-9**	15 ft.	8.5 ft. bgs
V-14	9-32 ft. bgs	**1-15**	20 ft.	2.9 ft. bgs
V-15	9-32 ft. bgs	**1-33**	24 ft.	11.1 ft. bgs
V-19	7-30 ft. bgs	**1-15**	30 ft.	2.9 bgs
V-20	7-30 ft. bgs	**2-6**	24 ft.	10.2 ft. bgs
V-24	6-24 ft. bgs	**2-4**	12 ft.	8.2 ft. bgs

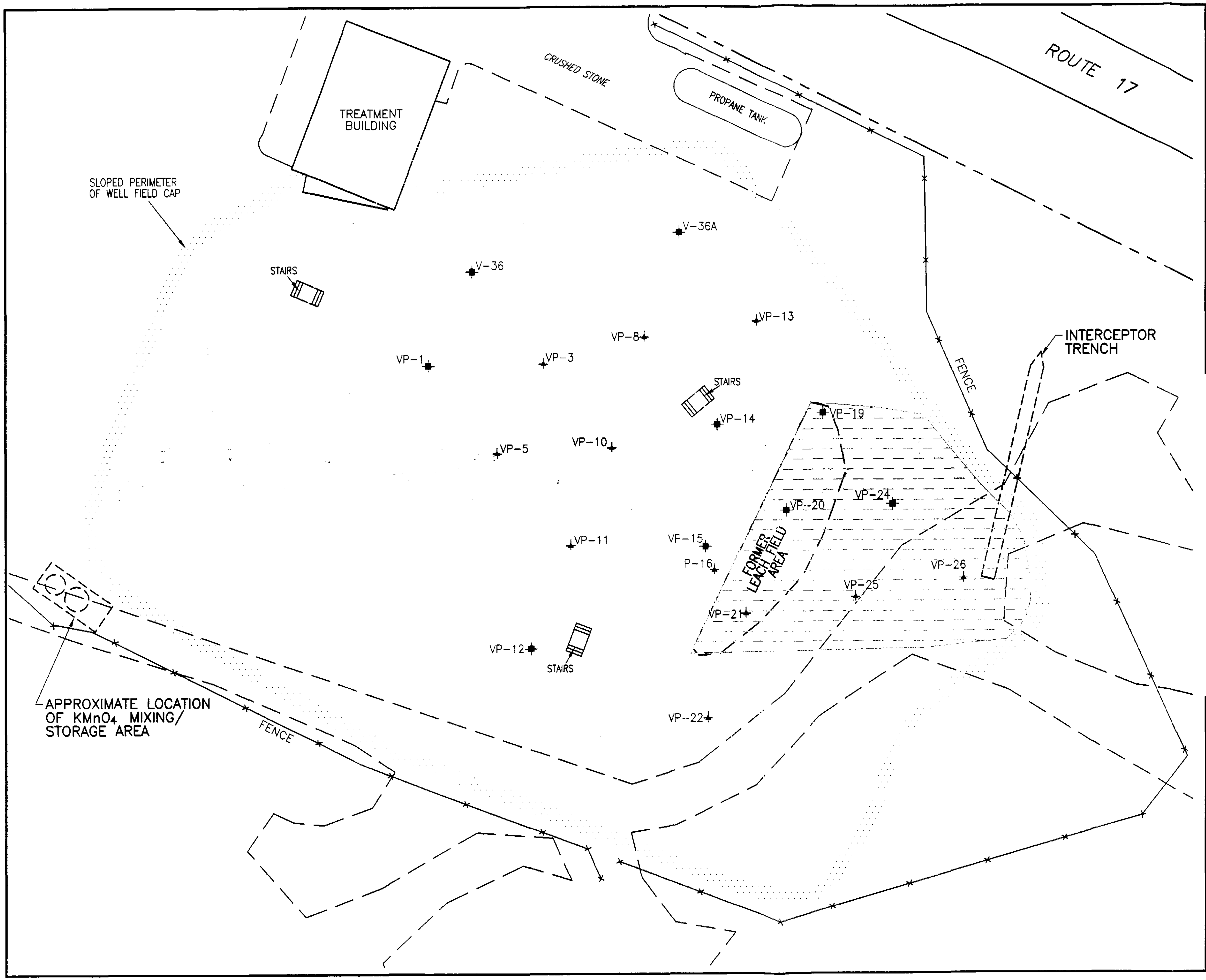
Table 7
Extrapolated Concentrations From Trend Analysis (and calculation of delta due to Permanganate)

Potassium Permanganate Test (Summer 1998)
Union Chemical Site, Hope, Maine

Value - Date Of Sampling	Trend Based on June 1997 To May 1999				Trend Based on November 1996 To May 1998
	Compound Concentrations				
	cis-1,2-DCE	1,1-DCA	TCE	Total Chlorinated Compounds	Revised Total Chlorinated Compounds
Calculation of Projected Impact of P&T Reduction					
April '98 (measured) – 4/8/98	1,200	1,100	460	4,122	4,122
Oct '98 (projected) – 10/13/98	1,231	1,043	374	3,580	4,001
April '99 (projected) – 4/6/99	903	734	211	2,386	2,961
Projected Percent Reduction (P&T)					
April '98 to Oct. 1998	-3%	5%	19%	13%	3%
April '98 to April 1999	25%	33%	54%	42%	28%
Actual Impact of P&T Reduction					
April '98 (measured) – 4/8/98	1,200	1,100	460	4,122	4,122
Oct '98 (measured) – 10/13/98	1,300	1,200	410	2,274	2,274
April '99 (measured) – 4/6/99	250	290	200	840	840
Actual Influent Percent Reduction					
April '98 to Oct. 1998	-8%	-9%	11%	45%	45%
April '98 to April 1999	79%	74%	57%	80%	80%
Delta (Percent Reduction due to Permanganate)					
April '98 to Oct. 1998	-6%	-14%	-8%	32%	42%
April '98 to April 1999	54%	40%	2%	38%	51%

Notes:
P&T - Pump & Treat
All results in ug/L
Measured values correspond to values measured on the sampling dates shown.
Projected values were obtained from an exponential decay curve, fit to measured data, with points interpolated from equation (Appendix D)

FIGURES



LEGEND

SOIL VAPOR EXTRACTION WELL
COMBINED SOIL VAPOR EXTRACTION AND PUMPING WELL
PUMPING WELL
HOT AIR INJECTION POINT
+ VP-13 PUMPING WELL ADDITION POINT
■ V-36A SOIL VAPOR EXTRACTION ADDITION POINT

EXTERIOR TREATMENT SYSTEM PIPING
▨ CONTAMINATED SOIL BETWEEN FORMER LEACH FIELD AND INTERCEPTOR TRENCH

MAP SOURCE: 1] AutoCAD SITE PLAN PREPARED FOR UNION CHEMICAL COMPANY RDRA TRUST BY MAINE COAST SURVEYING, ELM STREET, DAMARISCOTTA, MAINE, LAST REVISED NOVEMBER 4, 1992; 2] "MONITORING WELL AND PIEZOMETER LOCATION PLAN" PREPARED FOR UNION CHEMICAL TRUSTESS BY CANONIE ENVIRONMENTAL, FIGURE 4, 9/27/88.

0 30 60
SCALE FEET

N

Original includes color coding.

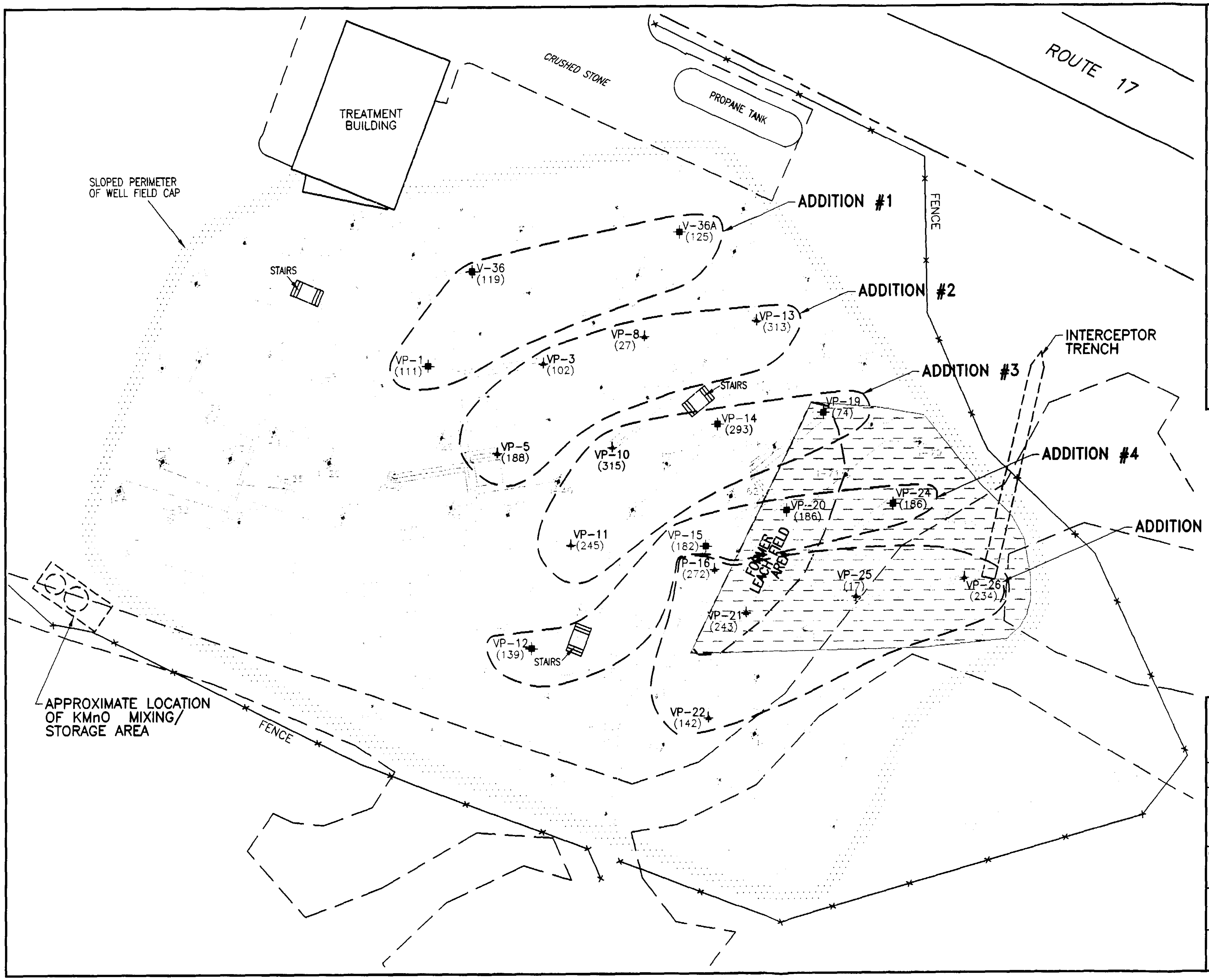
FLUOR DANIEL GTI
100 RIVER RIDGE DRIVE
NORWOOD, MA 02062
(781) 769-7600

GAUGING DATE: NA	DRAWING DATE: 11/24/98	ACAD FILE: 102589S4

SITE MAP - $KMnO_4$ ADDITION WELL LOCATIONS

CLIENT: UNION CHEMICAL RD/RA TRUST	PM: PF
LOCATION: SOUTH HOPE KNOX COUNTY, MAINE	PE/PG: MD

DESIGNED:	DETAILED:	PROJECT NO.:	FIGURE:
	DR/JC/EMD	83001-9999	1



LEGEND

SOIL VAPOR EXTRACTION WELL

COMBINED SOIL VAPOR EXTRACTION AND PUMPING WELL

PUMPING WELL

HOT AIR INJECTION POINT

V-36A SOIL VAPOR EXTRACTION ADDITION POINT

VP-13 PUMPING WELL ADDITION POINT
(313) - LBS. OF $KMnO_4$ ADDED TO WELL

EXTERIOR TREATMENT SYSTEM PIPING

CONTAMINATED SOIL BETWEEN FORMER LEACH FIELD AND INTERCEPTOR TRENCH

MAP SOURCE: 1] AutoCAD SITE PLAN PREPARED FOR UNION CHEMICAL COMPANY RDRA TRUST BY MAINE COAST SURVEYING, ELM STREET, DAMARISCOTTA, MAINE, LAST REVISED NOVEMBER 4, 1992; 2] "MONITORING WELL AND PIEZOMETER LOCATION PLAN" PREPARED FOR UNION CHEMICAL TRUSTESS BY CANONIE ENVIRONMENTAL, FIGURE 4, 9/27/88.

0 30 60
SCALE FEET

Original includes color coding.

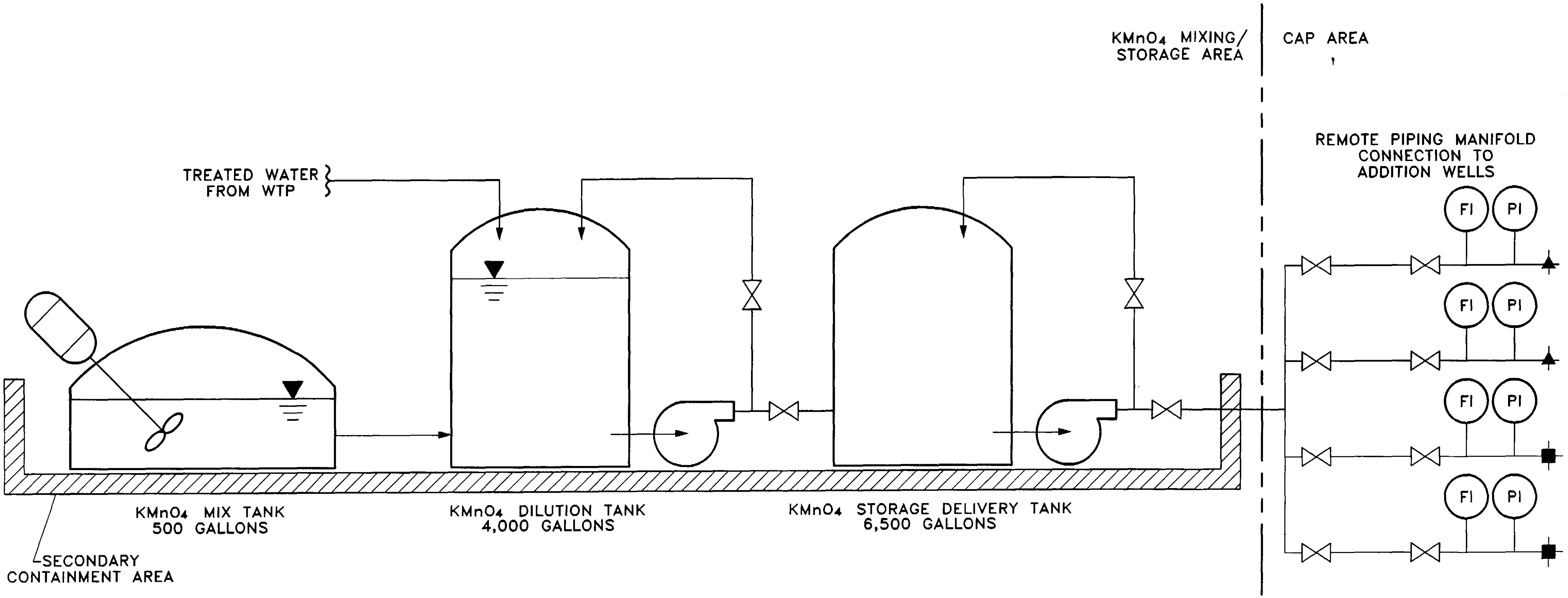
FLUOR DANIEL GTI
100 RIVER RIDGE DRIVE
NORWOOD, MA 02062
(781) 769-7600

GAUGING DATE:	DRAWING DATE:	ACAD FILE:
NA	11/25/98	102589S5

SITE MAP - SEQUENCE OF $KMnO_4$ ADDITION ACTIVITIES

CLIENT:	UNION CHEMICAL RD/RA TRUST	PM: PF
LOCATION:	SOUTH HOPE KNOX COUNTY, MAINE	PE/PG: MD
DESIGNED:	DETAILED: DR/JC/EMD PROJECT NO.: 83001-9999	FIGURE: 2

PROCESS FLOW DIAGRAM - $KMnO_4$ SOLUTION MIXING/DELIVERY SYSTEM
UNION CHEMICAL SITE SUMMER 1998



FLUOR DANIEL GTI

100 RIVER RIDGE DRIVE
NORWOOD, MA 02062
(781) 769-7600

SYSTEM DATE:	DRAWING DATE:	ACAD FILE:
SUMMER 1998	11/25/98	PFLOW-01

PROCESS FLOW DIAGRAM
$KMnO_4$ SOLUTION MIXING/
DELIVERY SYSTEM

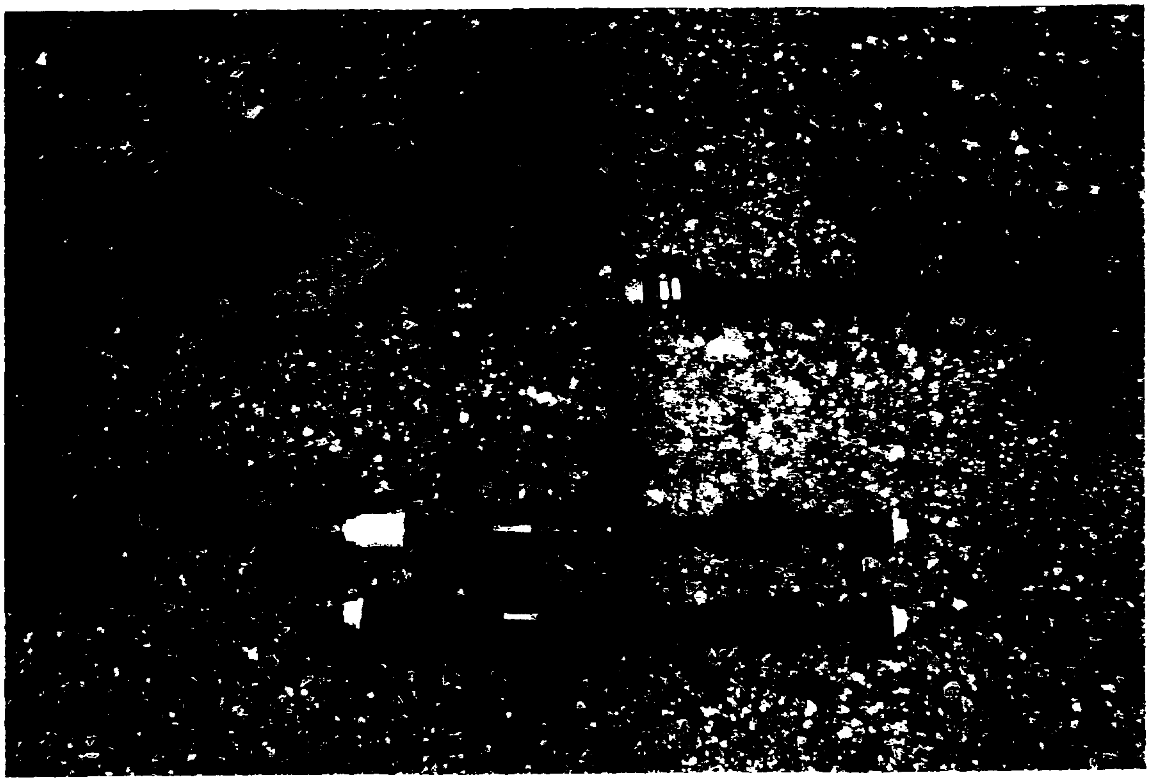
CLIENT:	UNION CHEMICAL RD/RA TRUST	PM: PF
LOCATION:	SOUTH HOPE KNOX COUNTY, MAINE	PE/PG: MD

DESIGNED:	DETAILED:	PROJECT NO.:	FIGURE:
	DR/JC/EMD	83001-9999	3

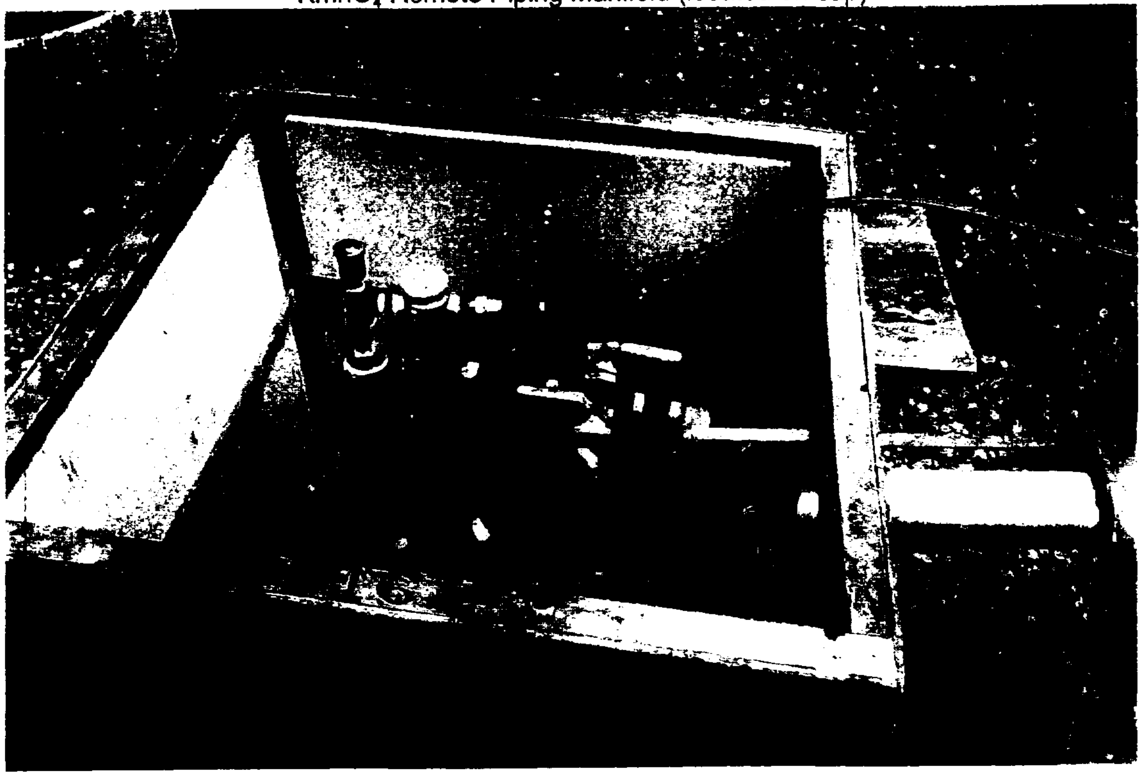
APPENDIX A

PHOTOGRAPHS

$KmnO_4$ Addition Test - Union Chemical Site -Summer 1998



$KmnO_4$ Remote Piping Manifold (located on cap)

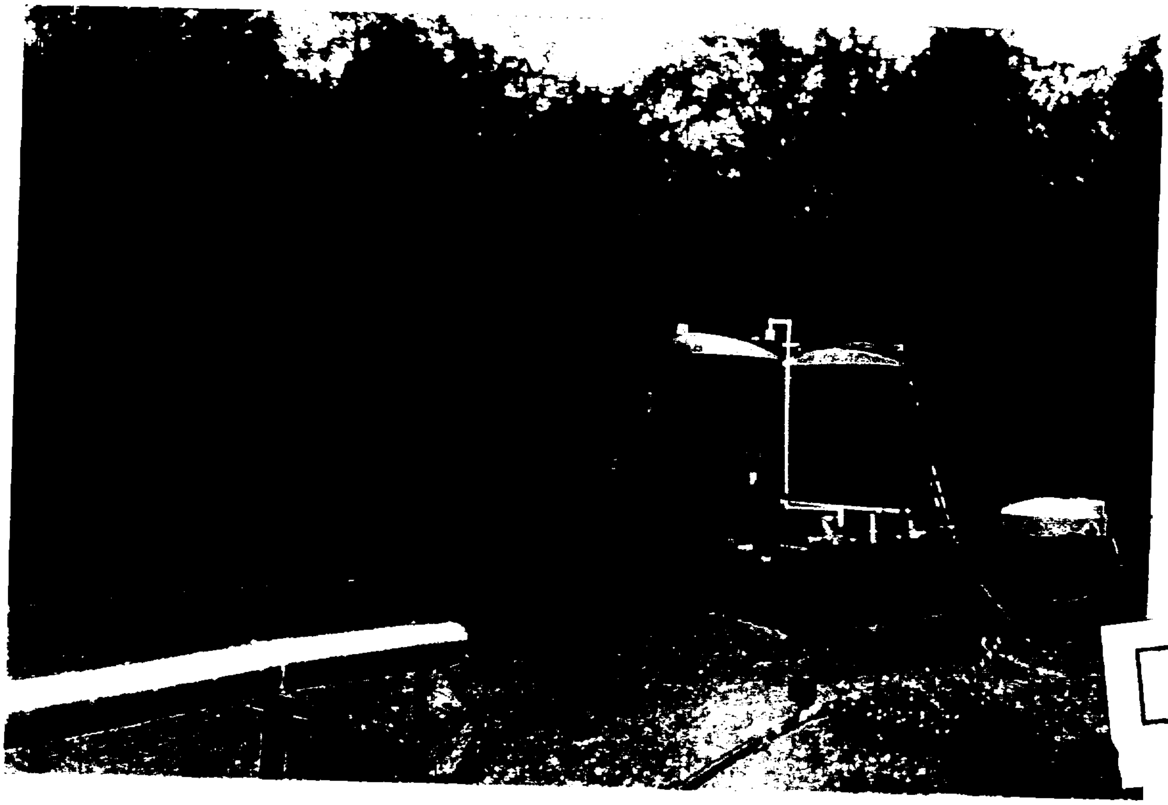


$KmnO_4$ Well Head Connection - Groundwater Pumping Well

Originals in color.

$KMnO_4$ Addition Test - Union Chemical Site - Summer 1998

$KmnO_4$ Mixing/Storage/Secondary Containment Area (Front View)



Originals in color.

$KmnO_4$ Mixing/Storage/Secondary Containment Area (looking from cap)

APPENDIX B

MATERIAL SAFETY DATA SHEETS

Harcros Chemicals Inc

Kansas City, Kansas

MATERIAL SAFETY DATA SHEET Page 1

PRODUCT NAME : POTASSIUM PERMANGANATE FREEFLO — Date: 12-AUG-1998 09:34:42.64
PRODUCT CODE : 00459 — 55# DRUM

CAS #: 007722647 — MSDS No. 001179 — Revision No./Date 03 970603
Detail Number 00606/02

FORMULA: KMn04
CHEM. FAMILY: bleaching agents (oxidizers)
CHEMICAL NAME AND SYNONYMS:
Potassium Permanganate, Nuggets, FF, Tech, USP;
Permanganic Acid Potassium Salt;
Chameleon Mineral;
Candy's Crystals;
Permanganate of Potash;
Cairox Potassium Permanganate;
MSDS 001179 DETAIL 00606
SUPPLIERS NAME : Harcros Chemicals Inc.
5200 Speaker Road
Kansas City KS 66106-1095

SUPPLIERS PHONE NUMBER : 913-321-3131
TRANSPORTATION EMERGENCY PHONE NUMBER : 1-800-424-9300

S.A.R.A. INFORMATION

HAZARDS : Acute Fire Reactivity Chronic
PHYSICAL DATA : Pure Solid

SECTION I HAZARDOUS INGREDIENTS

Ingredient Cas Number	MAX % W/W	SARA APPLIES 312	SARA APPLIES 313	SARA APPLIES 372	AIR CONTAMINENT LEVELS TWA/TLV (ppm)	STEL (ppm)	CEIL (ppm)	SKIN	AGENT
Potassium Permanganate Potash Permanganate (CAS # 7722-64-7)	99.0	Y	Y	Y	As Manganese TLV 0.2 mg/m3 ACGIH CEILING 5.0 mg/m3 OSHA				

SECTION II HEALTH HAZARDS

POTENTIAL EFFECTS OF EXPOSURE
EYES
Eye contact with product may cause burns irreversible damage
SKIN
Skin contact may cause irritation burns skin damage
INHALATION
Inhalation may cause irritation lung damage, damage to respiratory system

Continued On Page 2

SECTION II HEALTH HAZARDS (CONTINUED)

INGESTION
Ingestion may cause severe burns gastrointestinal damage
TARGET ORGANS
OVEREXPOSURE MAY CAUSE DAMAGE TO,
DISORDERS OF, OR ADVERSELY AFFECT THE FOLLOWING SYSTEMS, FUNCTIONS, ORGANS: all body tissues lungs central nervous system
FIRST AID
FIRST AID EYES
Immediately flush eyes with plenty of water for at least 15 minutes, while holding eyelids apart to ensure flushing of entire surface. Call a physician.
FIRST AID SKIN
Immediately flush skin with plenty of water for at least 15 minutes, while removing contaminated clothing and shoes. Thoroughly clean clothing and shoes before reuse. Call a physician.
FIRST AID INHALATION
Remove to fresh air. If not breathing give artificial respiration, preferably mouth to mouth. If breathing is difficult give oxygen. Call a physician.
FIRST AID INGESTION
Do not induce vomiting. Rinse mouth with water. Dilute stomach contents by drinking water. If vomiting occurs spontaneously, keep head below hips to prevent breathing vomit into lungs. Call a physician immediately.
OTHER INFORMATION
ROUTES OF ENTRY
eye contact skin contact inhalation

SECTION III SPECIAL PROTECTION

PROTECTIVE EQUIPMENT
PROTECTIVE EQUIPMENT EYES
chemical goggles faceshield Always wear eye protection when working with chemicals.
PROTECTIVE EQUIPMENT SKIN
impervious gloves clean body covering clothing rubber apron rubber boots
PROTECTIVE EQUIPMENT INHALATION
If exposure limits are exceeded, or if exposure may occur, use a NIOSH/MSHA respirator approved for your conditions of exposure. Refer to the most recent NIOSH publications concerning chemical hazards, or consult your safety equipment supplier. Respiratory protection programs must be in compliance with OSHA requirements in 29 CFR 1910.134. For emergencies, a NIOSH/MSHA approved positive pressure breathing apparatus should be readily available.
VENTILATION REQUIRED:
Adequate ventilation is required to minimize exposure or to maintain exposure levels below OSHA/ACGIH requirements. Local mechanical ventilation may be required.
ADDITIONAL PROTECTIVE MEASURES
Safety shower, eye wash fountain, and washing facilities should be readily available.

SECTION IV FIRE & EXPLOSION HAZARD DATA

Continued On Page 3

PRODUCT NAME : POTASSIUM PERMANGANATE FREEFLO Date: 12-AUG-1998 09:34:43.74
PRODUCT CODE : 00459 55# DRUM

SECTION IV FIRE & EXPLOSION HAZARD DATA (CONTINUED)

Flash Point (METHOD): > OR = N/A
Flammable Limits (% Volume in Air) UPPER: N/D Lower: N/D

HMIS Info	Health : 2	NFPA Info	Health : 2
	Fire : 0		Fire : 0
	React : 0		React : 0
	Special : X		Special : 0

EXTINGUISHING MEDIA
flood with water
FIRE FIGHTING PROCEDURES
Prevent human exposure to fire, fumes, smoke, and products of combustion. Evacuate non essential personnel. Firefighters should wear full face, self contained breathing apparatus and impervious protective clothing.
UNUSUAL FIRE & EXPLOSION HAZARDS
Toxic fumes may be released. Product is an oxidizer. It may react vigorously with organics or other materials resulting in an explosion and fire.

SECTION V PHYSICAL DATA

Boiling Point: N/D
Freezing Point: N/D
Specific Gravity (H(2)O=1): > OR = 2.7000 @ 68 deg. F
Vapor Pressure (MM HG.): N/D
Vapor Density (AIR=1) : N/D
Evaporation Rate (NA =1): N/D
Solubility in Water: 6%
Percent Volatile by Volume: N/D
pH: aqueous approx. N/D
Appearance:
SOLID - POWDER, CRYSTAL, FLAKE, GRANULE
TABLET, PRILL, BRIQUETTE, ETC.
Odor :
NIL

SECTION VI REACTIVITY DATA

STABILITY
Stable
INCOMPATABILITY
inorganic acids metals/metal blends Product is an oxidizer. It may react vigorously with organics or other materials resulting in an explosion and fire. Avoid contact with strong reducing agents which include hydrogen, hydrazine, sulfides, sulfites, and nitrites.

Continued On Page 4

SECTION VI REACTIVITY DATA

(CONTINUED)

HAZARDOUS DECOMPOSITION PRODUCTS
fumes of metal oxides
HAZARDOUS POLYMERIZATION
Will not occur

SECTION VII SPILL AND LEAK PROCEDURES

STEPS TO BE TAKEN IF MATERIAL IS RELEASED OR SPILLED:
Sweep, shovel, or pick up and return to dry, clean container. EPA banned the land disposal of D001 ignitable waste oxidizers. These wastes have to be deactivated by reduction (see below). To clear contaminated floors flush with abundant quantities of water into sewer, if permitted by Federal, State, and Local regulations. If not, collect water and treat chemically. (See below).
DEACTIVATION OF D001 IGNITABLE WASTE OXIDIZERS BY CHEMICAL REDUCTION; Reduce material in aqueous solution with sodium thiosulfate (Hypo), a bisulfite or ferrous salt solution. The bisulfite or ferrous salt may require some dilute sulfuric acid to promote rapid reduction. Neutralize with sodium bicarbonate to neutral pH if acid was used. Decant or filter and mix formed sludge with sodium carbonate and deposit in an approved landfill. Where permitted, the sludge can be drained into sewer with large quantities of water. Contact Carus Chemical for additional recommendations.
DISPOSAL METHOD
Dispose of material in accordance with all Federal, State and local regulations. Local regulations may be more stringent than Federal or State.

SECTION VIII

Proper Shipping Name: POTASSIUM PERMANGANATE

Hazard Class: 5.1, UN1490, PGII
Label Requirements: OXIDIZER
Reportable Quantity: None

SECTION IX ADDITIONAL INFORMATION

PRECAUTIONS
Wear protective equipment when handling. Use only with adequate ventilation. Wash thoroughly after handling. Do Not breathe dust. Do Not get in eyes, on skin, or clothing. Do not swallow.

HANDLING
Do Not apply heat to container. For manufacturing use only. ATTENTION: This container hazardous when emptied. Since emptied container contains product residues (vapor or liquid), all labeled hazard precautions must be observed.
STORAGE
Keep container closed when not in use. Store in a cool dry place. Keep out of reach of children.

Continued On Page 5

SECTION IX ADDITIONAL INFORMATION (CONTINUED)

NAME: GENE TURNER

DATE ISSUED: 930913
DATE REVISED: 970603

< = LESS THAN
> = MORE THAN

N/A = NOT APPLICABLE
N/D = NOT DETERMINED
N/E = NOT ESTABLISHED

UNK = UNKNOWN

The information provided in this Material Safety data sheet has been obtained from sources believed to be reliable. Harcros Chemicals Inc provides no warranties, either expressed or implied and assumes no responsibility for the accuracy or completeness of the data contained herein. This information is offered for your information, consideration , and investigation. You should satisfy yourself that you have all current data relevant to your particular use. Harcros Chemicals Inc knows of no medical condition, other than those noted on this material safety data sheet, which are generally recognized as being aggravated by exposure to this product.

APPENDIX C

FIELD DATA

FIELD GC DATA

The following information is included for the reader's information only. This information was extracted from the original report submission, and included as an Appendix for completeness. This information was not used for interpretation purposes.

TABLE C-1
Summary of Pre- and Post-Addition Field GC Results
Dissolved Organic Concentrations in Groundwater

Potassium Permanganate Test (Summer 1998)
Union Chemical Site, Hope, Maine

Sample Time	*Sample Date*	*TCE (ug/l)*	*PCE (ug/l)*	*o-Xylene (ug/l)*	*1,2-DCE(c&t) (ug/l)*
P-1					
Post-Addition	7/28/98	454	BDL	BDL	BDL
Post-Addition	8/17/98	324	BDL	3	BDL
Post-Addition	9/22/98	BDL	BDL	BDL	BDL
P-2					
Pre-Addition	6/05/98	159	23	912	1
Post-Addition	6/18/98	14	1	4	1
Post-Addition	7/07/98	16	18	1	1
Post-Addition	7/28/98	13	1	1	1
Post-Addition	9/22/98	0	BDL	BDL	BDL
P-3					
Pre-Addition	6/05/98	1472	BDL	10	BDL
P-5					
Pre-Addition	6/05/98	246	43	1132	170
Post-Addition	7/21/98	213	17	5	BDL
Post-Addition	7/28/98	359	BDL	BDL	BDL
Post-Addition	8/04/98	BDL	BDL	BDL	81
Post-Addition	9/22/98	BDL	BDL	11	BDL
P-6					
Pre-Addition	6/23/98	21	65	2	BDL
Post-Addition	8/10/98	31	241	5	80
Post-Addition	8/17/98	67	45	35	BDL

TABLE C-1
Summary of Pre- and Post-Addition Field GC Results Dissolved Organic Concentrations in Groundwater

Potassium Permanganate Test (Summer 1998)
Union Chemical Site, Hope, Maine

Sample Time	*Sample Date*	*TCE (ug/l)*	*PCE (ug/l)*	*o-Xylene (ug/l)*	*1,2-DCE(c&t) (ug/l)*
Post-Addition	9/22/98	23	74	BDL	54
P-8					
Pre-Addition	6/23/98	3759	1	14	162
Post-Addition	8/10/98	3386	1	35	914
Post-Addition	8/17/98	4869	1	8	655
Post-Addition	9/22/98	4226	BDL	140	237
P-9					
Pre-Addition	7/01/98	249	27	66	BDL
Post-Addition	7/17/98	66	BDL	BDL	BDL
Post-Addition	7/28/98	450	52	1048	BDL
Post-Addition	8/06/98	BDL	BDL	BDL	BDL
Post-Addition					
P-10					
Pre-Addition	6/22/98	1312	BDL	18	BDL
Post-Addition	7/07/98	1520	BDL	4	38
Post-Addition	9/22/98	69	BDL	BDL	6
P-11					
Pre-Addition	6/22/98	1	49	1	1
Post-Addition	7/07/98	791	96	1208	1965
Post-Addition	7/28/98	1	1	1	903
Post-Addition	8/04/98	938	170	37	1
Post-Addition	9/22/98	473	69	BDL	20
P-12					
Pre-Addition	7/01/98	230	13	51	624
Post-Addition	7/28/98	1315	51	300	BDL

TABLE C-1
Summary of Pre- and Post-Addition Field GC Results
Dissolved Organic Concentrations in Groundwater

Potassium Permanganate Test (Summer 1998)
Union Chemical Site, Hope, Maine

Sample Time	*Sample Date*	*TCE (ug/l)*	*PCE (ug/l)*	*o-Xylene (ug/l)*	*1,2-DCE(c&t) (ug/l)*
Post-Addition	8/10/98	504	51	114	BDL
Post-Addition	8/17/98	90	BDL	BDL	BDL
Post-Addition	9/22/98	91	58	103	234
P-13					
Pre-Addition	7/21/98	2470	12	12	549
Post-Addition	7/22/98	2442	10	8	440
Post-Addition	8/04/98	9440	BDL	BDL	1103
Post-Addition	8/17/98	4063	BDL	7	1160
Post-Addition	9/22/98	264	BDL	BDL	30
P-14					
Pre-Addition	6/23/98	399	57	4	74
Post-Addition	7/07/98	687	18	9	188
Post-Addition	7/28/98	36	BDL	65	365
Post-Addition	9/22/98	274	BDL	BDL	105
P-15					
Pre-Addition	6/23/98	1216	172	19	1899
Post-Addition	7/01/98	47	10	1	136
Post-Addition	7/07/98	32	1	2	10
P-16					
Pre-Addition	7/01/98	465	148	996	2336
Post-Addition	7/21/98	109	52	826	BDL
Post-Addition	10/26/98	1375	169	76	3219
P-16a					
Pre-Addition	7/01/98	195	50	1187	BDL
Post-Addition	10/26/98	85	BDL	BDL	BDL

TABLE C-1
Summary of Pre- and Post-Addition Field GC Results
Dissolved Organic Concentrations in Groundwater

Potassium Permanganate Test (Summer 1998)
Union Chemical Site, Hope, Maine

Sample Time	*Sample Date*	*TCE (ug/l)*	*PCE (ug/l)*	*o-Xylene (ug/l)*	*1,2-DCE(c&t) (ug/l)*
P-17					
Pre-Addition	7/01/98	16	BDL	3	179
Post-Addition	7/17/98	323	44	24	BDL
Post-Addition	7/28/98	BDL	BDL	BDL	232
Post-Addition	8/06/98	BDL	28	28	112
P-19					
Pre-Addition	6/23/98	482	BDL	BDL	5
Post-Addition	7/28/98	BDL	BDL	BDL	24
Post-Addition	8/17/98	311	BDL	BDL	80
Post-Addition	10/26/98	1336	BDL	BDL	102
P-20					
Pre-Addition	7/01/98	211	21	13	BDL
Post-Addition	7/07/98	543	BDL	6	22
Post-Addition	8/06/98	228	8	34	BDL
Post-Addition	8/17/98	437	160	BDL	BDL
Post-Addition	10/26/98	982	BDL	BDL	364
P-22					
Pre-Addition	8/03/98	6772	BDL	BDL	BDL
Post-Addition	10/26/98	987	104	1037	3378
P-23					
Pre-Addition	8/03/98	1521	112	1	1
Post-Addition	8/06/98	325	21	152	1
Post-Addition	8/17/98	415	21	933	1
Post-Addition	10/26/98	1420	89	263	8310
P-24					

TABLE C-1
Summary of Pre- and Post-Addition Field GC Results
Dissolved Organic Concentrations in Groundwater

Potassium Permanganate Test (Summer 1998)
Union Chemical Site, Hope, Maine

Sample Time	*Sample Date*	*TCE (ug/l)*	*PCE (ug/l)*	*o-Xylene (ug/l)*	*1,2-DCE(c&t) (ug/l)*
Pre-Addition	7/01/98	247	BDL	BDL	43
Post-Addition	7/17/98	288	BDL	BDL	27
Post-Addition	7/28/98	792	BDL	BDL	49
Post-Addition	8/06/98	290	BDL	BDL	131
Post-Addition	10/26/98	85	BDL	BDL	428
P-25					
Pre-Addition	7/17/98	664	448	1690	BDL
Post-Addition	9/22/98	483	283	1486	BDL
Post-Addition	10/26/98	805	367	2174	14
P-27					
Pre-Addition	8/03/98	1205	123	34	43
Post-Addition	8/17/98	309	28	2495	8
Post-Addition	9/22/98	239	324	1005	7
Post-Addition	10/26/98	420	882	320	40
P-28					
Pre-Addition	8/03/98	1281	464	86	26
Post-Addition	9/22/98	3460	BDL	BDL	BDL
Post-Addition	10/26/98	473	139	2246	52
P-29					
Pre-Addition	8/03/98	476	138	45	5062
Post-Addition	9/22/98	107	44	979	BDL
Post-Addition	10/26/98	336	108	1238	8398

Notes:
BDL – below detection limit of instrument
1 = post sampling event performed on 8/31/98
2 = post test sampling event performed on 10/7/98

Table C-2

Physical Parameters Monitoring - ORP

1998 Permanganate Addition
Former Union Chemical Site, Hope, ME

Site Id:	1998 ORP Data																	Statistics		
	6/9/98	6/16/98	6/17/98	6/18/98	6/19/98	6/23/98	6/25/98	6/29/98	7/2/98	7/6/98	7/9/98	7/15/98	7/23/98	7/31/98	8/5/98	8/7/98	8/14/98	Min	Max	Average
Pumping Wells																				
P-01	-136	-50	-61	-46	-31			-25					-59	-202	-21	-34	-33	-202.00	-21.00	-63.45
P-02	-107	-140	-133	-70	-30	-58	-14			-44	-70	149		-201	-149	22	10	-201.00	149.00	-59.64
P-03	-61	-50	-92	-96	▨	▨	▨	▨			-44							-96.00	-44.00	-68.60
P-04	-53							-80	-85	-55	-103	188		-200	-73	-90	2	-200.00	188.00	-54.90
P-05	-33				▨	▨	▨			380			227	-172	35	-25	-5	-172.00	380.00	58.14
P-06	-103				-72	-55	-75	-15			-89	220	-40	-185	-37	-64	26	-185.00	220.00	-40.75
P-08	-109	-112	-137	-118	▨ -118	▨ -100	▨	▨	▨							-37	-119	-137.00	-37.00	-106.25
P-09	-106						-163	-120	-190	-168	-91	215	6	-162	47	33		-190.00	215.00	-63.55
P-10	-111				-164	-150	-134	-125		-120	▨ -120	▨		502				-164.00	502.00	-52.75
P-11	-33				-101			-65			▨	▨	-200	-200	72	103	-41	-200.00	103.00	-58.13
P-12	-63						-143	-145	-125	-50	-76	224		-110	-85	-96	-89	-145.00	224.00	-68.91
P-13	-103	-134	-163	-161	-170		▨	▨	▨				-254	-254	58	104		-254.00	104.00	-119.67
P-14	-49					-45	-87	-80	94	-130					10	-88	-37	-130.00	94.00	-45.78
P-15	-128					-52	-110	-81	82	-65	-57							-128.00	82.00	-58.71
P-16							-175		-100	-160	-160	245			▨	▨	▨	-175.00	245.00	-70.00
P-16A							-200		-90	-77				-48				-200.00	-48.00	-103.75
P-17							-165		-135	-125	-145	-90	-110	-128	-85	-140	-81	-165.00	-81.00	-120.40
P-19							-101	30	101	-92					-15	-86	-71	-101.00	101.00	-33.43
P-20							-75		103	-85	-74	210		-213	-113	-96	-98	-213.00	210.00	-49.00
P-21															▨	▨	▨			
P-22							-90				-171	-73	-89	-207	▨ -187	▨ -125	▨	-207.00	-73.00	-134.57
P-23															-157	-133	-122	-157.00	-122.00	-137.33
P-24									96	-75	-89	103		-314	-58	-125	-122	-314.00	103.00	-73.00
P-25										-140	-150	-110	-114	-108	▨	▨	▨	-150.00	-108.00	-124.40
P-26										-12	-125		-55	-78	▨	▨	▨	-125.00	-12.00	-67.50
P-27													-138	-290	-164	-197	-129	-290.00	-129.00	-183.60
P-28															-194	-209	-196	-209.00	-194.00	-199.67
P-29													-202	-255	-195	-162	-115	-255.00	-115.00	-185.80
SVE Wells																				
V-1		▨	▨	▨	▨															
V-12													▨	▨						
V-14											▨	▨								
V-15													▨	▨						
V-19											▨	▨								
V-20													▨	▨						
V-24													▨	▨						
V-36		▨	▨	▨	▨															
V-36A		▨	▨	▨	▨															
B-series monitoring wells																				
B-8A(D)											-125							-125.00	-125.00	-125.00
B-12A(D)											-100							-100.00	-100.00	-100.00
MW-series monitoring wells																				
MW-14(S)									115									115.00	115.00	115.00
OW-series wells																				
OW-1-1D											-192							-192.00	-192.00	-192.00
OW-4-2S	10		46	52														10.00	52.00	36.00
Former Extraction Wells																				
EW-4	-280		-290	-253														-290.00	-253.00	-274.33
Piezometers																				
PZ-B-02	22		44	58														22.00	58.00	41.33
																		-314.00	502.00	-81.89

Notes:

▨ *Denotes addition well (i.e., well into which permanganate was being added at the time of measurement) - well purple at time of measurement*

☐ *Denotes well dry at time of gauging (no measurements taken)*

Wells which had no data collected or were not used as addition wells have been deleted from the table for brevity

Chart C-2a
ORP Data

Potassium Permanganate Test (Summer 1998)
Union Chemical Site, Hope, Maine

Original includes color coding.

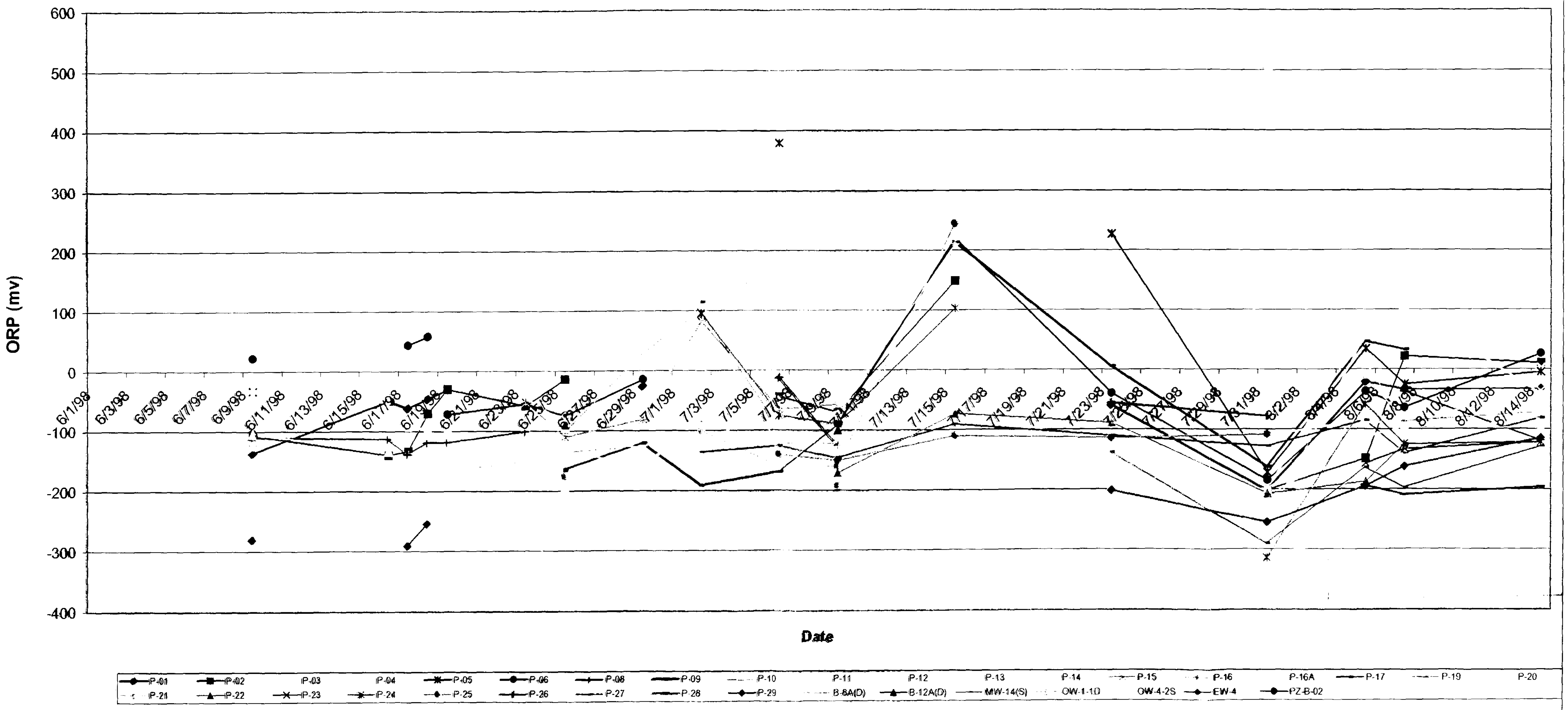


Table C-3

Physical Parameters Monitoring - pH

1998 Permanganate Addition
Former Union Chemical Site, Hope, ME

Site Id:	1998 pH Data																	Statistics		
	6/9/98	6/16/98	6/17/98	6/18/98	6/19/98	6/23/98	6/25/98	6/29/98	7/2/98	7/6/98	7/9/98	7/15/98	7/23/98	7/31/98	8/5/98	8/7/98	8/14/98	Min	Max	Average
Pumping Wells																				
P-01	7.50	8.00	8.00	8.50														7.50	8.50	8.00
P-02	7.70	8.00	8.00	7.70														7.70	8.00	7.85
P-03	7.70	7.30	7.40	7.30	▓	▓	▓	▓										7.30	7.70	7.43
P-04	7.20																	7.20	7.20	7.20
P-05	7.50				▓	▓	▓											7.50	7.50	7.50
P-06	7.60																	7.60	7.60	7.60
P-08	7.60	7.50	7.60	7.40	▓	▓	▓	▓	▓									7.40	7.60	7.53
P-09	7.80																	7.80	7.80	7.80
P-10	7.50										▓	▓						7.50	7.50	7.50
P-11	7.40										▓	▓						7.40	7.40	7.40
P-12	7.50																	7.50	7.50	7.50
P-13	7.80	7.70	7.70	7.70			▓	▓	▓									7.70	7.80	7.73
P-14	8.00																	8.00	8.00	8.00
P-15	7.80																	7.80	7.80	7.80
P-16															▓	▓	▓			
P-21															▓	▓	▓			
P-22															▓	▓	▓			
P-26															▓	▓	▓			
P-27															▓	▓	▓			
SVE Wells																				
V-1		▓	▓	▓	▓															
V-12													▓	▓						
V-13																				
V-14											▓	▓								
V-15													▓	▓						
V-19											▓	▓								
V-20													▓	▓						
V-24													▓	▓						
V-36		▓	▓	▓	▓															
V-36A		▓	▓	▓	▓															
OW-series wells																				
OW-4-2S	7.20		6.70	6.80														6.70	7.20	6.90
Former Extraction Wells																				
EW-4	8.00		7.80	7.70														7.70	8.00	7.83
Piezometers																				
PZ-B-02	7.00		6.20	6.60														6.20	7.00	6.60
																		6.20	8.50	7.54

Notes:

▓ *Denotes addition well (I.e., well into which permanganate was being added at the time of measurement) - well purple at time of measurement*

░ *Denotes well dry at time of gauging (no measurements taken)*

Wells which had no data collected or were not used as addition wells have been deleted from the table for brevity

Table C-4

Physical Parameters Monitoring - Depth to Water

1998 Permanganate Addition
Former Union Chemical Site, Hope, ME

Site Id:	1998 Depth to Water Data																	Statistics		
	6/9/98	6/16/98	6/17/98	6/18/98	6/19/98	6/23/98	6/25/98	6/29/98	7/2/98	7/6/98	7/9/98	7/15/98	7/23/98	7/31/98	8/5/98	8/7/98	8/14/98	Min	Max	Average
Pumping Wells																				
P-01	20.50																	20.50	20.50	20.50
P-02	46.70																	46.70	46.70	46.70
P-03	30.00				■	■	■	■										30.00	30.00	30.00
P-04	46.00																	46.00	46.00	46.00
P-05	57.00				■	■	■											57.00	57.00	57.00
P-06	43.00																	43.00	43.00	43.00
P-08	46.00				■	■	■	■	■									46.00	46.00	46.00
P-09	38.20																	38.20	38.20	38.20
P-10	50.10										■	■						50.10	50.10	50.10
P-11	50.00										■	■						50.00	50.00	50.00
P-12	43.00																	43.00	43.00	43.00
P-13							■	■	■											
P-14	61.30																	61.30	61.30	61.30
P-15	56.20																	56.20	56.20	56.20
P-16															■	■	■			
P-21															■	■	■			
P-22															■	■	■			
P-25															■	■	■			
P-26															■	■	■			
SVE Wells																				
V-1		■	■	■	■															
V-2	16.50	10.30	8.80	12.30	14.60						░							8.80	16.50	12.50
V-3	20.40	17.70	16.60	17.20							15.80							15.80	20.40	17.54
V-4									15.40					18.20				15.40	18.20	16.80
V-5	21.00	░	░	░														21.00	21.00	21.00
V-6					24.60						22.90							22.90	24.60	23.75
V-8	22.00	22.60	22.60	22.20														22.00	22.60	22.35
V-9									17.50					19.00				17.50	19.00	18.25
V-11					29.30						░							29.30	29.30	29.30
V-12									26.60				■	■				26.60	26.60	26.60
V-13		22.00	22.00	21.80														21.80	22.00	21.93
V-14											■	■								
V-15									░				■	■						
V-17									24.70					20.70				20.70	24.70	22.70
V-19									24.20		■ 24.20	■						24.20	24.20	24.20
V-20													■	■						
V-24													■	■						
V-30	12.90	12.20	11.80	11.30														11.30	12.90	12.05
V-31	13.80	12.00	11.00	11.90														11.00	13.80	12.18
V-36		■	■	■	■															
V-36A		■	■	■	■															
OW-series wells																				
OW-4-2S	23.00		20.60	11.00														11.00	23.00	18.20
Former Extraction Wells																				
EW-4	29.10		27.50	25.20														25.20	29.10	27.27
Piezometers																				
PZ-B-02	17.80		17.20	15.10														15.10	17.80	16.70
																		8.80	61.30	31.04

Notes:

■ *Denotes addition well (i.e., well into which permanganate was being added at the time of measurement) - well purple at time of measurement*

░ *Denotes well dry at time of gauging (no measurements taken)*

Wells which had no data collected or were not used as addition wells have been deleted from the table for brevity

FIELD IRON AND MANGANESE DATA

The following information is included for the reader's information only. This information was extracted from the original report submission, and included as an Appendix for completeness. This information was not used for interpretation purposes.

TABLE C-5
Field Parameters Monitoring – Iron and Manganese by Field test Kits

Potassium Permanganate Test (Summer 1998)
Union Chemical Site, Hope, Maine

	Pre-Addition Iron Conc. (mg/l)	*Post-Addition Iron Conc. (mg/l)*	*Pre-Addition Manganese Conc. (mg/l)*	*Post-Addition Manganese Conc. (mg/l)*
Addition #1				
P-2	0.5	0.5	0.06	0.14
P-3	2.7	0.7	0.85	0.525
P-5	1.0	0.9	0.625	>1.0
P-8	1.1	3.1	0.575	>1.0
P-13	3.0	2.8	0.7	0.85
Addition #2A				
P-1	--	--	--	--
P-2	0.5	1.1	0.14	0.2
P-6	1.8	1.5	1.0	>0.7
P-10	1.6	1.5	>1.0	>0.7
P-11	0.2	1.4	1.0	>0.7
Addition #2B				
P-3	--	--	--	--
P-10	1.6	1.5	1.0	>0.7
P-14	0.5	1.8	0.36	0.25
P-15	0.7	0.6	1.0	0.05
P-19	0.3	0.3	0.03	0.4
Addition #3				
P-9	2.5	3.4	>0.7	0.35
P-12	2.2	>5.0	>0.7	>0.7
P-15	>5.0	--	0.525	--

TABLE C-5
Field Parameters Monitoring – Iron and Manganese by Field test Kits

Potassium Permanganate Test (Summer 1998)
Union Chemical Site, Hope, Maine

	Pre-Addition Iron Conc. (mg/l)	*Post-Addition Iron Conc. (mg/l)*	*Pre-Addition Manganese Conc. (mg/l)*	*Post-Addition Manganese Conc. (mg/l)*
P-16	1.3	--	>0.7	--
P-16a	1.2	3.7	0.28	0.55
P-20	0.5	2.5	0.06	>0.7
P-24	0.0	1.0	<0.01	>0.7
P-27	0.5	2.0	0.45	0.65
Addition #4				
P-9	0.5	0.5	0.525	0.08
P-16	1.0	--	>0.7	--
P-16a	>5.0	>5.0	0.6	0.6
P-17	1.5	1.8	0.55	>0.7
P-20	0.5	0.3	0.27	>0.7
P-24	0.3	0.5	0.02	0.04
P-25	0.4	--	0.13	--
Addition #5				
P-22	0.5	--	0.27	--
P-23	0.3	0.8	>0.7	>0.07
P-27	0.0	0.0	0.28	0.26
P-28	0.3	0.5	0.2	0.26
P-29	0.7	0.5	0.24	0.25

NOTES:
= NOT SAMPLED
Total iron and manganese concentrations were measured by use of Hach Field Kits.

APPENDIX D

DATA ANALYSES FOR VOC REDUCTION CALCULATIONS

Table D-1
Historical Plant Influent

Potassium Permanganate Test (Summer 1998)
Union Chemical Site, Hope, Maine

Site Id:	Period	Date	Chlorinated VOCs								Non-Chlorinated VOCs (BTEX)				Total Chlorinated VOCs (ug/L)	Total Non-Chlorinated VOCs (ug/L)	TOTAL VOCs (ug/L)
			cis-1,2-DCE (ug/L)	2-Butanone (ug/L)	1,1-DCA (ug/L)	TCE (ug/L)	1,1,1-TCA (ug/L)	1,1-DCE (ug/L)	VC (ug/L)	Other (ug/L)	Total X (ug/L)	T (ug/L)	E (ug/L)	B (ug/L)			
Groundwater Closure Standards			70	170	5	5	200	7	2	-	10,000	2,000	700	-			
SP-1/INF	Jan-96	average	3,300	*1,800*	990	1,100	970	200	<250U	500	3,250	2,600	820		8,860	6,670	15,530
SP-1/INF	Feb-96	average	2,560	4,057	1,108	1,334	214	120	<120U	841	1,756	2,657	449		10,234	4,862	15,096
SP-1/INF	Mar-96	average	6,100	*3,700*	2,300	2,200	1,600	230	<250U	670	5,000	2,200	1,300		16,800	8,500	25,300
SP-1/INF	Apr-96	average	4,700	7,450	3,100	3,200	1,500	455	<250U	2,125	4,100	4,150	1,010		22,530	9,260	31,790
SP-1/INF	May-96	5/21/96	1,700	6,900	970	1,500	260	<50U	<120U	15	820	1,400	*120*		11,345	2,340	13,685
SP-1/INF	Jun-96	6/29/96	930	4,200	1,300	1,000	290	57	<50U	520	1,690	1,000	340		8,297	3,030	11,327
SP-1/INF	Jul-96	none	No Influent Sampling Completed during this month														
SP-1/INF	Aug-96	8/20/96	2,300	7,100	2,600	1,700	750	200	<50U	1,210	2,600	1,300	860		15,860	4,760	20,620
SP-1/INF	Sep-96	none	No Sampling Completed - No water treated during this month, SVE system operated for limited time														
SP-1/INF	Oct-96	10/7/96	No influent samples during this month – Analysis for Inorganics Only														
SP-1/INF	Nov-96	11/19/96	3,900	*0.2*	3,700	3,900	2,400	570	*35*	1,394	9,200	2,100	1,800	4	15,899	13,104	29,003
SP-1/INF	Dec-96	12/23/96	9,900	14,000	13,000	15,000	2,700	<100U	<250U	1,720	12,100	5,900	2,800		56,320	20,800	77,120
SP-1/INF	Jan-97	1/6/97	3,500	1,600	1,800	2,400	910	370	*56*	994	4,300	1,500	930	2	11,630	6,732	18,362
SP-1/INF	Feb-97	2/11/97	1,700	2,500	1,700	1,400	1,200	140	18	259	3,700	700	*84*	1	8,917	4,485	13,402
SP-1/INF	Mar-97	3/4/97	820	1,100	660	630	380	*32*	18	330	2,170	330	260	1	3,970	2,761	6,731
SP-1/INF	Apr-97	4/8/97	840	910	760	470	250	39	4	432	1,820	250	300	1	3,705	2,371	6,075
SP-1/INF	May-97	5/8/97	2,000	950	1,800	1,400	560	210	<50U	534	4,200	620	840	<50U	7,454	5,660	13,114
SP-1/INF	Jun-97	6/10/97	2,400	1,200	1,900	1,800	950	230	53	693	6,300	600	3	2	9,226	6,905	16,131
SP-1/INF	Jul-97	7/23/97	3,100	1,500	3,300	2,000	720	680	86	1,051	7,800	1,100	1,000	3	12,437	9,903	22,340
SP-1/INF	Aug-97	8/14/97	3,000	1,300	2,600	1,700	430	580	78	644	6,800	910	1,500	<50U	10,332	9,210	19,542
SP-1/INF	Sep-97	9/4/97	1,400	1,300	2,500	1,100	290	310	*36*	626	2,130	630	210	<50U	7,562	2,970	10,532
SP-1/INF	Oct-97	average	2,600	1,050	1,600	955	54	290	34	310	3,750	515	550	2	6,893	4,817	11,710
SP-1/INF	Nov-97	11/6/97	2,900	1,900	3,100	1,300	48	650	71	416	5,300	760	1,000	2	10,385	7,062	17,447
SP-1/INF	Dec-97	12/10/97	3,700	1,700	2,900	1,800	280	520	<10U	402	6,000	950	980	<10U	11,302	7,930	19,232
SP-1/INF	Jan-98	1/13/98	2,400	1,200	2,100	900	310	410	67	385	5,700	640	550	<10U	7,772	6,890	14,662
SP-1/INF	Feb-98	2/5/98	2,700	650	2,000	1,000	310	420	<10U	314	5,600	630	1,200	<10U	7,394	7,430	14,824
SP-1/INF	Mar-98	3/5/98	1,200	880	1,000	610	140	75	36	131	2,160	260	340	<10U	4,072	2,760	6,832
SP-1/INF	Apr-98	4/8/98	1,200	1,100	1,100	460	65	92	<10U	105	2,360	200	360	<10U	4,122	2,920	7,042
SP-1/INF	May-98	5/7/98	1,700	1,100	1,800	890	110	320	57	392	3,700	380	780	<10U	6,369	4,860	11,229
SP-1/INF	Jun-98	6/11/98	100	830	100	340	42	110	17	160	2,160	210	310	<10U	1,699	2,680	4,379
SP-1/INF	Jul-98	7/9/98	1,200	960	1,600	340	98	250	40	248	3,070	300	580	<10U	4,736	3,950	8,686
SP-1/INF	Aug-98	8/11/98	*980*	*400*	*960*	190	83	160	35	164	*1,900*	*220*	*430*	1	2,972	2,551	5,523
SP-1/INF	Sep-98	9/9/98	1,100	270	1,000	530	26	140	42	157	1,400	110	190	<10U	3,265	1,700	4,965
SP-1/INF	Oct-98	10/13/98	1,300	190	<10U	410	20	200	41	113	1,860	200	350	<10U	2,274	2,410	4,684
SP-1/INF	Nov-98	11/5/98	1,000	410	1,200	120	<10U	93	18	19	1,460	99	240	<10U	2,860	1,799	4,659
SP-1/INF	Dec-98	12/9/98	450	40	520	170	12	24	7	31	110	<2U	<2U	<2U	1,254	110	1,364
SP-1/INF	Jan-99	1/7/99	440	140	550	180	17	30	5	35	390	49	60	<2U	1,397	499	1,896
SP-1/INF	Feb-99	2/23/99	660	94	970	420	38	120	35	127	580	48	100	<5U	2,464	728	3,192
SP-1/INF	Mar-99	3/3/99	700	29	910	490	55	130	47	137	500	54	79	<2.5U	2,498	633	3,131
SP-1/INF	Apr-99	4/6/99	250	54	290	200	7	13	5	21	158	14	25	<2U	840	197	1,037
SP-1/INF	May-99	5/3/99	1,500	270	1,600	420	120	170	61	170	2,030	110	260	<5U	4,311	2,400	6,711
SP-1/INF	Jun-99	6/7/99	820	200	1,300	190	90	88	21	47	820	64	110		2,756	994	3,750

Notes:

Values exceeding Groundwater Closure Standards shown in emboldened text

Each sampling event is listed by date, in cases where multiple sampling events occurred in the same month, the values listed are the average for all the samples collected

All other analytes are the sum of all other VOC constituents present at less than 1% of the total VOCs

Data qualified with a D, E, # (inorganics) or J been used at their reported concentration, qualified data shown in italicized text

Non-detectable concentrations are shown as less than the detection limit

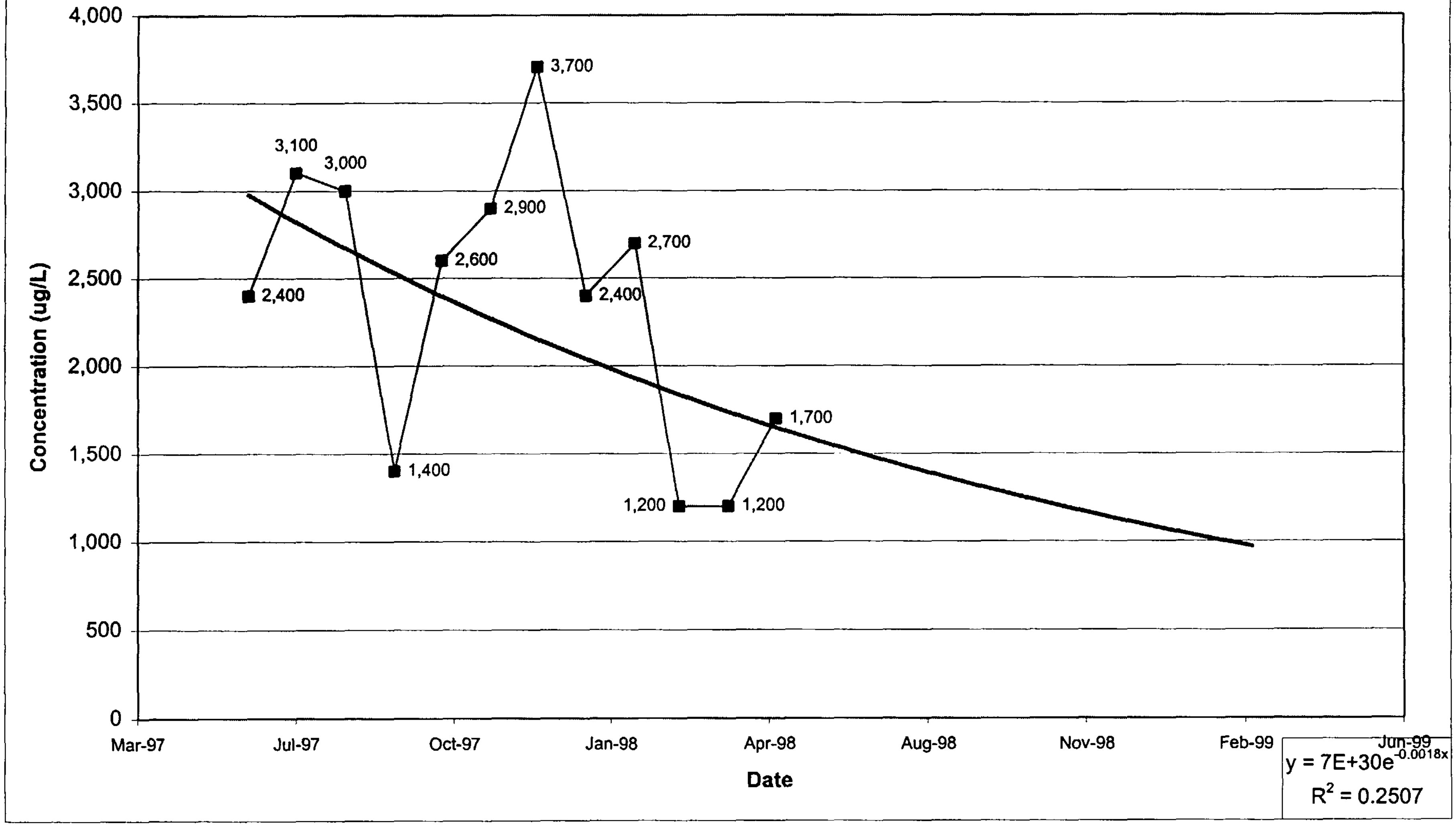
DMF sample from 12/29/97 reported under date 12/10/97 above

[- - - -] *Indicates Permanganate Test ongoing during this period (1998)*

Treatment Plant cis-1,2-DCE with Exponential Fit Trendline

Union Chemical Site (June 1997 - May 1998)

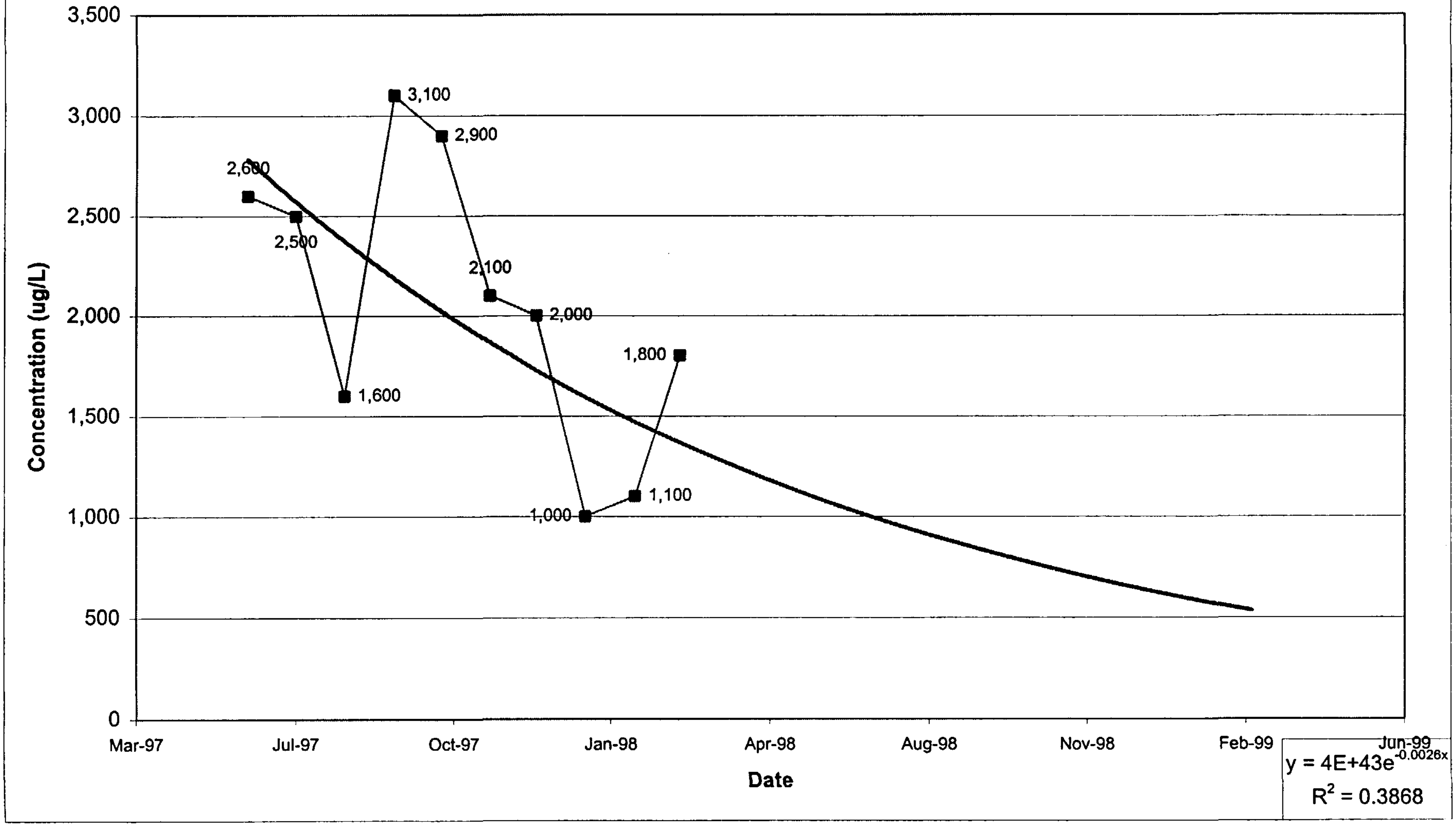
Source: Historical Monthly Treatment Plant Influent Sampling (EPA 8260)



Treatment Plant 1,1-DCA with Exponential Fit Trendline

Union Chemical Site (June 1997 - May 1998)

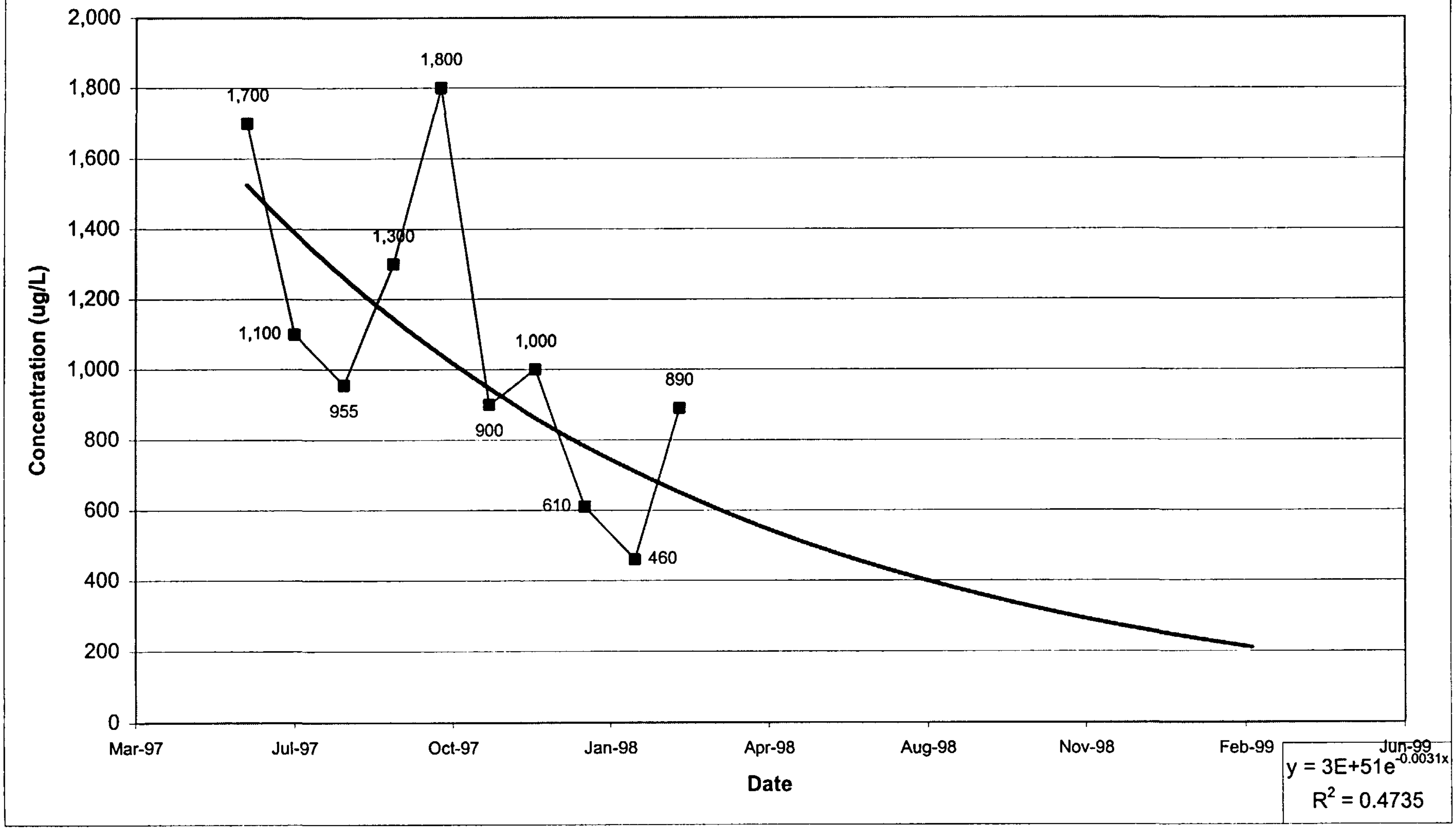
Source: Historical Monthly Treatment Plant Influent Sampling (EPA 8260)



Treatment Plant TCE with Exponential Fit Trendline

Union Chemical Site (June 1997 - May 1998)

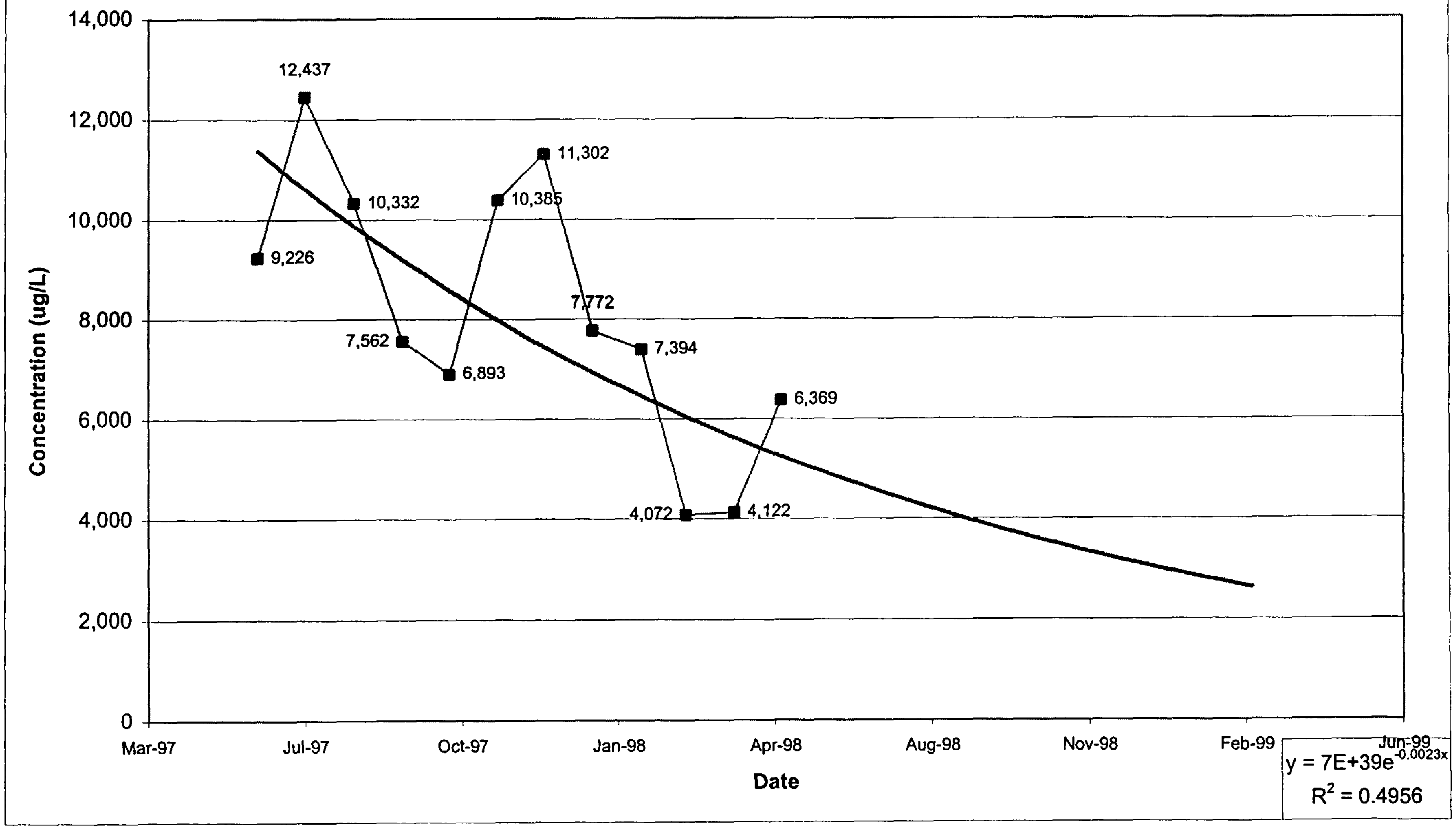
Source: Historical Monthly Treatment Plant Influent Sampling (EPA 8260)



Treatment Plant Total Chlorinated VOCs with Exponential Fit Trendline

Union Chemical Site (June 1997 - May 1998)

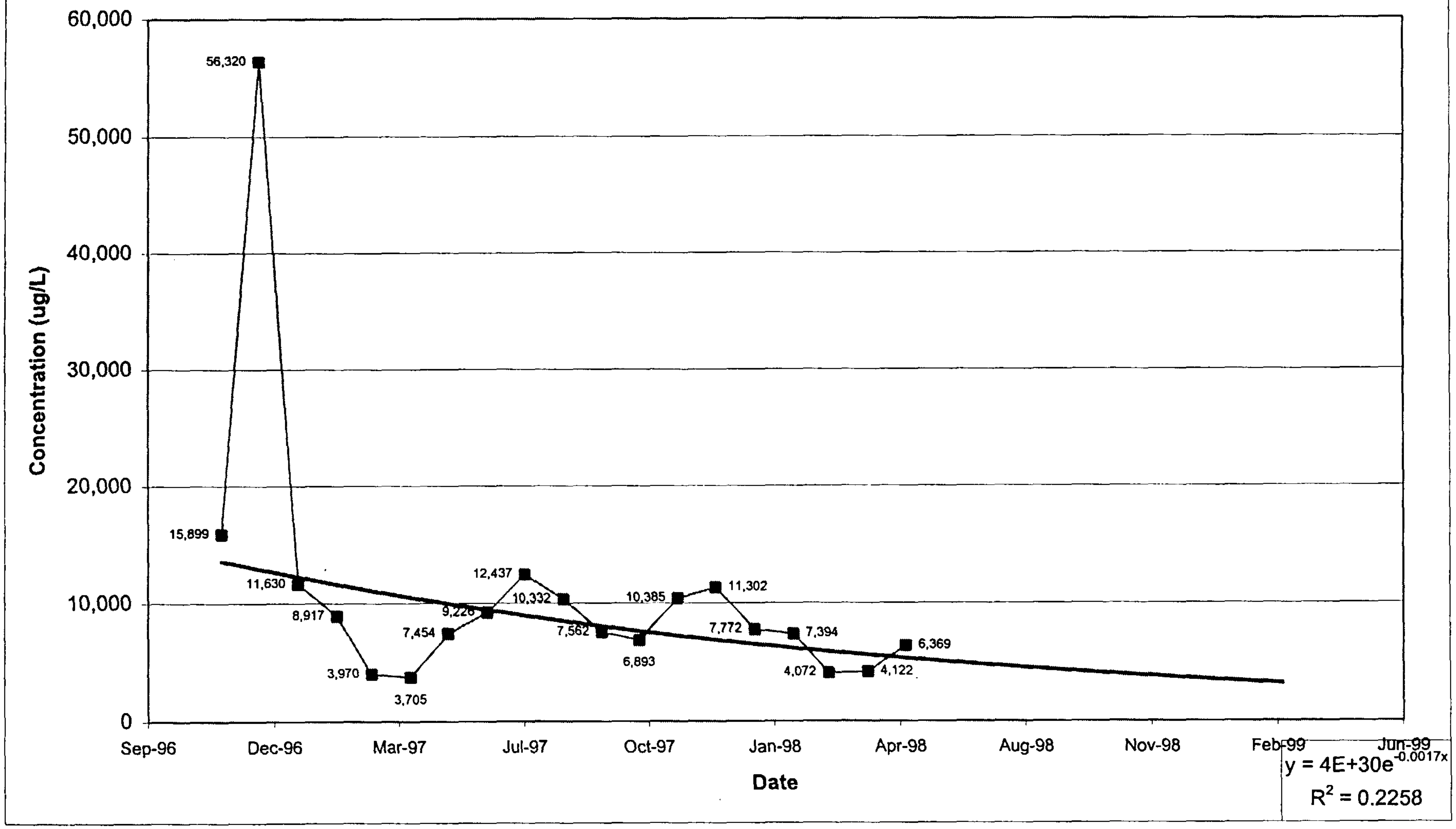
Source: Historical Monthly Treatment Plant Influent Sampling (EPA 8260)



Treatment Plant Total Chlorinated VOCs with Exponential Fit Trendline

Union Chemical Site (November 1996 - May 1998)

Source: Historical Monthly Treatment Plant Influent Sampling (EPA 8260)



P:\Union Chemical\Maine\Data\treatment plant.xls

APPENDIX E

RESPONSE TO AGENCY COMMENTS ON INTERIM REPORT

RESPONSES TO AGENCY COMMENTS

INTERIM POTASSIUM PERMANGANAGE REPORT

1. Page 1, Section 1.1: The section heading is "permanganate (MnO_4) Properties". The text starts off with Potassium permanganate ($KmnO_4$) and later switches to permanganate. Are permanganate and potassium permanganate being interchanged in the text for each other? Permanganate and potassium permanganate are different compounds. Amend the section heading and/or the text to clarify this section.

   Response: *The key ion in oxidation is the permanganate ion (MnO_4^-) typically delivered as potassium permanganate ($KMnO_4$) or sodium permanganate ($NaMnO_4$). The term permanganate has been used to denote this ion, irrespective of the cation used for supply (either K^+ or Na^+). However, except for a few locations where the context is the permanganate ion, the text has been revised to refer to potassium permanganate as this was the chemical used at the project site.*

2. Page 1, Section 1.1, Second Paragraph: Provide the citation of the reference(s) documenting the research conducted at the University of Waterloo.

   Response: *Reference added*

3. Page 2, Section 1.1, Third Paragraph, Second Sentence: The Material Safety Data Sheets in Appendix B are for potassium permanganate ($KmnO_4$) not permanganate (MnO_4). Amend the text.

   Response: *Text amended in several locations to provide clarification, as noted above in Response 1..*

4. Page 5, Section 1.4.2: The letter report referred to in this paragraph pre-dates the work performed, i.e. 1/13/97 vs. 10/97. The correct data of the letter report is January 13, 1998. Correct the text.

   Response: *Corrected as noted.*

5. Page 5, Section 2.2, First Paragraph: The potassium permanganate was added to the bedrock as well as the overburden through the injection into ground water pumping wells. Amend the text to reflect this change.

   Response: *The text has been revised accordingly.*

6. Page 6, Section 2.2, First Paragraph: If the SVE wells are screened to a depth of 25 to 30 feet ("upper" overburden), how was their "target area" 30 to 50 feet bgs? Infiltration may have supplied some $KmnO_4$ to this lower zone but the "target area" would appear to be across the screened interval, i.e. above 25 to 30 feet bgs. The text also states the ground water pumping wells are screened below 35 feet bgs and are targeting the "lower" overburden and shallow

bedrock zones. This target zone would appear to be below 35 feet, which would overlap with the area identified for the SVE wells. This paragraph is confusing. Amend text to clarify confusion.

Response: *If the distinction between upper and lower burden is made in a "general" sense (e.g., upper overburden referring to soils below the water table extending downward to depths of 30 feet while lower overburden refers to the saturated soils overlying bedrock extending upward to a depth of 30 feet), then the SVE wells are screened in the upper portion of the aquifer, while the pumping wells are screened in the lower portion of the aquifer. This distinction is generalized; some wells are screened through the aquifer while others are more distinct. The following table illustrates the general screened interval. The text has been revised to make this more clear.*

SCREENED INTERVAL in SVE AND PUMPING WELLS

Union Chemical Site
Hope, Maine

WELL ID	SURFACE ELEVATION (feet)	DEPTH TO BEDROCK (feet bgs)	SCREENED INTERVAL TOP (feet bgs)	SCREENED INTERVAL BOTTOM (feet bgs)	AQUIFER STRATA SCREENED
P-1	368.6	45.0	38.0	50.0	LOB
P-2	368.5	51.0	39.0	56.0	LOB
P-3	372.3	53.0	43.0	58.0	LOB
P-4	369.6	55.0	31.5	60.0	LOB
P-5	371.6	55.0	42.0	60.0	LOB
P-6	371.8	60.0	42.5	65.0	LOB
P-8	373.2	45.0	33.0	50.0	LOB
P-9	369.0	60.0	38.0	65.0	LOB
P-10	373.5	52.0	37.0	57.0	LOB
P-11	373.2	63.0	42.0	68.0	LOB
P-12	371.4	65.0	39.0	70.0	LOB
P-13	373.3	60.0	45.0	65.0	LOB
P-14	372.9	58.0	42.0	63.0	LOB
P-15	372.9	62.0	41.0	67.0	LOB
P-16	370.5	62.0	37.0	67.0	LOB
P-16A	370.5	69.0	41.0	74.0	LOB
P-17	371.0	61.0	32.0	66.0	LOB
P-19	369.6	66.0	45.0	71.0	LOB
P-20	369.4	62.0	39.0	67.0	LOB
P-21	368.5	60.0	33.0	65.0	LOB
P-22	366.4	64.0	35.0	69.0	LOB
P-23	368.6	61.0	30.0	66.0	LOB
P-24	363.0	65.0	38.0	70.0	LOB
P-25	364.8	64.0	35.0	69.0	LOB
P-26	358.7	60.0	26.0	65.0	UOB/LOB
P-27	351.8	58.5	9.5	63.5	UOB/LOB
P-28	349.2	60.0	5.0	65.0	UOB/LOB
P-29	352.3	53.5	6.5	58.5	UOB/LOB
V-1	368.6	NE	2.0	20.0	UOB
V-2	368.5	NE	1.5	19.5	UOB
V-3	372.3	NE	6.0	23.5	UOB
V-4	369.6	NE	6.5	24.0	UOB
V-5	371.6	NE	7.0	25.0	UOB
V-6	371.8	NE	8.0	26.0	UOB
V-7	360.6	NE	2.5	20.0	UOB
V-8	373.2	NE	6.5	24.5	UOB
V-9	369.0	NE	5.0	23.0	UOB

V-10	373.5	NE	9.3	27.5	UOB
V-11	373.2	NE	9.0	27.0	UOB
V-12	371.4	NE	7.3	25.3	UOB
V-13	373.3	NE	8.0	26.0	UOB
V-14	372.9	NE	9.0	32.0	UOB/LOB
V-15	372.9	NE	9.0	32.0	UOB/LOB
V-17	371.0	NE	8.5	31.0	UOB/LOB
V-18	363.7	NE	6.5	24.5	UOB
V-19	369.6	NE	7.0	30.0	UOB
V-20	369.4	NE	7.0	30.0	UOB
V-21	368.5	NE	6.5	29.5	UOB
V-22	366.4	NE	5.5	28.5	UOB
V-23	368.6	NE	5.5	28.5	UOB
V-24	363.0	NE	6.0	24.0	UOB
V-25	364.8	NE	9.0	27.0	UOB
V-26	358.7	NE	6.0	24.0	UOB
V-30	369.4	NE	4.0	22.0	UOB
V-31	367.7	NE	1.5	19.5	UOB
V-32	367.0	NE	3.0	21.0	UOB
V-33	368.1	NE	3.5	18.5	UOB
V-34	366.5	NE	2.0	17.0	UOB
V-35	366.8	NE	1.5	17.5	UOB
V-36	370.8	NE	3.5	21.5	UOB
V-36A	372.0	NE	6.0	24.0	UOB

Notes:

UOB (< 30 feet bgs)	*Upper Overburden Aquifer (shallow saturates aquifer)*
LOB (> 30 feet bgs)	*Lower Overburden Aquifer (deeper saturated aquifer)*
NE	*None Encountered (depth to bedrock greater than depth of exploration)*
Bgs	*below ground surface*
*P-**	*Pumping Well*
*V-**	*Vapor Extraction Well*

7. Page 8, Table: The labeling of the application points on this table is not always identical to the locations illustrated on Figure 2. For example, in the table Addition Area #2 references 4 pumping wells as P-3, P-5, P-8, and P-13. These same pumping wells are identified as VP-3, VP-5, VP-8, and VP-13 on the figure. Similar discrepancies exist for Addition Areas #3, #4, and #5. Correct discrepancies so that the Table on page 8 and figure 2 labeling are consistent.

   Response: *The table refers to the wells correctly –* ***Figure 2*** *was color coded (blue for P-* pumping wells, red for V-* vapor extraction wells) in the legend to correspond to the table. Although most well addition points consist of a well couplet (VP-*), either the pumping well or the vapor extraction well were added into at each point.*

8. Page 8, Table, Addition Area #5: Amend the "Location:" to read "hydraulically downgradient portion of the cap" instead of "hydraulically upgradient portion of the cap".

   Response: *Amended*

9. Page 9, Table, DQO #10: Delete the "a" before the word "wells".

   Response: *Corrected; also corrected on heading to* ***Section 3.1.10****.*

10. Page 10, Section 3.1.1, Action 1: Table 1 not Table 2 is the correct reference here. Correct the text.

    Response: ***Table 2*** *is correct reference denoting the addition rate per well. No changes made.*

11. Page 11, Section 3.1.2, Action 2: The text indicates that a slug test was conducted on well P-8 and that the data is included in Table 7. According to Table 7, slug testing was not conducted after addition of potassium permanganate on well P-8. Which is correct? Correct this discrepancy.

    Response: *Reference to well P-8 deleted from text.*

12. Page 12, Section 3.1.7, First Paragraph: Explain/define what is meant by "significant changes in the ORP".

    Response: *The term "significant" was used to convey an interpreted measurement of impact greater than the background scatter of measured data. The text has been revised to explain that differences from negative to positive ORP values are indicative of the presence of potassium permanganate.*

13. Page 12, Section 3.1.7, Second Paragraph: Refer to Comment #6 above in addition to the following. What was the actual depth to water for the SVE wells? This paragraph indicates the soils were dewatered to a depth of 55 feet. If the SVE wells were screened to a maximum depth of 30 feet, what data indicate the unsaturated soils extended to 55 feet? Explain.

    Response: *The ground water table in the vapor extraction wells at the time of addition was unknown. The vapor extraction wells were dry, indicating that the ground water table would be anticipated to be present at some elevation beneath the screened interval of the soil vapor extraction wells. As the average depth of the vapor extraction wells is approximately 25 feet and these wells were dry (due to pumping of the surrounding extraction wells), IT believes that the majority of the potassium permanganate filled pore spaces and migrated laterally and vertically downward to the depth of 30-55 feet (estimated).*

    No changes made. See also response to questions #6 previously. This paragraph does not indicate that soils were dewatered to a depth of 55 feet, only that the potassium permanganate was anticipated to flow into the lower portion of the aquifer by dissolution processes. In cases where potassium permanganate was added into the pumping wells, the potassium permanganate would be anticipated to impact the deeper portions of the overburden aquifer and the bedrock.

14. Page 16, Section 3.2.1, Top Paragraph: Provide a reference for the MEDEP's appraisal of the modifications that were implemented.

    Response: *The Project Engineer was contacted concerning this appraisal. According to his report, this notification was made in the periodic site status reports.*

15. Page 16, Section 3.2.2, Last Sentence: Provide text to explain how the "potassium permanganate within the well casing was monitored daily until it had been flushed naturally from the well."

    Response: *Monitoring was completed using a combination of visual (i.e., colorimetric) and physical (e.g. ORP) monitoring. Each well was monitored until the observed color returned to clear and the ORP returned to baseline conditions. The absence of color (i.e., indicating the potassium permanganate was "flushed" from the well may have resulted from expenditure of the permanganate oxidant through reaction, hydrogeologic conditions (e.g., flow or dissolution) or a combination of both. The important item of note in this section is that the wells returned to baseline conditions quickly, without the need to complete additional "flushing". Text added to section as clarification.*

16. Page 16, Section 3.3, First Bullet: First, of the 5 pumping wells identified as "demonstrating significant contaminant reduction", two wells (P-3, P-8) have data for only two of the four compounds in Table 3. For example, in Table 3 well P-3 has analytical results for only TCE and 1,2 DCE and 1,2 DCE concentrations increased. P-8 has no xylene or PCE data. How can these two wells be labeled as "demonstrating significant contaminant reduction"? This statement is very misleading, therefore, amend the text.

    Response: *This section has been deleted from the report. An explanation has been provided regarding inconsistencies within the well-specific data evaluations.*

    Second, based on the above, the questions arises as to which wells were used to calculate the average percents? All five wells could not have been used since there is no analytical data for some of these wells. Provide the actual data used in the text.

    Response: *This section has been deleted from the report. An explanation has been provided regarding inconsistencies within the well-specific data evaluations. Plant influent data has been used to calculate percent reductions.*

17. Page 16, Section 3.3, Second Bullet: First, the heading for this section is "Analysis of Pre and Post-Test Laboratory Data", why are "field GC data" being discussed? Second, the detection limit(s) of the field GC data is not known and it varies from test to test. How can conclusions and comparisons about contaminant reduction or rebound be made based on data that is incomplete (varying detection limit information that is not provided or known)? Therefore, the field GC data is not reliable and must not be used to base conclusions and comparisons on. The field GC data does not exist may be presented, however, its use must be limited and its usability (reliability) qualified in the document.

Response: *The reference in this section to the GC data was meant to provide complimentary data, supplementing the analytical data. The GC data is meant as a Level II data set to assist in data review and, as such, may be used with qualification. The GC data is contained in a different table and clearly referred to as GC data. To eliminate confusion, this table has been moved to Appendix D. Further, the text has been revised to distinguish between laboratory and field data..*

18. Page 16, Section 3.3, Fourth Bullet: Where is the DMF data presented? If not presented in this document, provide the data in the next version of this document.

Response: *DMF data was summarized on* ***Table 3****. Reviews of the DMF data however did not show the same trends as the VOCs. This likely results from the different alignment of the highest concentrations of DMF versus the other VOCs. In addition, DMF is not as oxidizable as the other VOCs and is not anticipated to have as large an impact compared to the VOCs. For completeness, the DMF data was left on* ***Table 3****; comments related to DMF were stricken from the text.*

19. Page 17, Section 3.3, Bullet at top of page: There are significant discrepancies between the field and laboratory results for iron and manganese. Provide in the text an explanation for these differences.

Response: *Field data for iron and manganese did not correlate with the laboratory results. This may result from the methodology, sample handling, pressure of oxidants, time-sensitive changes in valence or other possible factors. As this data was collected as Level II data, this information has been included as an appendix but has not been used for discussion or interpretation.*

20. Page 17, Section 3.3, Analysis of the Field Gas Chromatograph Data, First Bullet: As stated above in Comment #17, the detection limit of the field GC varies from test to test. How were the percent reductions calculated? The field GC data is not reliable and because of the varying detection limits may indicate a reduction in contaminant levels when in fact an increase has occurred and vice versa. If the field GC data is used to make observation, provide text that discusses its reliability and usability.

Response: *See response to previous questions #17. Also to avoid confusion, this text was moved to Appendix D unchanged from the original report and is provided for information only. Percent reduction calculations were based on plant influent.*

21. Page 17, Section 3.3, Analysis of the field Gas Chromatograph Data, First & Second Bullets: First, in calculating the average percent, which results were used when there are multiple post-addition results?

Second, how are the "below the detection limits" (bld) handled in the calculation?

Third, well p-3 has no post-addition data. How can it display significant contaminant reduction? Explain.

Fourth, provide a figure which clearly illustrates all of the wells from which samples (either laboratory or field analyses) were collected. The present figures do not show all of the sampling locations identified in this section or Table 4.

Response: *See response to question #20. Data moved to* ***Appendix D*** *for information purposes only. Percent reduction calculations were based on plant influent.*

22. Page 18, Section 3.3 Geosoft Contouring of the Data: What data, laboratory or field GC, was used in generating the concentration contour maps. As indicates in previous comments, the field GC data is of limited use.

Response: *All data used for the generation of these plots was Level III data from the analytical laboratories. No FGC data was used. However, the text has been revised to note that these maps are no longer being used to calculated VOC reductions.*

23. Page 18, Section 3.3, Geosoft Contouring of the Data: Provide the calculations which support the percent reductions and mass removed. These may be placed in an appendix.

Response: *The Geosoft maps are not longer being used to calculate VOC reductions.*

24. Page 19, Section 4.0, Item #1: What data (laboratory or field CG) was used to calculate the percent of contaminant mass reductions? Based on the reliability of the data, only the laboratory data is to be used to calculate the percent of contaminant mass reductions.

Response: *See response to questions #22 and 20. The text has been revised to base percent reductions on laboratory data only, based on plant influent.*

25. Page 19, Section 4.0, Item #2: The data in Table 6 does not support the conclusion that "significant reductions in total iron concentrations" occurred in ground water. The data shows minimal changes or increasing and decreasing concentrations. There is no overall trend that can be discerned. Amend the text to reflect the data.

Response: *Agreed. The text has been revised accordingly.*

EPA COMMENTS ON

Interim Test Report for the Potassium Permanganate Addition

November 30, 1998

1. p1, Sec 1.0 2nd ¶: The approved work plan for the potassium permanganate addition included using the April 1999 data to evaluate the efficacy of the method. The revised report will need to include these data.

   The need for this is also noted in Section 5.1 of Surface Water and Ground water Monitoring Report, Twenty-fourth Quarter (October 1998), January 29, 1999, stating that the increased acidity measured in the wells may be result of the $KMnO_4$ addition. It would therefore seem that final evaluation of the addition would need to be done after the system returns to pre-existing conditions.

   Response: *The report includes the April 1999 data..*

2. p1, Sec 1.1, table: The equation for PCE indicates hydrogen and chloride ions being formed. Will these combine to form hydrochloric acid? If so, what impact will there be?

   Response: *Hydrogen and chloride ions may bond to form HCl (hydrochloric acid) resulting in decreased pH. Alternatively these free ions may remain free (H^+ hydrogen ion also reduces pH while chloride may increase ambient chloride concentrations) or form other precipitates (salts). The complex geochemistry of the soils, groundwater and the chemical reactions makes it impossible to predict the specific outcome.*

3. p3, Sec 1.2, 1st ¶: The travel time from an injection point would seem to be independent of the spacing of other points, either other injection points or monitoring wells. These other points would only provide a point of measurement.

   Response: *Correct, text revised to reflect distance, not spacing.*

4. p4, Sec 1.4: change section heading to "~~Summary of~~ Past $KMnO_4$ Testing Activities".

   Response: *Done*

5. p6, 1st full ¶: Throughout this document, there are varying ranges presented for SVE depths, pumping well depths, screen locations, and implied water table elevations. Provide (1) a figure showing these ranges, and (2) revise the document so that the references to these depth are consistent.

   Response: *A table has been provided in response to MEDEP comments (comment #6). The well screen intervals across the site vary depending upon the location (i.e., wells in the leach field tend to be deeper to provide soil remediation at deeper levels) and the site grade. Correspondingly, it is difficult to remain consistent in discussing the screens across the entire site.*

Text was reviewed to improve consistency. IT attempted to prepare a graphic illustrating screened intervals, however due to the number and spacing of the wells, the graphic was virtually unreadable and not provided in this report.

6. p12 Sections 3.1.5 and 3.16, and page 13, Occurrence #1: These three sections state that there is further discussion of the respective topic in Section 4.0. Section 4.0 lists the conclusions. There is no discussion, nor even any mention of ORP, end products of the oxidation, or generation of CO_2 gas in Section 4.0 or elsewhere. All these topics need to be discussed. Section 3.3 would appear to be the appropriate section.

   Response: ***Section 3.3*** *was expanded to include additional discussions requested.*

7. p15, 1st bullet: The statement that "The rates of addition to the SVE wells were <u>intentionally set</u> at a lowered (msp) addition rate..." does not seem to mesh with the statements in Section 3.1.4 (As shown in Table 2, the addition wells, regardless of whether they were SVE or GW extraction wells, generally demonstrated consistent infiltration rates) and Section 3.1.7 (As discussed above, only slight differences were observed in the infiltration rates for either SVE or GW pumping wells). One might suspect that this statement on page 15 is a post-addition spin and not part of the original work plan.

   Response: *This comment is not a "post-addition test spin" as implied; rather the level of permanganate was indeed intentionally set lower to minimize the potential for flow into the upper soils as stated. This was done so that permanganate would not be introduced into the upper soils that were to be sampled during the soil closure sampling activities in the Fall of 1998. IT believed that introducing permanganate into the upper soils would bias the confirmatory closure soil sampling program, preventing the collection of representative samples.*

8. p15, 1st and 2nd bullets: See comment above regarding depths of SVE, and note that Table 9 indicates the depths of the SVE to be 10-20 feet bgs.

   Response: *This table has been corrected to provide screened intervals, consistent with newly provided table of screened intervals.*

9. p16, Section 3.3: This section contains summary statements regarding changes in conditions, yet there are concerns with many of these. Sometimes field GC data appears to be compared to laboratory data, sometimes a subset of addition wells are used to make a statement about the entire site, sometimes different sets of monitoring points are used to develop pre- and post-addition comparisons. These situations place a cloud over the outcome or certainly, the extent of the outcome of this potassium permanganate study.

   Response: *This section has been revised to provide improved data analysis.*

10. p18, Evaluation of the Geosoft Contour Maps: Looking at the Q#24 report, it appears that the majority of wells included in the regular twice-a-year sampling have decreasing trends of VOCs. Consequently, the reduction in concentrations should not be attributed solely to the influx of $KMnO_4$.

    Response: *This was considered in the data analysis section as potential antecedent trend.*

11. p19, Sec 4.0, #1: Perhaps the statement that mass reductions of 40-50% were achieved is taking the previous comment into consideration, but it varies from the statement on the previous page that 40% reduction for total VOCs was achieved. This drift of statements from one section of the report to another distracts the reader, wondering whether the author or authors are trying to cover all bases. As with the issue of depths, use the same figure or percent of same figure/percent throughout the report.

    Response: *This section of the report has been revised.*

12. p19, Sec 4.0, #2: I think what Table 5 and 6 provide is a very sharp contract between laboratory and field methodology for measuring iron – there does not appear to be any reduction based on the field data.

    Response: *Correct, field data did not correlate with laboratory data. To remove potential confusion, field data has been appendicized for information only. Field data was not used for further analysis.*

13. figures 4, 6 and 8: A cursory review found that the concentrations reported for B-6B-I. were from the Quarter #23 sampling in April 1998, not June 1998 as indicated in the legend. Please review figures for consistency with the data.

    Response: *Figures were reviewed for consistency with **Table 3A** and **3B**.*

APPENDIX F

AGENCY COMMENTS CORRESPONDENCE DATED FEBRUARY 2, 2000

United States Environmental Protection Agency
One Congress Street, Suite 1100
Boston, MA 02114-2023

February 2, 2000

Union Chemical Site Group
c/o American Environmental Consultants
Attn: Mr. Randy C. Smith
30 Purgatory Road
Mont Vernon, NH 03057-0310

RE: Test Results for Potassium Permanganate Additions - Summer 1998, Revision 1
Union Chemical Company Superfund Site

Dear Mr. Smith:

EPA has reviewed the September 17, 1999 Test Results for Potassium Permanganate Additions - Summer 1998, Revision 1, submitted by IT Corporation on behalf of the Settling Defendants pursuant to the Union Chemical Consent Decree, Civil Action No. 91-0392-P-C.

EPA, with review and comment by Maine DEP, has concluded that because of the insufficient data collected before and after the permanganate addition and the lack of consistent trends in the available data, it would not be productive to make another revision of this document. EPA notes that it concurred with the level of pre- and post-test sampling efforts. Therefore, rather than revising the document, the attached comments (with the exception of the disclaimer which shall go in front of the document) shall be attached to it as an appendix. Please resubmit the document with the attachments by March 1, 2000.

For your convenience, I am also sending this letter and comments via e-mail. Please contact me at (617) 918-1373 if you have any questions about the enclosed comments.

Sincerely,

Terrence Connelly
Maine, Vermont, and Connecticut Superfund Section

Enclosure

cc: David Egan, IT Corporation
Rebecca Hewett, Maine DEP
Brian Powers, Hope Committee for a Clean Environment

DISCLAIMER STATEMENT TO BE PLACED AT THE FRONT OF THE DOCUMENT

"Disclaimer: This document is a draft document prepared by the Settling Defendants pursuant to the Union Chemical Company Consent Decree which has not received final acceptance by the U.S. Environmental Protection Agency. The opinions, findings, and conclusions expressed are those of the authors. EPA has decided not to require a final document. Its opinions and conclusions are expressed as an appendix to this document."

GENERAL COMMENTS on

Test Results for Potassium Permanganate Additions - Summer 1998, Revision 1

1. IT Corporation has evaluated from many perspectives all the data collected during the 1998 permanganate additions at the Union Chemical Company Site and has drawn qualitative and (semi)-quantitative conclusions from these evaluations. Unfortunately, it appears that for a variety of reasons, with the heterogenous conditions at the site the likely principle reason, EPA can only agree with the qualitative conclusion that the addition of potassium permanganate appears to be assisting in the degradation of the groundwater contaminants. As noted by IT Corporation at the September 14, 1999 meeting, quantifying the reduction was not one of the data quality objectives established for this pilot study. Therefore, attempts to quantify the reduction based on the 1998 pilot study should be de-emphasized.

2. In hindsight, the agencies and IT Corporation could have done better in planning how the 1998 permanganate addition would be evaluated. All the data quality objectives, from maintaining hydraulic control, evaluating worker safety procedures, to avoiding impact to the soil closure sampling, were met. Yet, what was not included as a data quality objective and what remains as the big question from the perspective of the public, the agencies, and the consultant (albeit each entity may have a different interest in answering this question): did the permanganate have a beneficial impact on the groundwater contamination at the Site? It appears that the rush to get in the field minimized the planning of how to measure the impact and how to distinguish that impact from the ongoing groundwater extraction system, and for that matter, from the ongoing natural attenuation.

3. Perhaps due to the overlap of the 1998 report review, the recently concluded 1999 field season, and the discussions on rebound assessment, the assertion that ORP is a viable indicator of permanganate residue has become overstated as a supportable conclusion from the 1998 pilot study. Review of the available data overwhelmingly does not show a correlation between ORP measurements and presence of permanganate.

4. The September 1999 revisions, made in response to agency comments on the November 1998 draft report and incorporating the April 1999 data, have provided a much more readable and consistent document.

PAGE-SPECIFIC COMMENTS on
Test Results for Potassium Permanganate Additions - Summer 1998, Revision 1

5. p4, Sec 1.3, 2nd paragraph The text indicates that "The depth to water is variable, but tends to be 15 to 20 feet" Clarify whether the depth estimate (i.e., 15 to 20 feet) is measured from the original topography or the present (after capping) topography.

6. p13, Sec 3.1.5, Result, #1 and #2.: Unfortunately, these paragraphs over-state the data:
☐ of the ORP measurements of the 24 monitoring points, 11 had positive ORPs with the highest measurement at 224 and 13 had all negative measurements.
☐ of the 20 addition points, one had a measurement of 502, two more were above 200, and five remained negative
☐ the correlation between purple water and high ORP measurements is not supported by the data presented. All three addition wells which were measured at the same time purple water was observed had negative values.
☐ it is stated that purple water was visually identified in some downgradient wells. Per the data presented in Table C-2, none of the monitoring wells are recorded as having purple water. All of the addition points are recorded as purple during the respective addition periods; none are depicted as having purple water prior to their respective additions - i.e., no purple water observed during upgradient additions
☐ it is stated that effects were seen as much as 25 feet away from addition points. Given that the groundwater velocity under non-pumping conditions is estimated to be approximately 17 feet/year, or 1½ feet/month, it seems incongruous that effects were observed 25 feet away in a period of a few weeks when the pumping rate of the extraction system was less than 5 gpm.
☐ in reviewing the data, all parties should keep in mind the limitations of field screening data (Level I). For example, regardless of the measurement point location, of the eleven measurements taken on July 15, nine of these locations had their maximum ORP measurement, including all four monitoring points that are, at least, sidegradient to the addition areas.

7. p18, Sec 3.1.12, Item #3: The text states "...two (2) were within 20 feet of the soil closure sample location." Clarify whether this means 20 feet horizontally, vertically or both.

8. p19, Sec 3.2.2, Next to last sentence: Define what "monitored daily" consists of. Was this visual for color, ORP reading or both?

9. pp19-20, Sec 3.3.1: The section indicates that ten wells show the relationship between $KMnO_4$ and ORP. Reviewing the data presented on Table C-2 , adding dates for the five addition areas, and combining this with Figure 2 with the statement that impact was not further than twenty-feet, all of the ten have contra-indications to this relationship:

☐ P-2, P-4, P-6, and P-9 are all upgradient or sidegradient to addition areas, so it would appear that either hydraulic control is not being maintained, these ORP readings are in error, or that the ORP naturally fluctuates across the site and therefore can not be used as an indicator;

☐ P-11, an Area #3 addition point, was negative before addition, purple during (no readings taken), negative after, then positive during additions in downgradient Area #5;

☐ P-12, sidegradient to Area #3, had one positive reading when Area #3 additions were made and yet it was negative when additions were made to its coupling point, V-12, in Area #4;

☐ P-13, an Area #2 addition point, was negative before addition, purple during (no readings taken), negative after, then positive during additions in downgradient Area #5;

☐ P-16 appears to demonstrate the relationship, except for the distance involved. It was negative during additions to Area #2, then had a positive reading during Area #3 (whose addition points are between forty and fifty feet from P-16). No subsequent readings are reported during Area #4 additions when $KMnO_4$ was added to V-15, just ten feet upgradient of P-16 or during its use as an addition point in Area #5;

☐ P-20 and P-24 have positive readings during additions to Areas #2 and #3 (thirty to seventy feet upgradient), but both are strongly negative during additions to their coupling points, V-20 and V-24, in Area #4.

10. pp21-22, Sec 3.3.2.1: The crux of the problem, trying to establish the impact of $KMnO_4$ on VOC concentrations with the available data.

☐ VOC Reductions due to Groundwater Extraction System: Curve projections suggest the extraction system is still efficiently removing VOCs which runs counter to the commonly-held expectation that the system would have experienced a decreasing return by now. Yet, the scatter of the influent data is so large that the statistical correlation is poor, and therefore the curve projections become questionable.

☐ Geosoft Contour Maps: It is unclear from this explanation whether the inability to construct accurate Geosoft contour maps is from the lack of monitoring locations or that sufficient data was not collected.. This also appears to be the situation with the pumping wells: there are 29 pumping wells, the maps constructed from the quarterly monitoring typically rely on data from 16 - 22 wells. Therefore it would appear that there are sufficient locations but that the data was not included to implement this form of evaluation.

☐ Periodic Monitoring Data: If the majority of monitoring points are beyond the area of influence for the 1998 permanganate application, and are within the groundwater extraction system capture zone, then that data would seem to provide an excellent picture of the impact from the groundwater extraction system. Reviewing the maps from the April 1999 sampling event, it appears that ten of fifteen overburden wells and four of eight bedrock wells are within the pumping wells' capture zone - which I thought was the main purpose of the monitoring network, to monitor the changes in groundwater quality due to the extraction system - and therefore could be considered representative of changes attributed to it. Unfortunately, as noted in the subsequent paragraph, the data from the monitoring points do not present a statistically strong downward trend.

☐ Individual Well Comparisons: EPA agrees with both points noted here; there is not a consistent trend of the data, and that the frequency of sampling was not sufficient to assess impact from permanganate in individual wells. Which is acceptable in that the groundwater remediation goal is restoration of the entire aquifer, not just individual points. It just does not provide a method to evaluate the effect of permanganate.

☐ Evaluation of Plant Influent: EPA agrees with the use of plant influent as representative of the VOC reduction in the treatment area, though it is not clear why the combination of water from both treated and untreated areas negates the effect of mixing. Looking at Appendix D, perhaps if the treatment plant concentration data were normalized to mass removed, then the curve projections may have shown a better statistical fit.

11. pp22-24, Sec 3.3.2.2: The methodology as outlined here was agreed upon by EPA and Maine DEP. Unfortunately, as noted in the discussion of the previous section, the data for input into this methodology is suspect, and consequently, the output from the methodology is also suspect.. The two points supporting a greater reduction from the permanganate appear valid, yet there are also problems with what is pointed out for individual compounds: 1,1-DCA reduction is calculated to be 40%, 2% for TCE. As noted on page 1 and in IT Corp's September 29, 1999 presentation at One Financial Center in Boston, permanganate is more effective oxidizing chlorinated ethenes rather than ethanes. A review of Tables 3A and 3B suggest significant reductions of both 1,1-DCA and 1,1,1-TCA in many (but not all) wells, for example P-12, P-16A, B-6A-D, and B-6B-I . Should these reductions be attributed to the extraction system?

12. pp24-25, Sections 4.0 and 5.0 Conclusions and Recommendations: The interim test demonstrated injection into the subsurface was possible and could be done safely. The use of ORP as an indicator, as presented in this application, is questionable. This may be due to the frequency of measurements, the amount of permanganate used (as compared to subsequent application in 1999), or the reliability associated with Level I data.

    The available VOC data, notwithstanding several attempts and a great deal of effort to analyze it, is unfortunately, because of the scatter of values, sampling frequency, and locations of the sampling points, reduced to anecdotal status in determining the effectiveness of this effort in reducing VOCs. Based on the 1998 interim effort, the beneficial technical and economic potential of permanganate addition cannot be quantified and remain unproven.

13. Table 3A: As examples of the difficulty in assessing the data, consider the cis-1,2-DCE data for P-22 and P-24:

	P-22		P-24
pre-test 1998	2,200		
post-test 1998 (10/07)	960		
pre-test 1999 (04/07)	1	04/07	160

pre-test 1999 (04/23)	960	04/09	4

or the 09/01/98 and 10/07/98 data for P-29.