Office of Solid Waste and
Emergency Response
(5102G)

USEPA-540-R-013-014
January 16, 2013
www.epa.gov/superfund/cleanup/
postconstruction/optimize.htm
www.clu-in.org/optimization

Optimization Review
Ogallala Ground Water Contamination Superfund Site
Operable Unit 2 (Tip Top Cleaners)

Ogallala, Nebraska

OPTIMIZATION REVIEW

OGALLALA GROUND WATER CONTAMINATION SUPERFUND SITE
OU 2 (TIP TOP CLEANERS)
OGALLALA, NEBRASKA

Report of the Optimization Review
Site Visit Conducted at the Ogallala Ground Water Contamination Superfund Site, OU2, on
24 July 2012

Final
16 January 2013

EXECUTIVE SUMMARY

USEPA's definition of optimization is as follows:

"Efforts at any phase of the removal or remedial response to identify and implement actions that improve the action's effectiveness and cost-efficiency. Such actions may also improve the remedy's protectiveness and long-term implementability which may facilitate progress towards site completion. To identify these opportunities, regions may use a systematic site review by a team of independent technical experts, apply techniques or principles from green remediation or Triad, or apply some other approach to identify opportunities for greater efficiency and effectiveness. Contractors, states, tribes, the public, and PRPs are also encouraged to put forth opportunities for the Agency to consider."

An optimization evaluation considers the following: goals of the remedy; available site data; the conceptual site model (CSM); remedy performance; protectiveness; cost-effectiveness; and closure strategy. A strong interest in sustainability has also developed in the private sector and within federal, state, and municipal governments. Consistent with this interest, optimization now routinely considers green remediation and environmental footprint reduction during optimization evaluations. An optimization evaluation includes reviewing site documents, interviewing site stakeholders, potentially visiting the site for one day, and compiling a report that includes recommendations in the following categories:

- Protectiveness
- Cost-effectiveness
- Technical improvement
- Site closure
- Environmental footprint reduction

The recommendations are intended to help the site team identify opportunities for improvements in these areas. In many cases, further analysis of a recommendation, beyond that provided in this report, may be needed prior to implementation of the recommendation. Note that the recommendations are based on an independent evaluation, and represent the opinions of the evaluation team. These recommendations do not constitute requirements for future action, but rather are provided for consideration by the Region and other site stakeholders. Also note that while the recommendations may provide some details to consider during *implementation*, the recommendations are not meant to replace other, more comprehensive, planning documents such as work plans, sampling plans, and quality assurance project plans.

Site-Specific Background

The Ogallala Ground Water Contamination Superfund site was identified in 1989 through municipal well sampling. Tetrachloroethene (PCE), a solvent commonly used in dry cleaner operations, was the primary ground water target chemical of concern (COC) that was identified for remediation purposes. A comprehensive remedial investigation (RI) was conducted in 1995 and 1996. Additional investigations were also conducted following completion of the RI to define the plume.

Summary of Conceptual Site Model

The source of the tetrachloroethene (PCE) ground water plume is believed to be associated either with the release of condensate or equipment leaks containing PCE from the Tip Top Cleaners indoor operations to the surface/subsurface. Residual PCE mass released to the subsurface appears to have been immobilized within the vadose zone and at the capillary fringe above the water table in the immediate vicinity of the release area at a maximum depth of approximately 16 feet below ground surface (ft bgs). It is surmised that the released PCE was in relatively small quantities over an extended timeframe, so the total mass of the PCE released was not at a level that resulted in the generation of pooled dense non-aqueous phase liquids (DNAPL) layers or extensive vertical migration below the depth of the water table. The plume extended to the east-southeast by advection with the flow of the shallow aquifer ground water. Soil vapor extraction (SVE), and later soil excavation, has likely mitigated most of the long-term PCE mass flux to the dissolved phase.

The site contamination is apparently restricted to the unconsolidated alluvial deposits. These deposits are largely sandy silt and clay from the surface to depths of 17 ft bgs near the Tip Top site. These fine-grained materials overlie highly permeable shallow sands and gravelly sands comprising the shallow aquifer. Ground water flow is to the east to east-southeast. Ground water on the flow paths emanating from the site would appear to discharge to gravel pit lakes south of US Highway 30 or to the South Platte River. Based on historical water level measurements, the depth to groundwater fluctuates annually between approximately 15 and 18 ft bgs.

The plume as depicted in the initial RI reports was quite narrow and at least a half-mile long. Ground water contamination essentially is limited to PCE. PCE concentrations have been as high as 1,200 micrograms per liter (ug/L) in OU2-MW-2, and concentrations in the 100s of ug/L extended to OU2-MW-7 in the early 2000s. Recent concentrations have diminished significantly, and detections of PCE above its ground water remedial action objective (RAO) are limited to monitoring wells within 300 feet of the source area along North Spruce Street.

Summary of Findings

In-situ chemical oxidation (ISCO) using sodium permanganate was conducted by the United States Environmental Protection Agency (USEPA) following the issuance of the Record of Decision (ROD) starting in September 2006 and continuing through the third quarter of l 2011. ISCO injection events were also performed prior to the issuance of the ROD as part of the interim response action and served as an initial pilot/treatability study. Injection of oxidant occurred at various locations within the plume, but was primarily concentrated just downgradient of the source area. Building demolition and soil excavation was conducted in 2011 to remove remaining source area PCE mass that was contributing to long-term groundwater mass flux. The ISCO injections were conducted more-or-less quarterly over five years. Monitoring following treatment is to follow the injection period for another five years or until the groundwater RAOs are attained.

Based on a review of the information provided to the optimization review team, the Site visit conducted on July 24, 2012, and interviews with persons knowledgeable about the Site, the following are the key findings from this optimization evaluation:

- The remedial strategy used for the site is sound.

- The primary data gap for the ground water plume is the full definition of the plume. Based on the recent PCE detection in the direct push sampling point along East G Street, it appears that the plume is not bounded on the downgradient end. The monitoring network is concentrated on the previously observed plume axis, and does not include bounding wells to the north or south of the inferred plume. This plume delineation data gap primarily applies to the intermediate and deeper zones of the shallow aquifer unit between a depth of approximately 30 and 65 ft bgs. The existing monitoring network appears to have delineated the upper portion of the shallow aquifer unit to a depth of approximately 30 ft bgs. Monitoring wells MW-10 and MW-11 provide data concerning the north and south edges of the plume at locations near but downgradient of the source area.

- Another potential data gap is the remaining residual PCE mass within the source area shallow saturated zone following the soil excavation. The possibility that more than a minimal level of residual mass still remains immobilized within the top of the source area saturated zone could result in observed rebound of groundwater concentrations following the completion of the ISCO injection events.

- The empirical approach that has been used to evaluate the effectiveness of the ISCO treatment suggests that permanganate has been distributed throughout the ground water plume, but it is difficult to determine the overall treatment level until rebound testing has been performed over a sufficient period of time. The ISCO design approach did not account for the natural soil oxidant demand or PCE mass that exists in the adsorbed phase or as residual mass remaining in the source area shallow saturated zone. The transect injection approach relies on ground water advection to distribute the permanganate throughout the ground water plume to affect treatment.

- If the plume is found to exist outside the current network, or a rebound in PCE groundwater concentrations is observed following the completion of ISCO treatment, additional permanganate injections may be necessary to treat the remaining residual PCE mass, or the Agencies will have to assess the ability of natural processes (essentially sorption and dispersion) to prevent exposures and eventually attain the ground water RAOs.

Summary of Recommendations

Recommendations are provided to improve remedy effectiveness, reduce cost, provide technical improvement, and assist with accelerating site closure. It should be noted that the Project Team has elected to be proactive and already has plans to implement most of the recommendations outlined below based on a review of a draft of this report. Plans, as communicated by the Project Team, to implement specific recommendations are also described below. Recommendations and planned response actions associated with the above criteria are as follows:

- The current extent of the ground water plume needs to be more fully verified to assure that the very promising concentration reductions have actually occurred throughout the plume. Monitoring points that bound the plume in the cross-gradient and downgradient directions are needed. Planned assessment activities communicated by the Project Team include vertical profiling and plume delineation in the area of monitoring well MW-8 using a combination of various direct-push techniques such as membrane interface probe ([MIP], soil gas measurements), electrical conductivity ([EC], mapping tool for soil types), hydraulic profiling tool (measure of formation permeability for preferential migration pathway identification), and soil/groundwater grab sampling. The field data collection using these direct-push techniques will be used to identify locations for the installation of additional nested monitoring wells within the intermediate and deeper zones of the shallow aquifer unit.

- It is also recommended, if logistically feasible, that soil and “grab” groundwater samples be collected in the source area as part of the upcoming planned source area monitoring well installation or any future Geoprobe site assessment sampling to measure the level and extent of residual PCE mass still remaining. Upcoming planned source area assessment activities communicated by the Project Team include the following: 1) use of MIP/EC to provide vertical profiling of PCE mass presence in the saturated zone; 2) installation of monitoring well nests (screened in both the shallow and intermediate zones of the shallow aquifer unit) based on the initial MIP/EC findings; and 3) collection of two saturated zone source area soil samples for analysis of volatile organic compounds (VOCs) and permanganate natural oxidant demand (PNOD) to evaluate residual source area PCE mass and provide a quantitative measurement of the PNOD for further evaluation of the ISCO design approach. It should also be noted the installation of additional monitoring wells in the source area had been proposed by the project team prior to this optimization study.

- The quarterly sampling at the site should be continued for no more than another few quarters, and then semi-annual sampling could be conducted. This represents a cost reduction of approximately $36,000 per year or a total of $108,000 (6 times $18,000 per round). The Project Team has communicated its intent to modify the future ground water sampling frequency to a semi-annual basis.

- Future sampling for downgradient wells could be conducted solely for volatile organic compounds (VOCs) by passive diffusion bags (PDBs). The Project Team has communicated its intent to modify future ground water sampling events for the downgradient wells to include only VOCs using PDBs.

- If a rebound in the PCE ground water concentrations is observed, an additional injection event of permanganate that includes locations both upgradient (northwest) of the excavation area and directly within the source area is recommended. The permanganate dosage should be increased to allow injection of adequate oxidant to treat the remaining residual PCE mass and account for the demands from any natural organic matter in the soil and aquifer matrix. The Project Team will evaluate PCE rebound during the future semi-annual ground water sampling events. If needed, additional injections of permanganate will be considered based the observed rebound levels. The scope of any future permanganate treatment events would consider injections both upgradient to the northwest of the source area and within the source area, with the injection volumes and dosages based on using the results of the PNOD tests, groundwater analyses, and soil analyses to determine the total PCE mass and corresponding oxidant demand.

NOTICE

Work described herein was performed by the US Army Corps of Engineers (USACE) Environmental and Munitions Center of Expertise (EM CX) for the U.S. Environmental Protection Agency (USEPA). Work conducted by USACE EM CX, including preparation of this report, was performed under Interagency Agreement DW96921926. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

PREFACE

This report was prepared as part of a national strategy to expand Superfund optimization practices from site assessment to site completion (the Strategy) implemented by the United States Environmental Protection Agency (USEPA) Office of Superfund Remediation and Technology Innovation (OSRTI). The project contacts are as follows:

Organization	Key Contact	Contact Information
USEPA Office of Superfund Remediation and Technology Innovation (OSRTI)	Jennifer Edwards	US USEPA Headquarters, 1200 Pennsylvania Ave, NW, Mail Code 5204P, Washington DC 20460 Edwards.Jennifer@epamail.epa.gov 703-603-8762
US Army Corps of Engineers, Environmental & Munitions Center of Expertise (Contractor to USEPA)	Dave Becker	1600 Capitol Ave., Suite 9200, Omaha, NE 68102-9200 Dave.J.Becker@usace.army.mil 402-697-2655

LIST OF ACRONYMS

bgs	below ground surface
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
cm/sec	centimeter per second
COC	chemical of concern
CSM	conceptual site model
DCE	1,2-cis-dichloroethene
DNAPL	dense, non-aqueous liquid
FS	Feasibility Study
g/kg	grams per kilogram
ISCO	in-situ chemical oxidation
kg/cu m	kilograms per cubic meter
lbs	pounds
LTM	long-term monitoring
MCL	maximum contaminant level
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
NPL	National Priorities List
OSRTI	Office of Superfund Remediation and Technology Innovation
OU	operable unit
PCE	tetrachloroethene
PDB	passive diffusion bag
PRP	Potentially Responsible Party
P&T	pump and treat
QAPP	Quality Assurance Project Plan
RAO	remedial action objective
RI	remedial investigation
ROD	Record of Decision
RSE	Remediation System Evaluation
SDWA	Safe Drinking Water Act
sq ft	square feet
sq m	square meters
SVE	soil vapor extraction
TCE	trichloroethene
ug/kg	micrograms per kilogram
ug/L	micrograms per liter
VC	vinyl chloride
VOC	volatile organic compound
USACE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency

TABLE OF CONTENTS

List of Tables

Figures

Attachments

1.0 INTRODUCTION

1.1 PURPOSE

During fiscal years 2000 and 2001, independent Remediation System Evaluations (RSEs) were conducted at 20 operating pump and treat (P&T) sites (i.e., those sites with P&T systems funded and managed under Superfund by the United States Environmental Protection Agency (USEPA), other federal agencies, and by the States). Due to the opportunities for system optimization that arose from those RSEs, USEPA Office of Superfund Remediation and Technology Innovation (OSRTI) has incorporated RSEs into a larger post-construction complete strategy for Fund-lead remedies as documented in OSWER Directive No. 9283.1-25, *Action Plan for Ground Water Remedy Optimization*. Concurrently, USEPA developed and applied the Triad Approach to optimize site characterization strategies, methods and technologies, including the increased use of conceptual site models (CSMs) as the basis for identifying project data gaps, and using those gaps to guide the development of site characterization objectives and work plans. USEPA has since expanded the reach of optimization to encompass reviews at the investigation stage of projects (such as for the BBM Site). USEPA's definition of optimization is as follows:

"Efforts at any phase of the removal or remedial response to identify and implement actions that improve the action's effectiveness and cost-efficiency. Such actions may also improve the remedy's protectiveness and long-term implementability which may facilitate progress towards site completion To identify these opportunities, regions may use a systematic site review by a team of independent technical experts, apply techniques or principles from green remediation or Triad, or apply some other approach to identify opportunities for greater efficiency and effectiveness. Contractors, states, tribes, the public, and Potentially Responsible Parties (PRPs) are also encouraged to put forth opportunities for the Agency to consider."

The Strategy also encourages other activities designed to facilitate better site characterization, remedy selection, and design and construction by applying various techniques and optimization lessons learned to improve a given project's scope, schedule and cost.

As stated in the definition, optimization refers to a "systematic site review", indicating that the site as a whole is often considered in the review. Optimization can be applied to a specific aspect of the remedy (e.g., focus on long-term monitoring [LTM] optimization or focus on one particular operable unit [OU]), but other site or remedy components are still considered to the degree that they affect the focus of the optimization. An optimization evaluation considers the goals of the remedy, available site data, CSM, remedy performance, protectiveness, cost-effectiveness, and closure strategy. A strong interest in sustainability has also developed in the private sector and within federal, state, and municipal governments. Consistent with this interest, OSRTI has developed a Green Remediation Primer (http://cluin.org/greenremediation/), and now routinely considers green remediation and environmental footprint reduction during optimization evaluations. The evaluation includes reviewing site documents, potentially visiting the site for one day, and compiling a report that includes recommendations in the following categories:

- Protectiveness
- Cost-effectiveness
- Technical improvement
- Site closure
- Environmental footprint reduction

The recommendations are intended to help the site team identify opportunities for improvements in these areas. In many cases, further analysis of a recommendation, beyond that provided in this report, may be needed prior to implementation of the recommendation. Note that the recommendations are based on an independent evaluation, and represent the opinions of the evaluation team. These recommendations do not constitute requirements for future action, but rather are provided for consideration by the Region and other site stakeholders. Also note that while the recommendations may provide some details to consider during implementation, the recommendations are not meant to replace other, more comprehensive, planning documents such as work plans, sampling plans, and quality assurance project plans.

The national optimization strategy includes a system for tracking consideration and implementation of the optimization recommendations and includes a provision for follow-up technical assistance from the optimization team as mutually agreed upon by the site management team and USEPA OSRTI.

1.2 TEAM COMPOSITION

The optimization team consisted of the following individuals:
Table 1.

Name	Affiliation	Phone	Email
Jennifer Edwards	US USEPA OSRTI	703-603-8762	Edwards.Jennifer@epa.gov
Dave Becker	USACE EM CX	402-697-2655	Dave.J.Becker@usace.army.mil
Mark Rothas	USACE EM CX	402-697-2580	

1.3 DOCUMENTS REVIEWED

The following documents were reviewed. The reader is directed to these documents for additional site information that is not provided in this report.

- Removal Action Report, OU 2, TetraTech, October, 2011
- Feasibility Study Report Addendum, Black & Veatch, October, 2005
- Remedial Investigation Report, Addendum No. 1, Tip Top Cleaners OU2, Black & Veatch, August, 2004
- Record of Decision, OU 2, February, 2006
- Long-Term Remedial Action Source Area Evaluation Report, OU 2, Black & Veatch, February, 2009
- LTRA Quarterly Cleanup Status Reports Nos. 3 (2 Figures only, 2007), 5 (November 2007), 13 (December 2009), 23 (June 2012), Black &Veatch
- Injection Reports, April 2007- April 2011, GSI, various.
- Ogallala Water Supply Remedial Investigation Report, Fluor Daniel Environmental Services, October 1996

- OU2 Site Management Plan, GSI, August 2006
- Tip Top Cleaners OU2 Post-Action Plan, Black & Veatch, September 2006
- Draft Remedial Action Basis of Design Report, Black & Veatch, April 2006
- First Five-Year Review Report, USACE Kansas City District for US USEPA, September 2011
- Work Completion Report for Direct-Push Technology Well Construction and ISCO Treatment, Environmental Restoration, Phases II (April 2003) and III (October 2003)

1.4 QUALITY ASSURANCE

This optimization evaluation utilizes existing environmental data to interpret the conceptual site model, evaluate remedy performance, and make recommendations to improve the remedy. The quality of the existing hydrogeologic and chemical data is evaluated by the optimization team prior to using the data for these purposes. The evaluation for data quality includes a brief review of how the data were collected and managed (where practical, the site Quality Assurance Project Plan [QAPP] is considered), the consistency of the data with other site data, and the use of the data in the optimization evaluation. Data that are of suspect quality are either not used as part of the optimization evaluation or are used with the quality concerns noted. Where appropriate, this report provides recommendations made to improve data quality.

1.5 PERSONS CONTACTED

The following individuals associated with the site were present for the visit:
Table 2.

Name	Affiliation	Phone	Email Address
Bill Gresham	US USEPA, Region 7 Remedial Project Manager	913-551-7804	Gresham.Bill@epamail.epa.gov
John Flint	Nebraska Department of Environmental Quality	308-632-0544	john.flint@nebraska.gov
Gary Felkner	Black & Veatch, Site Manager		
Curt McCoy	Black & Veatch		

2.0 SITE BACKGROUND

2.1 LOCATION

The Ogallala Ground Water Contamination Superfund Site, Tip Top Cleaners OU2, is located at 116 West 5th Street in the central part of Ogallala, Nebraska. Ogallala is in the west-central portion of Nebraska, just north of the South Platte River and west of the confluence of the North Platte and South Platte Rivers. See Figure 1 for the site location.

2.2 SITE HISTORY

2.2.1 HISTORIC LAND USE AND OPERATIONS

The Tip Top Cleaners site was a dry cleaning establishment located in a neighborhood of mixed residential and commercial land use. The dry cleaner was in operation until the 1990s. The building was used primarily for storage, or was unused for a period of time until April 2011 when the structure was demolished to allow excavation of remaining contaminated soil at the site. The site is now a concrete-paved parking area. No change in land use is anticipated.

The ground water contaminant plume extends from the former dry cleaner east-southeast through the central portion of Ogallala in an area of residential and commercial land use. The plume may extend south of US Highway 30 into an area of sand and gravel mining. One residential well located approximately 1,600 feet downgradient of the site was identified. This well became inoperable in the mid-2000s and has been properly abandoned.

2.2.2 CHRONOLOGY OF ENFORCEMENT AND REMEDIAL ACTIVITIES

The Ogallala Ground Water Contamination Superfund site was identified in 1989 through municipal well sampling. Tetrachloroethene (PCE), a solvent commonly used in dry cleaner operations, was the primary ground water target chemical of concern (COC) that was identified for remediation purposes. Two main ground water plumes were identified during investigations by Nebraska Department of Environmental Quality (NDEQ) and USEPA. A southern plume and its sources are addressed under Operable Unit (OU) 1. The northern plume originating at Tip Top cleaners was identified by NDEQ in the early 1990s and is addressed as OU2. A comprehensive remedial investigation (RI) was conducted in 1995 and 1996, including the OU2 area. A comprehensive feasibility study (FS) was published in 1997. Additional investigations, including direct-push ground water sampling, were conducted by NDEQ in 2000 to define the plume.

USEPA conducted a ground water treatability study for OU2 in 2001 and early 2002 using sodium permanganate. The study showed promise for the technology. USEPA also implemented source control at the Tip Top Cleaners site by installation of a soil vapor extraction (SVE) system south of the cleaners. The system ran from February to October 2002.

USEPA conducted additional characterization (including direct-push sampling) and monitoring activities for ground water through 2004. During the period February 2003 through March 2004, USEPA conducted injection of permanganate into the ground water plume, primarily in the upgradient half of the plume. Addendum 1 to the RI Report was published in August 2004. An addendum to the FS was published in October 2005. A Record of Decision (ROD) for OU2 was issued in February 2006.

In-situ chemical oxidation (ISCO) using sodium permanganate was conducted by USEPA following the issuance of the ROD from 2007 until 2011. Injection of oxidant occurred at various locations within the contaminant plume, but were primarily concentrated just downgradient of the source area.

Additional characterization of the source area was conducted by USEPA in 2008. The work included direct-push soil sampling and ground water sampling. Based on this work, additional source removal was planned. Building demolition and soil excavation was conducted by USEPA in 2011. Soil was excavated to depths as great as 16 ft bgs on the Tip Top property and portions of adjacent parcels. Excavation was limited by West 5th Street and to some extent by nearby occupied buildings. At least two additional monitoring wells, OU2-MW-10 and OU2-MW-11, were installed at some time following the RI addendum.

Also in 2011, USEPA Region 7 prepared a five-year review for both OU1 and OU2. The primary issue raised for OU2 was the potential for vapor intrusion in buildings directly over the plume. Limited indoor air quality testing was conducted during the remedial investigation for OU2 in 2004 and consisted of Summa canisters placed in the basement of four homes in the OU2 study area. Based on that sampling, USEPA determined that the risks posed were in the acceptable range.

2.3 POTENTIAL HUMAN AND ECOLOGICAL RECEPTORS

The contamination in OU1 and OU2 originally threatened both municipal and domestic wells. The City of Ogallala relocated its well field to a location northeast of the city in the early 1990s, and terminated use of the previously impacted wells. The residential well in the OU2 plume (OU2-Res Well 4 on maps) was rendered inoperable and properly abandoned in the mid-2000s.

During the RI phase, the OU2 plume was identified as a possible source of impact to the surface water quality in Gravel Pit Lake south of US Highway 30. Gravel Pit Lake is potentially in the apparent migration path of the shallow OU1 plume, and represents another possible exposure point. The OU2 plume has not impacted the Gravel Pit Lake as indicated by the absence of any OU2 plume constituents in the surface water samples that have been collected to date. . No apparent ecological impacts can be directly related to OU2.

Currently, the only potentially complete pathway may be via indoor air in buildings overlying the plume, but past sampling has not indicated an unacceptable risk. The USEPA is considering the recommendations for additional characterization of indoor air impacts in the 2011 five-year review report.

2.4 EXISTING DATA AND INFORMATION

2.4.1 SOURCES OF CONTAMINATION

The source of the PCE contamination was the operation of Tip Top Cleaners. The exact nature of the releases is not clear, but seemed to have been concentrated immediately south and southeast of the Tip Top building. There did not appear to be a relationship between the site contamination and utility corridors. It appears that the 2011 excavation has removed the bulk of the remaining source mass.

2.4.2 GEOLOGY SETTING AND HYDROGEOLOGY

Ogallala is located in the valley of the South Platte River and is underlain by unconsolidated alluvium (sediments deposited by streams) related to migration of the South Platte River across its floodplain. This alluvium overlies poorly consolidated to cemented sediments of the Ogallala Formation. The Ogallala Formation is Miocene in age and consists of interbedded sand, gravel, silt, and clay largely deposited by ancestral rivers pre-dating the South Platte. The alluvium and Ogallala Formation, as well as deeper Tertiary-aged units, comprise the High Plains aquifer system in western Nebraska.

The site contamination is apparently restricted to the unconsolidated alluvial deposits. These deposits are largely sandy silt and clay from the surface to depths of 17 feet below ground surface (bgs) near the Tip Top site, but only extend to depths less than 5 ft bgs near the downgradient end of the plume. These fine-grained materials overlie highly permeable shallow sands and gravelly sands comprising the shallow aquifer. These sands and gravelly sands have varying amounts of clay and silt and extend to depths of 40 to 50 ft bgs. The uppermost subunit of the Ogallala Formation at the site is the Ash Hollow Member. The Ash Hollow is primarily clay and forms a reasonably effective aquitard preventing migration of site contamination into the more permeable units within the Ogallala Formation. Note that the deeper portions of the Ogallala Formation to the south have been impacted by COCs originating from OU1.

Ground water is encountered in the sands and gravelly sands, and piezometric heads are slightly above the contact with the overlying clayey and silty materials, making the shallow aquifer locally confined. Farther downgradient, the water table occurs in the sands and the aquifer is unconfined. Ground water flow is to the east to east-southeast as indicated in past reports at the site. Ground water on the flow paths emanating from the site would appear to discharge to gravel pit lakes south of US Highway 30 or to the South Platte River. Gradients in the shallow aquifer are typically near 0.0015. Hydraulic conductivities were estimated in the remedial investigations to be approximately 0.004 centimeters per second (cm/sec) to 0.3 cm/sec and averaged 0.04 cm/sec. These are typical of sands and gravelly sand. There is a very slight downward hydraulic gradient. Variations in the water table elevation are small (a few feet, based on recent data).

2.4.3 SOIL CONTAMINATION

Soil contamination was delineated at the Tip Top Cleaners site. Concentrations of PCE observed in soil during the Source Area Evaluation were as high as 45,000 micrograms per kilogram (ug/kg) in shallow soil under the southern portion of the building slab. PCE concentrations were typically hundreds of ug/kg in soils at depth outside the building. Confirmatory soil samples taken at the completion of source excavation were generally below100 ug/kg (and all were below a stated soil remediation goal of 550 ug/kg). The soil excavation essentially went to the water table or the top of the aquifer.

2.4.4 SOIL VAPOR CONTAMINATION

Soil vapor concentration data were not available.

2.4.5 GROUND WATER CONTAMINATION

Figure 1 shows the most recent ground water contaminant plume (April 2012). Ground water contamination is essentially limited to PCE. Limited detections of TCE have been observed, generally below the MCL of 5 micrograms per liter (ug/L). PCE concentrations have been as high as 1,200 ug/L in OU2-MW-2, and concentrations in the 100s of ug/L extended to OU2-MW-7 in the early 2000s. Concentrations had exceeded the 5 ug/L PCE clean-up level in

OU2-MW-8, the farthest downgradient well directly along the axis of the OU2 plume. Recent concentrations have diminished significantly, and detections of PCE above its clean-up level are limited to monitoring wells within 300 feet of the source area along North Spruce Street. Concentrations in other monitoring wells have largely declined to non-detectible levels as of April 2012.

The plume as depicted in reports is quite narrow and at least a half-mile long. Based on profiling done using passive-diffusion bag (PDB) samples in shallow monitoring wells, the concentrations are well distributed in the upper part of the shallow aquifer. Monitoring wells OU2-MW-11 and OU-2-MW-10 are deeper, and PDB profiling in the screened interval in OU2-MW-10 also suggests the groundwater plume is limited to the upper part of the shallow aquifer, at least in the upgradient portion of the plume.

A recent (within the past year) direct-push sampling location just north of OU2-MW-8 at the inferred downstream end of the OU2 plume had PCE detections greater than 30 ug/L.

2.4.6 SURFACE WATER CONTAMINATION

Although sampling is conducted as part of OU2 at the Gravel Pit Lake south of US Highway 30, and contaminants have been previously detected in the lake, no PCE has been detected there. The OU2 plume has not impacted Gravel Pit Lake as indicated by the absence of OU2 plume constituents in the surface water of the Gravel Pit Lake. Past detected contaminants in surface water samples (TCE, DCE, and VC) are more similar to those found in the OU1 plume, though these could possibly be reductive dechlorination daughter products of PCE. The sampling of the lake for the purposes of the OU2 remedy could be discontinued, though continued sampling for the purposes of the OU1 remedy would likely be required. Since the analysis of the samples for OU1 purposes would likely include quantification of the normal EPA SW846 method 8260B list, including PCE, the results of sampling of the lake for OU1 purposes should be shared with the OU2 project team. .

2.4.7 SEDIMENTS

No sediment contamination related to OU2 has been identified.

3.0 DESCRIPTION OF PLANNED OR EXISTING REMEDIES

3.1 REMEDY AND REMEDY COMPONENTS

According to the OU2 ROD, the selected remedy included the following components:

- Treatment of ground water through ISCO using sodium permanganate
- Continued monitoring of the ground water quality
- Limiting access to ground water through enforcement of the City of Ogallala ordinance prohibiting the use of ground water for domestic use in the city limits
- Conducting a comprehensive survey of residential well use.
- Implement whole-house treatment for any residential wells in use.
- Installing additional monitoring wells

The ISCO injections were conducted quarterly over five years beginning in September 2006. Monitoring following treatment is to follow the injection period for another five years or until clean-up levels are attained.

The City of Ogallala does have an ordinance in place that precludes the use of ground water for domestic use within the city limits. It is presumed that all potentially impacted domestic wells have been identified and only one, residential well 4, was in the path of the OU2 plume. Additional monitoring wells have been installed since the ROD, and recently additional wells have been proposed for the former Tip Top Cleaners source area itself.

Table 1 summarizes the ISCO injections that were done following the issuance of the ROD. Additional injections were also done prior to the ROD but the locations were not certain. No further ISCO injections are planned pending evaluation of the ongoing monitoring results and rebound testing.

Table 3. In-situ Chemical Oxidation Activities at the Tip Top Cleaners Site

Date	Gallons of 40% Permanganate Injected	Area 1	Area 2	Area 3	Areas 4&5	Area 6&7
December 2001 Treatability Study	10	12 injection pts, locations uncertain				
January 2003[1] thru August 2005 (10 events)	1,373 (minimum)	None	10 pts, 16-31' for some rounds and none in other rounds	10 pts, 15-30'	12 pts 13-28' in Area 4 12 pts 12-27' in Area 5	9 pts, on East C St., 11-26' upgradient of these Areas for some rounds or none for other rounds
September/December 2006[2]	384	6 pts, 17-26' SE of cleaner building	12 pts, 16-25' both sides of street	5 pts, 16-25'	6 pts 12-39' in Area 4, 5 pts 11-37' in Area 5	5 pts 11-20' in Area 6, 6 pts 11-20' in Area 7
March/June 2007	384	6 pts, 17-26' SE of cleaner building	12 pts, 16-25' both sides of street.	5 pts, 16-25'	6 pts 12-39' in Area 4, 5 pts 11-37' in Area 5	5 pts 11-20' in Area 6, 6 pts 11-20' in Area 7
September/December 2007	262	33 pts, W,E, N, SE of building	12 pts	None	None	None
March/June 2008	262	27 pts, W,E, N, SE	12 pts	6 pts	None	None
September/December 2008	186	14 pts, E only	12 pts	6 pts	None	None
March/June 2009	192	14 pts, E only	12 pts	6 pts	None	None
September/December 2009	192	14 pts, E, SE	12 pts, W side of street only	6 pts	None	None
March/June 2010	192	14 pts, E, SE	12 pts	6 pts	None	None
September 2010	96	14 pts, E, SE	12 pts	6 pts	None	None
December 2010	121	10 pts, N, NW, E	24 pts	6 pts	None	None
March/June 2011	242	10 pts, N, NW, E	24 pts	6 pts	None	None
Total Injection Volume	3,896	219 pts, mostly downgradient of cleaners	231 pts	113 pts	36 pts in Area 4 and 33 pts in Area 5	20 pts near Area 6 7 pts in Area 7

[1]Each injection was 10 gal of 5% permanganate solution per 3 feet
[2]Each injection was 10 gal of 5% permanganate solution per 3 feet

3.2 REMEDIAL ACTION OBJECTIVES AND STANDARDS

The ROD for OU2 identified the following RAOs:

- Prevent ingestion of ground water containing site contaminants in excess of current regulatory standards
- Prevent degradation of surface water by ground water in excess of Nebraska Surface Water Criteria for PCE
- Restore the aquifer to MCLs within a reasonable timeframe (i.e., 20 years)
- Prevent further contaminant migration in ground water

The clean-up goals (MCLs) for the site contaminants are summarized in Table 4.

Table 4. Clean-up goals (Maximum Contaminant Levels [MCLs]) for Site Contaminants.

Contaminant of Concern	MCL (ug/L)
Carbon tetrachloride	5
1,1-Dichloroethylene	7
Cis-1,2-Dichloroethylene	70
Tetrachloroethylene	5
Trichloroethylene	5
Vinyl Chloride	2

3.3 PERFORMANCE MONITORING PROGRAMS

The monitoring network at the Tip Top Cleaners OU2 site involves 18 permanent monitoring wells that have essentially been sampled quarterly since the initiation of permanganate injections. All but one of these wells are screened in the shallow alluvial aquifer. Two locations (OU2-MW-5/5B and OU2-MW-7/7B) have paired wells, one screened over 10 feet in the upper portion of the shallow aquifer, and the other (with a "B" designation) screened over 20 feet in the deeper portion of the shallow aquifer. Two of the newest wells, OU2-MW-10 and -11, have longer screens (30 feet) that span much of the shallow aquifer. One well, RW1, was installed for other purposes at the City's maintenance yard. Sampling of a former residential well (designated "Res Well 4" in tables in the Cleanup Status Report) occurred until October 2007, after which the well was found inoperable or abandoned.

The monitoring well locations have generally been located based on past direct-push sampling or the observations from existing monitoring wells. As a result, most of the monitoring wells for OU2 are located along the initially observed axis of the PCE plume. The closest permanent monitoring wells to the former Tip Top Cleaners building were located on the west side of Spruce Avenue, perhaps 100 feet downgradient of the site. Recent reports from Black and Veatch have proposed additional monitoring points at the Tip Top site itself.

Analysis of ground water has included volatile organic compounds (VOCs) for all rounds, and for metals and geochemical parameters for selected rounds, most recently in August 2011. Field measurements are made for oxidation-reduction potential, pH, temperature, specific conductance, and dissolved oxygen, based on the observations made during the site visit. Permanganate is qualitatively assessed based on the intensity of the purple/pink color of samples. Color intensity is matched to a table of standard colors and a number between 0-10 is assigned (though this scale was not consistently used – early in the program, a scale of 0-3 was used).

Water level measurements are also made at the time of the quarterly sampling events. Reports of the results include water levels data from a few monitoring points from the northeast edge of the OU1 study area. These include USEPA-9A and USEPA-11A. Surface water elevations are measured in Gravel Pit Lake at point SW-1.

4.0 CONCEPTUAL SITE MODEL

This section discusses the optimization team's interpretation of existing characterization and remedy operation data to explain how historic events and site characteristics have led to current conditions. This CSM may differ from that described in other site documents.

4.1 CSM OVERVIEW

The site is conceptually simple as the vadose zone source has largely been removed and the ground water plume is limited to the shallow sand and gravel aquifer. Remedial actions have removed a substantial amount of the mass that had been released.

4.2 CSM DETAILS AND EXPLANATION

The source of the PCE ground water plume is believed to be associated either with the release of condensate or equipment leaks containing PCE from the indoor dry cleaner operations to the surface/subsurface. The historical soil and ground water sampling data would indicate that it is very unlikely that there is any pooled accumulation zones/layers of dense, non-aqueous phase liquid (DNAPL) at the site. Residual PCE mass released to the subsurface appears to have been immobilized within the vadose zone and at the capillary fringe above the water table in the immediate vicinity of the release area at a maximum depth of approximately 16 ft bgs. The immobilized PCE mass then served as the source of the mass flux to ground water via dissolution into surface infiltration and ground water flow. It is surmised that the released PCE was in relatively small quantities over an extended timeframe, so the total mass of the PCE released was not at a level that resulted in the generation of pooled DNAPL layers or extensive vertical migration below the depth of the water table (i.e., PCE mass not large enough to overcome the capillary pore pressures that would have displaced water from the soil pore structure to allow for continued downward vertical migration).

The plume extended to the east-southeast with the flow of the shallow aquifer ground water. SVE, and later soil excavation, has likely mitigated most of the long-term PCE mass flux to the dissolved phase. The downgradient end of the plume probably underlies areas of industrial land use and the South Platte River floodplain. There is little to no natural biodegradation of dissolved phase PCE occurring at the site. Available dissolved oxygen and oxidation-reduction potential data that was reviewed suggests that the shallow aquifer conditions are predominantly aerobic, whereas PCE preferentially biodegrades under anaerobic conditions. The plume may be or have been subtly influenced by other stresses on the aquifer, including production, domestic, and remediation wells. These may include the City of Ogallala municipal wells, Residential Well 4 or other domestic wells, RW1 at the City Maintenance Yard, or OU1 activities.

Permanganate injections have introduced oxidant that has reacted with both the residual and dissolved phase PCE mass and natural organic matter in the soil. The permanganate reactions have been concentrated in the area just downgradient of the source, as that is where the bulk of the injections have occurred.

4.3 DATA GAPS

The primary data gap for the ground water plume is the full definition of the plume. The monitoring network is concentrated on the previously observed plume axis, and does not include bounding wells to the north or south of the inferred plume. Based on the recent PCE detection in the direct push sampling point along East G Street, it appears that the plume is not bounded on the downgradient end. There is no upgradient/background well near the source. This plume delineation data gap primarily applies to the intermediate and deeper zones of the shallow aquifer unit between a depth of approximately 30 and 65 ft bgs. The existing monitoring network appears to have delineated the upper portion of the shallow aquifer unit to a depth of approximately 30 ft bgs. Monitoring wells MW-10 and MW-11 provide data concerning the north and south edges of the plume at locations near and downgradient of the source area.

Other possible data gaps involve the direction of ground water flow and the natural oxidant demand. The ground water flow directions are difficult to fully discern based on the wells, including EPA-7. Flow could be due east or even locally southeast. The survey datum for top-of-casing of monitoring well EPA-MW7 is suspect, and will be re-established at the earliest cost-effective opportunity according to feedback from the Project Team. Consequently, the suspect ground water elevation results for this monitoring well cannot be used when evaluating the ground water table elevations and flow direction, which makes the determination of ground water flow more difficult. The lower oxidant injection mass applied to the downgradient portion of the plume may not have been sufficient to address the oxidant demand posed by the PCE mass and natural soil organic matter in that portion of the treatment area, resulting in incomplete reaction with the contaminant.

Another potential data gap is the remaining residual PCE mass within the source area following the soil excavation. It is common for a substantial percentage of any release mass to migrate and become immobilized within the capillary/smear zone immediately above the depth of groundwater, as well as the top of the vadose zone through displacement of water from the soil pore structure. Neither soil excavation nor vadose zone treatment technologies such as SVE can effectively remove source area mass that has accumulated at these depths corresponding to high water saturation levels. Significant levels of residual PCE mass remaining within the shallow source area saturated zone could result in observed rebound of groundwater concentrations following the completion of the ISCO injection events.

4.4 IMPLICATIONS FOR REMEDIAL STRATEGY

The remedial strategy used for the site is sound. Filling of the data gaps will result in a more robust monitoring network and increased certainty in the conclusions about the permanganate injections. If the plume is found to exist outside the current network, or a rebound in PCE groundwater concentrations is observed following the completion of treatment, additional permanganate injections may be necessary to treat the remaining residual PCE mass, or the Agencies will have to assess the ability of natural processes (essentially sorption and dispersion) to prevent exposures and eventually attain the ground water RAOs.

5.0 FINDINGS

5.1 GENERAL FINDINGS

The observations provided below are not intended to imply a deficiency in the work of the system designers, system operators, or site managers, but are offered as constructive suggestions in the best interest of the USEPA and the public. These observations have the benefit of being formulated based upon operational data unavailable to the original designers. Furthermore, it is likely that site conditions and general knowledge of ground water remediation have changed over time.

5.2 SUBSURFACE PERFORMANCE AND RESPONSE

The implemented remedy appears at face value to have been largely successful as the downgradient PCE groundwater concentrations have dropped significantly. See Figure 2 for graphs of the concentrations over time in selected monitoring wells. In order to verify the success of the program, some data gaps need to be addressed, however.

The recent detection of 10s of ug/L of PCE in a direct-push sample north of OU-MW-8 raises a question of the definition of the plume. The persistent PCE concentrations in ground water just downgradient of the former Tip Top Cleaners site also suggest that one of the following influences may still be serving as a source of PCE mass flux to ground water: there may still be diffusion-limited mass-flux (i.e., matrix diffusion) originating from the source area or immobilized within finer-grained aquifer soil units; or more than a minimal level of residual mass still remains immobilized within the top of the source area saturated zone that continues to dissolve into ground water flow. Either of these potential PCE mass scenarios could continue to impact ground water quality in the absence of additional reactive permanganate.

The recent water levels near Spruce Street suggest a more eastward flow (e.g., in April 2012, the water levels in wells along the east side of Spruce Street are all within 0.02 feet and define a north-trending piezometric contour). The OU2 plume would be expected to be parallel to the nearby OU1 shallow plume, unless there is some mechanism that can explain converging flow (e.g., a pumping well or preferred high permeability pathway). Neither is known to currently exist based on available data. In fact, the reduction in municipal, remedial, and household irrigation pumping in the past 20 years may have removed possible causes for past converging flow. If ground water movement (and thus the plume) has become more easterly, the plume axis may have shifted somewhat to the north. The plume is likely to be quite narrow, given the small source footprint and the high ground water flux. The highly linear monitoring network would not be able to distinguish between actual remediation and a shift in the location of the plume axis. Although it is likely that the plume has been largely successfully treated, without bounding monitoring points, it is not possible to exclude a shift in the plume axis as the cause for the declining downgradient concentrations.

The water levels at monitoring well EPA-7 seem inconsistent with the water levels in nearby OU2 monitoring wells. For example, water levels in April 2012 suggest a southward flow near the Tip Top site if monitoring well EPA-7 water levels are used. It may be that the survey benchmark/reference of the measurement point for this well (and possibly monitoring wells EPA-9A and -11A) may differ from the survey basis for the OU2 wells. As discussed in Section 4.3, the Project Team reported that survey datum for top-of-casing of monitoring well EPA-MW7 is suspect, and will be re-established at the earliest cost-effective opportunity.

The extent of the plume downgradient of East G Street has not been determined. Even though there may not be complete exposure pathways to the east-southeast, the plume is not currently fully defined and it cannot be assured that no exposure exists. This plume delineation data gap primarily applies to the intermediate and deeper zones of the shallow aquifer unit between a depth of approximately 30 and 65 ft bgs. The existing monitoring network appears to have delineated the upper portion of the shallow aquifer unit to a depth of approximately 30 ft bgs. Monitoring wells MW-10 and MW-11 provide data concerning the north and south edges of the plume at downgradient locations near the source area.

As discussed in Section 4.3, it is difficult to evaluate the level of the residual source area PCE mass that may still remain in the shallow saturated zone, as well as the effectiveness of the upgradient ISCO injections at treating the source area. Even though permanganate injection events occurred upgradient and just to the east of the source area, and permanganate was placed in the bottom of the excavation that could have affected a level of treatment of any remaining residual PCE mass, no direct injections have occurred directly within the shallow aquifer below the source area to date. Soil and/or groundwater sampling has not been performed within this shallow source area saturated zone to measure the level of residual PCE mass that may still remain and serve as a continuing long-term source of mass flux to ground water. It is also difficult to determine the influence of immobilized PCE within finer-grained aquifer soil units that can result in long-term matrix diffusion impacts to ground water. Either one of these PCE mass scenarios could pose a constraint to achieving the ground water RAOs or significantly increase the timeframe.

The water levels and PCE concentrations at the site of the Tip Top building, itself, would be useful data for assessing the potential for continuing contaminant concentrations. An upgradient well would verify flow directions in the vicinity of the former source.

The monitoring frequency has been quarterly at the site. Given the extensive history of sampling and the lack of exposure points, the sampling frequency could be reduced without sacrificing the ability to detect significant changes. Additional quarterly sampling through 2012 would be appropriate to assess the impact of the permanganate injections, but subsequent sampling could be less frequent. The Project Team has communicated its intent to modify the future ground water sampling frequency to a semi-annual basis.

5.3 COMPONENT PERFORMANCE

The ISCO injection design approach and protocol was established based on injection volumes and protocol used during the treatability study performed during the interim removal action that was included in the *Basis of Design Report (BVSPC June 1, 2006).* Since the results of the treatability study showed decreasing PCE concentrations, the injection design protocol was determined to be an effective approach and thus was carried through to the full-scale treatment program.

The ISCO treatment program involved the injection of approximately 23,000 gallons of 5% sodium permanganate solution into the shallow aquifer over a number of years. At a 5% (by weight) concentration, there would be about 0.42 pounds (lbs) of permanganate per gallon. Therefore, just less than 10,000 lbs (4.54×10^6 grams) of permanganate have been injected into the aquifer. The design for the injection appears to have been based on calculations of the dissolved phase PCE mass in the aquifer, the mass of permanganate needed to react with the contaminant mass, and a multiplier of four to serve as a safety factor to account for other natural soil and aquifer material oxidant demand. This is not necessarily consistent with current practice (e.g., USEPA, 2006). Natural organic matter and reduced geochemical species (e.g., ferrous iron) may represent a substantial additional oxidant demand. Sorbed and diffusion-limited contaminant mass in low permeability aquifer soil units typically represent a greater percentage of the total contaminant mass than what resides in the dissolved phase, which equates to a significantly greater oxidant mass requirement than what was accounted for in the design approach. Remaining source area residual PCE mass could represent an even greater increase in the oxidant demand for that part of the treatment area, which also was not accounted for in the original design approach.

Typical natural oxidant demands for soil have ranged from less than 1 gram oxidant/kilogram of soil (g/kg) to over 60 g/kg according to a study performed by Geosyntec Consultants (Figure 3). If one even assumes a natural oxidant demand as low as 0.5 g/kg, the mass of oxidant injected would treat approximately $9x10^6$ kg of dry soil. Assuming a dry density of 1,300 kilograms per cubic meter (kg/cu m), this would represent just over 7,000 cu m. Further assuming a treated thickness of 3 meters (most injections were over the upper 10 feet), this would represent approximately 2,400 square meters (sq m) or 27,000 square feet (sq ft) - 100 by 270 feet. This would represent a very small fraction of the overall plume footprint. Based on this very rudimentary evaluation, it is possible that the ISCO injections may not have introduced an adequate mass of permanganate, particularly in the downgradient portion of the plume.

The ISCO design approach using injection transects represents more of a barrier wall concept than a grid approach to the injections. This type of barrier wall treatment concept relies on ground water advection to transport the injected permanganate and disperse it throughout the plume. The ISCO design did not include any type of tracer studies or ground water modeling to evaluate the level of oxidant dispersion and delivery that would occur throughout the plume. An empirical approach using the visible observation of permanganate coloring throughout the monitoring network, as well as the trend in PCE groundwater concentrations, has been used to evaluate the effectiveness of the permanganate delivery and dispersion throughout the plume. Based on this empirical approach, it appears that the injection spacings have generally been effective in the delivery of permanganate to portions of the plume downgradient of the various injection transects. However, the limited number of monitoring wells, as well as inconsistencies in the reported observation of observed coloring in the collected ground water samples (especially in the source area), makes it difficult to make conclusions regarding the overall effectiveness of the permanganate delivery throughout the plume. The adequacy of the monitoring network is critical to the evaluation of the barrier wall injection approach that has been used.

The injections were focused in Areas 1 and 2 near the source (about 60% of the volume/mass was injected in these areas). Most of the injection points were downgradient of the Tip Top Cleaners source area. Only limited injections occurred north and west of the former Tip Top Cleaners building. These injections (and leached permanganate from the permanganate that was placed at the bottom of the site excavation prior to backfilling) represent the only oxidant mass that would potentially treat contaminant that exists below the former building site. It is not clear if this would be adequate. April 2012 sampling suggests that residual permanganate exists along Spruce Street and in the vicinity of OU2-MW-3. Mass diffusing from the source area would potentially react with this residual mass.

As discussed above, the real metric for the success of the injections is the observed reductions in the PCE ground water concentrations, as well as the observed distribution of permanganate. If the PCE ground water concentrations are substantially reduced and do not significantly rebound, and the permanganate appears to have been well distributed, then the injections were successful. Based on the sampling of the existing monitoring well network, it appears the plume has been greatly reduced and only the area immediately downgradient of the source area (i.e., up to the first row of downgradient injection transects along Spruce Street) may have persistent low concentrations of PCE. Additional rebound sampling, as planned, will provide verification of the success of the injection program (and soil excavation conducted in 2011). If significant rebound is observed, particularly in the original Tip Top Cleaners source area, ISCO injections specifically into this source area (below the area of vadose zone soil excavation) would likely be warranted. If additional definition of the plume identifies other areas of PCE contamination requiring treatment, other injection locations/events may be appropriate.

5.4 REGULATORY COMPLIANCE

The project appears to have complied with regulatory requirements.

5.5 COMPONENTS OR PROCESSES THAT ACCOUNT FOR MAJORITY OF ANNUAL COSTS

As the remedy does not involve active treatment and no further permanganate injection activities are planned, the site costs are related primarily with sampling, analysis, and report preparation. Approximate recent site contract costs for such activities are under $80,000/year. This would include project management. Assuming quarterly sampling represents the bulk of the work, each sampling event may cost approximately $18,000. Labor costs for sampling, including mobilization from Kansas City, per diem costs, would probably be about $10,000. The analysis would probably cost less than $3,000. Report generation would account for the remaining balance. These costs appear to be reasonable.

6.0 RECOMMENDATIONS

Several recommendations are provided in this section related to remedy effectiveness, cost control, technical improvement, and site closure strategy. Note that while the recommendations provide some details to consider during implementation, the recommendations are not meant to replace other, more comprehensive, planning documents such as work plans, sampling plans, and quality assurance project plans. It should be noted that the Project Team has elected to be proactive and already has plans to implement most of the recommendations outlined below based on a review of a draft of this report. Plans recently communicated by the Project Team to implement specific recommendations are also described below.

Cost estimates provided herein have levels of certainty comparable to those done for CERCLA Feasibility Studies (-30%/+50%), and these cost estimates have been prepared in a manner generally consistent with USEPA 540-R-00-002, *A Guide to Developing and Documenting Cost Estimates During the Feasibility Study,* July, 2000. The costs presented do not include potential costs associated with community or public relations activities that may be conducted prior to field activities. The costs and environmental footprint impacts of these recommendations are summarized in Table 1.

Overall, the remedy appears to have been quite successful. Sections 4.0 and 5.0 of this report, however, have identified possible questions regarding the CSM and the effectiveness of the implemented remedy to achieve aquifer restoration. The recommendations related to improving effectiveness in Section 6.1 are focused on addressing the identified data gaps, but do not represent all of the information that may be needed to complete the CSM and appropriately modify the remedies. The recommendations in Section 6.1 do not discuss improving the ability of the existing strategy to restore ground water. These recommendations are presented in Section 6.4, where various remedial strategies are considered for moving forward if additional work identifies that the remediation has not been as complete as thought.

The optimization team identified opportunities to reduce the monitoring cost of operating the existing ground water remedies; however, the optimization team believes that the questions about the existing CSM makes providing cost reduction recommendations uncertain, as the level of effort for the monitoring may need to be changed. Minor recommendations for technical improvement are presented in Section 6.3.

6.1 RECOMMENDATIONS TO IMPROVE EFFECTIVENESS

6.1.1 PLUME VERIFICATION AND DEFINITION

The current extent of the ground water plume needs to be more fully verified to assure that the very promising concentration reductions have actually occurred throughout the plume. Monitoring points that bound the plume in the cross-gradient and downgradient directions are needed. One recommended approach would be to perform direct-push ground water sampling transects of three to four points at three locations, perhaps along Spruce Street, East B Street, and East G Street. In addition, an additional transect should be conducted to the east of East G Street (possibly south of East 1st Street along the projection of East H Street or East I Street) to verify the downgradient extent of the PCE plume identified north of OU2-MW-8. This would require access to commercial properties on the south side of East 1st Street.

The estimate to implement the recommended additional groundwater delineation work scope discussed above would be $15,000 for the initial Geoprobe delineation assessment employing transects downgradient and around the perimeter of the plume with associated groundwater sampling. Detailed backup and assumptions for these cost estimates are provided in Attachment A. Costs represent FS level preliminary estimates, and should not be used for budgetary purposes without further refinement of the work scope and detailed line item costs.

Upcoming planned assessment activities recently communicated by the Project Team include vertical profiling and plume delineation in the area of monitoring well MW-8 using a combination of various direct-push techniques such as membrane interface probe ([MIP], soil gas measurements), electrical conductivity ([EC], mapping tool for soil types), hydraulic profiling tool ([HPT], which measures formation permeability for preferential migration pathway identification), and soil/groundwater grab sampling. The field data collection using these direct-push techniques will be used to identify locations for the installation of additional nested monitoring wells within the intermediate and deeper depths of the shallow aquifer unit.

6.1.2 ADDITIONAL MONITORING WELLS

Based on the results of these verification transects, additional permanent monitoring points may then be needed. If in the somewhat unlikely event that the plume has indeed shifted northward based on the sampling results for one or more of the transects, a monitoring well on the current plume axis would be needed, and another well further north to bound the plume. The current wells would be used to generally bound the plume on the south. An additional monitoring well would be required at the downgradient end of the plume, even if no additional contamination is observed, to act as a defining point for the end of the plume. If contamination is observed farther downgradient, additional downgradient transects may be needed to bound the plume.

An on-site source area monitoring well is needed to determine concentrations at the location of the former Tip Top Cleaners site, and to verify the effectiveness of the recent soil excavation and assess rebound from the permanganate injections in the source area. An upgradient/background well may also be appropriate if there is any reason to question the impact from other sources/sites, or if impacts to ground water may have occurred from site operations (or vapor transport) in the upgradient direction.

A total of $17,000 to $24,000 would be required to install five to nine additional permanent monitoring wells (no groundwater sampling included). Detailed backup and assumptions for these cost estimates are provided in Attachment A.

It is also recommended, if logistically feasible, that soil and “grab” groundwater samples be collected during the installation of the recommended monitoring well and any future Geoprobe assessment activities performed in the source area. A representative number of shallow saturated zone soil samples and a “grab” ground water sample could be collected from the boring associated with the planned monitoring well installation immediately downgradient of the source area. As it would be located near the suspected source area towards the southern and southeastern ends of the former building, it could correspond to the location of the hand auger borings HA-1 thru HA-3 conducted for the pre-excavation source assessment that exhibited the highest PCE soil concentrations. During any other recommended direct-push work at the site, additional sampling could be conducted within the capillary fringe and uppermost portion of the saturated zone at other locations near the former Tip Top Cleaners building. This level of source area sampling would provide an indication of the remaining residual PCE mass that could serve as a long-term source of continuing mass flux to ground water that may lead to observed rebound at the downgradient monitoring wells. Alternatively, if the results from future ground water sampling events show evidence of rebound, then an additional mobilization would be required to perform this recommended source area sampling to target locations and depths for further treatment. As discussed in Section 6.4 in more detail, upcoming planned source area groundwater delineation activities communicated by the Project Team include vertical profiling of PCE mass presence in the saturated zone and installation of monitoring well nests (screened in both the shallow and deeper zones of the shallow aquifer unit) based on the initial findings from the vertical profiling. One or more source area monitoring wells had been proposed prior to the optimization study.

6.1.3 VAPOR INTRUSION ISSUE

The five-year review report raised questions about the potential for vapor intrusion into buildings overlying the OU2 plume and recommended that this pathway be more fully characterized. This optimization report endorses this recommendation, if it is discovered that the plume remediation was not as complete as it appears. Furthermore, this report assumes the vapor intrusion issue for both OU2 and OU1 will be appropriately pursued through actions recommended by the five-year review, and tracked separately from these optimization recommendations.

6.2 RECOMMENDATIONS TO REDUCE COSTS

Since the primary cost at the site is for continued monitoring for concentration rebound following the completion of the permanganate injection, the only way costs can be reduced is by modifying the nature of the monitoring program. The quarterly sampling at the site should be continued for no more than another few quarters, and then semi-annual sampling could be conducted. Such sampling reduction would not significantly affect the ability to verify adequacy of the remediation, since rebound effects tend to occur slowly and should be more evident closer to the source area. Semi-annual sampling would still allow sufficient time to implement additional remedial measures, if needed, without the plume migrating further or posing an unacceptable risk to a potential receptor. If semi-annual sampling is begun in mid-2013, that would have provided approximately two years of quarterly sampling, more than enough to assess fluctuations. Conditions at the site are not so dynamic as to require more frequent sampling beyond mid-2013. Annual sampling may be appropriate if only low concentrations are observed following two to three years of semi-annual sampling. Note that this would be a minor or possibly significant change to the OU2 ROD, as this ROD unfortunately specifies quarterly sampling until concentrations reach the RAOs. This change, if considered minor, would require a memorandum to the administrative record documenting the change in sampling frequency, or at most would require an Explanation of Significant Difference.

This reduction in sampling frequency would reduce the USEPA-funded sampling effort by six sampling events by mid-2016. This represents a cost reduction of approximately $36,000 per year or a total of $108,000 (6 times $18,000 per round). The Project Team has communicated its intent to modify the future ground water sampling frequency to a semi-annual basis.

The monitoring program could be reduced further by excluding wells from sampling. If the results of the verification sampling outlined in section 6.1 determined that the remaining plume is limited to areas west of East A Street, monitoring wells downgradient of OU2-MW-4 (eight shallow wells, including USEPA-11A) could be excluded from the monitoring program. This would clearly reduce sampling labor, analytical costs, and report effort/cost. Since the outcome of the verification sampling is not known, these reductions in cost are not quantified, but could be 30% of the per-round costs. The project team is encouraged, though, to consider such network reductions in the future based on those results. Note that any wells excluded from the sampling program should not be decommissioned as they potentially provide useful water level information for both OU2 and OU1. Well decommissioning would be done following full attainment of OU2 remedial goals. Lastly, sampling of Gravel Pit Lake should be conducted under OU1, not under OU2, as contaminants identified in these samples do not include PCE, though the VOC results should be shared with the OU2 project team.

6.3 RECOMMENDATIONS FOR TECHNICAL IMPROVEMENT

6.3.1 SAMPLING METHOD SIMPLIFICATION

The current program uses PDBs for VOC analysis combined with micro-purging to collect samples for geochemical parameters and metals. Given the current good understanding of the geochemistry and the lack of significant concentrations of oxidation-sensitive metals (i.e., chromium and selenium), future sampling for downgradient wells could be conducted solely for VOCs by PDBs. Grab samples to provide qualitative color evidence of the persistence of the permanganate could be obtained from near-source wells using disposable bailers or Hydrasleeve® samplers. This would somewhat reduce both the time necessary to conduct sampling and sampling complexity. This may even allow hiring of local sampling staff that would reduce travel and labor costs, though the cost savings from this have not been calculated. The Project Team has communicated its intent to modify future ground water sampling events for the downgradient wells to include only VOCs using PDBs.

6.3.2 VERIFICATION OF MONITORING WELL REFERENCE POINT ELEVATIONS

The unusual water levels in some of the USEPA-series monitoring wells installed south of the main OU2 plume suggests that it would be prudent to assure that the measurement reference points for the water levels are consistent with those of the other OU2 monitoring wells. When the recommended monitoring well(s) are installed and are surveyed, it is strongly recommended to have the surveyor resurvey all monitoring wells in the network. Assuming that a surveyor from North Platte or Scottsbluff, NE would conduct the work, it is estimated that the cost would not exceed $3,000. These costs do not include a project team member meeting the surveyor at the site and leading them to the wells. As discussed in Section 4.3, the Project Team reported that survey datum for top-of-casing of monitoring well EPA-MW7 is suspect and will be re-established at the earliest cost-effective opportunity.

6.4 CONSIDERATIONS FOR GAINING SITE CLOSE OUT

The existing site close-out strategy appears to have been successful. In the event that confirmatory sampling verifies that the remaining plume is very limited to areas near the former source, and that any downgradient contamination north of OU2-MW-8 is also very limited, sampling would be continued beyond 2016 at an annual frequency (or less) until results for PCE are below RAOs.

If verification sampling recommended in Section 6.1 indicates that the plume is more extensive than recently believed, additional permanganate injections would be required to address these portions of the plume. A similar strategy to what has been previously implemented would be appropriate, with some modification. Permanganate injection dosage for areas not previously treated needs to explicitly consider the natural soil and aquifer material oxidant demand in addition to that required to react with the contaminant.

In the source area, if continued sampling of existing monitoring wells and the sampling of the recommended new Tip Top source area well suggest that PCE concentration rebound has occurred, an additional injection event of permanganate that includes areas both upgradient (northwest) of the excavation area and directly within the source area is recommended. Again, the dosage should be increased to allow injection of adequate mass to treat the remaining residual PCE mass (determined based on soil sampling data instead of dissolved phase groundwater data) and account for the demands from any remaining natural organic matter in the soil and aquifer matrices.

As discussed in Section 6.1.1, an adequate level of soil sampling should be performed within the shallow saturated zone to properly quantify the remaining residual PCE mass. Representative soil samples corresponding to the injection depth should also be collected and analyzed for total natural oxidant demand. If the level and extent/thickness of any residual PCE mass layer is significant, a grid type of injection approach within the defined source area would be more effective than the current transect approach. Upcoming planned source area assessment activities communicated by the Project Team include the following: 1) use of MIP/EC to provide vertical profiling of PCE mass presence in the saturated zone; 2) installation of monitoring well nests (screened in both the shallow and deeper zones of the shallow aquifer unit) based on the initial MIP/EC findings; and 3) collection of two saturated zone source area soil samples for analysis of volatile organic compounds (VOCs) and permanganate natural oxidant demand (PNOD) to evaluate residual source area PCE mass and provide a quantitative measurement of the PNOD for further evaluation of the ISCO design approach. PNOD analyses were performed during the past source area soil excavation activities, but these soil samples were from the vadose/capillary zone where the silty-clay content (and corresponding organic carbon content) is higher than the more permeable sandy soil content predominant in the shallow aquifer unit, so the PNOD measurements may not have been representative for design evaluation purposes.

The transect approach to the injections would still be recommended for the scenario where some rebound is occurring because of matrix diffusion or adsorbed phase mass covering a larger downgradient area of the plume beyond the source area (i.e., source area residual PCE mass and its relative depth/thickness does not warrant further treatment). Additional monitoring would be needed following this injection event to determine if additional rebound would occur.

6.5 RECOMMENDATIONS RELATED TO ENVIRONMENTAL FOOTPRINT REDUCTION

Since the site does not currently have any active remediation, there is not much of an environmental footprint relative to some other post-ROD Superfund sites. The footprint is largely generated by sampling activities. There would also be an environmental footprint for any work to install additional monitoring wells at the site. The reduction in sampling frequency from quarterly to semi-annual would result in a reduction of environmental footprint of the remedy. For purposes of estimating a reduction in the footprint for greenhouse gases and other related metrics, it was assumed that three years of post-treatment sampling would remain to be performed, which would result in the elimination of six ground water sampling events total. At that point in time, any continued LTM program would likely occur on an annual basis under any scenario that would be considered, so it is not accounted for in the footprint reduction calculations.

To quantify this change, the SiteWise environmental footprinting tool was used. Though this tool does not precisely match the approach or quantify all of the metrics recommended by USEPA in its February 2012 guidance document "Methodology for Understanding and Reducing a Project's Environmental Footprint", it provides a quick and useful estimate of environmental benefits from this change. The footprint due to the implementation of additional direct-push sampling transects and the installation of additional monitoring wells was not computed using SiteWise as the exact scope of these activities are not yet known.

The reduction in footprint for the reduction in sampling assumes that the sampling team mobilizes from Kansas City, Missouri to the site. The use of low-flow sampling techniques was assumed (i.e., need to operate a generator during sampling), though use of PDBs is recommended above. A single mobilization was assumed for each sampling event involving a single light-duty truck and two sampling personnel. A total of 16 monitoring wells would be sampled over a two-day period. The sampling pump/generator was assumed to operate for a period of 15 minutes per monitoring well (4 hours total). Based on a review of the various sampling reports, it was assumed that no investigation-derived wastes would be generated for collection and off-site disposal. The reductions in the following footprint metrics were estimated:

- 3.3 metric tons of greenhouse gases mostly due to vehicle mobilization;
- 4.2 million BTUs of energy consumption mostly due to vehicle mobilization;
- $1.4x10^{-3}$ metric tons of nitrous oxides mostly due to vehicle mobilization;
- $4.3x19^{-5}$ metric tons of sulfur oxides due to vehicle mobilization; and
- $4.1x10^{-4}$ metric tons of PM10 due to vehicle mobilization and operation of the generator.

6.6 SUGGESTED APPROACH TO IMPLEMENTING RECOMMENDATIONS

The reduction in sampling frequency described in section 6.2 should be considered for implementation in mid-2013 (so there are eight post-injection quarterly sampling rounds). The simplification of the sampling method suggested in section 6.3.1 could be implemented with the next sampling round. This could be implemented regardless of the other recommendations. Other reductions in sampling at monitoring well locations as described in 6.2 are contingent on the outcome of the plume verification in 6.1.1. Monitoring will be on-going until MCLs are attained, per the ROD.

The plume verification direct-push sampling as described in 6.1.1 should be implemented. Additional monitoring well installation to redefine the plume axis and lateral limits would be conducted only if the results of the plume verification find that the plume may have shifted. An additional downgradient monitoring well would need to be installed regardless of the other results to define the downgradient extent of the plume. A source area monitoring well should be also installed at the Tip Top Cleaners site to verify PCE concentrations in the immediate area of the recent excavation, regardless of the other results. The verification of the monitoring point reference elevations recommended in section 6.3.2 could easily be done in conjunction with the surveying required for these new wells. Additional permanganate injections as described in 6.4 would only be considered if the plume has been found to be more extensive than currently inferred, or if concentrations rebound in the source area or immediately downgradient due to remaining source area residual PCE mass or matrix diffusion influences.

Table 5. Summary of Recommendations

Recommendation	Reason	Additional Capital Costs ($)	Estimated Change in Annual Costs ($)	Estimated Change in Life-Cycle Costs ($)*	Estimated Change in Life-Cycle Costs ($)**
6.1.1 Plume Verification and Definition	To assure that the plume has been remediated	$15,000	$0	$0	One-time cost
6.1.2 Additional Monitoring Wells	Additional monitoring wells required to monitor delineated plume and source area conditions	$17,000-24,000	$5000 if no other reductions in monitoring network, but could be offset by eliminating other wells (see sec. 6.2)	$15,000	Limited discount over 3 years
6.1.3 Vapor Intrusion: Recommendation From FYR	Verify that, if plume still exists, no unacceptable risk exists via indoor air	Not Determined (addressed in five-year review)	Not Determined	Not Determined	Not Determined
6.2 Reduce Monitoring Frequency	Quarterly sampling no longer necessary to meet project decision needs	None	($36,000) Does not include any reductions in the network. Such reductions could reduce costs an additional $5,000.	($108,000)	Limited discount over 3 years
6.3.1 Simplify Sampling Methods	Sampling should be primarily for VOCs, so PDBs are adequate	None	Not determined (included in savings for section 6.2)	Not determined (included in savings for section 6.2)	Not Determined
6.3.2 Verify Monitoring Well Survey	Assure consistent reference elevations for piezometric measurement at OU2	$3,000	None	None	None
6.4 Additional Permanganate Injection	If the plume is found to be persistent, additional permanganate injection may be needed	Unknown at this time. Depends on the results of additional sampling.	Unknown at this time. It is not clear relative to what reference any cost savings would be calculated.	Unknown at this time. It is not clear relative to what reference any cost savings would be calculated.	Unknown

Numbers in parentheses are reductions in cost.

Figures

Figure 1. Site Location and April 2012 PCE Plume

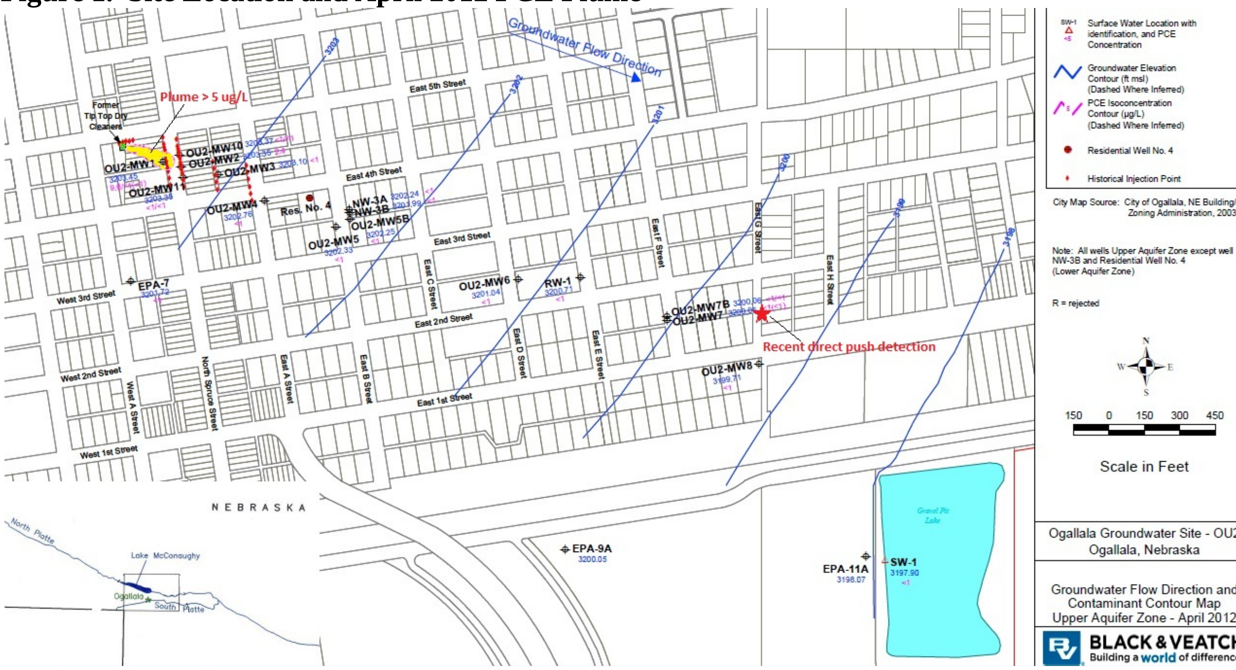


Figure 2. PCE Concentration Trends for Monitoring Wells along Plume Axis

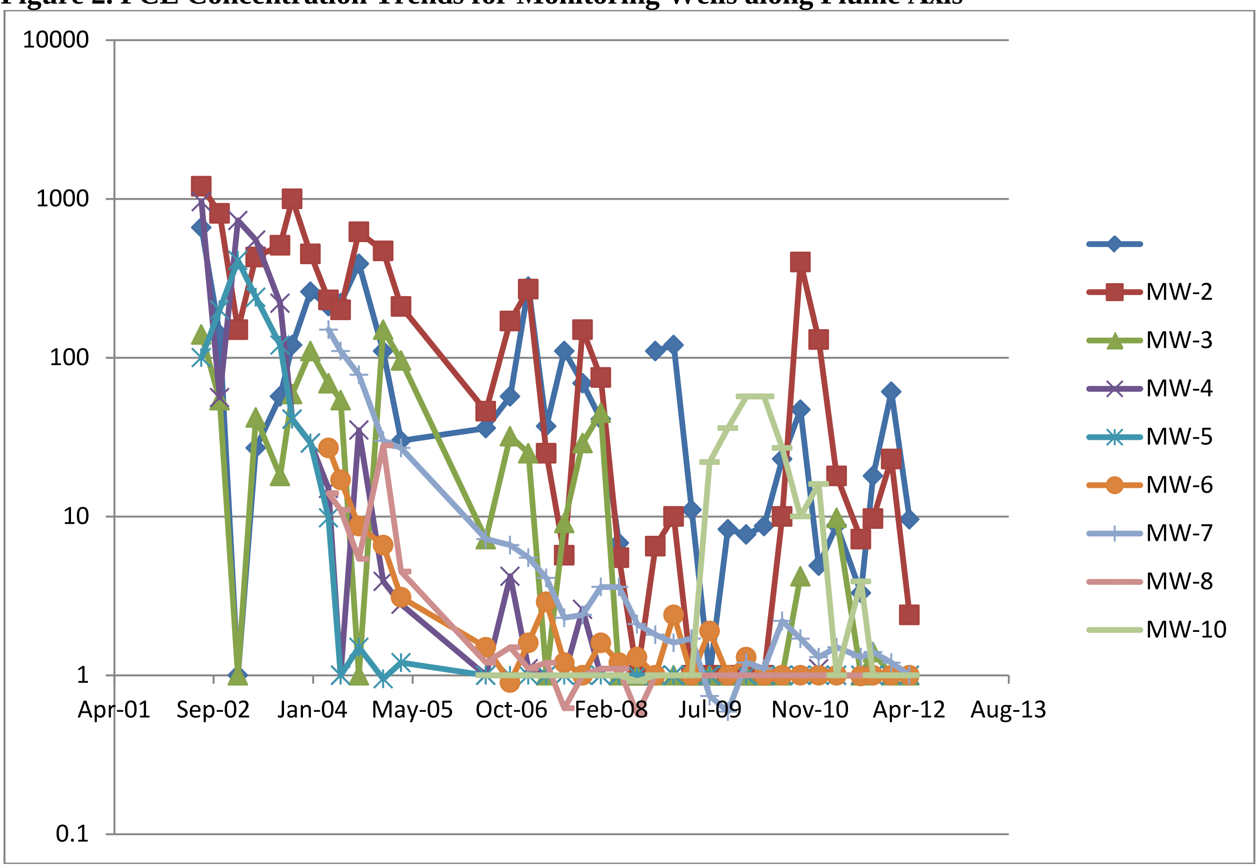
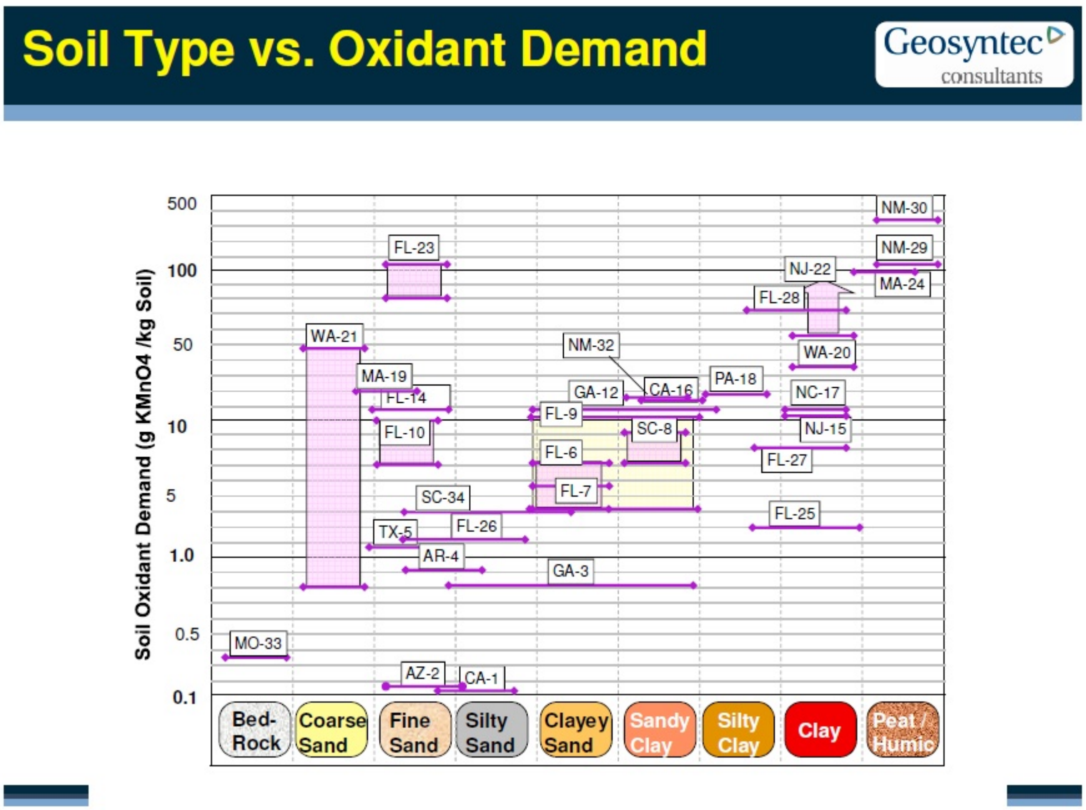


Figure 3. Sample Natural Oxidant Demand for Soils, Geosyntec Consultants, 2011.



Attachment A: Cost Estimate Back-up Assumptions and Table for Additional Sampling

Basis: 1) Initial delineation would use a Geoprobe rig to install temporary wells or sample groundwater using a peristaltic pump. Three to four transects would be performed downgradient and around the perimeter of the plume, with three to four sample locations per transect. For costing purposes, it is assumed a total of 12 boring locations would be sampled. This work scope would take two field days to complete. Each location would be sampled for VOCs with three additional QC samples (15 samples total) using normal laboratory turnaround time. 2) Permanent monitoring wells would be installed based on the delineation results. A total of five to nine monitoring wells would be installed. This work scope would take two to three field days to complete (based on three wells/day). Well construction would be flush-mounted, 2-inch PVC completed to a depth of 30 ft bgs. The wells would be developed immediately upon installation using disposable bailers or a downhole pump (i.e., no surging would be performed). Sampling costs and collection/disposal costs for soil cuttings and purge water were not included. 3) All boring locations would be blind drilled with no split-spoon sampling or borehole logging. 4) Contractor labor hours account for travel from Kansas City (8 hours each way), preparation of a boring location map and well completion logs, compilation of analytical data, and field work related project management. 5) Costs associated with preparation of a work plan or final report were not included. It is assumed that the groundwater delineation field work and sampling results would be incorporated into already budgeted periodic status reports.

	Cost Item	Unit Cost	Unit	Subtotal
I)	Geoprobe Delineation			
	Driller Mobilization	$1,000	lump sum	$1,000
	Geoprobe (1 person)	$1,500/day	2 days	$3,500[1]
	Project Manager	$125/hour	6 hours	$800
	Geologist	$80/hour	50 hours	$4,000
	CAD	$65/hour	4 hours	$300
	Vehicle/PID/Expenses	$350/day	2 days	$700
	Analytical/Shipping	$200/sample	15 samples	$3,400[1]
	Well Materials	$100/well	12 wells	$1,400[1]
	TOTAL			**@$15,000**
II)	Permanent Well Installations			
	Driller Mobilization	$1,500	lump sum	$1,500
	Drill Rig (2 people)	$2,500/day	2-3 days	$5,800-$8,700[1]
	Well Materials	$500/well	5-9 wells	$2,900-$5,200[1]
	Purge Pump	$50/day	2-3 days	$100-$200[1]
	Project Manager	$125/hour	6 hours	$800
	Geologist	$80/hour	50-65 hours	$4,000-$5,200
	CAD	$65/hour	6 hours	$400
	Vehicle/PID/Expenses	$350/day	2-3 days	$700-$1,100
	Survey Equipment	$100/day	2-3 days	$200-$300
	TOTAL			**@$17,000-$24,000**

Notes: 1) A 15% subcontractor mark-up was included in this subtotal to provide a conservative estimate.
2) Subtotals were rounded off as appropriate.
3) Unit costs are for cost estimating purposes only, and do not reflect actual contractual rates.
4) Costs represent Feasibility Study level preliminary estimates, and should not be used for budgetary purposes without further refinement of the work scope and detailed line item costs.

Attachment B: SiteWise Results for Environmental Footprint Reduction for Sampling Program Change

Sustainable Remediation Summary - Longterm Monitoring

Activities	GHG Emissions	Percent Total	Total Energy Used	Percent Total	Water Consumption	Percent Total	NOx Emissions	Percent Total	SOx Emissions	Percent Total	PM10 Emissions	Percent Total	Accident Risk Fatality	Percent Total	Accident Risk Injury	Percent Total
	metric ton	%	MMBTU	%	gallons	%	metric ton	%	metric ton	%	metric ton	%		%		%
Consumables	0.00	-	0.0E+00	-	NA	NA	NA	-	NA	-	NA	-	NA	NA	NA	NA
Transportation-Personnel	3.30	99.0	4.2E+01	98.9	NA	NA	1.4E-03	96.6	4.3E-05	100.0	2.0E-04	47.6	9.4E-05	100.0	7.5E-03	100.0
Transportation-Equipment	0.00	-	0.0E+00	-	NA	NA	0.0E+00	-	0.0E+00	-	0.0E+00	-	0.0E+00	-	0.0E+00	-
Equipment Use and Misc	0.03	1.0	4.5E-01	1.1	0.0E+00	0.0	4.8E-05	3.4	0.0E+00	-	2.2E-04	52.4	0.0E+00	-	0.0E+00	-
Residual Handling	0.00	-	0.0E+00	-	NA	NA	0.0E+00	-	0.0E+00	-	0.0E+00	-	0.0E+00	-	0.0E+00	-
Total	3.34	100.0	4.22E+01	100.0	0.00E+00	0.0	1.42E-03	100.0	4.32E-05	100.0	4.12E-04	100.0	9.36E-05	100.0	7.53E-03	100.0

Additional Sustainability Metrics

Non-Hazardous Waste Landfill Space (tons)	0.0
Hazardous Waste Landfill Space (tons)	0.0
Topsoil Consumption (yd^3)	0.0
Cost of Phase ($)	0.0
Lost Hours - Injury	0.1

Footprint Reduction

Total electricity replacement (MWh)	0.00E+00
Total electricity replacement (mmBtu)	0.00E+00
Landfill gas reduction (metric ton CO_2 e)	0.00E+00
GHG emissions (metric ton CO2 e)	0.00E+00
NOx emissions (metric ton)	0.00E+00
SOx emissions (metric ton)	0.00E+00
PM10 emissions (metric ton)	0.00E+00