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Remediation System Evaluation (RSE)
Baytown Township Superfund Site

Lake Elmo, Minnesota

REMEDIATION SYSTEM EVALUATION

BAYTOWN TOWNSHIP SUPERFUND SITE
LAKE ELMO, MINNESOTA

Report of the Remediation System Evaluation

Final Report
June 30, 2011

Prepared by
US Army Corps of Engineers Environmental and Munitions Center of Expertise

NOTICE

Work described herein was performed by the US Army Corps of Engineers Environmental and Munitions Center of Expertise (USACE CX) in Omaha, Nebraska for the U.S. Environmental Protection Agency (USEPA). Work conducted by the USACE CX, including preparation of this report, was performed under Work Assignment #58 of EPA contract EP-W-07-078. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

PREFACE

This report was prepared as part of a project conducted by the USEPA Office of Superfund Remediation and Technology Innovation (OSRTI) in support of the "Action Plan for Ground Water Remedy Optimization" (OSWER 9283.1-25, August 25, 2004). The objective of this project is to conduct Remediation System Evaluations (RSEs) at selected pump and treat (P&T) systems that are jointly funded by USEPA and the associated State agency. The project contacts are as follows:

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ACRONYM LIST

ARAR	Applicable or Relevant and Appropriate Requirements
bgs	Below Ground Surface
cfm	Cubic feet per minute
COC	Chemical of Concern
CT	Carbon Tetrachloride
FS	Feasibility Study
GAC	Granular Activated Carbon
gpm	Gallons per Minute
HDPE	High Density Polyethylene
ISBT	In-situ Biological Treatment
ISCO	In-situ Chemical Oxidation
LTM	Long-Term Monitoring
MAC	Metropolitan Airports Commission
MDH	Minnesota Department of Health
MHRL	Minnesota Health Risk Limit
MNA	Monitored Natural Attenuation
MPCA	Minnesota Pollution Control Agency
NAE	Natural Attenuation Evaluation
NAS	Natural Attenuation Software
NPDES	National Pollution Discharge Elimination System
O&M	Operation & Maintenance
ORP	Oxidation-Reduction Potential
OSRTI	Office of Superfund Remediation and Technology Innovation
OSWER	Office of Solid Waste and Emergency Response
PLC	Programmable Logic Controller
POC	Point of Compliance
PP	Proposed Plan
PVC	Polyvinyl chloride
RAO	Remedial Action Objective
ROD	Record of Decision
RPM	Remedial Project Manager
RSE	Remediation System Evaluation
SAP	Sampling and Analysis Plan
SWCA	Special Well Construction Area
TCE	Trichloroethylene
UIC	Underground Injection Control
USGS	United States Geological Survey
VFD	Variable Frequency Drive
ZVI	Zero Valent Iron

1.0 INTRODUCTION

1.1 PURPOSE

During fiscal years 2000 and 2001, independent reviews called Remediation System Evaluations (RSEs) were conducted at 20 operating Fund-lead pump and treat (P&T) sites (i.e., those sites with P&T systems funded and managed by Superfund and the States). Due to the opportunities for system optimization that arose from those RSEs, EPA's Office of Superfund Remediation and Technology Innovation (OSRTI) has incorporated RSEs into a larger post-construction strategy for Fund-lead remedies as documented in OSWER Directive No. 9283.1-25, *Action Plan for Ground Water Remedy Optimization*. 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 as a pilot effort considers green remediation during independent evaluations.

The RSE process involves a team of expert hydrogeologists and engineers, independent of the site, conducting a third-party evaluation of the operating remedy. It is a broad evaluation that considers the goals of the remedy, site conceptual model, available site data, performance considerations, protectiveness, cost-effectiveness, closure strategy, and sustainability. The evaluation includes reviewing site documents, potentially visiting the site for one day (not performed as part of this RSE work scope), and compiling a report that includes recommendations in the following categories:

- protectiveness;
- cost-effectiveness;
- technical improvement;
- site closure; and
- sustainability.

The recommendations are intended to help the site project team identify opportunities for improvements. In many cases, further analysis of a recommendation, beyond that provided in this report, may be needed prior to its implementation. Note that the recommendations are based on an independent evaluation, and represent the opinions of the RSE evaluation team. These recommendations do not constitute requirements for future action, but rather are provided for consideration by the USEPA Region and other site stakeholders.

The Baytown Township Superfund Site (Site) was selected by EPA OSRTI based on recommendations from the USEPA Remedial Project Manager (RPM) for the Site. The Site consists of three operable units that include portions of Baytown Township, the City of Lake Elmo, West Lakeland Township, and the City of Bayport, Minnesota. This RSE focuses on the source area remediation associated with Operable Unit 3 (OU3), also known as the Hagberg Property, which currently manages migration of the trichloroethylene (TCE) groundwater plume. The work scope for the RSE also included a review of the long-term monitoring (LTM) protocol for OU1, which includes the portion of the groundwater plume off-site from OU3 and the associated residential homes and private wells. The hydraulic containment system that is presently the primary remedial action associated with OU3 has been in operation since March 2008. The Minnesota Pollution Control Agency (MPCA) has been the lead regulatory agency for the Site under a State Superfund Contract with the USEPA. Under this agreement, the MPCA assumed full responsibility at 13 state-enforcement lead sites, including Baytown Township.

1.2 TEAM COMPOSITION

The RSE evaluation team comprised the following individuals:

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1.3 DOCUMENTS REVIEWED

The RSE evaluation team largely relied on data in electronic format provided by the MPCA. An electronic data base was provided that consisted of sampling results (contaminant concentrations and geochemical parameters) for groundwater, private well carbon system sampling, and treatment system process monitoring. Other electronic data provided to the RSE team included flow rates and meter readings, operations costs, and as-built drawings.

Documents reviewed by the RSE evaluation team included the following:

- "Record of Decision for the Baytown Township Superfund Site, May 2000 (ROD)"
- "Record of Decision Amendment for the Baytown Township Superfund Site, July 2007 (Amended ROD)"
- "Capture Zone Analysis of the Baytown Superfund Site Hydraulic Barrier, October 2010 (Capture Zone Analysis)"
- "Source Area Feasibility Study, June 2009 (Source Area FS)"
- "Natural Attenuation Evaluation, June 2009 (NAE)"
- "2009 Annual Report, June 2010 (2009 Annual Report)"
- "Program Review for Residential Well Sampling and GAC Management, May 2010 (2009 GAC Program Review)"
- "Quarterly Progress Reports, 2009 – 2010 (Progress Reports)"
- "Monthly Progress Reports, July 2008 - June 2009 (Progress Reports)"
- "Financial Status Report, 2008 – 2009"
- "Design Review Report, August 2006"
- "Bidding Documents for Hydraulic Barrier Remediation System, September 2007 (Design Specifications)"
- "Assessment Activities, June 2007"
- "Subsurface Assessment Report, May 2006"
- "2004 Source Zone Assessment Report, June 2005"

- "Five-Year Review Report, March 2007"
- "Sampling and Analysis Plan, December 2009 (SAP)"

1.4 BASIC SITE INFORMATION AND SCOPE OF REVIEW

This section presents background information related to site location, history, hydrogeologic setting, potential receptors, and site conceptual model and associated source area and groundwater impacts.

1.4.1 LOCATION

The Site is located in central Washington County, Minnesota. It is defined by a 12.5-square mile Special Well Construction Area (SWCA) designated by the Minnesota Department of Public Health (MDH). The Site is approximately bounded on the north by 50^{th} Street North and on the south by 20^{th} Street North, and includes portions of eastern Lake Elmo, the portion of Baytown Township east of the Lake Elmo Airport, northern West Lakeland Township, and the southern two-thirds of Bayport to the St. Croix River.

Baytown Township is a developing rural/suburban residential area on the eastern edge of the Minneapolis-St. Paul metropolitan area. The land use is primarily agricultural and residential. The Lake Elmo Airport is located near the western end of the groundwater plume, and is currently administered by the Metropolitan Airports Commission (MAC). An estimated 5,000 people live in the area.

1.4.2 SITE HISTORY, POTENTIAL SOURCES, AND RSE SCOPE

In June of 1987, the MDH sampled private wells in the area surrounding the former Bayport dump, just west of Bayport, as part of a state-wide program to determine water quality near solid waste facilities. TCE and carbon tetrachloride (CT) were detected in several of the private wells that were tested. Initially, the MPCA identified the Lake Elmo Airport as the suspected source of the TCE impacts to the private wells, and in 1988 requested that MAC initiate site assessment activities. Four phases of assessment were performed by MAC in the area of the airport from May 1988 through 1991. Based on the findings, MAC concluded that there was no direct link between the airport site and TCE impacts to the private wells. TCE was primarily detected in the Prairie du Chien aquifer unit, which is located approximately 100 feet below ground surface (bgs) in the vicinity of the airport. TCE was also detected in monitoring wells located upgradient of the airport site.

Assessment activities conducted by the MPCA between 2002 and 2006 further delineated the TCE groundwater plume and traced it back to the suspected source area upgradient of the airport site. The primary source of the TCE impacts to groundwater was found beneath the Hagberg Property, located at 11325 Stillwater Boulevard in Lake Elmo. This property was previously occupied by a metal working facility between 1940 and 1968, but is currently occupied by a gasoline station and grocery store. Assessment activities were performed on the Hagberg Property between 2004 and 2007 to further define the source area and delineate the groundwater impacts on the property. A discrete vadose zone source area has not been identified to date. The highest TCE groundwater concentrations have been found adjacent to the east and west sides of the southern portion of the main building on the Hagberg Property. Logistical constraints posed by the building presence have prevented groundwater sampling beneath the building.

To date, remedial actions included within the RSE work scope have involved the following:

- The MDH implemented an SWCA for the site in May of 1988, which informs homeowners with private wells and drillers about the potential for groundwater contamination in the area, and also restricts and regulates new potable water well completions;

- Granular activated carbon units (GACs) were installed in residential homes with private wells impacted by TCE above specified action levels, which are sampled and changed out on a pre-determined schedule;

- A groundwater pump and treat (P&T) system, consisting of four extraction wells and an air stripper treatment system, was installed along the eastern property boundary of the Hagberg Property and began operation in March of 2008 to contain off-site migration of the TCE groundwater plume and facilitate natural attenuation of the off-site portion of the plume; and

- An LTM program for the private water supply wells and monitoring wells has been implemented to clearly define the edges of the plume, identify increasing or decreasing trends, as well as evaluate on-site remediation progress and its influence on possible off-site natural attenuation mechanisms.

1.4.3 HYDROGEOLOGIC SETTING/SITE CONCEPTUAL MODEL

The general geology of the site consists of 75 to 100 ft of unconsolidated sediments overlying bedrock. The unconsolidated sediments consist of glacial tills, outwash, and undifferentiated drift. Along the St. Croix River valley, the sediments consist of river terrace deposits that are filling the former river valley. Assessment activities around the Lake Elmo airport showed silty, sandy, and gravelly clays near the surface, overlying sand and gravel outwash deposits. The two bedrock formations of primary interest are the Prairie du Chien Dolomite and Jordan Sandstone. The glacial drift is directly underlain by the Prairie du Chien Dolomite, which ranges in thickness from 100 to 145 ft. Much of this formation is highly fractured with solution cavities. The Jordan Sandstone underlies the Prairie du Chien and ranges in thickness from 85 to 100 ft.

The unconsolidated sediments of the glacial drift, Prairie du Chien Dolomite, and Jordan Sandstone appear to act as a single aquifer through which groundwater flows predominantly west to east and discharges to the St. Croix River. The Prairie du Chien/Jordan aquifer is the primary source for water supply in the Twin Cities area, and represents the aquifer unit where the residential private wells in the Baytown Township site area draw their water supply. Beneath the Lake Elmo Airport and further west, the first groundwater encountered is in the unconsolidated sediments at a depth ranging between 35 and 65 ft bgs depending on topography. Near the southeast corner of the airport and further east, the first groundwater encountered is in the Prairie du Chien Dolomite. The potentiometric surface slopes downward through the Prairie du Chien Dolomite to the east. Near the St. Croix River, the water table is once again in the unconsolidated sediments, where the former river valley is eroded down through the Prairie du Chien Dolomite.

The vertical hydrogeology for the source area on the Hagberg property is characterized by three water-bearing units located within the unconsolidated soils above bedrock. These units consist of a shallow perched water unit and middle and deeper groundwater units. The shallow perched water unit occurs at a depth of approximately 30 to 40 ft bgs, and is underlain by a discontinuous clay layer that does not appear to extend to the northern portion of the Hagberg Property. The soil types of the perched groundwater zone and vadose zone soils above it consist of a mixture of silts and sands with interbedded pockets of lower permeability silty clays. The middle groundwater unit is located beneath this first discontinuous clay layer at a depth of approximately 50 to 80 ft bgs, and is underlain by a second clay layer that appears to be continuous beneath the Hagberg Property. This second clay layer ranges between 4 and 16 ft in thickness and is acting as a confining layer for the deeper groundwater unit, as well as a barrier to downward vertical migration of TCE-impacted groundwater. The horizontal extent of this deeper clay confining layer is not known. The soil types for the middle groundwater unit consist of larger pockets of silty sands with smaller pockets of lower permeability silty clays. The deeper groundwater unit consists of more permeable sands to silty sands until approaching the bedrock groundwater units.

TCE groundwater impacts have been measured within the source area in the perched water and middle groundwater units, but were not found in groundwater samples collected from temporary sampling locations screened in the deeper groundwater unit. Permanent monitoring wells have been installed and screened at different depths within the perched water and middle groundwater units, while groundwater samples were also collected from temporary screened intervals at different depths within these units during the assessment activities for vertical delineation. TCE groundwater impacts were found at each of these different screening intervals within the perched water and middle groundwater units, including permanent monitoring wells screened immediately above the clay confining layer.

The highest TCE groundwater concentrations have been measured within the middle groundwater unit at sampling locations immediately to the east and west of the southern end of the main building around permanent monitoring wells MW-18 and MW-37 (refer to Figure 5A [TCE Groundwater Concentrations] from the 2009 Annual Report). The pattern of the TCE groundwater data, in combination with PID soil screening measurements at depth for the assessment borings, suggests that the primary source area is located either beneath the southern portion of the main building or immediately to its west in the vicinity of monitoring well MW-37. PID readings at monitoring well MW-37 at depths of 35 to 45 ft bgs (i.e., above the top of the middle groundwater unit) ranged between 100 and 900 parts per million (ppm), while the TCE soil concentration in a sample collected at a depth of 45 ft bgs was 62 milligrams per kilogram (mg/kg). These were by far the highest levels measured in any of the assessment borings. The PID readings measured at monitoring well MW-18 were much lower, so impacts on the eastern side of the building are believed to be an artifact of either downgradient groundwater movement or horizontal spreading of non-aqueous phase liquid (NAPL) mass within the more permeable sandy soil unit above the saturated zone. The assessment data has not indicated any significant source-area residual TCE mass in either the vadose zone or the perched water unit, with the largest amount of TCE mass residing within the middle groundwater unit and concentrated beneath and around the southern end of the main building. An initial groundwater grab sample collected during the drilling of monitoring well MW-18 located immediately east of the suspected source area had a TCE concentration of 89,000 micrograms per liter (µg/L), which exceeds the 1% solubility rule-of-thumb often used as a screening method for potential NAPL presence. However, the magnitude of the TCE groundwater concentrations across the suspected source area, in combination with the predominant pattern of decreasing concentrations with depth in vertical profile borings and nested monitoring wells, suggests that major NAPL pockets or accumulation layers are not a primary concern for remedial evaluation and design purposes (i.e., dissolved phase TCE and possible small NAPL pockets within the lower permeability silty clay soil horizons are the primary media of concern).

As mentioned above, TCE was measured at lower concentrations within the perched water unit and was not found in the deeper groundwater unit. Several of the downgradient off-site monitoring wells and the residential private wells, which have TCE groundwater impacts at much lower concentrations, are screened in the deeper Prairie du Chien Dolomite and Jordan Sandstone bedrock units. The pattern of the TCE groundwater data suggests that vertical downward migration is the predominant pathway in the source area between the perched water and middle groundwater units, with the second clay confining layer serving as a barrier for further downward migration on the Hagberg Property. From this point, horizontal downgradient advective flow is the likely predominant mechanism of contaminant migration. Given the lack of an identified confining unit at assessment locations downgradient from the Hagberg

Property, as well as TCE impacts to monitoring and residential private wells at depths to over 200 ft bgs, it appears that the unconsolidated and bedrock groundwater units are hydraulically connected with a vertical downward gradient component (upward and downward vertical gradients have been measured during historical assessment activities). At some locations, the drilling of the private wells may have driven TCE-impacted groundwater to lower depths. Available information indicates that vertical hydraulic connectivity exists between the unconsolidated and bedrock aquifer units. The much lower TCE groundwater concentrations measured in the farther downgradient and residential private wells again support the absence of a DNAPL phase and the decision to focus on TCE in the dissolved phase as the primary media of concern for purposes of the identified remedial components in the ROD and Amended ROD.

1.4.4 POTENTIAL RECEPTORS

Private wells represent the primary source of potable water for the Baytown Township area, and are the critical receptors of concern for the TCE groundwater plume. An indoor vapor exposure survey of the main building on the Hagberg Property did not identify risk levels warranting remedial action. In June of 1987, the MDH sampled private wells in the area surrounding the former Bayport dump, which is approximately five miles northeast of Lake Elmo, as part of a state-wide program to determine water quality near solid waste facilities. TCE and CT were detected in several of the private wells that were tested. As a result of the presence of these chemicals of concern (COCs) in private wells, the MDH issued a well drilling advisory (i.e., SWCA) in 1988 for a 12.5 square-mile area. There are approximately 650 homes and several businesses located within the SWCA. COCs have not migrated to any surface water body discharge receptors above regulatory levels, and thus surface water has not been identified as a media of concern.

In April of 1999, approximately 250 private wells within the drilling advisory area were sampled to evaluate the extent and magnitude of the COC impacts to potential receptors. TCE was found in 157 of these private well samples, but CT was not detected. The majority of the impacted private wells are screened in the Prairie du Chien Dolomite aquifer, but TCE was also detected in private wells screened in the Jordan Sandstone aquifer. The depth of many of the private wells is unknown due to the lack of reliable records.

GAC units were installed to treat potable water from private wells that had TCE concentrations detected above the Minnesota Health Risk Limit (MHRL) of 5 micrograms per liter (µg/L). These GAC systems are sampled and the carbon replaced on a pre-determined schedule based on statistical evaluation of the sampling data trends. Private wells not impacted by TCE above its MHRL are periodically sampled based on statistical evaluation of data trends, and fitted with GAC units if TCE concentrations exhibit an increasing trend and exceed a pre-determined action level. The private well sampling program and data are evaluated on an annual basis and modifications implemented as needed. The 2009 GAC Program Review was reviewed as part of this RSE.

1.4.5 DESCRIPTION OF GROUNDWATER PLUME

TCE groundwater impacts within the source area on the Hagberg Property have been measured within the perched water and middle groundwater units, but were not found in groundwater samples collected from temporary sampling locations screened in the deeper groundwater unit. The highest TCE groundwater concentrations have been measured within the middle groundwater unit at sampling locations immediately to the east and west of the southern portion of the main building around permanent monitoring wells MW-18 and MW-37 (refer to Figure 5A [TCE Groundwater Concentrations] from the 2009 Annual Report). The pattern of the TCE groundwater data, in combination with PID soil screening measurements at depth for the assessment borings, suggests that the primary source area is located either beneath the southern portion of the main building or immediately to its west in the vicinity of monitoring well MW-37. Several of the downgradient off-site monitoring wells and the residential private wells, which have TCE groundwater impacts at much lower concentrations, are screened in the deeper Prairie du Chien Dolomite and Jordan Sandstone bedrock units. The pattern of the TCE groundwater data suggests that vertical downward migration is the predominant pathway in the source area between the perched water and middle groundwater units, with the second clay confining layer serving as a barrier to further downward migration on the Hagberg Property. From this point, horizontal downgradient advective flow is the likely predominant mechanism of contaminant migration. It appears that the unconsolidated, Prairie du Chien Dolomite, and Jordan Sandstone bedrock groundwater units are hydraulically connected and exhibit a vertical downward gradient component. Consequently, TCE-impacted groundwater apparently migrated to lower depths within the deeper bedrock units as the plume moved downgradient towards the residential areas, thus impacting private wells screened in the bedrock units.

Water quality within the deeper Jordan Sandstone aquifer has been investigated through the installation of monitoring wells at the Lake Elmo airport and the sampling of private wells screened in that formation. Most of the private wells installed subsequent to the establishment of the SWCA in 1988 have been screened within the Jordan Sandstone. The residential sampling event conducted in October of 1999 found TCE impacts in some of the private wells east of the Lake Elmo airport that are screened in the Jordan Sandstone at depths of 220 to 270 ft bgs, with a maximum concentration of 55 µg/L. TCE concentrations above the MHRL continue to be found in private wells screened in the Jordan Sandstone.

The horizontal extent of measurable TCE concentrations in groundwater reaches the St. Croix River located approximately 5 miles directly east of the Hagberg Property, with concentrations above the MHRL extending approximately 4.5 miles. The width of the TCE plume above the TCE MHRL is approximately 0.5 miles. The horizontal extent of the groundwater plume is depicted in the figure provided by MPCA titled “TCE Groundwater Concentrations in Tunnel City Aquifer”.

While the total number of private wells impacted by TCE above its MHRL has decreased over time, a slight increasing trend has been observed within clusters of private wells. Even though it is not believed that the TCE plume is still expanding above its MHRL further downgradient, portions of the downgradient plume in the area of the residential private wells appear to be in a state of flux within the aquifer units, causing localized variations in ground water concentrations.

2.0 SYSTEM DESCRIPTION

The project team performed a mini-feasibility study (FS) in 2005 to evaluate potential remedial treatment technologies to contain off-site migration of TCE-impacted groundwater from the source area on the Hagberg Property. Based on the information presented in the mini-FS, the project team proposed implementation of a hydraulic barrier system in its Proposed Plan (PP) issued in March of 2007. The hydraulic barrier system consists of groundwater extraction wells installed along the eastern and southeastern perimeter of the Hagberg Property and an air stripper system to treat the TCE-impacted groundwater. Treated groundwater is re-infiltrated to the subsurface using a horizontal injection well system, with the water being used for irrigation purposes during seasonal needs.

2.1 EXTRACTION SYSTEM

The groundwater extraction system consists of four wells screened in the middle groundwater unit. Two of the extraction wells (RW-1 and RW-2) are installed directly east of the southern portion of the main building on the Hagberg Property, while the other two extraction wells (RW-3 and RW-4) are installed south and southwest of the main building (refer to Figure 2B [Existing Monitoring Well Source Area Map – North] from the SAP). The extraction wells are six inches in diameter and installed to a depth of approximately 75 to 80 ft bgs with a 20-ft screened interval. A transducer coupled to a submersible pump with a variable frequency drive (VFD) motor is designed to maintain a constant water level within each extraction well, which is set using the treatment system's programmable logic controller (PLC). The submersible pumps have an optimal pumping capacity of 25 gallons per minute (gpm). Current pumping rates range between approximately 8 and 14 gpm for each of the extraction wells, with extraction well RW-4 currently shut down. Extraction well RW-4 was shut down to reduce the overall system pumping rate and capture influence based on the capture analysis performed in October of 2010. Operating at a reduced extraction rate also reduces consumption of carbon dioxide (CO_2) from the anti-fouling system installed during 2010 (refer to Section 4.5.4).

The extraction wells are piped individually below grade to a central treatment building. The transfer piping is of Schedule 40 PVC construction, and the conveyance trenches are marked with copper tracer wire to facilitate location for future maintenance, if needed. Control valves and flow measurement devices are located inside the treatment building to facilitate operation and allow each extraction well to be monitored and controlled separately.

2.2 TREATMENT SYSTEM

The treatment system is PLC controlled and primarily consists of a low profile air stripper unit followed by a solids filtration system. Treated water is discharged via an underground horizontal infiltration system that supplies irrigation water to an adjacent municipal baseball field during seasonal needs. The individual extraction well lines are manifolded together inside the treatment building and routed to the air stripper unit. Since there is no equalization tank, the water flows directly from the manifold line into the air stripper. The low profile air stripper has four trays with a maximum design capacity of 150 gpm and operating design capacity of 100 gpm. The influent TCE design concentration used for sizing the air stripper and blower was 1,200 µg/L, with a design effluent concentration of less than 1 µg/L. The blower operating airflow rate is typically approximately 700 to 800 cubic feet per minute (cfm), and includes a VFD motor that can be manually adjusted using the PLC to modify the airflow rate. The current total influent pumping rate from the extraction wells is approximately 20 to 35 gpm, which yields an air to water treatment ratio for the stripper unit of approximately 150 to 300. Recent TCE total influent concentrations to the air stripper have ranged between approximately 250 and 700 µg/L. As previously mentioned, the pumping rates for the individual extraction wells have been recently reduced, and extraction well RW-4 shut down, to decrease the overall system pumping rate and influence based on the results of the October 2010 groundwater capture analysis.

The air stripper sump pump is fitted with a VFD motor and level sensor to allow programming by the PLC to maintain a fixed water level to minimize pump cycling. The air stripper sump and a floor sump are fitted with high/high level controls to shut down the extraction wells and air stripper in the event of an upset condition. Treated groundwater from the air stripper unit is routed through a solids filtration system that consists of two parallel systems, each configured with two bag filter units and then a cartridge filter unit in series (i.e., three filter units in series). The bag filter units are currently equipped with five- and one-micron bags in series, while the cartridge filter unit is equipped with one-micron cartridges. After the treated groundwater passes through the solids filtration system, it is routed to a 10,000-gallon storage tank and gravity fed into the horizontal piping infiltration system.

The groundwater infiltration system consists of two parallel 6-inch (in) diameter high density polyethylene (HDPE) slotted pipes that are each 520 ft in length. One of the infiltration pipes are operated at a time, with discharge to the second pipe rotated when the first pipe becomes clogged by sediment and biological fouling and requires rehabilitation. A CO_2 injection system was recently added for the treated groundwater to address the injection piping fouling issue. The CO_2 injection system serves as a method of pH/carbon dioxide equilibrium adjustment to minimize the precipitation of iron and calcium carbonate. Precipitation is caused by the volatilization of natural CO_2 levels from groundwater and the resulting pH and equilibrium shifts during air stripping treatment (refer to Section 4.5.4). The position of the CO_2 injection within the process flow design was not available in any of the documents or drawings that were received. However, the injection point for the CO_2 is believed to be between the filtration system and the discharge line from the 10,000-gallon storage tank. The means for introducing the CO_2 into the water was not available in any of the documents or drawings that were reviewed. Consequently, the diameter of the injection port air-line, or whether or not there is some sort of a fine-bubble diffusion device, is unknown.

The air stripper system and PLC have been designed with the flexibility to add either granulated activated carbon (GAC) liquid or vapor treatment systems or a second air stripper system if dictated by future site conditions.

2.3 MONITORING PROGRAM

The monitoring program for the site is substantial. A total of 28 monitoring wells are identified in the SAP for the site, and there have been as many as 600 residential and municipal wells that have been or currently are being sampled. Approximately 190 wells have GAC as a well-head treatment system. The monitoring wells are generally located on the Hagberg’s Market property, east-southeast of that property toward the Lake Elmo Airport, or on the airport property. Almost all of the residential wells are located east of the airport, extending almost to the St. Croix River. The residential wells vary in depth, but most are completed in bedrock at depths up to 480 feet and an average (at least for the wells of known depth) of about 260 feet. Municipal wells in Bayport are also monitored. The monitoring wells near the site are screened in the unconsolidated deposits, while some monitoring wells downgradient of the Hagberg’s Market property are completed in bedrock.

Sampling of the monitoring wells is supposedly on a quarterly to annual basis based on a review of the SAP, though some of the 28 wells (mostly at or near the airport) do not appear to have been sampled recently. The residential wells (without GAC units) are sampled on a frequency depending on the concentration observed in the last sampling round, with a quarterly sampling frequency for wells with TCE concentrations of 4.3 to 4.9 µg/L and a two-to-four year frequency (or, in practice, less) for wells with concentrations under 0.9 µg/L.

Sampling of monitoring wells is conducted using low-flow sampling techniques. Residential wells are sampled at a tap (before the carbon system, if one is present). Results for monitoring well sampling are reported in quarterly operations and monitoring reports. Residential well sampling data is managed in a spreadsheet.

3.0 SYSTEM OBJECTIVES, PERFORMANCE, AND CLOSURE CRITERIA

This section presents the Site remedial action objectives (RAOs) and various performance and closure criteria that are currently in place and applicable to the RSE review.

3.1 CURRENT SYSTEM OBJECTIVES AND CLOSURE CRITERIA

The Amended ROD references RAOs associated with the source area (aka Hagberg Property) and downgradient groundwater. Section H ("Remedial Action Objectives") of the Amended ROD states the overall groundwater RAOs as follows:

- Minimize migration of the contaminant plume;
- Restore the aquifer to drinking water standards; and
- Reduce the time necessary for downgradient wells to remain on GAC filters.

Section F ("Data Certification") of the Amended ROD states the following specific RAO for groundwater: "Allowing for natural attenuation, the goal is to achieve the MHRL residential drinking water standard (i.e., 5 µg/L) in the downgradient dissolved phase plume by Manning Avenue." It also states that, "Cleanup levels at 11325 Stillwater Boulevard (source area, aka Hagberg Property) will be evaluated during the primary source area feasibility study." Section L ("Amended Selected Remedy") of the Amended ROD references the original ROD, where one of the action components included the following: "developing a groundwater model….to evaluate future chemical fate and transport scenarios, especially the potential for further horizontal and vertical migration…."

A natural attenuation evaluation (NAE) was conducted that included an evaluation of TCE subsurface natural biodegradation by reductive dehalogenation, as well as the back-calculation of a TCE target source area objective that would achieve the RAO at Manning Avenue based on the development of a natural attenuation factor using linear regression analysis of concentrations along a plume centerline. This analysis yielded a TCE target source area objective of 108 µg/L that would achieve the RAO at the Manning Avenue point-of-compliance (POC). The natural attenuation factor derived using this analysis represents an overall factor encompassing combined degradation/reduction mechanisms (e.g., biodegradation, dispersion, etc.).

Section I ("Source Area Containment Methods") of the Amended ROD references the need for further evaluation of source area treatment methods. In response to this ROD requirement, a pilot study for in-situ oxidation (ISCO) was performed in November of 2007. A brief discussion of the ISCO pilot study findings is presented in Section 4.5.6. Following the completion of the ISCO pilot study, the Source Area FS was prepared, which included the pilot study findings along with an evaluation of other potential source area treatment technologies. The general conclusions of the Source Area FS involved not implementing any other remedial technologies within the source area because of likely ineffectiveness, while deferring implementation of ISCO until further assessment and groundwater sampling trends could be evaluated.

3.2 TREATMENT PLANT OPERATION STANDARDS

A discharge permit for the infiltration of treated groundwater from the air stripper system was not provided for review as part of the RSE evaluation. Being a CERCLA site, a discharge permit is not necessarily required. National Pollution Discharge Elimination System (NPDES) permitting requirements or underground injection control (UIC) permits are typically considered “Applicable or Relevant and Appropriate Requirements (ARAR)” for analogous discharges. Section M (“Statutory Determinations”) of the Amended ROD references the MHRL of 5 µg/L as the groundwater discharge objective for TCE. The air stripper effluent design basis referenced in the Design Specifications references an objective of <1 µg/L.

4.0 FINDINGS

This section presents the findings of the RSE evaluation team based on its review of documents referenced in Section 1.3. Findings are broken down by Site Conceptual Model, LTM program, key components of the hydraulic barrier treatment system, and other remedial action tasks.

4.1 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 groundwater remediation have changed over time.

4.2 SUBSURFACE PERFORMANCE AND RESPONSE

This section presents an analysis of the assessment work performed to date, including the Site Conceptual Model, LTM network and data collection, and analysis of the hydraulic control system capture influence.

4.2.1 PLUME CAPTURE

The performance of the current extraction system was evaluated. Performance was assessed following the multiple steps or lines of evidence approach provided in the USEPA capture zone guidance document titled "A Systematic Approach for Evaluation of Capture Zones at Pump and Treat Systems, January 2008". These lines of evidence include analysis of piezometric levels, calculation of a capture zone width, and analysis of chemical concentration trends. No modeling was conducted for this analysis, and no site ground water model appears to exist for the site.

Analysis of piezometric levels was not independently conducted as water level measurements were not readily available for recent quarters. Groundwater contour maps provided by the MPCA suggest a reasonable capture by the hydraulic barrier system with extraction wells RW-1, RW-2, and RW-3 operational.

Calculation of the capture zone width requires independent estimates of hydraulic conductivity for the pumped aquifer. Although several tests have been conducted using the extraction wells and water levels measured in nearby monitoring wells, no results for typical and systematic analysis of the hydraulic response to pumping have been identified. Some of the tests involved the simultaneous pumping of more than one extraction well. This complicates the analysis. A simple analysis was conducted for the response in monitoring well MW-36 to the pumping of extraction well RW-2 for about two days in December of 2010. After correction of the response for the drop in atmospheric pressure that occurred during the period, about 0.6 feet of drawdown was observed in monitoring well MW-36 after one day. Given a distance of approximately 70 feet, saturated thickness of 35 feet, and a pumping rate of about 8 gpm (typical for RW-2 in 2010), a range of hydraulic conductivities of 14 to 50 feet/day was estimated using the Theis equation for various storage coefficients (0.001 to 0.10) for this semi-confined aquifer.

Note that a storage coefficient of 0.10 did not yield a hydraulic conductivity that could match the drawdown. A range of 14 to 50 feet/day was used in estimating the capture zone widths.

The maximum capture zone widths were computed by the equation: $w_{max} = Q/(K*i*b)$, where Q is the pumping rate, K is the hydraulic conductivity, i is the gradient, and b is the saturated thickness, all in consistent units. The maximum capture zone width occurs some distance upgradient of the extraction wells. The capture zone width at the point along the flow lines at the extraction well itself is half the maximum width. The capture zone calculations do not account for the well interference. Table 4-1 below presents the results of the calculations.

Table 4-1. Computed Capture Zone Widths (assuming range of hydraulic conductivities and pumping rates)

Extraction Well	Pumping Rate (gpm)	Hydraulic Conductivity (ft/day)	Saturated Thickness (ft)	Gradient	Max Capture Width (ft)	Geometric Mean (ft) (at well)
RW-1	11	14	35	0.015	280 (best)	110 (60)
	6	50	35	0.015	50 (worst)	
RW-2	10	14	35	0.015	260 (best)	120 (60)
	7	50	35	0.015	50 (worst)	
RW-3	5	14	20	0.015	240 (best)	130 (60)
	5	50	20	0.015	70 (worst)	

Values represent best case and worst case values, and a geometric mean for the maximum capture zone width is provided

Based on the computed capture zone widths, it would appear that the well spacing and pumping rates would likely provide adequate capture. However, pumping rates cannot be allowed to drop significantly due to fouling or scaling of the extraction wells. There is a chance that complete capture may not be provided at extraction wells RW-1 and RW-3 if hydraulic conductivities near these wells are higher at those locations. The higher pumping capacity at extraction well RW-2 would suggest a greater hydraulic conductivity exists at that location or the construction of RW-2 allows a greater flow rate relative to the other wells.

The available information from third quarter 2009 through third quarter 2010 on TCE groundwater concentrations in monitoring wells was compiled. Trends were qualitatively evaluated for monitoring wells MW-25, MW-26, MW-28, MW-33, MW-34, MW-35 and extraction wells RW-1, RW-2, and RW-3 (see Section 4.2.2 for discussion of quantitative evaluation of monitoring well trends). Each of the monitoring wells, with the exception of MW-28, are adjacent to or downgradient of the extraction wells. Monitoring well MW-28 is upgradient of extraction well RW-1. In almost every case, the concentrations of TCE has systematically declined in both monitoring wells and extraction wells, and some declines have been substantial (>65%) in a short time. Even upgradient of extraction well RW-1, monitoring well MW-28 shows about a 45% decline in TCE. It is not clear if the declines are due to the capture of the mass flux from the source area or the pilot testing of ISCO using permanganate. The results at monitoring well MW-28 suggest the pilot test for permanganate may be affecting chemical concentration trends. Still, the results are not inconsistent with successful capture.

Overall, the information does tentatively support the conclusion that the hydraulic barrier system is capturing the bulk of the TCE mass emanating from the source area. If any feature downgradient of the extraction wells were minor sources in the past, such as the former septic field south of RW-3, mass from these sources would not be captured. The question may then be whether the use of the pump and treat system is the appropriate and most sustainable mass flux control technology to allow the remainder of the large plume to attenuate over time.

4.2.2 GROUND WATER CONTAMINANT CONCENTRATION TRENDS

As noted previously, the highest TCE groundwater concentrations have been measured within the middle groundwater unit at on-site sampling locations immediately to the east and west of the southern portion of the main building on the Hagberg Property. TCE groundwater concentration trends at the Hagberg Property appear to be declining overall with time, in part due to the operation of a hydraulic containment system and in part due to the ISCO pilot study performed at the site. See Section 4.3.1 and Section 4.3.6, respectively, for further discussions of these system components. However, there are some notable exceptions to the generally-declining trend in TCE concentrations.

As shown in Table 4-2, concentrations in monitoring well MW-18, located east of the main building at the site, have rebounded significantly since completion of the ISCO pilot study. This is most likely due to downgradient migration of TCE mass that was previously located beneath the main building on the Hagberg Property and unaffected by the pilot study. This response is not totally unexpected. Well MW-37, located just west of the main building, shows a decreasing trend at the 80% confidence level when considering all of the sampling events available since the ground water extraction system was started. However, when considering the five most recent sampling events the trend changes to an **increasing** trend at the 80% confidence level. No trend is apparent at the 90% confidence level for MW-37 when using either the latest five or all available sampling events. Wells MW-18 and MW-37 are completed in the mid- to upper-sections of the middle ground water unit and are located upgradient of the ground water extraction system.

Wells located downgradient of the extraction system and completed in deeper portions of the middle ground water unit (MW-33, MW-35, MW-38, and MW-39) show no discernible trend at either the 80% or 90% confidence level when evaluated by Mann-Kendall analysis, with one exception. MW-35 shows an increasing trend at the 80% confidence level when evaluating all available sampling events since startup of the ground water extraction system. Aside from this one exception the concentrations are stable, indicating little significant variation in TCE concentrations over time. This appears to indicate that the ground water extraction system has reduced or cut off mass flux to downgradient portions of the plume but plume attenuation is not yet occurring as anticipated, possibly due to re-equilibration of the plume after separation from the source. Continued monitoring will provide data to inform future trend analyses.

Data is lacking to determine recent concentration trends in airport property wells. Further downgradient, in the residential wells, TCE concentration trends are for the most part stable. However, there are isolated instances where trends appear to be increasing or decreasing (as determined using a Mann-Kendall analysis) at distances of a few miles from the source area. In some cases increasing trends exist in wells with concentrations near the MHRL of 5 μg/L for TCE.

TABLE 4-2: Mann-Kendall Analysis for Wells On/Near Hagberg Property

Well Number

Sample Date	MW-17 TCE Conc.	MW-18 TCE Conc.	MW-19 TCE Conc.	MW-21 TCE Conc.	MW-23 TCE Conc.	MW-25 TCE Conc.	MW-26 TCE Conc.	MW-28 TCE Conc.	MW-33 TCE Conc.	MW-34 TCE Conc.	MW-35 TCE Conc.	MW-37 TCE Conc.	MW-38 TCE Conc.	MW-39 TCE Conc.	MW-40 TCE Conc.
18-Apr-07	8.4				30.3		186.0								
12-Jul-07	8.0				34.7		181.0								
8-Nov-07	8.8				190.0		197.0								
12-Dec-07		40,700.00	82.6	994.0		281.0		4230.0							
29-Jan-08		38,800.00	79.2	1000.0		279.0		3820.0							
22-Feb-08		34,900.00	97.5	1140.0	16.7	301.0		1840.0					**GW Extraction System Started March 2008**		
23-May-08	8.8	397.00	94.2	832.0	382.0	274.0	474.0	2100.0	937.0	6130.0	1000.0	14400.0			
12-Aug-08	7.8	858.00	66.9	264.0	157.0	87.3	262.0	1070.0	1050.0	855.0	978.0	8440.0			
3-Dec-08	8.4	70.60	81.3	63.5	78.3	72.8	268.0	1880.0	3450.0	144.0	1710.0	8970.0			
7-Apr-09	6.7	5,380.00	83.0	9.5	16.2	31.8	168.0		3410.0	52.8	1460.0	4860.0			
18-Jun-09								2650.0							
5-Aug-09													364.0	1650.0	1290.0
1-Sep-09	6.9	2,100.00	174.0	12.8		23.8	277.0	3110.0	7760.0	62.4	3200.0	5690.0	473.0	1360.0	2200.0
22-Dec-09	7.4	2,380.00	96.7	9.7	54.3	28.1	470.0	1200.0	5130.0	52.3	2150.0	6580.0	633.0	1630.0	869.0
20-Apr-10	7.6	3,250.00	93.5	9.5	86.5	16.9	468.0	964.0	1390.0	85.3	2080.0	5850.0	625.0	1240.0	510.0
16-Sep-10	7.0	12,100.00	61.4	7.1	15.2	11.4	262.0	571.0	423.0	44.1	1220.0	6490.0	562.0	1720.0	529.0
80% Conf Trend[a]	Decreasing	**Increasing**	No Trend	Decreasing	Decreasing	Decreasing	No Trend	Decreasing	No Trend	Decreasing[d]	**Increasing**	Decreasing [c]	No Trend	No Trend	Decreasing
90% Conf Trend[a]	No Trend	**Increasing**	No Trend	Decreasing	Decreasing	Decreasing	No Trend	No Trend	No Trend	Decreasing[d]	No Trend	No Trend	No Trend	No Trend	No Trend
Sample Depth	34-44	48-53	39-49	50-55	60-70	48-58	58-68	75-80	65-75	40-50	61-71	45-55	85-90	85-90	40-50
Stable/Not Stable[b]			**STABLE**				**STABLE**		**STABLE**	**STABLE** [d]			**STABLE**	**STABLE**	

[a] Trends were calculated using data from May 2008 - present, after performance of the ISCO Pilot Study and start-up of the ground water extraction system.
Mann-Kendall analysis was performed using a spreadsheet developed by Wisconsin Department of Natural Resources (available at http://www.dnr.state.wi.us/org/aw/rr/archives/pub_index.html#TECHNICAL-PE).

[b] Stability test is only performed if no trend exists at the 80% confidence level at the well. Stability test uses the coefficient of variation, as proposed by Wiedemeier et al, 1999.

[c] When evaluating the most recent 5 sampling rounds there is an INCREASING trend at the 80% confidence level and NO TREND at the 90% confidence level.

[d] When evaluating the most recent 5 sampling events there is NO TREND and the plume is STABLE.

4.2.3 DATA GAPS

There appear to be several data gaps in the information that was provided for review of this project. Limited permanent well density, both horizontally and vertically, in the vicinity of the Hagberg Property and airport make it difficult to prepare potentiometric surface maps to determine horizontal and vertical groundwater flow directions and gradients. Similarly, there does not appear to be a clear understanding of TCE distribution or extent in the vicinity of the source area (primarily in the near-downgradient area from the Hagberg Property). Monitoring wells, while generally installed in a downgradient direction along the axis of the plume, do not provide sufficient resolution to determine the northern and southern lateral extent of the TCE plume between the source area and the Manning Avenue POC. This makes it difficult to determine the optimum location(s) for any potential in-situ treatment off the Hagberg Property or to determine if such treatment would even be appropriate.

There is a general absence of aquifer parameter data (e.g., hydraulic conductivity, storativity, etc.) or consistently-recorded piezometric data that could be used to model estimated transport time/distance and potential TCE degradation. An estimate or determination of vertical groundwater gradients also was not apparent in the documents reviewed. This information is important to determine if the plume is moving vertically or potentially sorbing/volatilizing/diffusing into the aquifer.

Data regarding the screened or open interval of residential wells is uncertain. Many wells lack information on well depth, ground elevation, casing depth, or the formation the well is completed in. This compromises the usefulness of the data in determining whether TCE is impacting a particular formation, and also makes it difficult to determine potential impacts to newly-drilled wells.

4.3 COMPONENT PERFORMANCE

This section presents a summary of the O&M performance for the primary components of the hydraulic barrier treatment system based on a review of the documents provided as part of this RSE evaluation. Minor operational or O&M recommendations not discussed in Section 6.0 are also presented in this section. In general, the air stripper treatment system appears to be operating effectively in accordance with its design specifications and with minimal downtime problems. Reported operating times in the periodic status reports have been consistently in the range of 85% to 99%. TCE effluent concentrations after treatment were reported to be less than 1 µg/L for each of the monthly sampling events, so the regulatory discharge level of 5 µg/L has not been exceeded. The project team has a systematic program in place to identify chronic system operating or shutdown problems and implementing corrective actions in a timely manner.

4.3.1 EXTRACTION SYSTEM

The project team currently does not track specific capacity data for the individual extraction wells in a centralized location or by a designated individual to evaluate potential fouling. Since PLC settings for the in-well transducers are designed to maintain constant water levels within the extraction wells, a loss in specific capacity would correlate to a decreasing trend in the average pumping rate, which would also equate to a reduced capture zone. A review of the Progress Reports did not identify any obvious reductions in the average pumping rates, except when the rates were throttled by design for operational reasons. The Progress Reports did not note any fouling or other types of pumping problems with the extraction wells. For O&M tracking and evaluation purposes, it is recommended that pumping rates for the individual extraction wells be manually or electronically recorded in a centralized location by a designated individual for ease of access, with any manual adjustments to the pumping rates or drawdown levels, etc. also recorded.

The primary operational problems identified in the Progress Reports for the extraction wells were the malfunctioning of the level transducers and logistical issues associated with the removal and disassembling of the submersible pumps and other components for inspection, maintenance, or repairs. The malfunctioning level transducers appear to have been repaired or replaced. Detailed drawings or descriptions of the submersible pump assemblies were not provided as part of the RSE review, so it was difficult to evaluate its configuration for ease of removal, as well as any modifications that may have been made to date by the project team. Action items were noted in the Progress Reports concerning the need to modify the submersible pump assemblies for ease of removal, but it could not be determined if these modifications have been completed for each of the extraction wells. Detailed O&M logs were not provided, nor operator interviews conducted, as part of this RSE review to pursue this evaluation further. If not already implemented, an improved submersible pump assembly could consist of the following components: 1) attachment of appropriate hooks and cable to allow attachment to a winch system to pull out the entire assembly (e.g., pump and in-well piping and controls; 2) use of camlock fittings to attach shorter pipe length sections to allow ease of disassembly during removal for draining, inspection, and cleaning; and 3) use of tie clips to attach electrical cables to the piping assembly.

Problems associated with sediment build-up at the bottom of the extraction well, well/pump screen fouling, or plugging of the influent piping were not indicated in the Progress Reports or operating data provided as part of the RSE review. However, the extraction wells have not been operated for a long period of time and fouling from sediment build-up within the well or well screen (or pump and piping) could become a problem in the future. It is not known if the project team performs periodic routine inspections and cleaning of the extraction well pumps, piping, and controls. If not currently done, it is recommended that the submersible pumps be pulled from the extraction wells on a quarterly or semi-annual basis for inspection and cleaning along with the influent piping and control cables. At the same time, sediment levels at the bottom of the extraction wells should be measured, and the wells purged and re-developed as needed. Recommendations in Section 6.3.2 for the groundwater infiltration system associated with excessive fouling and the need for periodically cleaning/jetting of the well screens and piping also apply to the extraction wells. Tracking of the specific capacities/pumping rates described above will also help identify well screen plugging problems.

4.3.2 AIR STRIPPER

The air stripper treatment system appears to be operating effectively with minimal downtime problems. As mentioned above, detailed O&M logs were not provided, nor operator interviews conducted, as part of this RSE review to further evaluate operation of the air stripper system. The primary causes of shutdown of the air stripper system appeared to be the following: 1) power outages; 2) false positive high/high level alarm conditions; and 3) high pressure alarm shutdown due to plugging of the solids filtration system by precipitated particulates and resulting high back-pressure conditions.

Each of the above shutdown problems appeared to have been addressed by the project team. The Design Specifications indicate that the PLC includes a programmed function that will restart the air stripper system in the event of an outage once power has been restored, as long as no other alarm conditions have been activated. It was not evident, however, in the review of the periodic status reports and operating data that this PLC function was performing properly following each of the power outages, with the system restarting on its own as intended without an operator having to be on-site to manually reset the control panel. It was later reported that this power outage system restart feature is present, but is currently disabled, because of the potential for discharging a small volume of untreated influent water upon restart. This feature can be made functional at the discretion of the project team, depending on an evaluation of the potential downside of discharging untreated influent water upon restart (option also exists to test/sample effluent upon re-start before re-setting functionality). The high/high alarm shutdown problems appeared to have been addressed by replacing a few of the level alarm sensors. The project team implemented a program to replace the bag filters on a more frequent basis, as well as periodically back-flushing the system with an acid solution, to reduce the frequency of plugging of the solids filtration system from precipitation caused by air stripping treatment.

As discussed in Section 2.2, the current total influent pumping rate is approximately 20 to 35 gpm versus the air stripper design capacity of 100 to 150 gpm (and maximum air stripper unit operating capacity of 1,000 gpm). In addition, the current TCE influent concentration ranges between approximately 250 and 700 µg/L versus the design influent concentration of 1,200 µg/L. Consequently, the air stripper system and corresponding current air/water ratio of 150 to 300 is likely over-sized versus the original design specifications. It is not believed that the air stripper system design and operating parameters (e.g., blower air flow rate) have been re-evaluated by the project team since start-up. There were no indications in the Progress Reports or operating data provided for the RSE review that such a follow-up evaluation has been performed or the blower airflow rate subsequently reduced. It is suspected that the intent to maintain the TCE effluent concentration below analytical detection limits has been a decision driver not to change the original operating parameters for the air stripper system. Since the air stripper blower is already equipped with a VFD motor, the airflow rate can be easily reduced by adjusting its PLC setting.

4.3.3 SOLIDS FILTRATION SYSTEM

As discussed in Section 2.2, treated water from the air stripper unit is routed through a solids filtration system that consists of two parallel systems, each configured with two bag filter units and then a cartridge filter unit in series (i.e., three filter units in series). The bag filter units are currently equipped with five- and one-micron bags in series, while the cartridge filter unit is equipped with one-micron cartridges. The Design Specifications originally called for 100-micron filter bags and 10-micron filter cartridges. The reason for reducing the micron ratings for the filter media could not be determined from the documentation provided as part of the RSE review, but was likely done to address potential fouling problems with the horizontal groundwater infiltration piping system. However, it is the experience of one of the members of the RSE review team that use of the lower micron size filter media often exacerbates the precipitation of metal complexes (especially iron oxides) from groundwater due to similar mechanisms as those resulting from air stripping treatment. Micron ratings for solids filtration media of 10 to 100 are typically adequate to remove a sufficient level of suspended solids and metal precipitates following air stripping to prevent maintenance problems from fouling build-up (higher micron ratings are preferable if adequate solids removal is achieved). If a need for the smaller micron size filter media has not been documented to date, then it is recommended that larger micron size filter media be tried and samples collected before and after the solids filtration system for suspended solids visual observation and laboratory analysis for comparison purposes. Visual inspection of the transfer piping and infiltration system piping should also be performed to evaluate potential plugging issues. An increase in the micron size rating for the filter media may result in less frequent change-outs, as well as a corresponding waste/cost reduction and reduced number of system shutdowns from high back-pressure conditions. It is at the discretion of the project team whether to change to larger micron size solids filtration filters, depending on the outcome of any evaluation and sampling.

Plugging of the filter screens that house the bag filters was identified by the project team as the major contributor to the chronic system shutdowns caused by high back-pressure conditions. Once sections of the screens become plugged, less surface area is available for water to flow through to the filter bags, thus causing the back-pressure to build rapidly and create system shutdowns. This problem was addressed by periodically back-flushing the system with an acid solution to remove the encrustation on the surface of the screens. This corrective measure appears to have been effective at reducing the number of system shutdowns due to the plugging of the solids filtration system and high back-pressure conditions.

4.3.4 GROUNDWATER INFILTRATION SYSTEM

After the treated groundwater passes through the solids filtration system, it is routed to a 10,000-gallon storage tank and gravity fed into the horizontal piping infiltration system. The groundwater infiltration system consists of two parallel 6-inch (in) diameter high density polyethylene (HDPE) slotted pipes that are each 520 ft in length. The infiltration pipes were installed to a depth of 24 ft bgs using directional drilling to allow the discharge of treated groundwater to the vadose zone to percolate to the shallow unconsolidated groundwater unit. One of the infiltration pipes are operated at a time, with discharge to the second pipe rotated when the first pipe becomes clogged by sediments and biological fouling and requires rehabilitation. Level sensors were installed in the infiltration wells that shut down the entire treatment system in the event a well becomes plugged or fails to discharge water to the vadose zone and the water level backs up.

One of the infiltration pipes became plugged in November of 2009 and caused a treatment system shutdown via a high water level alarm condition from the resulting back-up. The infiltration system was changed over to the second pipe, and a subcontractor retained to jet clean/acid wash the plugged pipe. A video inspection was also performed of the plugged piping, which showed the bottom half of the pipe covered with white scaling associated with calcium carbonate build-up.

The build-up of calcium carbonate in the injection piping was determined to be a result of precipitation from groundwater due to a pH shift in the treated effluent because of the removal of carbon dioxide during the air stripping process. In response to the calcium carbonate precipitation fouling problem, a CO_2 injection system was recently added for the treated groundwater on a trial basis. The CO_2 injection system serves as a method of pH/carbon dioxide equilibrium adjustment to minimize the precipitation of calcium carbonate from solution. This post-treatment set-up was installed during the first quarter of 2010. The CO_2 injection system was reported by Mr. Kurt Schroeder of the MPCA to still be in operation. However, the system temporarily ran out of CO_2 for about four months during the summer of 2010. Besides pH data, further evaluation data and documentation of its effectiveness at reducing the level of calcium carbonate precipitation was not provided for review, nor were operator interviews conducted, as part of the RSE review process. If not already performed, it is recommended that pre- and post-treatment visual observations and sampling (e.g., CO_2, total suspended and dissolved solids, pH, total calcium or calcium carbonate, hardness, alkalinity) be performed for comparison purposes to evaluate the effectiveness of the CO_2 injection system at reducing calcium carbonate precipitation. Further recommendations regarding the fouling of the infiltration pipes are presented in Section 6.3.3.

4.3.5 SYSTEM CONTROLS

The air stripper system and controls are operated by a PLC system. Based on a review of the Design Specifications, the PLC system and corresponding controls and alarm conditions are sound and provide an adequate level of protectiveness from typical system upset scenarios. The PLC system is also equipped with remote telemetry to allow routine operating parameters to be observed and alarm conditions to be communicated to an off-site location. The remote telemetry functionality serves to reduce system downtime when alarm conditions occur. The PLC also includes the flexibility to incorporate additional equipment or controls if needed based on future site conditions. The RSE review team does not have any recommendations for modifications to the air stripper treatment system controls.

4.3.6 ISCO PILOT STUDY

To support the source area treatment component of the Amended ROD, an ISCO pilot study was performed in November of 2007. The ISCO pilot study was centered near monitoring well MW-18 located immediately east of the southern portion of the main building on the Hagberg Property, which represented the sampling location with the highest TCE groundwater concentrations during the initial phases of the source area assessment. An initial grab groundwater sample collected from the boring during installation of monitoring well MW-18 had a TCE concentration of 89,000 µg/L at a depth of 48 to 53 ft bgs. Sodium permanganate (permanganate) was injected during a single event at seven locations (IP-1 thru IP-7; refer to Figure 7 [ISCO Full-Scale Conceptual Model] from the Source Area FS) centered near monitoring well MW-18 and to its south and west. Injection points IP-1 and IP-2 were advanced at an angle of approximately 15 degrees from vertical to access an area beneath the building on the west side. The injection depths for each boring ranged between approximately 40 and 60 ft bgs, corresponding to the upper half of the middle groundwater unit.

Baseline and follow-up groundwater samples were collected from monitoring well MW-18 and nearby monitoring wells to evaluate treatment effectiveness. Other subsurface indicator parameters of anaerobic biological activity (e.g., total chlorides and ethene as end products; presence of dehalococcoides as key bacteria species for reductive dehalogenation) were not measured during the pilot study, nor were additional well points installed to more comprehensively evaluate permanganate distribution and treatment effectiveness and influence. Three follow-up groundwater sampling events were performed in December of 2007, January of 2008, and February of 2008, corresponding to a pilot study timeframe of approximately three months. The hydraulic barrier system was started in March of 2008, which then altered subsurface equilibrium conditions that did not allow for further evaluation of rebound conditions after the ISCO injections.

The following were the key findings from the ISCO pilot study (refer to Figures 5 thru 7 [Pilot Test Performance Monitoring – TCE Concentrations] from the Source Area FS for TCE groundwater concentration trends):

- Significant TCE reductions were measured in groundwater samples collected from monitoring well MW-18, with initial decreases from a baseline concentration over 50,000 µg/L to approximately 25,000 µg/L through the February sampling event followed by further decreases to as low as 400 µg/L.

- Decreases in TCE concentrations were also measured in groundwater samples collected from other monitoring wells, most notably monitoring wells MW-21 and MW-28 where the baseline concentrations were approximately 5,000 µg/L and 1,600 µg/L versus a low of approximately 1,000 µg/L and 200 µg/L, respectively, following the ISCO injections.

- The most dramatic decreases in TCE concentrations occurred following start-up of the hydraulic barrier system, so it is not known if the pumping served to reduce the concentrations by dilution or possibly enhanced the mixing and contact of permanganate within the formation.

- Reductions in TCE concentrations were approximately 50% of the baseline concentrations at monitoring wells MW-18 and MW-21 prior to start-up of the hydraulic barrier system.

- As indicated above, there was a lag period of approximately four months prior to the most significant reductions in TCE concentrations, which can be attributed to either dilution or mixing created by the start-up of the hydraulic containment system or a diffusion mass transfer limitation that affected contact between the permanganate and TCE (e.g., due to lower permeability lenses or high organic carbon content from the finer grained soil type presence).

- Increasing concentration trends for total sodium were measured in groundwater samples collected from monitoring wells located downgradient of the injection locations, suggesting influence and distribution of the permanganate treatment.

- Some rebound has occurred in the TCE concentrations at monitoring well MW-18 following the May 2008 sampling event, with concentrations increasing to approximately 12,000 µg/L – this rebound concentration could be attributed to operation of the hydraulic barrier system, but is still less than the baseline concentration prior to the ISCO injections.

4.3.7 PRIVATE WELL SAMPLING AND GAC MANAGEMENT PROGRAMS

The 2009 GAC Program Review was used as the basis to evaluate the private well sampling and GAC management programs. There are currently 178 residences with GAC units installed that require management. These residences have had TCE concentrations in their potable well supply water that exceed its MHRL of 5 µg/L. Another 309 residences have their private wells sampled on a quarterly to every six year basis, but currently do not have GAC units installed. The residences that have their private wells sampled but do not have GAC units are within the area (or provide perimeter delineation) of the TCE plume and continue to be monitored for increasing trends that may exceed its MHRL.

The GAC management program consists of the following: scheduling of GAC change-outs; sampling of the GAC systems; maintenance of GAC units; and installation and removal of GAC units based on the sampling data. Most of the GAC systems consist of two 90-pound units configured in series. At the time of change-out, the lead canister is removed and replaced by the second canister and a new canister is then installed in its place. Goals of the GAC management program are as follows:

- Treat TCE concentrations in potable water sources to below its MHRL;

- Manage GAC change-outs to prevent break-through of the second carbon unit in series;

- Collect sampling data that allows for comprehensive evaluation of change-out frequency; and

- Develop a change-out schedule that is relatively simple and easy to manage.

Statistical evaluations of the sampling data and change-out information are performed on an annual basis. The statistical analyses are then used to modify change-out and sampling schedules or as decision-making criteria to add or remove individual GAC systems or trigger the sampling of private wells. The statistical analyses and decision-making criteria presented in the 2009 Annual GAC Program Review are considered sound and represent state-of-the art practices. Recommendations for adjustments to the GAC management program are described in Section 6.2.2.

4.4 COMPONENTS OR PROCESSES THAT ACCOUNT FOR MAJORITY OF ANNUAL COSTS

Annual O&M costs for 2009 were provided by the MPCA and are presented below. The annual O&M costs include the following: operation and maintenance labor and materials for the air stripper treatment system; engineering support for the air stripper treatment system; sampling and analytical costs for the private wells and GAC units; change-out of the GAC units; LTM sampling and analytical costs; preparation of the Progress Reports for the treatment system and LTM results; and overall project management.

Item Description	Approximate Annual Cost
Hydraulic Barrier Operations (includes project management, engineering support, and progress report preparation)	$116,000
Utilities - Electricity (2009 electricity bills) - Bottled water (2009 bills)	$8,000 $7,700 $300
Private Well GAC Change-out Program	$16,000
MDH Analytical for Private Wells	$39,000
LTM Sampling and Analysis (also includes private well and GAC sampling and database management)	$52,000
Total	**$231,000**

Because the annual O&M costs were provided with minimal breakdown for the various tasks and components, it was not feasible to perform any kind of analysis of specific items or cost reduction opportunities. Based on O&M information provided in the Progress Reports, it does not appear that any chronic system problems (besides those discussed above) have contributed to excessive costs or represent significant cost reduction opportunities. The Progress Reports state that operator visits are performed every two weeks, which is considered reasonable for this type of treatment system and associated O&M requirements. The information and alarm condition notifications provided by the remote telemetry system already allow for a reduction in site visit frequency and associated costs. Potential cost reduction opportunities associated with the various remedial components in the ROD are discussed in Section 6.2.

For future evaluation purposes, it is recommended that the costs for specific O&M tasks be tracked from an accounting perspective and broken down into as much detail as possible to facilitate analysis and comparisons and allow various cost reduction opportunities/actions to be identified/quantified. Recommended O&M cost breakdowns by specific tasks include the following: 1) treatment system routine O&M labor and materials (broken out separately); 2) treatment system non-routine O&M labor and materials for equipment trouble-shooting and repairs/replacement; 3) treatment system subcontractor and equipment for trouble-shooting and repairs/replacement (broken out separately); 4) infiltration system and transfer piping cleaning or repairs; 5) engineering support and trouble-shooting; 6) LTM labor and materials; 7) LTM analytical; 8) private well and GAC sampling and materials; 9) private well and GAC analytical; 10) GAC change-outs; 11) report preparation; and 12) overall project management. The costs associated with any major non-routine O&M trouble-shooting, repairs, or equipment replacement should also be tracked independently if possible.

5.0 EFFECTIVENESS OF THE SYSTEM TO PROTECT HUMAN HEALTH AND THE ENVIRONMENT

This section presents a brief summary of the evaluation of the overall effectiveness of the various remedial action components included in the ROD and Amended ROD at protecting human health and the environment.

5.1 GROUNDWATER

There are no current, known exposures to TCE-impacted groundwater. As discussed in Sections 1.4.4 and 1.4.5, TCE has been detected in residential home private wells at concentrations above the MHRL. These private wells have been equipped with GAC systems and placed on a sampling and change-out management program. To date, TCE concentrations have remained below the MHRL of 5 µg/L in samples collected between the two GAC carbon units in series, so there have been no break-through incidents and subsequent exposures to the general public. Both GAC units are changed out following a sampling event if the TCE concentration in the sample collected between the two GAC units in series exceeds 3 µg/L, providing an added level of protection from TCE exposure to the general public. The GAC treatment systems must remain in place at residential homes where the TCE concentration exceeds the MHRL in the potable well water, or until such time as an alternative municipal water supply is provided to this area of Baytown Township.

Based on findings presented in the NAE from preliminary natural attenuation modeling simulations, a projection of the timeframe to achieve the TCE RAO for groundwater of 5 µg/L could not be made using the current data set. One of the remedial objectives for the installation of the groundwater hydraulic barrier system at the boundary of the source area on the Hagberg Property was to contain the off-site migration of TCE-impacted groundwater. Prevention of off-site migration of TCE-impacted groundwater should enhance the ability of natural attenuation to reduce concentrations over time by mitigating the additive effects of a continuing source of TCE mass to the downgradient portion of the plume. The current data set, however, is inadequate to evaluate whether downgradient subsurface conditions are conducive to the biodegradation of TCE by reductive dehalogenation. The decreasing trends in TCE concentrations with distance and depth within the various groundwater units suggest that natural attenuation with distance downgradient due to dispersion or other abiotic mechanisms is occurring. Given the size of the plume and likely timeframe since the release(s) occurred, and based on case studies for other sites with TCE-impacted groundwater, it is anticipated that it may take decades to attain the TCE RAO at the Manning Avenue POC and locations further downgradient throughout the plume. In addition, further TCE source area mass reduction on the Hagberg Property is recommended to enhance the ability of natural attenuation mechanisms to achieve the TCE target source area objective of 108 µg/L and shorten the required operating timeframe and corresponding O&M life cycle cost for the hydraulic containment system. Further treatment technologies are still under consideration to reduce the TCE source area mass on the Hagberg Property, with the objective to decrease the timeframe necessary to achieve the TCE RAO at the Manning Avenue POC.

5.2 SURFACE WATER

As discussed in Section 1.4.5, the horizontal extent of the TCE groundwater plume reaches the St. Croix River. However, based on the results of the Baseline Risk Assessment (BRA) and a comparison against applicable ARARs, surface water was not identified as a media of concern in the ROD and was not included as part of this RSE evaluation.

5.3 AIR

Air emissions from the stripper system contain TCE volatilized from impacted groundwater. An active gasoline service station and store currently operates on the Hagberg Property where the air stripper system is located. Consequently, workers and patrons of the establishment, as well as any nearby residents or businesses, could be exposed to the TCE air emissions from the air stripper system. The 2009 Annual Report states that air emission modeling and a corresponding risk assessment was performed during the design process for the air stripping system, and "the air emission modeling indicated that emissions did not present a significant risk." It is assumed that the air emission modeling and risk assessment satisfied any permitting and/or ARAR requirements. An air permit was not provided with the documentation for the RSE evaluation.

5.4 SOIL

Soil was not identified as a media of concern in the ROD and there are no soil RAOs for the Site.

5.5 WETLANDS AND SEDIMENTS

Wetlands and sediments were not identified as a media of concern in the ROD.

6.0 RECOMMENDATIONS

This section presents recommendations by the RSE evaluation team regarding items for consideration by the site project team that could positively affect the overall effectiveness of the ongoing remedial actions, improve efficiencies or operations, accelerate the overall remediation timeframe, or reduce any of the O&M life cycle cost components. The recommendations are broken out by effectiveness (Section 6.1), life cycle cost reductions (Section 6.2), technical improvements (Section 6.3), exit strategy (Section 6.4), and sustainability considerations (Section 6.5). A listing of the recommendations presented in this section, along with estimated annual and life cycle costs or savings, are presented in Table 6-1.

6.1 RECOMMENDATIONS TO IMPROVE EFFECTIVENESS

This section presents recommendations by the RSE evaluation team designed to improve the effectiveness of components of the Site remedy specified in the ROD and Amended ROD.

6.1.1 IMPLEMENT ISCO WITHIN SOURCE AREA

The RSE evaluation team recommends implementing ISCO treatment (or an alternative treatment technology) within the source area on the Hagberg Property on a more aggressive schedule than proposed in the Source Area FS in order to reduce the TCE mass flux from the source area to a level that will allow eventual attainment of the TCE target source area objective of 108 µg/L by natural attenuation mechanisms. Given the current LTM data, relevant case studies, and experience of the RSE evaluation team, there are no indicators that support the attainment of the target objective and subsequent shutdown of the source area hydraulic containment system in a reasonable timeframe without further reduction in the TCE source area mass flux. This recommendation is based on the following justifications:

- Any TCE mass removal that would be achieved by moving forward with ISCO treatment would be permanent and justify the related expenditures. As discussed in Section 6.1.2, ISCO treatment can be implemented in a phased manner to control the timing and level of expenditures and allow the termination of treatment activities. A decision can be made at any point during the phased implementation to terminate ISCO treatment if a satisfactory level of progress towards attaining the TCE target source area objective has not been achieved to justify continued expenditures.

- Adequate assessment data has been generated to move forward with the ISCO source area treatment. Given the limited effectiveness of injection technologies in treating lower permeability soil units similar to the silty clay layer above the middle groundwater unit, additional monitoring or assessment data will not appreciably enhance the knowledge-base and effectiveness of the ISCO injections (or alternative technology). The optimal data that could be generated at this time would come from monitoring the source area as part of an ISCO injection program.

  The multiple assessment phases have generated adequate data related to horizontal and vertical delineation of source area impacts and subsurface geology to move forward with an ISCO injection program within the middle groundwater unit. Numerous borings have been located in the suspected source area on the east and west sides of the main building (refer to Figure 7

[ISCO Full-Scale Conceptual Model] from the Source Area FS). Grab groundwater samples were collected at multiple depths during the drilling of several of these borings to provide a vertical profile of TCE impacts based on a combination of grab and permanent monitoring well sampling concentrations and PID field screening readings. Borings MW-18 and F-29 provide a vertical profile of TCE impacts on the east side of the suspected source area; while borings MW-37, F-30, and F-32 provide the same on the west side of the building. TCE groundwater concentrations and PID field screening readings were at least an order-of-magnitude lower in samples collected from the shallow perched water unit (depth of approximately 30 to 40 ft bgs) versus middle groundwater unit (depth of approximately 50 to 80 ft bgs) in each respective boring, with the highest TCE groundwater concentrations found at a depth of approximately 50 ft bgs (i.e., top of the middle groundwater unit). Given the number of years since the release incident(s), the presence of any significant NAPL pockets beneath the building that may be immobilized within the lower permeability silty clay layer immediately above the middle groundwater unit (e.g., above approximately 45 ft bgs) should at least yield some pattern of higher PID or TCE groundwater concentrations at shallower depths around the perimeter of the building, which has not been observed to date.

- Based on the assessment data, it is believed that the TCE release(s) in the source area was either small and frequent or slow and somewhat continuous from a very localized source (e.g., small spills, dry well or sump, below-grade degreaser unit leak) located in the area of the southern portion of the main building. This release pattern then resulted in a predominantly narrow, vertical migration distribution pathway through the higher permeability shallow sandy soil unit, and then through vertical fracturing in the initial discontinuous silty clay layer, until reaching the saturated zone depth that served as a migration barrier at the top of the middle groundwater unit. Under this Site Conceptual Model, the top of the middle groundwater unit and the bottom of the overlying silty clay unit would represent the primary TCE mass accumulation depth, where NAPL could then spread laterally within the more permeable sandy soil unit, and transfer into the dissolved phase through contact with the saturated zone and infiltration (e.g., would be consistent with high initial PCE concentration in grab sample near the top of middle groundwater unit at monitoring well MW-18). Thin pockets of NAPL ganglia are also likely immobilized within the pore structure of the lower permeability silty clay layer at depths between 35 and 50 ft bgs beneath the building as a result of NAPL spreading and capillary zone forces. This slight adjustment to the Site Conceptual Model would explain the current absence of significant vadose zone impacts, and the assessment results showing high concentrations of TCE mass within or immediately above the middle groundwater unit. This Site Conceptual Model yields a thin and relatively small NAPL zone near the top of the middle groundwater unit and the bottom of the overlying silty clay unit resulting from capillary forces, which is consistent with the assessment data, which would then correspond to a lesser amount of TCE mass that should be more amenable to source area treatment. Similar distributions in contaminant mass have been observed by the RSE evaluation team at other chlorinated solvent remediation sites.

- TCE groundwater concentrations and PID field screening readings collected from boundary or downgradient borings MW-19/23, MW-21/22, MW-25, F-37, F-38, and F-42 also show the same pattern, which is reflective of horizontal movement from the source area depths of impact. Based on the assessment data, the ISCO injection program should initially be focused on the middle groundwater unit at a depth of approximately 45 to 70 ft bgs where the highest levels of TCE source area mass currently reside, which is consistent with conclusions presented in the Source Area FS. The assessment data is also consistent with the Site Conceptual Model of subsurface geology that generally shows more permeable soil types across the middle groundwater unit that serves as a zone of accumulation and horizontal movement.

- The southern portion of the main building, where the primary source area has been identified, is only approximately 40 ft wide and 60 ft long. This area beneath the main building represents a minor data gap given the assessment data that has been collected from the east and west sides. Given the logistical constraints posed by the building to sampling beneath it, limited useful data can currently be collected prior to moving forward with an ISCO injection program. Establishing a comprehensive monitoring program as part of an ISCO injection program can also fill in some of the assessment data gaps regarding subsurface heterogeneities and hydraulic connectivity.

- The LTM data currently does not support the shutdown of the source area hydraulic containment system located on the Hagberg property in a reasonable timeframe without implementation of more aggressive source area treatment. Significant and consistent decreasing trends in TCE groundwater concentrations have not been identified to date, especially in the source area on the Hagberg Property. Influent TCE concentrations to the air stripper treatment system and source area monitoring wells have exhibited stable trends during sampling events from the last few years. The compounds cis-1,2-dichloroethene (DCE) and vinyl chloride (VC), which are daughter products of biodegradation of TCE by reductive dehalogenation, have not been measured at significant or consistent concentrations either within the source area or downgradient, suggesting that biodegradation of TCE is not occurring at a rate that would achieve the TCE target source area objective of 108 µg/L in a reasonable timeframe. The daughter product DCE was detected in only five of the source area monitoring wells during the September 2010 sampling event, with the only significant detection at monitoring well MW-37 representing 8.5% of the TCE concentration (6,490 µg/L TCE versus 554 µg/L DCE); while the daughter product VC was only detected in a single source area monitoring well during this sampling event at a very low concentration (6.6 µg/L at monitoring well MW-37). This conclusion was also included in the NAE. Alternatively, degradation may be taking place by abiotic mechanisms that would not generate the daughter products DCE or VC.

- The ISCO pilot study showed reductions in TCE groundwater concentrations at monitoring well MW-18 from over 50,000 µg/L in the baseline sample to less than 100 µg/L in post-treatment samples prior to rebound. The reduction in the TCE groundwater concentration at monitoring well MW-18 remained at over an order-of-magnitude following rebound after start-up of the hydraulic containment system until the most recent sampling event in September 2010. In September the TCE concentration increased to over 12,000 µg/L, approximately one-quarter the baseline concentration of 50,000 µg/L. The ISCO pilot study program did not include the source area identified on the west side or beneath the main building, which likely contributed to the rebound observed at monitoring well MW-18.

- Elevated initial dissolved phase TCE concentrations were measured in vertical samples collected from borings immediately to the east and west of the southern portion of the main building, which are still reflected in more recent groundwater samples collected from monitoring wells MW-18 and MW-37. Given the mostly sandy soil conditions across the middle groundwater unit, this source area mass should be amenable to ISCO treatment as demonstrated during the pilot study. The more aggressive schedule for source area treatment should reduce the timeframe to achieve the TCE target source area objective of 108 µg/L, which in turn will reduce the overall project life cycle costs for continued operation of the hydraulic barrier system and LTM.

Despite the positives aspects associated with implementing more aggressive source area treatment described above, the RSE evaluation team acknowledges the concerns communicated by the MPCA regarding critical unknowns related to potential NAPL presence beneath the building or immobilized within the lower permeability silty clay layer above the middle groundwater unit. The presence of significant residual NAPL mass within these areas that may be inaccessible to treatment could prevent the ultimate attainment of the TCE target source area objective and increase the overall life cycle costs. The presence of the main building over the potential source area and continuing active site operations have limited access to this area during the various phases of assessment. Recommendations for further NAPL assessment activities given the presence of the main building are presented in Section 6.1.5.

Because of the limited site data and uncertainties associated with overall treatment effectiveness, a cost for this recommendation has not been included. At this point in time, this level of cost estimate and projection of remediation /natural attenuation timeframes would be of limited value because of the numerous assumptions that would be required (such as source area mass, number and location of injection points, number of separate injection events required, and distribution and mass flux reductions that could be achieved by treatment). This analysis could be revisited by the project team if additional source area mass distribution information is generated in the future. More accurate cost estimates can be generated by the project team as the treatment evaluation process progresses and vendor quotations are solicited (e.g., refer to Section 6.1.4 for an analysis tool that can be used to evaluate an approximate "break-even" point comparing source area treatment versus P&T). Ultimately, the MPCA and USEPA will need to make a business decision regarding the implementation and timing of more aggressive source area treatment versus continued operation of the P&T system.

6.1.2 PHASED IMPLEMENTATION OF ISCO SOURCE AREA TREATMENT

Because of the assessment data gaps, complexity of the subsurface heterogeneities, and difficulties in evaluating the positive or negative impacts of operation of the hydraulic containment system on the distribution of injected permanganate, it is recommended that the ISCO source area treatment (or alternative technology) be implemented in a phased manner. A phased implementation (i.e., observation method) of the ISCO source area treatment would have the following benefits:

- The data gaps and influences described in Section 6.1.1 could be evaluated using a systematic observational approach to allow more targeted treatment of the TCE source area mass and cost effective use of resources based on observed trends in groundwater concentrations;

- The ISCO treatment protocol can be adjusted or expanded as needed based on monitoring data and observed TCE groundwater trends, or treatment can be discontinued to collect additional assessment data (and possibly change source area treatment technologies), which will better manage long-term life cycle costs. Any costs incurred by source area treatment will still provide the benefit of permanent TCE source area mass reduction.

- The need to achieve a TCE target source area concentration of 108 µg/L (or alternative concentration) to attain the RAOs at the Manning Avenue POC leaves some flexibility to not require treatment of the entire horizontal extent and vertical depth of groundwater impacts. Sufficient TCE source mass reduction may be achieved to meet this target concentration by initially focusing on the middle groundwater unit (i.e., zone of greatest TCE source area mass), which will result in a reduction in project life cycle costs.

Tracer Study

It is recommended that a tracer study be performed prior to moving forward with the ISCO injections to evaluate hydraulic connectivity. A tracer study will serve to fill in some of the assessment data gaps beneath the building (including groundwater velocity) to allow for a prediction of horizontal and vertical permanganate distribution. A more comprehensive monitoring network will need to be installed to support the tracer study and ISCO injection program. The monitoring network will need to cover both the west and east sides of the building and downgradient locations to provide a sufficient number of tightly-spaced sampling locations to allow for measurement of changes in subsurface chemistry, TCE groundwater concentration reduction trends, and permanganate distribution both horizontally and vertically throughout the treatment area. Nested monitoring points should be installed to allow for vertical monitoring of the treatment area. The monitoring points can be installed either as temporary wellpoints screened at multiple depths or small diameter nested wells. The ISCO injection system monitoring network should be installed prior to initiating the tracer study, and can be used to serve as multiple injection and monitoring points during the tracer study to reduce the data gaps in subsurface transport pathways prior to initiating the ISCO injection program, which will in turn optimize its implementation and cost effectiveness.

A conservative tracer such as potassium bromide is recommended for the study. It should be injected at multiple depths on the west side of the main building corresponding to the planned ISCO treatment zone. The hydraulic barrier system should be shut down during the tracer study to eliminate its influence. Downgradient measurements of tracer migration should be made at both horizontal and vertical sampling locations to measure its movement and distribution. The tracer study will require a sufficient timeframe to adequately measure downgradient velocity and vertical and horizontal distribution prior to re-starting the hydraulic barrier system. The USACE RSE review team would welcome further consultation with the project team or review of generated work plans on an as needed basis regarding the development and execution of the tracer study and evaluation of the monitoring data generated.

Phased Approach to Permanganate Injections

Multiple rounds of ISCO injections will likely be required to achieve adequate source area treatment and TCE mass reductions. As discussed above, it is recommended that the ISCO injection program (or alternative technology) be implemented in a phased manner. The first round of ISCO injections should focus strictly on the identified source area and depth of greatest TCE mass accumulation. This includes the eastern and western sides of the southern portion (thinner section) of the main building at a depth between 45 and 70 ft bgs. Focusing on this area of higher TCE concentrations represents a much smaller initial injection area than what was depicted in the Source Area FS (refer to Figure 7 [ISCO Full-Scale Conceptual Model] from the Source Area FS), which will result in more controlled life cycle project expenditures for source area treatment. Necessary monitoring data (including rebound concentrations) collected during source area treatment would provide further information that can be used to evaluate the presence and location(s) of remaining NAPL mass and continued refinement of the Site Conceptual Model, including beneath the building. If a determination is made during this phased source area treatment implementation process that a significant amount of untreated NAPL mass remains inaccessible for treatment either beneath the building or within the silty clay layer above the middle groundwater unit, which in turn is causing a significant rebound condition that is preventing acceptable progress towards meeting the TCE target source area objective, a decision can be made to terminate further source area treatment and re-visit the long-term remedial action approach for the Hagberg property. Fracturing technologies could also be considered for implementation to access and treat residual NAPL mass immobilized within the silty clay layer above the middle groundwater unit and beneath the building.

ISCO injections on the west side of the building should be performed first and extend to approximately boring F-32 to the west and the mid-point between borings F-33 and F-37 to the south. The hydraulic barrier system should be shut down for a minimum of one month (three months would be optimal) following these initial injections until evidence of distribution has been measured on the east side of the building. The estimated groundwater velocity of 1 ft/day should allow for observation of permanganate distribution on the east side of the building within a month of the initial injections. Shutting down the hydraulic barrier system would result in some amount of off-site migration of dissolved phase mass during the injection timeframe. However, the off-site TCE mass flux would be considered minimal in relation to the mass that has already migrated off-site since the release incident; the benefits associated with eliminating a major potential negative influence variable on the evaluation of the effectiveness of the ISCO injections are believed to outweigh this downside. The TCE mass reduction that should be achieved during the ISCO injections may also further reduce the off-site TCE mass flux during this shutdown period for the hydraulic barrier system.

The hydraulic barrier system should then be re-started to allow for evaluation of any positive or negative influence of its operation on permanganate distribution. ISCO injections on the east side of the building should then be performed and extend to approximately pilot study injection points IP-3 and IP-7 to the east and slightly beyond IP-5 to the south. The same protocol regarding operation of the hydraulic barrier system should be followed to allow permanganate distribution to be evaluated with it on and off. Injection borings immediately adjacent to the east and west walls of the building should be drilled on an angle in an attempt to get as much permanganate as possible beneath the building. Vertical borings should then be placed next to these wall borings to treat the required depth at those locations.

The protocol for the second round of ISCO injections should be based on the evaluation of the monitoring data from the initial round of injections. It is anticipated that at least one more round of ISCO injections should be performed as described above, with operation or shutdown of the hydraulic barrier system being based on the observed permanganate distribution and treatment being more effective with it on or off. The hydraulic barrier system can remain in operation (but is not recommended based on discussions between the RSE evaluation team and an ISCO/ISBT vendor) if there is minimal observed negative influence on permanganate distribution and treatment from its operation. Because the influence of the hydraulic barrier system was extrapolated to extend to the west side of main building at higher pumping rates, its operation at increased pumping rates could have a positive impact on permanganate distribution by drawing it beneath the building. The need and protocol for future rounds of ISCO injections would then be based on the observed trends in the TCE groundwater concentrations.

If adequate decreasing trends in TCE concentrations are not observed to attain the TCE source area target objective of 108 µg/L (or alternative concentration) in a reasonable timeframe, future injection programs may need to be expanded to include more of the Hagberg Property source area (e.g., to the north or west) or the shallow perched water unit. At this point, additional vertical assessment data may also be needed. Consideration may also need to be given to the installation of a horizontal well injection system beneath the building if adequate permanganate distribution is not observed between the west and east sides of the building. If additional source mass would be hypothesized above the regional water table based on the response to other remedial efforts, it may be appropriate to consider traditional vadose zone source area treatment technologies. Soil vapor extraction may be appropriate, though high soil moisture content may limit air flow. Pilot testing and soil gas sampling under the Hagberg building would be appropriate as described above.

It may be possible to use recovery wells RW-5 and RW-6 as part of the injection program, particularly the deeper zones if the injection area is extended to the north for future events. Use of recovery wells RW-5 and RW-6 for the initial "hot spot" injection events around the southern portion of the main building would not likely be an effective delivery mechanism for the following reasons: 1) the wells are located at too great a distance from the target "hot spot" area; 2) injection at these locations would not allow for direct contact of the amendments with the primary target TCE source area mass (especially on the west side of the building); and 3) a much higher volume of amendment would need to be injected to account for contact with the impacted area beneath the northern portion of the building, which would run contrary to the recommended phased injection approach to better manage costs.

The USACE RSE evaluation team would welcome further consultation with the project team or review of generated work plans on an as needed basis regarding the development and execution of the ISCO injection program. The Interstate Technology and Regulatory Council (ITRC) also has various references and decision-making tools available to assist the project team in the evaluation and implementation of ISCO at the site.

A cost savings for this recommendation has not been included, since it is more of a methodology type of recommendation tied to implementing a source treatment technology that has yet to be done. The recommendation is intended as a method to control costs and resources during implementation of the source area treatment, and does not have a specific work scope or basis of comparison to estimate cost savings. If desirable, the project team can generate an estimated project life cycle cost savings following implementation of a source treatment technology if this recommendation is followed and results in a reduction of the area treated, etc.

6.1.3 CONSIDERATION OF IN-SITU BIOLOGICAL TREATMENT

In-situ biological treatment (ISBT) can be considered as a source area treatment technology either on a stand-alone basis or as a polishing step in combination with ISCO. ISBT would involve re-circulation of a substrate (e.g., lactate, vegetable oils) and possible bioaugmentation with dehalococcoides microorganism inoculations to promote degradation of the daughter products DCE and VC. Bioaugmentation with dehalococcoides may be required to promote the final degradation steps involving DCE and VC if sufficient naturally occurring colonies do not exist in the subsurface. Various permutations of ISBT and associated products are available for consideration, including products that combine ISBT amendments with bioaugmentation and/or zero valent iron (ZVI) amendments. Products that combine ISBT with ZVI amendments theoretically work by promoting degradation by both reductive dehalogenation and abiotic reduction mechanisms, which could be advantageous for this application given the relative absence of naturally occurring biological activity (i.e., shallow groundwater units exhibit oxidizing conditions). Given the high groundwater velocity and TCE concentrations, a permanent injection well system may need to be installed to allow for higher volume amendment injections on a pulsed basis for optimal effectiveness. A pilot study would be required to evaluate the subsurface for conditions conducive to reductive dehalogenation during amendment addition (e.g., presence of dehalococcoides microorganisms). However, based on discussions between the RSE evaluation team and a vendor practitioner of both ISCO and ISBT remediation processes, ISCO or stand-alone ZVI injections would be the preferred technology for the subsurface conditions and TCE groundwater concentrations on the Hagberg property versus ISBT for the reasons discussed below. Fracturing technologies could be used, if needed, to try and treat the lower permeability silty clay zone above the middle groundwater unit (including beneath the building).

If an asymptotic plateau occurs for TCE groundwater concentrations after implementation of multiple ISCO injection phases, consideration can also be given to the implementation of ISBT as a treatment train technology to achieve the TCE source area target objective. ISBT represents a slower-acting technology that does not require immediate contact between the injection chemical and TCE mass. ISBT could prove more effective at treating the more difficult-to-reach TCE mass that is immobilized within the lower permeability silty clay layer immediately above the middle groundwater unit through longer acting amendment persistence, desorption capabilities, and more effective distribution properties by groundwater flow and dispersion. It is also more effective in treating lower TCE residual concentrations as a polishing step after the initial source area treatment has reached its asymptotic plateau for the same reasons.

Even though ISBT represents a potentially viable treatment option for the source area, the implementation of ISCO is believed to offer the following advantages based on current information and subsurface conditions:

- The pilot study results have already demonstrated ISCO's potential effectiveness at reducing TCE source area groundwater concentrations. Further evaluation of potential source area treatment technologies would continue to delay implementation and reduction in long-term TCE mass flux needed to progress towards attainment of the TCE target source area objective in order to discontinue operation of the hydraulic containment system.

- The shallow groundwater units exhibit aerobic conditions with relatively high dissolved oxygen and oxidation-reduction potential (ORP, aka redox) levels, while ISBT requires anaerobic conditions to promote the necessary micro-organism growth and degradation mechanisms. Even though the amendments that would be injected as part of ISBT are designed to drive the subsurface anaerobic to provide the necessary conditions, the need to shift the natural subsurface redox conditions to this extent could limit the effectiveness of ISBT and increase its life cycle cost because of additional amendment injection requirements. If a decision is then made to implement ISCO or another technology instead of ISBT, additional time may then be required prior to the implementation of source treatment to allow subsurface redox conditions to return to its natural state.

- It is anticipated that the potential lower life cycle cost benefits often associated with ISBT versus ISCO would be off-set by the potential for longer treatment timeframes and amendment additions to address the initial aerobic subsurface conditions and TCE source area mass. The likely need for bioaugmentation of dehalococcoides microorganisms (if naturally occurring levels are not sufficient) to degrade daughter product concentrations of DCE and VC within the boundaries of the Hagberg property during ISBT via reductive dehalogenation in order to prevent off-site migration could also increase the life cycle costs. It may be difficult to ascertain this information for evaluation versus ISCO based on a simple pilot study (conversely, it is also difficult to estimate the number of amendment injections and volume for ISCO based on its pilot study to confidently estimate a total life cycle cost without a better delineation of the source area mass and potential rebound).

- ISCO has more of a proven track record than ISBT in treating the higher dissolved phase groundwater concentrations present in the source area, but also may exhibit higher levels of rebound than ISBT following treatment if significant NAPL mass is present and/or immobilized within the lower permeability silty clay layer immediately above the middle groundwater unit (or pockets located within the saturated zone).

- The degradation rate is much faster for ISCO than ISBT, which would result in a faster TCE mass flux reduction and better ability to evaluate long-term treatment effectiveness and endpoints. The high groundwater velocity would likely flush slower-acting ISBT amendments too quickly for optimal contact and treatment, which would result in higher life cycle costs through an increased number of injections and need for other additives to promote soil adherence or reduced viscosity.

- Performing an ISBT pilot study could negatively skew the results of the initial round(s) of ISCO injections, if selected, by driving the subsurface conditions anaerobic and resulting in higher amendment requirements and lesser treatment effectiveness.

- Based on USACE experience and treatment vendor feedback, there is a high probability for biofouling of the hydraulic containment system extraction wells due to enhanced bioremediation during the implementation of ISBT. The need to continue operation of the hydraulic containment system during and after amendment injections would need to be assessed and considered in making a decision as to the application of either ISCO or ISBT, because of the reduced in-situ treatment effectiveness that would result from the mixing and increased flushing rates through the treatment zone. Because of its faster-acting reaction times, the hydraulic containment system would need to be shut down for a much shorter timeframe if ISCO is implemented (e.g., three months for ISCO versus six to twelve months for ISBT).

Because of the limited site data and uncertainties associated with overall treatment effectiveness, number of injections, etc., a cost comparison of ISCO versus P&T and/or ISBT has not been included. At this point in time this level of cost estimate would be of limited value because of the numerous assumptions regarding source area mass / distribution and implementation / treatment timeframes that would be required for these technologies. More accurate cost estimates can be generated by the project team as the treatment evaluation process progresses and vendor quotations are solicited (e.g., refer to Section 6.1.4 for an analysis tool that can be used to evaluate an approximate "break-even" point comparing source area treatment versus P&T).

6.1.4 POTENTIAL LIFE CYCLE COST SAVINGS OFFERED BY SOURCE AREA TREATMENT

As discussed in Section 6.1.1, more aggressive source area treatment to expedite the removal of TCE mass versus natural attenuation offers the potential benefit of reduced life cycle costs through earlier shut down of the hydraulic containment system. The objective of more aggressive source area treatment would be to reduce the overall TCE mass to a level that would allow eventual attainment of the TCE target source area objective of 108 µg/L by a combination of natural attenuation mechanisms and reduced mass flux into the dissolved phase from NAPL/adsorbed phases located either in the saturated zone or lower permeability silty clay layer above the middle groundwater unit. The RSE evaluation team attempted to use available natural attenuation models to evaluate the level of source removal and natural attenuation timeframe needed to meet the TCE target source area objective.

Different monitored natural attenuation (MNA) software packages for this application were initially evaluated. A determination was made that the USGS's Natural Attenuation Software (NAS)was the best fit for the application needs and available data. Simulations using REMChlor, which is a more recently developed software package, require estimates of contaminant source area groundwater concentrations, total mass at the time of release (T_0) and site-specific biodegradation constants, and does not have the capability to calculate biodegradation or other attenuation constants using site-specific data. NAS also offered the benefits of setting T_0 at the current time and use of an overall attenuation factor with distance calculated by one of the software modules using chemical and bioparameter data from individual monitoring wells (similar to what was done in the NAE). Dissolution (i.e., flushing) was assumed to be the primary removal mechanism for the source area TCE mass (i.e., no biodegradation assumed). Other chemical and hydrogeologic input parameters were obtained from historical reports or assumed/calculated based on experience and contaminant physical properties. Both NAS and REMChlor require estimates of the total source area TCE mass for its source removal modules. The absence of historical spill data or TCE saturated zone soil concentrations across the potential source area limited the ability to estimate the TCE source area mass with any degree of confidence. Only a single TCE soil data point of 62 mg/kg was collected near the vadose zone, which corresponded to the interface with the middle groundwater unit at monitoring well MW-37. This single data point was extrapolated over an assumed source area and thickness to obtain a total mass. USEPA analytical modeling equations for equilibrium between soil concentrations and leachate concentrations at the water table interface were used to verify that this TCE soil concentration was a reasonable representation for the highest grab sample groundwater concentrations measured during the initial assessment phases. For sensitivity analysis purposes, multiple simulations were run using ranges of key input parameters such as hydraulic conductivity, gradient, and total TCE mass.

The NAS simulations, results, and supporting discussions have not been included in this RSE Lite report, because the results do not reflect observed site conditions. Therefore, these results should not be used for future decision-making purposes. The source removal/dissolution module of the NAS software is dominated by groundwater velocity. Given the high estimated groundwater velocity for the site, the natural attenuation timeframes to reach the TCE target source area objective were grossly underestimated when compared to current historical sampling data. The source removal module does not account for the following: soil heterogeneities; lack of contact between contaminant mass that often resides in soil micropores and groundwater movement through soil macropores; and mass transfer limitations. NAS and other MNA models also do not account for continued contaminant mass flux from residual impacts that may still remain in the vadose zone. The simple "Batch Flushing" analytical equation model, which is based on a similar source depletion term, was run for comparison purposes and yielded similar MNA timeframe estimates as the NAS simulations.

The NAS modeling did provide average stabilization timeframe estimates between 11 and 37 years to obtain the RAO at Manning Avenue once the TCE target source area objective of 108 µg/L has been reached. This result may be reasonable, given that the groundwater plume stabilization module is not dependent on the results derived from the source removal module, and the horizontal attenuation rates that serve as the primary input variables are based on actual monitoring well data.

As an alternative to the modeling simulations, the RSE evaluation team also looked at source removal analytical equations developed by Newell and Adamson (Remediation, Autumn 2005[1]) that serve as the basis of the source removal module for REMChlor. Even though these equations also do not incorporate hydrogeologic and mass transfer limitations described above, various equations were developed to incorporate analogous "tailing" phenomena based on observations during bench-scale studies. The "First-Order" and "Compound" source model depletion equations incorporate a "tailing" concept into their derivations. These modeling equations essentially provide ratios of timeframes to achieve groundwater RAOs by natural attenuation with and without source removal (i.e., source area treatment versus straight natural attenuation) at different levels of source removal.

Even though these source depletion modeling equations do not provide quantitative estimates for remediation timeframes (unless one of the timeframes is estimated independently), the information can be used for future decision-making purposes as discussed later in this section. The projected potential life cycle cost savings associated with more aggressive source area treatment that could be achieved by reducing the operating timeframe for the hydraulic containment system can be viewed as a "break-even cost" for evaluation and decision-making purposes regarding implementation of a specific source area treatment technology.

The following present the "First-Order Decay" and "Compound" Model equations:

<u>First Order Decay Model</u>: $RTF_{SD}/RTF_{MNA} = \ln[C_g /(C_0 x RF)]/\ln[C_g/C_0]$

<u>Compound Model</u>: $RTF_{SD}/RTF_{MNA} = [1-\ln(C_g/(C_0 x RF)]/[1- \ln(C_g/C_{0)}]$

where:
RTF_{SD} = remediation timeframe with source depletion
RTF_{MNA} = remediation timeframe for monitored natural attenuation without source depletion
C_g = RAO in micrograms per liter = 108 µg/L for Hagberg Property
C_0 = original concentration in micrograms per liter = approx. 6,000 µg/L at MW-37 for more recent sampling events
RF = ratio of source mass immediately after source treatment depletion to original mass (i.e., remaining percentage of source area mass)

Ratios of the remediation timeframe for source treatment versus monitored natural attenuation (i.e., represents continued operation of the hydraulic containment system with no further source treatment)

[1] Charles Newell and David Adamson, REMEDIATION, Autumn 2005

were calculated using the above groundwater concentrations and RF values of 10%, 20%, 30%, and 40%, which represent a range of source area mass reductions of 60% thru 90% (refer to Table 6-2).

For the more complex heterogeneous soil conditions within the Hagberg Property source area, the projected TCE source mass reduction is assumed to range between 70% and 80%, which yields a remediation timeframe ratio of approximately 0.60 to 0.70 using the more commonly used "First-Order Decay Model" (ratios of 0.65 to 0.75 similar for the "Compound Decay Model"). An MNA timeframe of either 10 years or 15 years was assumed to achieve the TCE target source area objective of 108 µg/L for evaluation purposes, which yields the following results: assuming a 10-year MNA timeframe, source area treatment would reduce the timeframe for operation of the hydraulic containment system by three to four years; while assuming a 15-year MNA timeframe would result in a reduced timeframe for operation of the hydraulic containment system by four to six years if source area treatment were implemented. Using an annual O&M cost of approximately $125,000 per year for the hydraulic containment system provided by the MPCA for 2009 (refer to Section 4.4) would yield a total potential life cycle cost savings of $375,000 to $500,000 assuming a 10-year MNA timeframe and $500,000 to $750,000 assuming a 15-year MNA timeframe. The range of potential life cycle cost savings associated with more aggressive source area treatment would continue to increase as the assumed MNA timeframe and the percent of source area mass reduction increases. This range of potential cost savings that could be achieved by earlier shutdown of the hydraulic containment savings can be used in a break-even analysis in a comparison versus potential source area treatment technologies.

A net present value analysis of the potential cost savings was not performed, because of the crude nature of this cost analysis and the unknown timeframe over which the costs of a specific source area treatment technology would be incurred. It also should be noted that any impacts to either the MNA or source treatment remediation timeframes that could result from continued leaching/mass flux of contaminants immobilized within the vadose zone silty clay layer above the middle groundwater unit is not accounted for in the modeling equations. Recommendations for additional source area assessment on the Hagberg property are presented in Section 6.1.5. Additional assessment would help reduce the number of unknowns regarding TCE mass distribution above the middle aquifer unit. The presence of a significant amount of TCE mass above the middle aquifer unit could continue to contribute long-term mass flux to the dissolved phase, thus lengthening the remediation timeframe. As discussed in Section 6.1.2, a phased approach to the implementation of ISCO (or an alternative technology) for source area treatment would provide a method of cost control and allow for progressive observational evaluation of the effectiveness of source area treatment before committing to further rounds of treatment injections or expansion of the treatment area, including an opportunity to terminate further source area treatment if projected progress in reducing TCE groundwater concentrations is not achieved.

6.1.5 RECOMMENDATIONS FOR ADDITIONAL SOURCE AREA ASSESSMENT

The project team may elect to collect additional vadose zone or NAPL assessment information to further evaluate the potential for an unknown NAPL source beneath the building prior to moving forward with source area treatment. If pursued, the option exists to perform some combination of "real-time" field screening/sampling and/or a soil vapor extraction [SVE] pilot study on the east and west sides of the building around monitoring wells MW-18 and MW-37 to further evaluate potential NAPL sources and removal. An SVE pilot study would perform the dual purpose of identifying potential NAPL presence beneath the building within the shallower vadose zone depths (i.e., provides some level of accessibility) based on measured off-gas TCE concentrations, as well as evaluating the feasibility of performing SVE within the more heterogeneous soil types and the associated mass removal rates that could be achieved.

It is recommended that comprehensive soil stratigraphy mapping be combined with field measurements of soil gas and vertical soil and groundwater sampling across the vadose and saturated zones (shallow perched and middle groundwater units) in a grid-like fashion at multiple depths as part of a single sampling event to attempt to map TCE concentrations to specific soil units and depths. This level of comprehensive sampling coverage as part of a single event would provide a larger representation of the accessible treatment area at a single point in time versus the current sampling database. A membrane interface probe (MIP) would provide the needed capabilities to perform the vadose zone and saturated zone NAPL assessment.

If performing an SVE pilot study, collection points or extraction wells should be screened at multiple depths representing more permeable soil horizons above and below the lower permeability silty clay layer (approximately 40 to 50 ft bgs) and the depth immediately above the shallow perched water unit. These depths represent the suspected depths where "treatable" NAPL accumulation could pool. Temporary wells would likely need to be installed to perform an SVE pilot study, with the option to use a directional drilling technique to allow data collection from beneath the building.

Besides direct sampling, other methods are available to infer the presence of NAPL. Consistent with one of the recommendations in the NAE, the most effective alternative method to infer potential NAPL presence would be to evaluate the rebound in groundwater concentrations following shutdown of the hydraulic barrier system for a pre-determined period (e.g., three to six months). The magnitude and rate of rebound versus historical maximum TCE concentrations at individual monitoring locations could serve as an indicator of the potential amounts and locations of immobilized NAPL that could better focus future remediation and monitoring resources. A slower rebound rate that ultimately yields TCE concentrations approaching historical maximum concentrations could confirm the presence of significant immobilized NAPL mass within the silty clay layer above the middle groundwater unit; while faster rebound rates or limited rebound would infer NAPL presence predominantly within the more readily treatable middle groundwater unit or limited NAPL mass, respectively. Operation of the hydraulic barrier system during the ISCO pilot study served to limit the conclusions that could be made regarding treatment effectiveness and potential rebound effects from immobilized NAPL, which could be better evaluated with this type of rebound study. As mentioned in Section 6.1.2, the mass flux of TCE off-site during the shutdown of the hydraulic barrier system during this rebound assessment period would be small in relation to the mass that has already migrated off-site as a trade-off for the collection of this potentially critical data. The rebound testing could possibly be coordinated with other testing that may also require temporary shutdown of the hydraulic barrier system (e.g., pilot testing) to minimize the amount of downtime for critical data collection purposes. Additional monitoring wells/piezometers may need to be installed prior to any rebound or pilot testing, with emphasis on locating sampling locations along both sides of the building near suspected NAPL accumulation areas.

6.1.6 PERFORMANCE-BASED CONTRACTING FOR SOURCE AREA TREATMENT

The various permutations available for the implementation of ISCO and ISBT, and limited tools available to predict their performance capabilities, complicate the process of selecting a source treatment technology and preparing corresponding request for proposal (RFP) documentation for a performance-based contract. One option available to address this issue, and also offer some long-term cost protection, would be to implement a performance-based contracting approach for the source area treatment using lump sum and unit cost pricing structures. If the project team prefers the flexibility to implement other source area treatment technologies besides ISCO, the option exists to leave the bid specifications open-ended regarding treatment technologies and amendment products, and allow the bidders to develop and specify their own approach (including use of treatment trains for further polishing). The RFP, instead, would list specific performance-based conditions and metrics that would need to be met for base payments and "reward" compensation. The bidders should include all details regarding their treatment approach, injection protocol, treatment timeframes, etc. in their RFP submissions, as well as project descriptions detailing similar sites where their technology was successfully implemented.

Given the difficulty in tying treatment performance to the attainment of groundwater RAOs, especially regarding timing and influence of post-treatment MNA, it is recommended that any performance metrics be based on percent total mass removed or mass flux reductions, where measurement protocols would need to be developed but should be feasible. Under this approach, it is also recommended to place the onus on the contractor to propose what they need regarding a monitoring system and sampling parameters, as well as the need for a pilot study or additional assessment information, as part of their RFP submission. If the project team elects to take this open-ended approach to source treatment, there would be no benefit to performing any other pilot studies for alternative treatment technologies, since each remedial contractor would propose preferred approaches often using proprietary amendment products for their treatment applications.

Since there is a direct correlation between percent reduction in total mass/mass flux and the resulting timeframe reduction for MNA to achieve the TCE target source area objective, which in turn equates to life cycle cost savings for operation of the hydraulic containment system, it is recommended that base level performance metrics be developed that tie directly to base compensation. In addition, "reward" metrics can also be developed for achieving higher removal levels that would be tied to bonus compensation if achieved. Any bonus compensation for higher removal levels would need to be equated to cost savings from earlier shutdown of the hydraulic containment system. Penalty metrics could also be developed and tied to a final payment if "rebound" in groundwater concentrations occurs in the treatment area above a certain level within a specified timeframe (e.g., six months or a year). One downside to the performance-based contract approach involves limited flexibility to address the potential need to either expand the source zone treatment area or alter the treatment approach based on the monitoring results. A decision would need to be made to either agree to pricing for the modified work scope with the original remedial contractor or to re-open the bidding process for the entire source area treatment.

6.1.7 MORE RIGOROUS EVALUATION OF HYDRAULIC BARRIER CAPTURE INFLUENCE

The USEPA guidance "A Systematic Approach for Evaluation of Capture Zones at Pump and Treat Systems (January 2008)" specifies the need to develop "converging lines of evidence" by applying multiple techniques to evaluate capture and thus increase the confidence in the conclusions. Each of the evaluation techniques is subject to limitations, and in most cases, no single line of evidence will conclusively differentiate between successful and failed capture. Techniques that can be used to evaluate groundwater capture zones include the following: 1) use of water level data to develop potentiometric surface maps; 2) use of groundwater flow calculations to estimate capture zone widths; 3) numeric or analytical modeling to simulate water levels in combination with particle tracking and transport modeling; and, 4) evaluation of groundwater contaminant concentration trends. As discussed in Section 4.2.1, the Capture Zone Analysis essentially included two lines of evidence involving the use of groundwater flow calculations and pump test contours to estimate the capture zone width and the analysis of contaminant concentration trends near and downgradient of the extraction system. It is recommended that future capture zone analyses include at least two additional lines of evidence.

It is recommended that a periodic evaluation of water levels for the surrounding monitoring well network be performed with the hydraulic barrier system initially shut down (i.e., baseline levels), and then once static conditions are reached after the system is restarted. This will provide a basic line of evidence that shows an inward gradient towards each of the extraction wells and the overall capture zone influence. It may be necessary to install additional piezometers (including nested piezometers at different depths) to provide sufficient drawdown data to extrapolate contour lines. A second line of evidence would be the calibration of a groundwater model using historical water level data to extrapolate the overall capture zone and verify an inward gradient to the individual extraction wells. The available pumping test hydraulic responses need to be analyzed using standard pump test analysis techniques and tools (e.g., AQTESOLV) to determine independent estimates of hydraulic conductivity and storage coefficients. The third line of evidence would involve the plotting of TCE groundwater concentration trends for monitoring wells downgradient of the extraction wells, which should show a gradual decreasing trend if the TCE mass is being effectively captured by the hydraulic barrier system.

A more rigorous capture zone evaluation would provide a higher level of confidence that the hydraulic barrier system is meeting its performance objective of preventing further off-site dissolved phase TCE migration. It can also be used to adjust pumping rates to increase the capture zone influence if a determination is made that operation of the hydraulic barrier has a positive impact on the distribution of injected permanganate during ISCO source area treatment. As noted in Table 6-1, the capture zone evaluation (excluding the development of a ground water model) is estimated to take a qualified hydrogeologist approximately two days for analysis and preparation of a report section and figures for an annual report. Assuming $90/hour, this would be about $1,440 or roughly $1,500 per year. The USACE RSE review team would welcome further consultation with the project team on an as-needed basis regarding the development and execution of a more rigorous capture zone analysis, including performance of the modeling analysis.

6.1.8 IMPROVEMENTS TO THE MONITORING PROGRAM

The need to monitor residential wells in the distal end of the plume will not change in the foreseeable future as a potential direct exposure pathway to TCE-impacted ground water exists. Monitoring performed for the GAC management system, and for residential wells in general, appears logical and adaptable to changes in TCE concentrations. Continued performance of the GAC monitoring / management program will provide information on TCE concentrations and the effectiveness of the GAC units to eliminate potential exposures. The current GAC sampling program is adequate provided sufficient statistics have been developed regarding the relative lifespan of the GAC units once installed (i.e., confirmation that breakthrough does not occur sooner than the current 5-year sampling / change-out schedule). There are instances where wells were last monitored several years ago even though TCE concentrations in the last recorded sample exceeded the 5 µg/L MHRL. It is assumed these wells were fitted with GAC units and are now included as part of the GAC management system. To minimize potential State liability it is recommended that monitoring records for all residential wells be reviewed to determine if all wells that should be monitored are included in the monitoring program or that adequate justification is provided if a well is not included.

In many cases geochemical parameters appear to have been measured only once in on-site wells. If ISCO or ISBT is implemented (refer to Section 6.1.3), it is recommended that multiple sampling rounds be collected and evaluated to determine if ground water geochemical conditions are changing with time and with location, and to determine the potential impact of such changes on the effectiveness of ISCO or ISBT. Critical to this evaluation is a sampling of upgradient wells, which provides baseline groundwater conditions. Sampling of these wells will allow an evaluation of whether geochemical conditions change as groundwater moves from non-contaminated to contaminated portions of the aquifer(s). Ideally, more than one upgradient well will be sampled to provide a range of background conditions for comparison to monitoring wells impacted by the ISCO or ISBT.

It is recommended that trend analyses be performed on existing residential wells that appear to be near the 5 µg/L MHRL for TCE. While many wells demonstrate stable TCE concentrations, several residential wells located well downgradient of the site exhibit increasing trends. For example, 13167 30th St North (approximately two miles downgradient of the Hagberg Property) shows an increasing trend at the 90% confidence level from April 2006 to August 2010 using the Mann Kendall analysis spreadsheet developed by Wisconsin Department of Natural Resources (available at http://www.dnr.state.wi.us/org/aw/rr/archives/pub_index.html#TECHNICAL-PE). Similarly, 14041 Olinda Blvd N (approximately three miles downgradient of the Hagberg Property) shows an increasing trend at 90% confidence from March 2002 to April 2010. Approximately one mile northeast of the Site (15015 44th St N), an increasing trend is noted at the 90% confidence level with concentrations above the 5 µg/L MHRL.

Given the large distances between many of the wells, the variation and length of time between sampling events, and the three-dimensional nature of the plume, it is recommended that a Monitoring and Remediation Optimization System (MAROS) analysis be performed for wells in the vicinity of the source area and downgradient to the POC (from the Hagberg Property to and including the airport wells). This recommendation is made in part due to the lack of data regarding contaminant migration rates (as discussed in Section 4.2.3) and the fact that some on-site wells and some wells a short distance downgradient of the Hagberg property display increasing concentration trends. Even though the plume capture system has been operating for 3 years, the impacts of the system will not be seen in wells located further downgradient of the Hagberg property for some time. Establishment of a defensible and optimized monitoring program now would pay dividends in the long run. Such an analysis should provide improved understanding of plume dynamics upgradient of the POC, along with optimized sample locations and monitoring frequency to better define horizontal and vertical plume extent and concentration trends. This in turn should provide improved support for any decisions regarding continued operation of the plume treatment or capture system between the Hagberg property and the POC.

Costs for these recommendations have not been provided, since the identified tasks are broad in scope and are open to the discretion of the project team regarding implementation. The project team can generate cost estimates for any of the recommendations that it elects to implement once a specific work scope has been identified.

6.2 RECOMMENDATIONS TO REDUCE COSTS

This section presents recommendations by the RSE evaluation team designed to reduce costs of specific components of the site remedy specified in the ROD and Amended ROD.

6.2.1 REDUCE BLOWER AIRFLOW RATE

As discussed in Section 4.5.2, the air stripper is over-designed for its current operating conditions. The air stripper is a Carbonair Model 720, with an operating capacity of 40 to 1,000 gpm and 3,500 cfm maximum blower capacity. It is currently operating at a total influent pumping rate of approximately 30 to 40 gpm, which is at or below the lower end of the operating capacity. Since it is neither cost effective nor practical to replace the air stripper unit, it is recommended that other aspects of its operation be re-evaluated. In the event the air stripper must be replaced during the project life cycle, or an opportunity exists to move the unit to another CERCLA site that needs a higher capacity unit, then it is recommended that it be replaced with either a lower capacity air stripper unit (e.g., Carbonair Model STAT 80 or 180) or a carbon adsorption system sized for the influent conditions that exist at that time. Replacement of air stripper treatment with carbon adsorption treatment would reduce O&M requirements and costs and downtime through the elimination of the solids filtration system and automated controls, as well as mitigate much of the groundwater infiltration piping fouling problems caused by air stripping treatment. The current operating parameters and influent TCE groundwater concentrations should be amenable to carbon adsorption treatment.

It is expected that the air stripper blower airflow rate and corresponding air/water ratio is higher than what is needed to meet the TCE discharge criteria of 5 µg/L (even the <1 µg/L objective). A reduction in the blower airflow rate would represent a project life cycle cost savings through reduced electrical usage. Since the air stripper blower is already equipped with a VFD motor, the airflow rate can be easily reduced by adjusting its PLC setting. The design of the air stripper should be re-evaluated using existing operating conditions (e.g., four trays, pumping rate approximately 40 gpm, influent TCE concentration of 400-700 µg/L, and effluent target TCE concentration of 1-3 µg/L). This would involve re-running the vendor air stripper design simulations (or requesting simulations be re-rerun by Carbonair) using the current operating conditions to identify a new blower design airflow rate. The PLC setting should then be adjusted to correspond to the new blower design airflow rate. Effluent samples should be collected to evaluate the treatment efficiency soon after the blower airflow rate adjustment has been made, and the airflow rate further adjusted as needed based on the sampling results to achieve an optimal setting. It is possible that the air stripper blower airflow rate is already operating at a minimum level that prevents "weeping" of untreated water that could result in untreated water bypassing the trays. Because of this potential downside, it at the discretion of the project team (following discussions with Carbonair, the air stripper manufacturer) whether to move forward with this recommendation. One option would be to run some tests at a reduced blower airflow rate, and capture and sample the treated effluent water to determine if "weeping" is an issue.

A cost savings for this recommendation has not been provided, since the feasibility of implementing this recommendation must still be determined, and the re-design process necessary to identify an alternative lower airflow rate has not been performed. If a decision is made to move forward with this recommendation, the project team can easily estimate the cost savings realized by reducing the airflow rate (i.e., calculate horsepower difference between current and future airflow rates). The estimated annual energy cost savings will be on the low side, since the total annual energy usage cost for the site in 2009 was reported to be approximately $7,000.

6.2.2 ADJUSTMENTS TO GAC MANAGEMENT PROGRAM

The primary factors that were identified as having the greatest impact on the overall costs of the GAC management program were the residences that had 30-pound instead of 90-pound GAC units, as well as residences that had significantly higher than normal water usage. The residences with the smaller GAC units and higher water usage required more frequent sampling and change-outs. The reason for installing the 30-pound GAC units at some of the residences was not identified. It is recommended that further evaluation and a cost/benefit analysis be performed that addresses these two factors to try and reduce the future life cycle project costs of the GAC management program. Because of the anticipated lengthy duration of the GAC management program, any sustained cost reductions will have a significant impact on the total project life cycle costs. It is likely that certain logistical or space constraints may have prevented the installation of the larger 90-pound units at some of the residences. Re-visiting this issue may identify some other options that can be worked out with the respective residents that would allow for the installation of the larger GAC units. The residences with higher water usage had significant outdoor usage (e.g., pools, livestock, agricultural). It may be feasible to re-pipe some or all of these residences to segregate indoor versus outdoor uses. A revised baseline risk assessment would need to be performed to verify that an unacceptable risk would not result from the segregation of the outdoor water usage from GAC treatment. Any re-piping would need to be negotiated with the residents and designed to minimize impacts to the homeowners and their properties.

Costs and associated savings for this recommendation have not been provided, since the tasks are numerous and broad in scope and are open to the discretion of the project team regarding implementation. The project team can generate costs and savings estimates for any of the recommendations that it elects to implement once a specific work scope has been identified.

6.2.3 NO NEED FOR CLASS I, DIVISION I MOTORS

The Design Specifications indicate that the air stripper equipment motors and controls are rated for explosion-proof atmospheres (e.g., motors rated for Class I, Division I). Since chlorinated solvents are not flammable, and the corresponding groundwater concentrations are at low levels (< 1 milligram per liter [mg/L]), the treatment building should not qualify as a potentially explosive atmosphere. Explosion-proof motors and intrinsically safe controls cost approximately twice as much as their non-explosion-proof counterparts. Since the equipment has already been purchased and is still functioning properly, it is not cost effective at this point in time to replace any of the treatment system components. If any of the treatment system motors or controls must be replaced over their continuing life cycle, it is recommended that their replacements be rated for non-explosion-proof atmospheres.

Cost savings have not been provided for this recommendation, since no equipment/control replacement needs have been identified to date. If desired, the project team can keep a running accounting of cost savings realized from this recommendation as any related equipment/controls are replaced.

6.2.4 OPTIMIZATION OF GROUNDWATER MONITORING PROGRAM

Consideration should be given to using passive diffusion bag (PDB) samplers in monitoring wells. PDB samplers have several advantages over the currently-used low-flow sampling procedure, including sustainability benefits due to reduced labor and material costs. Multiple PDBs can be deployed at various levels in a well to provide data on vertical stratification (assuming well screen length is sufficient), or PDBs can be deployed in wells with multiple screened intervals. Assuming 16 monitoring wells are sampled by a two-person crew semi-annually and a potential half-hour per sample savings is realized relative to low-flow sampling, this translates to a savings of 32 person-hours. At a cost of $85/per person-hour, this could save over $2,500 per year. These savings are reflected in Table 6-1.

6.3 RECOMMENDATIONS FOR TECHNICAL IMPROVEMENT

This section presents recommendations by the RSE evaluation team designed to improve the technical implementation of specific components of the site remedy specified in the ROD and Amended ROD or the efficiency of specific O&M activities.

6.3.1 USE OF MORE RIGOROUS MNA MODELING

The NAE incorporated some basic natural attenuation equations to establish the TCE target source area objective of 108 µg/L based on achieving its RAO at the Manning Street POC. Attempts were also made to estimate the source area remediation timeframe based on calculating degradation constants for individual source area monitoring wells, but it was concluded that there were insufficient data trends to establish a source area degradation constant(s). It already has been established that the assessment data does not support consistent biotic natural attenuation/degradation of TCE in groundwater within the source area or downgradient, which is a major contributor to the inability to calculate a degradation constant using the existing LTM data.

It is recommended that a more rigorous groundwater natural attenuation model be developed for the projection of the remediation/natural attenuation timeframe, which ideally will also take into account TCE mass reductions from source area treatment. Another option would be to develop a mass flux approach to quantify the impacts of either natural attenuation or source area treatment over time. The use of a mass flux approach to evaluate source area TCE mass reduction and natural attenuation would require installation of additional monitoring wells and a more rigorous monitoring program to establish measurements along parallel flow paths along different segments of the plume. A more rigorous natural attenuation modeling approach involving the calibration of LTM data over time may also yield a higher TCE target source area objective (versus the current level of 108 µg/L generated in the NAE) that can also reduce the overall remediation timeframe and corresponding project life cycle costs. Data used for the natural attenuation analysis presented in the NAE may also be usable for a more rigorous modeling approach. Literature biodegradation values may be required for initial modeling runs, which can be complemented at a later date with calculated values using site-specific data following the completion of various stages of the source area treatment program. Use of a more rigorous modeling approach will also require the development of an approach to estimate representative baseline levels of the source area TCE mass.

It is also recommended that a more rigorous assessment of abiotic attenuation be considered in the attenuation modeling. There is at least one other site in the area (Twin City Army Ammunition Plant), where the presence of magnetite has been identified as a factor contributing to abiotic degradation of chloroethenes (see "Nonbiological Removal of cis-1,2-dichloroethylene and 1,1-dichloroethylene in Aquifer Sediment Containing Magnetite"; Mark L. Ferrey, Richard T. Wilkin, Robert G. Ford, and John T. Wilson; Environmental Science & Technology 2004 38 (6), 1746-1752). The presence of declining TCE concentrations along with the absence of significant concentrations of degradation products typically associated with biological processes (such as DCE and VC) indicate that abiotic processes may be taking place at the site. To support this line of evidence, it may be necessary to obtain core samples and perform a mineralogical analysis to determine if magnetite is present in the subsurface across the Site. Work done for the monitored natural attenuation study prepared by Terracon also noted the potential for TCE degradation catalyzed by magnetite.

6.3.2 CONTINUE EVALUATION OF GROUNDWATER INFILTRATION SYSTEM PLUGGING PROBLEM

It is possible that the pressure drop and surface area across the groundwater infiltration system piping is contributing to the calcium carbonate precipitation and encrustation at that location, as opposed to precipitation immediately after the air stripper that is not captured by the solids filtration system. If that is the case, then the CO_2 post-treatment injection system may not appreciably improve the screen fouling problems at the groundwater infiltration piping. Periodic video inspections of the groundwater infiltration piping should continue to be performed to verify the effectiveness of the post-treatment CO_2 injection or need for ongoing jet cleaning of the piping (including transfer piping). Recommendations provided in Section 5.0 of the 2009 Annual Report related to the groundwater infiltration system and CO_2 injection system are sound and follow-through should be verified, including video or manual inspections of the condition of the transfer piping.

If the CO_2 injections are not determined to appreciably improve the screen fouling problem for the groundwater infiltration piping, alternative treatment chemicals and approaches to minimize or treat the calcium carbonate fouling should then be evaluated. Possible alternatives include the following: 1) periodic flushing of the piping (including transfer piping) with an alternative acid treatment chemical blend; 2) jetting of injection piping on a pre-determined schedule in combination with an alternative acid treatment chemical blend; or 3) use of a sequestering agent or alternative method of pH adjustment. It is also possible that the means of transferring carbon dioxide into the liquid phase could be improved, to make the carbon dioxide system more effective at controlling fouling. If it is not already being used, a fine-bubble diffusion device could improve mass transfer. Also, it may be possible to introduce the CO_2 at a better location, in order to keep more of it in solution. The USACE RSE review team would welcome further consultation with the project team on an as-needed basis to discuss alternative treatment chemicals and suppliers, approaches, etc. to address the groundwater injection system fouling problem.

Costs for this recommendation have not been provided, since the tasks are broad in scope and are open to the discretion of the project team regarding implementation. These recommendations are more implementation oriented and already part of site O&M activities. The project team can generate cost estimates for any of the recommendations that it elects to implement once a specific work scope has been identified.

6.3.3 PERIODIC INSPECTION OF ELECTRICAL AND CONTROLS

Based on a review of the Progress Reports, the project team performs inspections and maintenance of the electrical and control systems on an as-needed basis to address system downtime problems. It is not known if inspections and operational checks are routinely performed on the electrical and control systems on a preventive maintenance basis. If not, it is recommended that inspections and checks of these critical systems be performed on a quarterly or semi-annual basis as a measure to prevent chronic shutdown problems. The electrical inspection would include the condition of the control panel and wiring, relays, PLC, etc. for wear and tear and needed repairs/replacement. The amperage draws of the equipment motors should also be measured to verify that the draws are within manufacturer specifications or if the motors require maintenance or repairs/replacement. The control system inspection program should include the cleaning of all probes, as well as the simulation of each of the operating and shutdown conditions included in the Design Specifications to determine proper functionality, or if any components or relays, etc. require maintenance or replacement. These inspections, observations, and any required corrective measures should be documented in the site treatment system operating record.

A cost or savings for this recommendation has not been provided, since it should be minimal and incorporated into routine site O&M activities and good practices. If not already performed, there may be an incremental cost associated with subcontracting a certified electrician to visit the site and inspect the equipment on a quarterly or semi-annual basis.

6.3.4 OPTIMIZE PROCESS FLOW CONFIGURATION FOR AIR STRIPPING SYSTEM

The current configuration has the solids filtration system between the air stripper and the 10,000-gallon holding tank. The system might operate more efficiently if the filtration units were placed downstream from the holding tank. Some solids would drop out in the holding tank, so the tank might need to be cleaned more frequently, but this might also reduce the frequency of changing the filter elements. Also, filtration of the water immediately before discharge to the infiltration gallery could better prevent suspended solids from reaching the groundwater infiltration system.

A cost for this recommendation has not been provided, since it should be minimal and its implementation is open to the discretion of the project team. The project team can generate a cost estimate, if needed, for implementing this recommendation.

6.3.5 PREPARATION OF AN ANNUAL REPORT

Groundwater data, extraction well performance, and modeling are reviewed relatively frequently at the Site to determine a path forward, but the RSE team is not aware of this analysis being documented or summarized in an annual report as is done at most other Superfund sites with long-term groundwater remedies. The RSE team suggests that the data analysis, Site Conceptual Model, and remedy performance be documented in a report on an annual basis. EPA document EPA-542-R05-010, *O&M Template for Groundwater Remedies,* can be used as guidance for this report. The USACE also has sample contract language to require contractors to collect and report the necessary data to support performance evaluation (see http://www.environmental.usace.army.mil/rse_checklist.htm). Depending on the amount of data that would be gathered and presented in the report, the expected costs would be approximately $10,000 to $25,000, as shown in Table 6-1. This would represent from 100 to 250 person-hours at an average cost of $100/hour for professional and support staff. Once an annual report is prepared, it can be used as a template for the following year's report. Costs would be expected to decrease over time.

6.3.6 IMPROVEMENT OF DATA MANAGEMENT

The current means of managing and reporting sampling and water level measurement data could be altered to make the data more usable for future evaluations of performance. A unified and updated database of sampling results, well construction, and water levels for monitoring wells, site extraction wells, and residential/municipal wells would greatly facilitate the assessment of plume conditions. Such a database could be linked to a Geographic Information System (GIS) or similar tool to facilitate the visualization of the data. Though a large initial investment would be required, there would be a pay-back in the reduced time for future analysis over the very long life cycle expected for this project, and in the ability to make better and more timely decisions.

A cost for this recommendation has not been provided, since the scope and level of work is unknown. The project team can generate a cost for this recommendation if implemented. Future labor savings from more usable data would be expected to offset any investment in additional labor, etc. associated with data management improvements.

6.4 CONSIDERATIONS FOR GAINING SITE CLOSE OUT

Previous recommendations related to the implementation of ISCO within the source area on the Hagberg Property on a more aggressive schedule, as well as more rigorous modeling and evaluation of natural attenuation and hydraulic barrier system capture influence also apply to the overall strategy to gain site close-out. The more aggressive schedule for source area treatment should reduce the timeframe to achieve the TCE target source area objective, as well as the RAO at the Manning Avenue POC. The calibration of a more rigorous natural attenuation model for the site should allow for more effective evaluation of source treatment on overall remediation timeframe, as well as possible adjustment of the TCE target source objective necessary to meet its RAO at the Manning Avenue POC.

6.5 SUSTAINABILITY CONSIDERATIONS

The recommendation to decrease the blower airflow rate to decrease electrical consumption presented in Section 6.2.1 would also qualify as a sustainability consideration and reduce the carbon footprint for the site. The project team has done an effective job of optimizing operation of the air stripper treatment system and reducing downtime, which also includes elements that positively address sustainability considerations as discussed in other sections of this RSE evaluation. The air stripper treatment system is relatively straight-forward and involves a small number of treatment operations. As such, there are a limited number of sustainability considerations that would be applicable to this site. The Progress Reports did not include data that could be used to perform a carbon footprint evaluation (e.g., use of SiteWise program), which is also typically not within the scope of an RSE Lite evaluation. The lack of breakdown provided for the annual project O&M costs also would not be conducive to performing a cost/benefit analysis for any sustainability considerations that may be identified. Qualitatively, the implementation of effective source treatment using ISCO or ISBT would allow a substantial reduction in life cycle carbon emissions and energy use compared to the current groundwater extraction and treatment.

Table 6-1. Recommendation Summary Table

Recommendation	Reason	Additional Capital Costs ($)	Estimated Change in Annual Costs ($/yr)	Estimated Change in Life-Cycle Costs $*	Discounted Estimated Change in Life-Cycle Costs $**
Sec. 6.1.1. Implement ISCO in Source Area	Effectiveness	Not calculated, additional testing required, as recommended in Sec. 6.1.2. Life cycle savings relative to long-term pump and treat operation could be substantial.			
Sec. 6.1.2. Phased Implementation of ISCO, Tracer Test	Effectiveness	Cost savings difficult to estimate and dependent on results. Phased approach meant to maximize design information prior to commitment to full treatment.			
Sec. 6.1.3. Consideration of Insitu Biological Treatment in a Treatment Train (following ISCO if necessary)	Effectiveness	Not calculated. Dependent on the outcome of ISCO. Cost estimate could be done prior to implementation			
Sec. 6.1.4. Improvements to the Monitoring Program	Effectiveness	$0	Not calculated	Not calculated	Not calculated
Sec. 6.2.1. Reduce Blower Airflow Rate	Cost Reduction (and Sustainability)	Not calculated	Could be estimated following re-design	Dependent on annual savings	Not calculated
Sec. 6.2.2. Adjustments to GAC Management Program	Cost Reduction	Not calculated. Depends on the specific changes that can and should be made at individual homes.			
Sec. 6.2.3. Eventually Replace Class I, Division I Motors	Cost Reduction	Future savings through decreased capital costs	$0	$0	Same as future capital cost savings
Sec. 6.2.4. Optimization of the Groundwater Monitoring Program	Cost Reduction	$0	($2,500)	($75,000)	($49,000)
Sec. 6.3.1. Use of More Rigorous MNA Modeling	Technical Improvement	$10,000 for simple initial modeling	Not calculated		

Recommendation	Reason	Additional Capital Costs ($)	Estimated Change in Annual Costs ($/yr)	Estimated Change in Life-Cycle Costs $*	Discounted Estimated Change in Life-Cycle Costs $**
Sec. 6.3.2. More Rigorous Evaluation of Hydraulic Barrier Capture Influence	Technical Improvement	$0	$1,500 (2 person-days)	$45,000	$29,400
Sec. 6.3.3. Continue Evaluation of the Groundwater Infiltration System Plugging Problem	Technical Improvement	Not estimated (for camera)	Not calculated		
Sec. 6.3.4. Periodic Inspection of Electrical System and Controls	Technical Improvement	$0	Minimal	Minimal	Minimal
Sec. 6.3.5. Optimize Process Flow Configuration for Air Stripping System	Technical Improvement	Not calculated			
Sec. 6.3.6. Preparation of an Annual Report	Technical Improvement	$0	$10,000 to $25,000	$300,000 to $750,000	$196,000 to $490,000
Sec. 6.3.7. Improvement of Data Management	Technical Improvement	Not calculated, but future time savings from more usable data would be expected to easily offset the investment in additional labor to enter and QC data in management system			
Sec. 6.4. Implement ISCO, MNA Modeling, Capture Zone Analysis (see above)	Site Closeout	Not calculated			
Sec. 6.5. Reduce Airflow in Air Stripper, Implement ISCO (see above)	Sustainability	See above.			

Costs in parentheses imply cost reductions
* assumes 30 years of operation with a discount rate of 0% (i.e., no discounting)
** assumes 30 years of operation with a discount rate of 3%
*** presented cost savings is the current reporting cost of $100,000 minus the suggested cost of $39,000 minus the $15,000 that was already counted for recommendation 6.2.1

TABLE 6-2. REMEDIATION TIME MODELING
(Source Depletion versus Natural Attenuation)

MODEL	RF	% Source Removal	C_g (ug/L)	C_o (ug/L)	RTR
FO	0.40	60%	108	6,000	0.77
FO	0.30	70%	108	6,000	0.70
FO	0.20	80%	108	6,000	0.60
FO	0.10	90%	108	6,000	0.43
CD	0.40	60%	108	6,000	0.82
CD	0.30	70%	108	6,000	0.76
CD	0.20	80%	108	6,000	0.68
CD	0.10	90%	108	6,000	0.54

FO - First Order Decay Model

CD - Compound Decay Model

RF - ratio of source immediately after depletion to original mass

Cg - groundwater remedial action objective

Co - original groundwater concentration

RTR - remediation time ratio (source depletion versus natural attenuation)

(Refer to Section 6.1.4 for analytical model equations and further discussions)