Feasibility Study

Commerce Street Plume Superfund Site
Williston, Vermont

Remedial Investigation / Feasibility Study
EPA Task Order No. 0036-RI-FS-019L

REMEDIAL ACTION CONTRACT
No. EP-S1-06-03

FOR

US Environmental Protection Agency
Region 1

BY

Nobis Engineering, Inc.

Nobis Project No. 80036

July 2015

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AC ACRONYMS AND ABBREVIATIONS

1×10^{-4}	1 in 10,000
1×10^{-6}	1 in 1,000,000
AIP	Alling Industrial Park
ARAR	Applicable or Relevant and Appropriate Regulation
bgs	Below ground surface
BTEX	Benzene, toluene, ethylbenzene and xylene compounds collectively
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CFR	Code of Federal Regulations
1,2-DCA	1,2-dichloroethane
cis-1,2-DCE	cis-1,2-dichloroethylene
CME	Contaminant mass estimate
COC	Contaminant of concern
CSM	Conceptual site model
CY	Cubic yards
DCE	Dichloroethylene
EPA	U.S. Environmental Protection Agency
ESB	Equilibrium Partitioning Sediment Benchmark
FS	Feasibility Study
GAC	Granular activated carbon
GRA	General Response Actions
HHRA	Human Health Risk Assessment
HI	Hazard Index
HQ	Hazard Quotient
I_k	Relative hydraulic conductivity
ISB	*In Situ* bioremediation
ISCO	*In Situ* chemical oxidation
K	Hydraulic conductivity
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Level Goals
Mitec Systems	Former Mitec Systems Corporation
MNA	Monitored Natural Attenuation
mg/Kg	milligrams per kilogram

NAPL	Non-aqueous phase liquid
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
Nobis	Nobis Engineering, Inc.
NPL	National Priorities List
O&M	Operations and Maintenance
OSHA	Occupational Safety and Health Administration
PAH	polycyclic aromatic hydrocarbons
PCE	tetrachloroethylene
PDI	Pre-design Investigation
PEC	Probable Effects Concentrations
PRG	Preliminary Remediation Goal
PVA	Present Value Analysis
POTW	Publicly Owned Treatment Works
RAO	Remedial Action Objective
RCRA	Resource Conservation and Recovery Act
RI	Remedial Investigation
RME	Reasonable maximum exposure
ROD	Record of Decision
RSL	Regional Screening Levels
SARA	Superfund Amendments and Reauthorization Act
Site	Commerce Street Plume Superfund Site
SLERA	Screening Level Ecological Risk Assessment
SVOC	semi-volatile organic compound
TBC	To-Be-Considered
TCE	trichloroethylene
TEC	Threshold Effect Concentration
TSDF	Treatment, Storage and Disposal Facility
μg/Kg	microgram per kilogram
μg/L	microgram per liter
VOC	Volatile organic compound
VT ANR	Vermont Agency of Natural Resources
VT DEC	Vermont Department of Environmental Conservation
VT DOH	Vermont Department of Health

ES EXECUTIVE SUMMARY

This Feasibility Study (FS) was prepared to present the development, screening, selection and detailed evaluations of candidate remedial alternatives to address chemical contamination at the Commerce Street Plume Superfund Site (Site) located in Williston, Vermont. This FS developed and evaluated a range of remedial alternatives to address potential health risks and contamination associated with Site-related contaminants of concern (COCs) in various environmental media.

Site History and Background

The Site is located in the town of Williston, Chittenden County, Vermont (Figure 1-1). The Study Area encompasses the former Alling Industrial Park (AIP) and a portion of the adjacent residential area to the west. AIP has had light industrial and commercial tenants since 1946 and the surrounding areas allow for mixed residential, business and industrial uses.

In 1979, Mitec Systems Corporation (Mitec Systems) leased Lot 7:19:11 (96 Commerce Street) and for the next five years discharged an undetermined quantity of rinse waters and sludge wastes containing chromium, cadmium, cyanide, nickel and industrial solvents associated with electroplating operations directly to the an unlined lagoon at the rear of the property. The distribution of contamination in the groundwater suggests that a sanitary leach field on the side of the building was also used for the disposal of industrial degreasers. After a Mitec Systems employee expressed concern to the Vermont Agency of Natural Resources in March 1982, the company was found in violation of hazardous waste regulations for the disposal of chromium-contaminated wastes. Contaminated soil was removed from the lagoon in 1985 and 1989.

In the following years, investigations determined that residential water supply wells were impacted with trichloroethylene (TCE) and tetrachloroethylene (PCE) and the wells were removed from service as drinking water sources. Additionally, elevated concentrations of TCE and PCE were detected starting in 1989 in the indoor air of six South Brownell Road residences. Monitoring was subsequently discontinued for most of these locations after the risk posed by indoor air was determined to be minimal.

Groundwater contamination continues to be detected in the area surrounding the 96 Commerce Street property. Public water is supplied throughout the Study Area and there are no current exposures. Previous investigations identified TCE, PCE, BTEX (collectively benzene, toluene, ethylbenzene, and xylenes), chromium, and cadmium in groundwater concentrations above their applicable state and federal standards. Of these contaminants, TCE and PCE were found to be the most widespread throughout the Study Area. The Vermont Department of Environmental Conservation (VT DEC) site investigation determined that metals contamination was confined to the areas near 96 Commerce Street and the central portion of the Study Area. The report concluded that metals were not likely to migrate much farther and should not present a risk to surface water.

Geology and Hydrogeology

The overburden subsurface lithology of the Site primarily consists of a sand unit that grades to silt at depth with some cross-bedding, clay, and glacial till. The sand unit extends to approximately 40 feet below ground surface (bgs) across the Study Area. Beneath the sandy material is a clay unit that appears to be continuous across the Study Area and is presumably acting as a barrier to the downward movement of contaminated groundwater. Beneath the clay layer is a dense glacial till that is expected to further impede groundwater flow between the overburden and bedrock. Bedrock (meta-dolostone) is encountered at approximately 100 feet bgs.

Depth to the water table in the shallow overburden aquifer (0 to 20 feet bgs) varies seasonally from 1.2 to 10 feet bgs. Groundwater flow is generally from north-northeast to south-southwest however, there is a component of radial flow in the central portion of the Study Area, with groundwater moving to both the southeast and southwest.

Nature and Extent of Contamination

A variety of chemicals was detected in Site soil and groundwater. Summaries of the nature and extent of volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), and metals for soil and groundwater are presented below. Analytical results were compared with available risk-based criteria and regulations, which were used as screening levels, to identify preliminarily contaminants of interest.

Soil – The primary contaminants are TCE, polycyclic aromatic hydrocarbons (PAHs), arsenic, and chromium. TCE was detected in surficial soil at 830 South Brownell Road at a concentration just under United States Environmental Protection Agency's (EPA) screening level for residential soil. This one sample was taken from an area where the resident discharges water pumped from the basement sump. PAHs were found near the former Mitec Systems lagoon. The highest chromium exceedances were found near the former Mitec Systems lagoon, but other soils away from known sources exceeded screening criteria as well, suggesting that total chromium, as well as arsenic, may also be partially attributed to a background condition. Chromium speciation analysis determined that the more toxic hexavalent chromium was only present in the vicinity of the former lagoon (Figure 1-2).

Groundwater – The primary contaminant is TCE. TCE contamination in the shallow overburden is limited to two locations within the Study Area: one area along the western boundary of the Study Area in the vicinity of the intersection of South Brownell Road and Shunpike Road, and the other area along the southeastern portion of the Study Area and adjacent to the unnamed stream.

TCE concentrations in the intermediate and deep overburden are greater than 10,000 µg/L with concentrations exceeding 50,000 micrograms per liter (µg/L) in the deep overburden. These concentrations suggest the presence of non-aqueous phase liquid (NAPL); however, NAPL presence has not been confirmed in the Study Area. Concentrations have been declining slowly from 2008 to 2012.

One residential property, 830 South Brownell Road, contained TCE detected at concentrations of 75 µg/L and 104 µg/L in water collected in the basement sump, which are indicative of a potential concern for unacceptable health risks to the residents. Surficial soil samples near the sump pump discharge location indicated TCE impacted soil. No other residential properties investigated contained TCE concentrations in water collected in the basement sumps or in surficial soil near the sump pump discharge locations.

Threats to Human Health

A human health risk assessment (Nobis, 2015b) was prepared to estimate potential current and future human health risks from the presence of contamination in the soil and groundwater and to provide the basis for determining appropriate remedial measures as part of a FS. The risk assessment evaluation identifies whether health risks exceed EPA's target risk range (1×10^{-6} to 1×10^{-4}, 1 in 1,000,000 and 1 and 10,000, respectively) for carcinogens and Hazard Index (HI) of 1 for non-carcinogens. The major contributors in soil to residential cancer risk include PAHs (benzo[a]anthracene, benzo[a]pyrene, and benzo[a]fluoranthene) and metals (hexavalent chromium and arsenic). The major contributors in groundwater to residential cancer risk include VOCs (1,2-dichloroethylene, cis-1,2-diclorothylene, methylene chloride, TCE, PCE, and vinyl chloride) and metals (arsenic, chromium, cobalt, and iron). TCE is the major contributor in groundwater to construction worker cancer risk and to residential vapor intrusion cancer risk.

Groundwater exposures scenarios include residential exposure to groundwater as a drinking water source, and construction worker exposures to shallow groundwater and VOCs in trench air during construction activities. Therefore, preventative remedial action is recommended for site-wide groundwater. Soil exposure through dermal contact is limited to the former lagoon area at 96 Commerce Street. Therefore, preventative remedial action is recommended for 96 Commerce Street. Vapor intrusion exposure is limited to 830 South Brownell Road because of groundwater infiltration into the basement sump at the residence. Although, the vapor intrusion pathway has been determined to be incomplete, vapor emanating from the water collected in the sump have the potential to impact the indoor air at the residence. Therefore, preventative remedial action is recommended for 830 South Brownell Road.

Threats to the Environment

A Screening Level Ecological Risk Assessment was prepared to determine whether exposure to contaminants present in sediment and surface waters in Site streams and wetlands is detrimental to ecological receptors. The major ecological habitats at the Site consist of a small, unnamed stream just east of Commerce Street, which flows in a southerly direction into Tributary #4 to Muddy Brook. A small wetland area is associated with the confluence of the unnamed stream and Tributary #4 at the southern end of Commerce Street beyond the Study Area. It is concluded that site-related VOCs entering the unnamed stream do not have a significant ecological impact on aquatic macroinvertebrates or the infauna or epifauna. Based on the quality of the habitats provided by the wetlands and minimal Site-related impacts, no further action will be considered.

Remedial Action Objectives

Based on the risk evaluations and the anticipated future use of the Site, the following groundwater, soil and vapor intrusion remedial action objectives (RAOs) were developed.

Soil

- Prevent potential future residential exposure to contaminants in soil at 96 Commerce Street above background levels that would result in an excess cancer risk between 1×10^{-4} and 1×10^{-6}, or a non-carcinogenic risk greater than an HI of 1.

Site-Wide Overburden Groundwater

- Prevent ingestion and other household uses of groundwater containing levels of site-specific contamination in excess of federal Maximum Contaminant Levels (MCLs), non-zero Maximum Contaminant Level Goals (MCLGs), or the Primary Groundwater Quality Enforcement Standards of the Vermont Groundwater Rule and Strategy, Environmental Protection Rules, Chapter 12, whichever is lower or, in their absence, a level that is set at a non-cancer Hazard Quotient (HQ) of 1 or an excess cancer risk between 1×10^{-4} and 1×10^{-6}.

- Prevent construction worker exposure to shallow groundwater and volatiles in trench air at concentrations that would result in an excess cancer between 1×10^{-4} and 1×10^{-6}, or a non-carcinogenic risk greater than an HI of 1.

- Minimize the migration of contaminants beyond the Class IV/Site boundary.

- Minimize the migration of contaminants to the unnamed stream and the wetlands at the confluence of the unnamed stream and Tributary #4 to Muddy Brook.

Indoor Air

- Prevent inhalation of contaminants from vapors emanating from contaminated groundwater that would result in an excess cancer risk between 1×10^{-4} and 1×10^{-6}, or a non-carcinogenic risk greater than an HI of 1.

Preliminary Remediation Goals and Screening Levels

VOCs, PAHs and specific metals were selected as groundwater, soil and vapor COCs based on the most conservative individual contaminant cancer risk estimates that exceeded 1×10^{-6} and/or non-cancer HIs exceeding 1. Preliminary Remediation Goals (PRGs) were developed to determine the allowable numeric chemical concentrations for COCs that are identified as primary contributors to human health risk (Tables 2-5 and 2-8).

Remedial Alternatives

Potentially viable remedial technologies and process options for COCs detected at concentrations above PRGs and screening levels were identified and screened according to their effectiveness, implementability, and relative cost. Candidate remedial technologies were assembled into an array of remedial alternatives to address the RAOs and evaluated for their effectiveness, implementability, and relative cost. Retained remedial alternatives were further developed and include the following options.

<u>Soil Alternatives</u> – Three soil remedial alternatives were retained for development and are summarized below. Statutorily required five-year reviews of the protectiveness of the remedy will be conducted with all soil alternatives.

> **Alternative SO1: No Action.** This alternative is a baseline alternative to compare other alternatives.
>
> **Alternative SO2: Limited Action/Institutional and Engineering Controls.** Alternative SO2 was developed as a limited action to restrict access to the impacted soil within the Study Area through engineered controls (fencing) and institutional controls. Alternative SO2 has low effectiveness but is retained for further evaluation due to the ease of implementation and the low capital and operation and maintenance (O&M) costs.
>
> **Alternative SO3 – Alternative SO3: Excavation and Off-Site Disposal.** Alternative SO3 removes contaminated soil in the area of the former lagoon at 96 Commerce Street and disposes of it off site at a licensed disposal facility. Alternative SO3 has high effectiveness, is easily implemented, and has medium and low capital and O&M costs, respectively, and is retained for further evaluation.

Groundwater Alternatives – Four groundwater remedial alternatives were retained for development and are summarized below. Statutorily required five-year reviews of the protectiveness of the remedy will be conducted with all groundwater alternatives.

Alternative GW1: No Action. This alternative is a baseline alternative to compare other alternatives.

Alternative GW2: Institutional Controls. Alternative GW2 was developed as a limited action to restrict access to the overburden groundwater. Institutional controls (deed restrictions and/or a municipal ordinance) would be implemented to prohibit use of existing wells for drinking and other household uses and the installation of any new wells for any purpose except as deemed necessary by EPA to implement the remedy; control inhalation and direct contact exposure to contaminated groundwater during excavation in saturated soils; and reclassify contaminated groundwater as Class IV (non-potable), restricting the installation of new wells or the modification of existing wells. Limit groundwater monitoring at the Class IV/Site boundary will track potential migration of contaminants. Alternative GW2 has low effectiveness but is retained for further evaluation due to the ease of implementation and the low capital and O&M costs.

Alternative GW3: Monitored Natural Attenuation and Long-Term Monitoring. Alternative GW3 uses monitored natural attenuation (MNA) to monitor the changes in the plume. Monitoring wells will be routinely sampled and evaluated for MNA parameters with annual reports documenting the data, evaluation, and trends. The institutional controls described in Alternative GW2 will also be implemented. Alternative GW3 has low effectiveness but is retained for further evaluation due to the ease of implementation and the low capital and O&M costs.

Alternative GW5: *In Situ* Treatment. Alternative GW5 includes treatment in the form of *in situ* chemical oxidation (ISCO) and/or *in situ* bioremediation (ISB) to reduce the concentrations in those portions of the plume ("hotspots") with the highest concentrations. MNA would be used in the remaining portions of the plume. Alternative GW5 has high effectiveness, is easy to implement, and has low and medium capital and O&M costs, respectively, and has been retained for further evaluation.

Vapor Intrusion Alternatives – Three vapor intrusion remedial alternatives were developed and are summarized below. Statutorily required five-year reviews of the protectiveness of the remedy will be conducted with all vapor intrusion alternatives.

Alternative VM1: No Action. This alternative is a baseline alternative to compare other alternatives.

Alternative VM2: Sump Pump, Vapor Venting, Treatment and Discharge. Alternative VM2 requires the continued operation of the sump pump, passive gas venting and sump water discharge system already installed at 830 South Brownell Road. The alternative requires the installation of a granular activated carbon (GAC) treatment system for the sump water discharge to the ground surface and indirectly to groundwater. The alternative will require an institutional control in the form of a deed restriction, requiring the continued operation of the already installed vapor mitigation system, and providing access to EPA and VT DEC for monitoring, maintenance of equipment and oversight.

Alternative VM3: Enhanced Vapor Mitigation. Alternative VM3 includes all elements described in Alternative VM2 to reduce the vapor inhalation risks of the residents of 830 South Brownell Road and, as determined necessary based on a risk analysis of additional data collected during pre-design, additional measures to supplement or replace the already installed system. Additional measures may include an active venting system, vapor barrier or other engineering controls. The alternative also includes a contingency to address other residential homes or commercial buildings in the vicinity of the plume if data collected during future sampling events for Five-Year Reviews or other reasons indicates a risk.

Detailed Analysis of Alternatives

In accordance with the National Contingency Plan (NCP), the retained remedial alternatives were assessed using nine evaluation criteria, including the following:

Threshold Criteria

1. Overall Protection of Human Health and the Environment;
2. Compliance with Applicable or Relevant and Appropriate Requirements (ARARs);

Primary Balancing Criteria

3. Long-Term Effectiveness and Permanence;
4. Reduction of Toxicity, Mobility, or Volume through Treatment;
5. Short-Term Effectiveness;
6. Implementability;
7. Cost;

Modifying Criteria

8. State Acceptance; and
9. Community Acceptance.

In conformance with the NCP, the seven criteria included in the Threshold Criteria and the Primary Balancing Criteria noted above were used to evaluate each of the retained alternatives. The last two Modifying Criteria, State, and community acceptance, will be addressed following the public comment period.

Comparative Analysis of Alternatives

After completion of the detailed evaluation of alternatives, a comparative analysis of the alternatives was performed to identify the alternative that satisfies the two threshold criteria of protection of human health and the environment and compliance with ARARs. The alternatives are then assessed to determine which option is the best based on the five balancing criteria.

1. **Overall Protection of Human Health and the Environment**

   Soil

   Alternative SO1 does not meet this threshold criterion. While Alternative SO2 restricts access to the impacted soil by the installation of a fence and includes institutional controls, the alternative does not include removal of the impacted material or the installation of a RCRA-compliant cap, and a fence is susceptible to damage, vandalism or trespass or other failure. Alternative SO3 removes the impacted soil and disposes of it at an off-site facility, effectively eliminating the potential for the soil to leach contaminants into the aquifer, and is the most protective of human health and the environment.

Groundwater

Alternative GW1 would not meet this threshold criterion. Alternatives GW2 and GW3 apply institutional controls to restrict access to the groundwater and GW3 adds a long-term monitoring plan but the alternatives do not remove or treat the impacted groundwater. Therefore, the potential for human contact or downgradient migration of the plume still exists. Alternative GW5 is a destructive technology that is also considered green and sustainable and will reduce and/or eliminate the contaminants in the hotspots of the plume, greatly reducing the amount of time that it will take to achieve the RAOs and PRGs. Alternative GW5 is the most protective of human health and the environment.

Vapor

Alternative VM1 and VM2 do not meet this threshold criterion. Alternative VM1 does not require the continued operation of the existing vapor mitigation system at 830 South Brownell Road as do Alternatives VM2 and VM3, nor does it require any additional engineering controls, contingent upon risk analysis of additional data to ensure protection of human health. Insufficient data currently exist to conclude that the existing vapor mitigation system at 830 South Brownell Road sufficiently mitigates vapor intrusion risk from vapors emanating from the groundwater under the basement. Alternative VM3 meets this criterion, as it would fully protect human health by requiring the supplementation or replacement of the existing system, as necessary, based on additional data. Alternative VM3 also contains a contingency to treat other homes in the vicinity of the groundwater plume if future data collection and analysis indicate an exceedance of risk.

2. **Compliance with ARARs**

Soil

Alternative SO1 will not meet the chemical-specific ARARs. Alternative SO2 would be designed to attain ARARs pertaining to wetlands and erosion and sediment control due to the installation of the fence; however, the alternative includes no other actions and does not trigger ARARs and To Be Considered (TBCs). Alternatives SO3 would be designed to attain ARARs pertaining to wetlands, stormwater runoff, and erosion and sediment control. The impacted soil removed will be characterized prior to off-site disposal to comply with the Resource Conservation and Recovery Act (RCRA) requirements. The Treatment, Storage, and Disposal Facility (TSDF) will be approved by the EPA Off-site Coordinator prior to disposal to ensure that the facility is in full compliance before receiving the material. Alternative SO3 would be the most compliant with ARARs.

Groundwater

Alternatives GW1, GW2, and GW3 would not attain protective concentrations for contaminants in groundwater based on chemical-specific ARARs and TBCs. Alternatives GW2 and GW3 add the implementation of institutional controls to reclassify impacted groundwater as non-potable and GW3 adds monitoring to evaluate plume changes and monitor natural attenuation of the plume and, therefore, meets ARARs. Alternative GW5 is the best, however, with respect to the compliance of ARARs since it would use active *in situ* treatment to attain protective concentrations for contaminants in groundwater based on chemical-specific ARARs and TBCs and includes monitoring to evaluate plume changes and monitor natural attenuation of the plume as well as institutional controls to reclassify impacted groundwater as non-potable.

Vapor

The vapor mitigation alternatives do not trigger location-specific or action-specific ARARs. No chemical-specific ARARs exist with respect to exposure to contaminants in vapor. Instead, cleanup levels are based on risk. Alternatives VM2 and VM3 require the continued operation of the existing system, and trigger the requirement to treat sump water prior to discharge. The alternatives include the use of GAC or another treatment system prior to discharge.

3. **Long-Term Effectiveness and Permanence**

Soil

Alternative SO1 provides the least long-term effectiveness and permanence because no actions will be taken to control exposure over time or to permanently reduce the level of contaminants in soil in the long term. Because SO2 requires a fence to be constructed around the impacted soil area to limit access to the area, it provides greater long-term protection, but a fence would be susceptible to vandalism, damage, and trespass, and would have to be maintained over time. Under Alternatives SO1 or SO2, little degradation or chemical reduction from the very toxic hexavalent chromium to the less toxic trivalent chromium would be expected over time. Alternative SO3 provides excellent long-term effectiveness and permanence and is the most effective of the three retained alternatives. There is no identified residual source beyond the impacted soil; therefore, once the soil is removed, the replacement fill is not expected to become impacted again.

Groundwater

Alternatives GW1, GW2, and GW3 would provide the least long-term effectiveness and permanence of the soil alternatives. They leave the most residual risk because no actions would be taken to permanently reduce the level of contaminants in the plume in the long term. Alternative GW5 would provide the highest level of long-term effectiveness and permanence because it relies on destructive *in situ* treatment to address the elevated contaminant concentrations.

Vapor

Alternative VM1 does not meet this criterion. Through the implementation of an institutional control, Alternative VM2 ensures the continued operation and maintenance of the existing vapor mitigation system at 830 South Brownell Road to help protect the residents in that home from harmful vapors until groundwater concentrations are reduced and no longer pose a potential inhalation risk. Alternative VM3 provides the best long-term effectiveness and permanence because it will require the improvement of the existing vapor mitigation system, as determined necessary based on additional data sampling and risk assessment. Alternative VM3 also includes a contingency to address additional homes surrounding the groundwater plume if future data and risk assessment determine it is necessary to address excessive risk.

4. Reduction of Toxicity, Mobility or Volume through Treatment

Soil

Alternatives SO1 and SO2 provide no active treatment for soil and, therefore, would not satisfy Comprehensive Environmental Response, Compensation and Liability Act's (CERCLA) statutory preference for treatment. Alternative SO3 will remove all of the accessible impacted soil from the Study Area. By removing the soil, the toxicity, mobility, and volume of the material is nearly eliminated and the PRGs and RAOs will be achieved.

Groundwater

Alternatives GW1, GW2, and GW3 provide no active treatment for groundwater and, therefore, would not satisfy CERCLA's statutory preference for treatment. Natural processes may gradually degrade and decrease the contaminant mass over the long term. Lack of an MNA program in Alternatives GW1 and GW2 would prevent any determination of cleanup progress, although limited monitoring along the Class IV/Site boundary with GW2 would establish whether the plume is migrating into new areas. Alternative GW5 includes *in situ* treatments that actively treat and destroy the contaminants.

Vapor

Alternative VM1 does not meet this criterion. Alternatives VM2 and VM3 use engineering controls (rather than treatment) to reduce the toxicity, mobility, and volume of vapors into 830 South Brownell Road. Per the requirement of an action-specific ARAR, however, these alternatives require treatment of groundwater collected from the sump in the basement at 830 South Brownell Road prior to discharge to the ground surface.

5. Short-Term Effectiveness

Soil

No active remedial actions are associated with Alternatives SO1 and SO2; therefore, no risks to the community, site workers, or the environment exist from implementation of these alternatives. Alternative SO3 will be effective in the short-term. Exposure and safety risks to workers are easily controlled through engineered controls and personal protective equipment, determined by environmental monitoring. Erosion control, traffic control, loading plans, and proper off-site disposal of the material will reduce the short-term impacts to the environment. Although, Alternatives SO1 and SO2 have a slightly better short-term effectiveness than Alternative SO3, only Alternative SO3 includes and active technology to treat or remove the material.

Groundwater

No active remedial actions are associated with Alternatives GW1, GW2, and GW3; therefore, there would be no short-term risks to the community, site workers, or the environment from implementation of these alternatives. Alternatives GW1, GW2, and GW3 would not achieve groundwater PRGs for over 115 to 250 years. Alternative GW5 is an active treatment alternative that would take place *in situ* in a heavily developed residential and commercial/industrial area. The risk of harm to the on-site worker can be mitigated through implementation of proper engineering controls and health and safety procedures. The potential risks to on-site workers and the community are expected to be minimal with proper controls. Alternative GW5 is expected to reduce the time to achieve PRGs and RAOs to between 50 and 75 years.

Vapor

There are no short-term risks to the community, site-workers, or the environment from implementation of Alternatives VM1, VM2, or VM3. Alternative VM3 will take longer to achieve than Alternative VM2 due to the need to collect additional data and perform a risk analysis, and contingent upon the results, augment or replace the existing system with an active vapor mitigation control system or other engineering control. Alternative VM3, however, is the only alternative that will fully address vapor inhalation at 830 South

Brownell Road and at other homes in the vicinity of the plume in the Study Area, as deemed necessary based on risk.

6. **Implementability**

Soil

Each of the soil alternatives are easy to implement. Alternative SO1 requires no action and is, therefore, the easiest. Alternatives SO2 and SO3 require actions that are included in the general construction field. Fence installation and contaminated soil removal contractors are readily available and do not require specialized equipment or materials. The location of the excavation, near the building, add slightly to the complexity of Alternative SO3 but with proper engineering and design, these complexities can be managed without sacrificing the impacted soil volume. Technologies to be used with each of the soil alternatives have been implemented and demonstrated to be effective at other sites with similar contamination.

Groundwater

Each of the groundwater alternatives are easy to implement. Alternative GW1 requires no action and is, therefore, the easiest. Alternative GW2 requires only administrative actions to enact institutional controls. Alternative GW3 requires a robust long-term monitoring plan; however, the locations have been monitored historically and are not likely to require significant effort beyond typical groundwater sampling activities. Alternative GW5 is the most difficult to implement because it requires several phases, designs, and mobilizations but the technology has been implemented and demonstrated to be effective at other Superfund sites with similar contamination and several contractors capable of performing the work are readily available.

Vapor

Alternative VM1 is easy to implement, as it requires no action other than Five-Year Reviews of the remedy. The system requirements under Alternatives VM2 and VM3 are easy to implement; contractors capable of designing and installing a sump discharge treatment system (e.g., running the discharge through GAC in a treatment shed on-site), and/or active venting or vapor barrier mitigation measures, if deemed necessary, are readily available.

7. Cost

Detailed breakdowns of capital costs, operations and maintenance costs, and present value analyses for each groundwater alternative are provided in Appendix D and summarized in Table 6-1. Total present value costs for each alternative are also shown on Table 6-1.

Soil

Alternative SO3 is the most expensive of the three alternatives; however, it is the only alternative that includes active remediation of the impacted soil.

Groundwater

Alternative GW5 is the most expensive of the four alternatives; however, it is the only alternative that includes active remediation of the impacted groundwater.

Vapor

Alternative VM3 is the most expensive of the three alternatives; however, it is the only alternative that includes continuation of the existing system and construction of additional systems if deemed necessary in the future.

1.0 INTRODUCTION

This Feasibility Study (FS) report for the Commerce Street Plume Superfund Site (Site) has been prepared by Nobis Engineering, Inc. (Nobis), as authorized by the United States Environmental Protection Agency (EPA) under Remedial Action Contract No. EP-S1-06-03, Task Order No. 0036-RI-FS-019L. The FS is focused on the contamination related to the Commerce Street Plume Superfund Site located in Williston, Vermont.

This FS report was prepared to identify and evaluate remedial options to address contaminated soil, groundwater and indoor air beneath and downgradient from the Study Area. The report was prepared consistent with the requirements of:

- the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) of 1980, as amended by the Superfund Amendments and Reauthorization Act (SARA) of 1986;

- the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) 40 Code of Federal Regulations (CFR) 300; and

- the Interim-Final *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (EPA, 1988).

1.1 Purpose and Scope

The purpose of this FS is to identify and evaluate appropriate remedial alternatives for the Study Area posing unacceptable human health or environmental risks as determined from information gathered during the Remedial Investigation (RI) (Nobis, 2015a and Nobis, 2015b), including the Human Health Risk Assessment (HHRA) and the Screening Level Ecological Risk Assessment (SLERA). The FS evaluates alternatives based upon the criteria defined in the NCP and CERCLA. As required by the statute, a no-action alternative is considered in the evaluations and a detailed analysis of selected remedies is provided for each area. FS activities include:

- developing remedial action objectives (RAOs);
- developing general response actions (GRAs);

- identifying areas and volumes requiring remedial action;
- identifying and screening of remedial technologies and process options;
- developing and screening of remedial alternatives;
- conducting a detailed analysis of retained remedial alternatives; and,
- conducting a comparative analysis of retained remedial alternatives.

This FS does not select a preferred alternative for the Study Area, but rather describes the alternatives under consideration. The preferred alternative will be identified in the Proposed Plan and will be subject to public comment. After addressing State and public comments on the proposed alternative, EPA will select a final remedy and issue a Record of Discussion (ROD).

1.2 Report Organization

This FS report was prepared in accordance with the *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (EPA, 1988) and is organized as follows:

- Section 1.0 presents the purpose of the FS and the conceptual site model (CSM). The CSM includes Site background, Site geology and hydrogeology, contaminant nature and extent, sources of groundwater contamination, contaminant fate and transport, receptor evaluation and summary of human health and ecological risk assessments. Section 1.0 is a summary of the information presented in the RI Report, Volumes I and II (Nobis, 2015a, and Nobis, 2015b).

- Section 2.0 presents the basis for action and the principal threats. This section links the results of the risk assessments to the selection of remedial technologies by developing the preliminary remediation goals (PRGs) and RAOs and listing the GRAs. Contaminants of concern (COCs) and applicable or relevant and appropriate requirements (ARARs) are also summarized.

- Section 3.0 presents estimated volumes, masses and areas of contamination to be addressed, and expands the GRAs for each Study Area medium of concern (soil, groundwater and indoor air) that could achieve RAOs. Remedial technologies applicable to each medium and GRA are then identified and screened for their effectiveness, implementability and cost.

- Section 4.0 develops the remedial alternatives and technologies retained from the evaluation in Section 3.0 and combines them into comprehensive remedial alternatives for the Site. The remedial alternatives developed in this section undergo a screening-level evaluation to eliminate those that are not effective; technically, administratively, or economically feasible; or do not enhance the range of available alternatives.

- Section 5.0 fully evaluates each remedial alternative based on: protection of human health; compliance with ARARs; short-term effectiveness; long-term effectiveness and permanence; reduction of contaminant mobility, toxicity, or volume through treatment; implementability and cost.

- Section 6.0 presents an evaluation of the relative performance of each alternative for each of the evaluation criteria considered in Section 5.0. The purpose of the comparative analysis is to identify the advantages and disadvantages of each alternative relative to one another.

Figures, tables, and appendices are presented at the end of this document.

1.3 Site Description

The Site is located in Williston, Chittenden County, Vermont, and four miles east of Burlington (Figure 1-1). The Study Area encompasses the former Alling Industrial Park (AIP) and a portion of the adjacent residential area to the west. AIP has had light industrial and commercial tenants since 1946 (Weston, 1998a). The Study Area is located within the Winooski River watershed at an elevation between 330 and 350 feet above mean sea level. The Study Area is roughly bounded to the north by Vermont State Route 2 (Williston Road), to the east by Harvest Lane, to the south by Omega Drive, and to the west by South Brownell Road (Figure 1-2). The final boundaries of the Site will be determined at the time of the ROD.

Current zoning allows for mixed residential, business and industrial uses. Commerce Street and the areas to the east are predominantly commercially zoned lots that are currently developed or in the process of being developed. Kirby Lane is entirely residential. South Brownell Road is residential with some commercial development. Public pedestrian access is unrestricted within the Study Area.

The ground surface over the entire area exhibits little relief and slopes gently to the southwest. Surface water at the Study Area consists of a small, unnamed stream just east of Commerce Street, which flows in a southerly direction into Tributary #4 to Muddy Brook. A small wetland area is associated with the confluence of the unnamed stream and Tributary #4 at the southern end of Commerce Street beyond the Study Area.

All surface waters in Vermont are State-designated areas for protection and maintenance of aquatic life under the Clean Water Act. The unnamed stream and associated wetlands were assessed for and found to be unlikely potential habitat for the two Vermont-listed threatened species – the eastern sand darter and eastern pearlshell mussel (Normandeau, 2004). No other rare, threatened, or endangered species have been identified (VT DEC, 2014). Downstream of the Study Area, Muddy Brook flows into the Winooski River, which is a known fishery.

On the western edge of the Study Area near the intersection of Shunpike and South Brownell Roads is an “unmapped intermittent stream” – a topographic depression with culverts in some areas that conveys intermittent groundwater discharge (VT DEC, 2014).

Compounds found in groundwater beneath the Study Area include trichloroethylene (TCE), tetrachloroethylene (PCE), benzene, toluene, ethylbenzene and xylene compounds (commonly referred to as BTEX), cadmium, and chromium. Previous studies identified three properties within the industrial park as locations of former manufacturing and/or fabrication operations that could have contributed to groundwater contamination. Refer to Figure 1-2 for the location of parcels identified by lot numbers in the discussion below and throughout this report.

1. **Lot 7:19:11 (former Mitec Systems property/96 Commerce Street)**: The property formerly leased by Mitec Systems Corporation (Mitec Systems) occupies one acre and currently includes one 6,000 square foot building. Mitec Systems manufactured electronic and microwave components. After an employee complaint was received in 1982, the Vermont Agency of Natural Resources (VT ANR) (now Vermont Department of Environmental Conservation [VT DEC]) inspected the facility and found Mitec Systems in violation of hazardous waste regulations regarding chromium-contaminated waste

disposal (Weston, 1998a). Two potential sources were identified on this parcel during the VT ANR investigations: an unlined wastewater disposal lagoon behind the building and a leach field next to it. The leach field was reportedly for sanitary use only; however, a significant TCE plume appears to be emanating from it.

2. **Lot 8:19:12 (Bove-Fagan property/87 Commerce Street)**: Two underground storage tanks were removed from this lot in 1994 revealing a previous release of BTEX compounds. Groundwater samples from shallow monitoring wells at the property contained elevated BTEX concentrations.

3. **Lot 8:19:2 (Former EMCO property/63 Commerce Street)**: Manufacturing operations began in 1947 and both a disposal pit and two outfall pipes protruding into the bank of the unnamed stream were identified in the back (eastern portion) of the property. Only Shelburne Industries, a tenant who manufactured sporting goods from 1958 to 1961, is thought to have used chlorinated solvents at this location (TRCC, 1993). Between 1995 and 1997, approximately 25 cubic yards (CY) of soil were removed from the former disposal pit and another 30 CY of sediment removed from the adjacent stream by the landowner (Weston, 1998b).

In September 2004, EPA proposed the Site for the National Priorities List (NPL) (a.k.a. “Superfund”) on the basis of the occurrence of contaminants, in particular TCE, in the groundwater. It was placed on the NPL in April 2005.

1.4 Site History

Development in the AIP started in 1946 when Alling Enterprises began manufacturing cup hooks and caster caps on Lot 8:19:2. Aerial photographs from 1937 show a vegetated area with a dirt road (later Commerce Street) surrounded by agricultural land (EPA, 2008). Since then, AIP has had and continues to have various light industrial and commercial tenants.

In 1960, George and Beatrice Alling developed and leased Lot 7:19:11 (96 Commerce Street) to the Sunshine Biscuit Company for use as a warehouse and distribution center until 1972. In 1972, an unlined lagoon was excavated and used until 1977 by Qual Tech (1972-1974) and North American Alloys (1974-1977) for on-site disposal of wastewater (NUS, 1987). Garmont

International operated a ski boot warehouse and distribution center on the property from 1977 to 1979. In 1979, Mitec Systems leased the property and for the next five years discharged an undetermined quantity of rinse waters and sludge wastes containing chromium, cadmium, cyanide, nickel, and industrial solvents associated with electroplating operations through a pipe that had been installed from the building directly to the unlined lagoon (Weston, 1998b). In addition, although the leach field was reportedly for sanitary use only, a TCE plume that appears to be emanating from it suggests that it was also used for the disposal of industrial degreasers. After a Mitec Systems employee expressed concern to the VT ANR in March 1982, the State found the company in violation of hazardous waste regulations for the disposal of chromium contaminated wastes. Contaminated soil was removed from the lagoon in 1985 and 1989.

In 1984, chromium was detected in groundwater in monitoring wells installed by Mitec Systems downgradient of the lagoon. In July 1985, sampling by Vermont Department of Health (VT DOH) showed six residential private drinking water wells downgradient of the lagoon and leach field to be contaminated with TCE and PCE at concentrations above federal maximum contaminant levels (MCLs) for drinking water. The wells were subsequently removed from service as drinking water sources, and residents were provided with an alternate drinking water supply.

Additionally, elevated concentrations of PCE and TCE were detected starting in 1989 in the indoor air of six South Brownell Road residences. Monitoring was subsequently discontinued for most of these locations after the risk posed by indoor air was determined to be minimal. The residence with the highest TCE concentrations was investigated further in 1996. The residence had a continuously operating sump pump that removed groundwater that accumulated in a sump beneath the basement floor. According to the VT DEC, venting the sump to the exterior of the house mitigated the indoor air concentrations of these contaminants to an acceptable concentration. The mitigation was done as part of a state-sponsored action (HSI GeoTrans, 2000).

Numerous groundwater, surface water, sediment, residential indoor air, and soil sampling events occurred between 1984 and 2002. In 1987 and 1988, concentrations of TCE and PCE were detected in groundwater up to 3,300 micrograms per liter (µg/L) and 660 µg/L, respectively, throughout the former AIP. In 1996, soil samples collected for the VT DEC identified TCE concentrations up to 1,790 micrograms per kilogram (µg/Kg) directly downgradient of the leach field located at 96 Commerce Street (the Mitec Systems property) (Binkerd, 1996). Additional studies detected dichloroethylene (DCE) concentrations of up to 180 µg/L, chromium at 3.4 µg/L, TCE at 170 µg/L, and vinyl chloride at 11 µg/L in a surface water sample collected from the stream and associated wetlands.

In 1999, groundwater samples taken by the VT ANR found TCE in groundwater at levels as high as 90,000 µg/L downgradient of 96 Commerce Street. In 2002, EPA detected elevated levels of 11 volatile organic compounds (VOCs) and 13 metals in monitoring wells located throughout AIP and surrounding residential areas.

Groundwater contamination continues to be detected in the area surrounding the 96 Commerce Street property. Public water is supplied throughout the Study Area and there are no current exposures. However, because the groundwater has a Vermont Class III designation, it has the potential to be used as a source of drinking water. If a water well is drilled within the plume, any users could be exposed to contaminated groundwater.

In summary, previous investigations identified TCE, PCE, BTEX, chromium and cadmium in groundwater concentrations above their applicable state and federal standards. Of these contaminants, TCE and to a lesser extent, PCE, were found to be the most widespread and are present in groundwater throughout the Study Area. The VT DEC site investigation (Binkerd Environmental, 1996) determined that metals contamination was confined to the areas near 96 Commerce Street (former Mitec Systems property) and the central portion of the Study Area. The report concluded that metals were not likely to migrate much farther and should not present a risk to surface water.

The current extents of soil and groundwater impacts are shown on Figures 1-3 and 1-4, respectively.

1.5 Geology and Hydrogeology

The following subsections describe the regional and site-specific geology, based on published maps and reports and the drilling programs conducted by previous contractors and Nobis. Additionally, surface geophysical surveys were conducted to determine the contacts for the various stratigraphic units. Ground penetrating radar, seismic refraction and seismic reflection were used to delineate the surface of the clay, till, and bedrock.

1.5.1 Surface Water Hydrology

The Study Area is located in the Lake Champlain drainage basin and Winooski sub-basin in the northwest portion of Vermont. The sub-basin drainage area is estimated to be 1,044 square miles.

Surface water in the Study Area consists of an unnamed stream located east of the AIP, which flows in a southerly direction into Tributary #4 to Muddy Brook. The stream has been referred to as an intermittent stream; however, it has been observed to flow continuously throughout the year, even in periods of relatively low surface water discharge in the area, such as the summer of 1999, when a river gauging station on the Winooski River recorded the lowest precipitation in more than 30 years. Tributary #4 joins the Muddy Brook one mile south of the Study Area, near Interstate 89. The Muddy Brook flows northward and joins the Winooski River, which flows to the northwest and discharges to Lake Champlain.

On the western edge of the Study Area near the intersection of Shunpike and South Brownell Roads is an “unmapped intermittent stream” – a topographic depression with culverts in some areas that conveys intermittent groundwater discharge (VT DEC, 2014).

1.5.2 Surficial Deposits

The borings installed for the RI and previous site investigations encountered three overburden units: a sand unit that grades to silt at depth with some cross-bedding, clay, and glacial till. The units are represented on cross-sections A-A’ through E-E’ (see Figures 1-5 through 1-10). The units are described separately below.

The stratigraphy observed is consistent with previously published interpretations for the area (Stewart and MacClintock, 1969; Denny 1974) that describe deltaic deposits overlying sub-aqueous fans, which in turn overlie lacustrine silts and clays. These strata were deposited during the retreat of the last continental glaciers less than 12,000 years ago.

Sand

A thick sand unit extends to approximately 40 feet below ground surface (bgs) across the Study Area. The sandy material generally fines downward, with medium to coarse sand noted in more shallow intervals (less than 20 feet bgs) and fine sand predominating below this depth. Silty layers were more common at depth; however, borings encountered units with varying amounts of silt throughout the sandy unit. Running or heaving sands were common from approximately 30 to 40 feet bgs, indicating that the material was composed of relatively fine and uniform grains that could readily flow under hydrostatic pressure.

The characteristics of the sand and silt layers observed during RI soil boring advancements were consistent with historical interpretations, confirming the relatively homogeneous nature of the fine sand and silt units in the Study Area.

Clay

Beneath the sandy material is a clay unit that appears to be continuous across the Study Area and is presumably acting as a barrier to the downward movement of contaminated groundwater. The contact between the sand unit and the clay is a sand/silt mixture consisting of thin, interbedded clay and silt layers and lenses.

Depth to the clay layer ranges from 36 to 54 feet bgs across the Study Area, with localized lows along Commerce Street and larger depressions in the east and west portions of the survey area. The unit's thickness varies from an estimated 7 to 29 feet. The contours of the clay surface are presented as Figure 3-7 of the RI.

Till

Beneath the clay layer, a dense glacial till was encountered at approximately 60 to 100 feet bgs. This unit is expected to impede groundwater flow between the overburden and bedrock. The till surface elevation is highest in the vicinity of the northern portion of Commerce Street, with relatively low elevations located to the west of Kirby Lane and within the southern portion of the Study Area. The contours of the till surface are presented as Figure 3-8 of the RI.

1.5.3 Bedrock

Bedrock in the area is mapped as the Beckman Formation, which is part of the Hinesburg Synclinorium structure. The Beckman Formation is Lower Ordovician in age and consists of white marble and massive gray limestone and dolomite. Bedrock was encountered by others in two borings at 99 feet bgs and 115 feet bgs in the Study Area, and was a meta-dolostone. The bedrock contour surface is presented in Figure 3-9 of the RI. The bedrock surface has a strong elevation change from the relatively high northeast section of the Study Area to the southeast, which coincides with a potential fracture zone noted by the seismic reflections. The topographic relief of the inferred bedrock surface across the Study Area is approximately 36 feet.

1.5.4 Hydrogeology

Synoptic water level measurement rounds, stratigraphic changes noted during drilling, and several sets of hydraulic conductivity tests from previous investigations were used to evaluate Study Area hydrogeology. Additional slug tests and Waterloo™ profiling were also conducted for the RI to expand the area evaluated and fill data gaps from the earlier investigations. The sand-silt aquifer is significantly more transmissive than the underlying clay and, therefore, is expected to be the dominant transport pathway for Study Area contaminants.

1.5.5 Groundwater Elevations – Sand Unit

The primary aquifer is the sand unit above the clay. In the RI, the sand unit has been separated into shallow overburden (less than 20 feet bgs), intermediate overburden (between 20 and 30 feet bgs), and deep (more than 30 feet bgs) overburden.

Based on measurements taken between 2008 and 2012, depth to groundwater (i.e., the water table) ranged from 1.2 to 10 feet bgs. In contrast, water levels in the intermediate and deep overburden were generally stable, with the average water level varying by about a foot. This may be in part due to the shallow water table with a relatively low horizontal gradient and the presence of numerous shallow topographical depressions and surface water bodies all of which will react significantly to local precipitation events. It is also possible that the presence of sumps in buildings may cause local disturbances in shallow groundwater levels.

Groundwater elevation contour maps based on water levels for the shallow overburden wells are presented in Figure 1-11 (low water table conditions) and Figure 1-12 (high water table conditions). Figure 1-13 depicts water level contours for intermediate/deep wells under low water table conditions and Figure 1-14 depicts intermediate/deep wells under high water table conditions. These conditions are described in detail in the following subsections.

1.5.6 Groundwater Flow Directions – Sand Unit

Groundwater flow in the primary aquifer is generally from north-northeast to south-southwest. However, the groundwater flow path has a component of radial flow in the central portion of the Study Area, with groundwater moving to both the southeast and southwest in both the shallower and deeper portions of the overburden and under low and high water conditions. This flow path probably exists because of two factors. First, the stream along the eastern boundary of the Study Area may create a localized southeasterly diversion to a generally southwesterly groundwater flow direction. In addition, the operation of sump pumps in several residences on South Brownell Road may cause localized westerly diversion to a generally southerly groundwater flow direction southwest of Kirby Lane.

A preferential flow path was likely created in 1985 and 1986 when the sewer and water lines were extended down Commerce Street. The sewer lines lie to the west of Commerce Street and the water lines to the east of Commerce Street. Based on a discussion with Bruce Hoar, Director of Williston Public Works, the sewer line trenches were dug to a minimum depth of 10 feet bgs; the water line trenches were dug to a minimum depth of 8 feet bgs (Town of Williston, 2014). The excavation of the trenches and any backfill would create isolated areas of higher permeability along the center of Commerce Street, relative to water levels collected in locations some distance from the utility trenches.

1.5.7 Gradients – Sand Unit

Gradients are a unitless measure determined by dividing the change in water level by the distance between measuring points. Larger gradients indicate a higher potential for groundwater movement.

Vertical Gradients

Vertical gradients were calculated at each point where a shallow and intermediate/deep overburden well couplet exists. Vertical gradients are tabulated in Table 3-3 and displayed on Figure 3-14 both in the RI. The vertical gradients in the Study Area are generally low and negative (downward), with only one cluster with gradients greater than 0.1 feet/foot. Gradients are more varied in the wells closest to the stream and in the central portion of the Study Area, possibly because of the influence of surface water on shallow groundwater elevations.

The low gradients indicate that groundwater (and by extension contamination) has a relatively low potential to move downward (or upward). This suggests that gravity and the denser-than-water properties of the contaminants at the Study Area remain the primary drivers for carrying dissolved contamination to deeper portions of the overburden aquifer.

Horizontal Gradients

Horizontal groundwater potentiometric surface gradients are summarized in Table 3-4 of the RI and are generally small. The horizontal gradients are slightly higher in shallow groundwater than in intermediate and deep groundwater and slightly higher during relatively high water level conditions. Horizontal hydraulic gradients are considered one of the primary driving forces in groundwater flow and contaminant transport. The low gradients in the Study Area indicate slow groundwater velocities, restricting the rate at which the plume will expand or migrate from its current size and location.

1.5.8 Hydraulic Conductivity – Sand Unit

Three methods were used to determine hydraulic conductivity (K). Single-well slug tests and a multi-well pump test were performed to determine hydraulic conductivity for the sandy aquifer materials in previous investigations. Slug tests were also conducted at new wells in January 2013. In addition, index of hydraulic conductivity (I_k) was determined as part of the Waterloo™ groundwater profiling performed in 2011. Results for all three methods are provided in Table 3-5 of the RI. The locations of the wells where slug tests were performed are provided in Figure 3-15 of the RI.

Based on the slug tests, shallow aquifer wells had a wider range of K-values and generally higher K-values than wells in deeper aquifers. Shallow aquifer (less than 20 feet bgs/water table) K-values ranged from 1 to 26 feet/day. Intermediate aquifer (screens generally deeper than 20 feet bgs, with a total depth of less than 30 feet bgs) K-values ranged from 0.86 to 8.76 feet/day. Deep aquifer (screen deeper than 30 feet bgs) K-values ranged from 1.1 to 9.4 feet/day. These values compare well to the values determined in previous reports.

The pumping test performed by HSI GeoTrans indicated that radial (lateral) hydraulic conductivity was significantly higher than vertical hydraulic conductivity (HSI GeoTrans, 2000). This is supported by drilling observations of layered sands and silts, as well as the Waterloo™ profile results, which indicated the presence of thin layers with contrasting hydraulic conductivities. Although soils were not logged, these layers likely represent lenses of relatively clean or silty sands.

The varying hydraulic conductivities create horizontal laminar flow, which has allowed the plume to disperse over most of the Study Area. The wide range of K-values in the shallow overburden is likely due to development in the area and a variety of fill materials and compaction used in the development of the AIP and residential areas. The layering of siltier materials with sandier materials in the intermediate and deep intervals allows groundwater and contaminants to migrate easier through these more conductive horizontal zones. This has resulted in a widespread plume both horizontally and vertically throughout the Study Area.

1.5.9 Groundwater Velocity – Sand Unit

Overburden groundwater velocities and vertical gradients were calculated for the Study Area based on the low water table conditions (fall 2010) and high water table conditions (fall 2011) using average hydraulic conductivities from the slug tests as described in the previous subsection for shallow and intermediate/deep aquifers.

Using a geometric mean K-value of 13 feet/day in the shallow overburden and 3.8 feet/day in the intermediate/deep overburden, six different groundwater velocities in the intermediate/deep overburden were calculated in the direction of groundwater flow along several portions of the Study Area.

When the different overburden units were averaged for both low and high water conditions, the average groundwater velocity was 0.18 feet/day, or 61 feet/year, across the Study Area. The highest groundwater velocities were calculated in the shallow groundwater. In general, groundwater velocities were higher during high water conditions.

1.5.10 Other Aquifers

The primary aquifer for the Study Area is the upper sandy material, which has a higher hydraulic conductivity in the upper portions (the medium to fine sand) and a lower conductivity in the lower interbedded silts and fine sands. Hydraulic testing was not conducted in the clay and till in the

Study Area. Hydraulic conductivity of clay is expected to be extremely low (less than an inch a day) (Freeze and Cherry, 1979). Therefore, the clay immediately beneath the sand aquifer is not expected to be a significant medium for transport of groundwater.

One monitoring well, BR-1, is screened within the glacial till directly above the bedrock. This well was originally intended to be in the bedrock but was completed in the till instead. Hydraulic conductivity testing performed in 2013 at BR-1 indicated that the conductivity was approximately 8.6×10^{-4} feet/day; however, other areas of the till may have significantly different conductivities due to the highly heterogeneous nature of till deposits.

No bedrock wells were available for testing. Study Area groundwater flow direction and velocity in either the bedrock or till aquifers could not be determined.

1.6 Nature and Extent of Contamination

This section presents the summaries of analytical results developed during several investigations to characterize the nature and extent of chemical contamination in the Study Area. Detailed evaluations of analytical results for chemicals detected in soils and groundwater are presented in the RI. Brief summaries of the contaminants found in the soil and groundwater matrices and water in basement sumps are presented below. The analytical results were compared to state and federal criteria and risk-based criteria, as appropriate. Soil results were compared to EPA Regional Screening Levels for residential and industrial scenarios, as appropriate, and the VT DOH risk-based residential soil concentrations for carcinogens. Groundwater results were compared to federal and state MCLs and the Vermont Primary Groundwater Quality Enforcement Standards. Water samples collected from a sump in the basement in one residence were compared to vapor intrusion screening levels (adjusting for an attenuation factor of 1) to evaluate potential risk from the inhalation of vapors emanating from the contaminated groundwater in the sump.

The most likely source of contamination in the Study Area, given the nature, extent and distribution of contaminants; processes typical to the electroplating industry; and known disposal practices, is the former Mitec Systems facility which leased Lot 7:19:11 (96 Commerce Street) between 1979 and 1986. During that time, Mitec Systems operated as an electroplater of microwave components. Although used by previous tenants on the property, a pipe installed in 1979 allowed

Mitec Systems to dispose of wastewater contaminated with chromium and spent chemicals directly from the building to an unlined lagoon (VT ANR, 1990). A leach field located adjacent to the building was reported for sanitary use only; however, a significant TCE plume appears to have emanated from it. Both areas are suspected sources of TCE, PCE and/or metals because of the electroplating operations performed at the property. Contaminated soil was removed from the wastewater lagoon in 1985, and additional soil was removed in 1989.

The following summary of the distribution of contaminants by environmental medium is described in detail in the RI.

1.6.1 Soil Summary

In soil, the primary contaminants are TCE, arsenic and chromium. Arsenic may be attributed to a background condition. The highest chromium exceedances were found near the former Mitec Systems lagoon, but other soils away from known sources exceeded screening criteria as well, suggesting that chromium may also be partially attributed to a background condition. The current extent of the soil impact is depicted on Figure 1-3.

TCE exceeded screening criteria in three borings in eastern portion of the plume at depths ranging from 25 to 40 feet bgs and TCE also exceeded screening criteria in one boring (SB-12-02) in the eastern portion of the plume at a depth of 20 to 25 feet bgs.

Concentrations of the polycyclic aromatic hydrocarbons (PAHs) benzo(a)anthracene, benzo(a)pyrene and benzo(b)fluoranthene exceeded their EPA residential regional screening level (RSL) in the SB-12-5 boring (located at 96 Commerce Street) sample. The concentration of benzo(a)pyrene also exceeded the industrial/commercial RSL and the Vermont risk-based soil screening level.

Samples were analyzed for total chromium and in some samples, further speciation analysis was done to determine if the chromium was trivalent or hexavalent (hexavalent chromium is the more toxic of the two forms). Total chromium was detected in every soil sample, with concentrations ranging from 10 milligram per kilogram (mg/Kg) to 320 mg/Kg. The maximum concentrations of total chromium (320 mg/Kg, 300 mg/Kg, and 260 mg/kg [duplicate]) were detected at SB-12-5 in the area of the lagoon located at 96 Commerce Street. All total chromium sample results exceeded EPA’s action level for hexavalent chromium, 0.29 mg/Kg. However, based on the speciation analyses, it was determined that hexavalent chromium was only present in the soil strata in the vicinity of the lagoon located at 96 Commerce Street. The chromium in the soil borings in the residential areas was the less toxic trivalent chromium.

TCE was detected in surficial soil at one of four boring locations at 830 South Brownell Road at a concentration just under EPA’s screening level for residential soil. This one sample was taken from an area where the resident discharges water pumped from the basement sump.

1.6.2 Groundwater Summary

Groundwater samples have been collected from a variety of monitoring wells throughout the Study Area since the 1980s. In 1987 and 1988, concentrations of TCE and PCE were detected in groundwater up to 3,300 µg/L and 660 µg/L, respectively, throughout the AIP. In 1996, samples collected by VT DEC identified TCE concentrations up to 1,790 µg/L directly downgradient of the leach field located at 96 Commerce Street. In 1999, groundwater samples taken by the VT DEC found TCE in groundwater at levels as high as 90,000 µg/L downgradient of 96 Commerce Street. In 2002, EPA detected elevated levels of 11 VOCs and 13 metals in monitoring wells located throughout the AIP and surrounding residential area. Groundwater contamination continues to be detected directly downgradient of 96 Commerce Street.

Currently, the primary contaminant in groundwater is TCE. TCE contamination in the shallow overburden is limited to two locations within the Study Area: one area along the western boundary of the Study Area in the vicinity of the intersection of South Brownell Road and Shunpike Road, and the other area along the southeastern portion of the Study Area and adjacent to the unnamed stream. TCE contamination is present in the intermediate and deep overburden groundwater throughout the entire Study Area. For the purposes of remedial technology evaluations in this FS, the plume area is divided along an axis parallel with Kirby Lane and is further referred to as the eastern portion of the plume and the western portion of the plume. While the contaminants in the two portions are similar, the western portion of the plume underlies the residential neighborhood of South Brownell Road and the eastern portion of the plume underlies the AIP. The current extent of groundwater impacts and the plume division areas are depicted on Figure 1-4.

TCE concentrations in the intermediate and deep overburden are greater than 10,000 µg/L, suggestive of a potential non-aqueous phase liquid (NAPL) source although NAPL has not been observed in any of the monitoring wells or vertical profiling locations, nor was it detected using field techniques during soil sampling. Historical groundwater analytical results indicate low concentrations of reductive dechlorination daughter products from the attenuation of TCE. The high concentrations of TCE, however, likely mask lower level daughter products in several wells due to elevated analytical quantitation limits. Additionally, the TCE concentrations have been declining slowly from 2008 to 2012 and historical geochemical results at several locations indicate that conditions suitable for reductive dechlorination are currently present. These factors suggest that reductive dechlorination and monitored natural attenuation (MNA) are supported in the overburden groundwater.

A few locations in the deep overburden have extremely high TCE concentrations likely due to back-diffusion of TCE from the fine-grained silt strata at depth providing a persistent source. These areas represent current sources of TCE contamination to the groundwater and are present in the intermediate overburden of the western portion of the plume and the intermediate and deep overburden of the eastern portion of the plume.

The eastern portion of the plume generally appears to end close to or just to the east of the unnamed stream. Hydraulic gradients in the vicinity of the stream are minimal, suggesting that most of the intermediate groundwater may flow beneath the stream rather than move upward to be intercepted by it. The plume is not well constrained in the southern-most portion of the Study Area and may eventually migrate toward Marshall Avenue. The plume extends slightly beyond South Brownell Road to the west where concentrations decrease quickly to below detection limits.

For a comprehensive description of the nature and extent of groundwater contamination including a discussion of the fate and transport of the contaminants in the overburden groundwater, refer to Sections 4 and 5 of the RI.

1.6.3 Groundwater in Basement Sumps Summary

In 2014, VT DEC analyzed groundwater collected from the sump in the basement at 830 South Brownell Road. TCE was detected at concentrations of 75 µg/L and 104 µg/L, which are indicative of a potential concern for unacceptable health risks to the residents.

Based on those results, EPA expanded the residential sump investigation. Sump water samples were collected from seven residences containing basements with sump pumps. Three residences contained sumps, which were dry at the time of sampling, and sediment was collected from the sumps in lieu of the water samples. TCE was not detected in any of these samples. Additionally, surface soil samples were collected from nine properties where sump water is discharged outside to the ground surface. Only one property, 830 South Brownell Road, had surficial soil impacts. (As noted in greater depth in the next section, it was otherwise determined that an indoor vapor intrusion pathway was generally incomplete across the Study Area.)

1.7 Conceptual Site Model

A CSM is the basis for developing and evaluating different remedial alternatives. The CSM is developed considering the data obtained during site investigation activities performed by Nobis during the RI in addition to background historical data and interpretations pre-dating the Site's inclusion on the NPL in 2005.

Several site investigations have been conducted since contamination was discovered in groundwater in 1985. Results from previous investigations were used to determine media and areas of interest and were incorporated into the current CSM for the Study Area.

In soil, the primary contaminants are arsenic and chromium. Arsenic may be attributed to a background condition. The highest chromium exceedances were found near the former Mitec Systems lagoon (refer to Figure 1-3), but other soils away from known sources, including the western portion of the Study Area, exceeded screening criteria as well suggesting that chromium may be partially attributed to a background condition as well. The more toxic hexavalent chromium was detected at elevated concentrations in the area of the former lagoon.

Overburden groundwater and contaminant flow is constrained by the local geology. The shallow materials are coarse-grained sands that grade to fine sand and silt at depth and readily transmit water. The sand and silt are layered with more fine materials, causing more lateral than vertical groundwater movement. The clay layer below the sand is generally 7 to 29 feet thick and the till below that extends to the bedrock surface and prevents further downward movement. Advective groundwater flow is primarily lateral rather than vertical; therefore, VOC concentrations at depth are likely to be from historical downward movement of NAPL and subsequent dissolution.

In groundwater, the primary contaminant is TCE, which was detected at extremely high concentrations especially in the intermediate and deep overburden. TCE concentrations there are greater than 10,000 µg/L, typically suggesting a potential residual NAPL source. The age of the release, the stratification of the overburden material, and the relatively flat hydraulic gradient suggest that it is more likely that the NAPL has dissolved and the high concentrations are a result of back-diffusion from the finer-grained material. Historical groundwater analytical results indicate the presence, albeit rare and at low concentrations, of reductive dechlorination daughter products from the attenuation of TCE. The high concentrations of TCE, however, likely mask lower level daughter products in several wells due to elevated quantitation limits. Additionally, the TCE concentrations having been declining slowly from 2008 to 2012 at most locations and historical geochemical results at several locations indicate that conditions suitable for reductive dechlorination are currently present. These factors suggest that reductive dechlorination and MNA are supported in the overburden groundwater even if direct evidence of it has not been observed. The lateral extent of TCE impacts are large and encompass most of the AIP and Kirby Lane; refer to Figure 1-4 for the extent of groundwater impacts.

TCE contamination in the shallow overburden is limited to two locations within the Study Area; one area along the western boundary of the Study Area in the vicinity of the intersection of South Brownell Road and Shunpike Road and the other area along the south eastern portion of the Study Area, downgradient of 96 Commerce Street and adjacent to the unnamed stream.

TCE contamination in the intermediate overburden of the plume is more extensive, but generally appears to end close to or just to the east of the unnamed stream near the eastern boundary of the Study Area. Hydraulic gradients in the vicinity of the stream are minimal, suggesting that the intermediate groundwater may flow beneath the stream rather than move upward towards the stream. However, based on the results of the porewater and surface water studies and limited amount of contamination to the east of the stream, it is apparent that discharge to the stream is occurring from the more shallow groundwater.

A few metals were detected above screening criteria in groundwater. Elevated cadmium was detected consistently in two wells, but these appear to be localized and not indicative of a larger issue. Lead and manganese concentrations exceeded screening criteria in a significant number of samples, but have not been linked to specific site-related sources and are common in New England.

In surface water and porewater at the stream in the eastern portion of the Study Area, the primary contaminant is TCE. However, despite the lack of daughter products in groundwater, both surface water and porewater show concentrations of TCE daughter products (cis-1,2-dichloroetheylene [cis-1,2-DCE] and vinyl chloride), suggesting that biodegradation is occurring in the groundwater discharge zone of the stream. The VOC concentrations are highest in the vicinity of the discharge area of the inferred eastern portion of the plume, but decrease downstream to undetectable levels in surface water due to dilution and volatilization.

It was determined that an indoor vapor intrusion pathway was generally not complete across the Study Area. This is likely due to the fact that the most contaminated portions of the groundwater plume are at depth and there exists a relatively thick (greater than 10 feet in most areas) layer of uncontaminated water above the plume which prevents vapors from accumulating in the vadose (soil) zone and migrating into structures. The one exception is 830 South Brownell Road where vapors that emanate directly from contaminated groundwater in the basement sump must be vented to the outside.

1.8 Basis for Action

To determine whether a response action is warranted at a Superfund site, risk management decisions need to assess whether there is a basis for action. If one or more conditions identified below are met, then a basis for action (EPA, 1997) will have been established to support the need for a response action under CERCLA:

- The cumulative excess carcinogenic risk to an individual exceeds EPA's acceptable risk range of 1 x 10^{-4} to 1 x 10^{-6} (using reasonable maximum exposure [RME] assumptions) for either the current or reasonably anticipated future land use;

- The non-carcinogenic hazard index is greater than 1 (using RME assumptions) for either the current or reasonably anticipated future land use;

- Site contaminants cause adverse environmental impacts; or

- Chemical-specific standards or other measures that define acceptable risk levels are exceeded, and exposure to contaminants above these acceptable levels is predicted for the RME.

An HHRA and a SLERA have been prepared in conjunction with the RI (Nobis, 2015b). These documents were completed to address the entire Study Area. The sections below outline the assessment approaches used and the current understanding of the human health and ecological risks at the Site.

1.8.1 Human Health Risk Assessment Summary

This section presents a summary of the baseline HHRA conducted for the Study Area. The objective of the HHRA was to determine current and potential future human health risks from the presence of contamination in the soil, groundwater, sediment, surface water and indoor air in support of the RI and to provide the basis for determining appropriate remedial measures (if applicable) for these media as part of this FS. Future land use is assumed to be residential, in consideration of the Town of Williston's zoning laws and the State of Vermont's groundwater restoration goals.

The Study Area encompasses the AIP and a portion of the adjacent residential area to the west. Surface water at the Study Area consists of a small, unnamed stream, which flows in a southerly direction to Muddy Brook. Receptors evaluated included current/future recreational visitors exposed to sediments and surface water at the unnamed stream, current/future construction workers exposed to shallow groundwater and vapors in excavation trenches, current/future residents potentially exposed to contaminants in shallow groundwater through inhalation of volatiles in indoor air, and future residents exposed to groundwater as drinking water. Future residential exposure to soil was evaluated semi-quantitatively.

The HHRA quantitatively evaluated non-cancer health hazards, cancer risks, and lead exposures. Table 1-1 presents a summary of the quantitative risk assessment findings for the Site.

Sediment and Surface Water

For current/future recreational visitors exposed to sediments and surface water, non-cancer health hazards (individual contaminant hazard quotients (HQs) or organ-specific hazard indices (HIs)) were less than one and the cancer risk estimates were within or less than the EPA targeted cancer risk range (1×10^{-4} to 1×10^{-6}).

Groundwater

For current/future construction workers exposed to shallow groundwater and VOCs in trench air during excavation activities, the cancer risk estimates are within the EPA targeted cancer risk range (1×10^{-4} to 1×10^{-6}); however, the RME HI is greater than 1, indicating potential adverse non-cancer effects for these construction workers. The only contaminant with an HQ in excess of 1 is TCE, which impacts the immune system.

For hypothetical future residents exposed to groundwater as drinking water, HIs are greater than 1 and cancer risk exceeds the EPA targeted cancer risk range (1×10^{-4} to 1×10^{-6}). TCE is the greatest contributor to the total HIs. Individual HQs for cis-1,2-DCE, methylene chloride, cobalt, arsenic, and iron are also greater than 1. Target organ-specific HIs exceed 1 for immune system, liver, kidney, thyroid, skin and gastrointestinal tract. The greatest contributors to cancer risk are TCE, chromium, methylene chloride, vinyl chloride, arsenic and 1,2-dichloroethane (1,2-DCA). Individual cancer risk estimates for each of these contributors are greater than 1×10^{-6} under the RME scenario. Lead evaluation results using the Integrated Exposure Uptake and Biokinetic model for estimating the probability of a child's blood lead concentration exceeding 10 µg/dL concluded lead was not an issue for hypothetical future residents drinking groundwater.

Soil

PAHs and metals are present at concentrations above screening levels at 96 Commerce Street and metals concentrations above screening levels at the properties along South Brownell and Shunpike Roads. EPA's semi-quantitative evaluation of soil concluded that non-cancer health hazards (individual contaminant HQs or organ-specific HIs) were less than one and the cancer risk estimates were within or less than the EPA targeted cancer risk range (1×10^{-4} to 1×10^{-6}). Chromium speciation data (December 2013) indicate that hexavalent chromium is present at 96 Commerce Street in the area of the former lagoon. A second more conservative risk assessment that assumes all the chromium detected is the more toxic hexavalent form resulted in unacceptable cancer risk of 1 in 1,000 (1 x 10^{-3}) for residential exposures to soil at 96 Commerce Street.

Vapor Intrusion

Current/future commercial workers and residents potentially exposed through inhalation of indoor air in businesses and homes overlying the VOC plume were evaluated. EPA conducted sub-slab soil gas and indoor air sampling at five residential and two commercial properties representative of conditions across the Study Area to evaluate this potential pathway. The results of this investigation did not show a complete widespread vapor intrusion pathway and no contaminants associated with the Study Area were detected above conservative health-risk based screening levels.

One residential property, 830 South Brownell Road, was determined to have impacted groundwater present in the basement. A sump originally installed by the property owner in the basement was found to be emanating vapors from the water impacting indoor air. EPA evaluated indoor air risk from direct inhalation of TCE volatilizing from exposed contaminated groundwater that could flood the basement at that location using water samples taken from the sump. The calculated residential indoor air risk, based a maximum TCE concentration of 104 µg/L and an attenuation factor of 1, is 9 in 100 (8.8 x 10^{-2}) which is higher than EPA's acceptable risk range. The non-cancer risk of residential exposure from inhalation of TCE volatilizing from contaminated groundwater at that location is an HI of 20,000, which is higher than the acceptable HI of 1.

VT DEC, in consultation with EPA, installed a vapor mitigation system with a hooded sump and line to discharge sump water to the outside, and a passive venting system to draw vapors outside. VT DEC also sealed up cracks and seams in the floor to minimize water infiltration. Following the mitigation work, one round of sampling in December 2014 was conducted by EPA, but no contaminants associated with the Study Area were detected above conservative risk based screening levels. Because EPA uses multiple rounds of data to make a vapor intrusion risk determination, EPA does not have sufficient data to determine if the system VT DEC installed adequately mitigates vapor intrusion risk without the collection of additional data and further risk analysis.

1.8.2 Ecological Risk Assessment Summary

This section presents a summary of the SLERA conducted for the Study Area. The objective of the SLERA was to estimate potential ecological risks from the presence of contamination in the sediment and surface water in support of the RI and to provide the basis for determining appropriate remedial measures (if applicable) for these media as part of this Feasibility Study.

Surface water at the Study Area consists of a small, unnamed stream just east of Commerce Street, which flows in a southerly direction into Tributary #4 to Muddy Brook. A small wetland area is associated with the confluence of the unnamed stream and Tributary #4 at the southern end of Commerce Street beyond the Study Area. The SLERA specifically focused on potential impacts to the benthic invertebrate community of the unnamed stream that intersects the contaminated groundwater plume.

The SLERA evaluated potential impacts by comparing pore water and sediment, and surface water chemical concentrations from samples collected at several locations (Figures 2-3 and 2-6 of Volume I of the RI, respectively) to screening benchmarks and by evaluating the results of a quantitative assessment of the benthic community habitat, structure and composition in the wetland Muddy Brook tributary adjacent to the Study Area.

Surface Water

Surface water and pore water concentrations were compared to available Ambient Water Quality Criteria and other benchmarks as well as upstream reference samples. In the most recent round of sampling the only chemical that exceeded a criterion or benchmark value was chloride at the two most downgradient sample locations (PW-17 and PW-20). Chloride and the associated increase in conductivity are not site-related and the levels observed in these samples appear to be related to other activities such as salting roads.

Sediment

There were several PAH exceedances of Threshold Effect Concentration (TEC) benchmarks in sediments: however there were no exceedances of Probable Effects Concentrations (PEC), and it was concluded that concentrations for chemicals with these associated benchmarks would not result in toxic effects. While no VOCs were detected in sediments, where available, detection limits were compared to equilibrium partitioning sediment benchmarks (ESBs) and it was determined that adverse impacts associated with VOCs were unlikely.

Benthic Community

The benthic community assessment evaluated habitat conditions and, infaunal and epifaunal benthic community metrics at several surface water and sediment sampling locations. The habitat assessment followed EPA's Rapid Bioassessment Protocol (EPA, 1999) and showed that habitat conditions were similar among the off-site, control station and three of the four downstream samples, indicating the community metric comparisons among stations are justifiable. Community metrics were lowest at stations PW-11 and PW-17 but recovered at the most downgradient station PW-20. The lower community metrics observed at stations PW-11 and PW-17 were attributed to the higher chloride and conductivity levels observed and not site-related contamination.

It is concluded that VOCs entering the unnamed stream do not have a significant ecological impact on aquatic macroinvertebrates or the infauna or epifauna and a Baseline Ecological Risk Assessment was not required.

1.8.3 Determination of the Basis of Action

Human health risk, environmental impact, and exceedance of regulatory standards for the areas of concern are evaluated to determine whether a basis for action exists. The basis for action for groundwater data from study area monitoring wells regardless of depth and potentially used as future drinking water includes the following factors:

- Contaminants in shallow groundwater and volatiles in trench air pose potential health risks that exceed the non-cancer HI of 1. As presented in Table 1-1, non-carcinogenic RME risks for shallow groundwater and volatiles in trench air for construction workers was estimated at an HI of 3.

- Contaminants in groundwater potentially used as future drinking water (all groundwater data from study area monitoring wells regardless of depth) pose potential health risks that exceed the EPA's threshold cancer risk level of 1×10^{-4}. As presented in Table 1-1, groundwater carcinogenic risks for hypothetical future residents using groundwater as drinking water was estimated at 9×10^{-2}.

- Contaminants in groundwater potentially used as future drinking water (all groundwater data from study area monitoring wells regardless of depth) pose potential health risks that exceed the non-cancer HI of 1. As presented in Table 1-1, non-carcinogenic RME risks for groundwater for hypothetical future residents using groundwater as drinking water ranged from 2,778 (adult) to 3,181 (child).

- Vapor inhalation risk based on TCE levels in sump water at 830 South Brownell Road that could flood the basement indicates a residential indoor air risk higher than EPA's acceptable cancer risk range of 1 x 10^{-4} to 1 x 10^{-6} and higher than EPA's non-cancer risk HI level of 1.

- Chemicals present in the finer grained sand and silts in the deeper portions of the overburden aquifer are continuing sources of groundwater contamination.

- Chromium (assuming all hexavalent chromium), arsenic, and PAHs in soils at 96 Commerce Street are present above risk-based levels.

- The SLERA determined that there are no site-related impacts to the unnamed stream.

Therefore, based on the factors presented above, response actions are warranted to address contaminated groundwater that poses human health risks that exceed acceptable thresholds, exceed regulatory standards, or may result in migration of contaminants from one environmental medium to another. In addition, response actions are recommended for soils at 96 Commerce Street based on the conservative assumption that all chromium detected in the area of the former lagoon is the more toxic hexavalent form.

2.0 REMEDIAL ACTION OBJECTIVES

RAOs consist of media-specific (e.g., water, soil), quantitative goals defining the extent of remediation required to protect human health and the environment. RAOs are used as the framework for developing remedial alternatives. To develop RAOs, it is first necessary to identify ARARs and PRGs.

2.1 Applicable or Appropriate and Relevant Requirements and To Be Considered Criteria

A preliminary identification of ARARs and To Be Considered (TBC) criteria has been performed. The ARARs and TBCs have been characterized as location-specific, chemical-specific, or action-specific. State and federal regulations, policies, and guidelines are included in the summary presented in Tables 2-1, 2-2, and 2-3.

The CERCLA and the NCP require that Superfund remedial actions must attain promulgated federal standards, requirements, limitations, or more stringent promulgated state standards determined to be legally applicable or relevant and appropriate to the circumstances at a given site. ARARs are federal environmental, state environmental, and facility siting requirements used to: (1) evaluate the appropriate extent of site cleanup; (2) define and formulate remedial action alternatives; and (3) govern implementation and operation of the selected action. Inherent in the interpretation of ARARs is the assumption that protection of human health and the environment is ensured.

To properly consider ARARs and to clarify their function in the remedy selection process, the NCP defines two ARAR components: (1) applicable requirements, and (2) relevant and appropriate requirements. These definitions are discussed in the following paragraphs:

Applicable Requirements. Applicable requirements are “those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility siting laws that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance found at a CERCLA site” (40 CFR 300.5 and 40 CFR 400(g)). To be applicable, a requirement must directly and fully address a CERCLA activity. For example, Resource Conservation and Recovery Act (RCRA) regulations governing the operation and design of a hazardous waste incinerator (40 CFR Part 264, Subpart O) apply to hazardous waste incinerators used at Superfund sites. To be considered applicable, state standards must be of general applicability and legally enforceable (i.e., promulgated), identified by the state in a timely manner, and more stringent than federal requirements (40 CFR 300.400(g)(4)).

Relevant and Appropriate Requirements. Relevant and appropriate requirements are “those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility siting laws that, while not “applicable” are to a hazardous substance, pollutant, contaminant, remedial action, location or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCA site that their use is well-suited to the particular site” (40 CFR 300.5 and 40 CFR 300.400(g)(2)). For example, RCRA landfill design standards could be relevant and appropriate to a landfill at a Superfund site, if the wastes being disposed of were sufficiently similar to RCRA hazardous wastes. Requirements under federal or state law may be either applicable or relevant and appropriate to CERCLA cleanup actions, but not both. However, requirements must be both relevant and appropriate for compliance to be necessary. In the case where both a federal and a state ARAR are available, or where two potential ARARs address the same issue, the more stringent regulation must be selected. The final NCP states that a state standard must be legally enforceable and more stringent than a corresponding federal standard to be relevant and appropriate (40 CFR 300.400(g)(4)).

The NCP at 40 CFR 300.430(f)(1)(ii)(C) provides several ARAR waiver options that may be invoked, providing that the basic premise of protection of human health and the environment is not ignored:

1. The alternative is an interim measure and will become part of a total remedial action that will attain the applicable or relevant and appropriate federal or state requirement.

2. Compliance with the requirement will result in greater risk to human health and the environment than other alternatives.

3. Compliance with the requirement is technically impracticable from an engineering perspective.

4. The alternative will attain a standard of performance that is equivalent to that required under the otherwise applicable standard, requirements, or limitation through use of another method or approach.

5. With respect to a state requirement, the state has not consistently applied, or demonstrated the intention to consistently apply, the promulgated requirement in similar circumstances at other remedial actions within the state.

6. For Fund-financed response actions only, an alternative that attains the ARAR will not provide a balance between the need for protection of human health and the environment at the site and the availability of Fund monies to respond to other sites that may present a threat to human health and the environment.

Substantive requirements pertain directly to the actions or conditions at a site, while administrative requirements facilitate their implementation. CERCLA on-site remedial response actions must only comply with all substantive requirements that are “applicable” or “relevant and appropriate,” but not the administrative requirements, such as any requirement to obtain federal, state, or local permits (CERCLA §121(e)). The NCP defines on-site as “the aerial extent of contamination and all suitable areas in very close proximity to the contamination necessary for implementation of the response action.” (40 CFR 300.5) Off-site response actions must comply with both the substantive and administrative requirements of an applicable (but not a relevant and appropriate) regulation, but such regulations pertaining to off-site actions are not classified as ARARs (EPA, 2007). As noted in the ARARs guidance (EPA, 1988): “The CERCLA program has its own set of administrative procedures, which assure proper implementation of CERCLA. The application of additional or conflicting administrative requirements could result in delay or confusion.”

To ensure that CERCLA response actions proceed as rapidly as possible, EPA has reaffirmed this position in the final NCP. The EPA recognizes that certain administrative requirements, such as consultation with state agencies and reporting, are accomplished through the state involvement and public participation requirements of the NCP. In the absence of federal- or state-promulgated regulations, there are many criteria, advisories, and guidance values that are not legally binding, but may serve as useful guidance for response actions. These are TBC guidance (EPA, 1988). These guidelines or advisory criteria should be identified if used to develop clean-up goals or if they provide important information needed to properly design or perform a remedial action. Three categories of TBC information are: (1) health effects information with a high degree of certainty (e.g., Reference Doses); (2) technical information on how to perform or evaluate site investigations or response actions; and (3) regulatory policy or proposed regulations (53 Federal Register 51436).

ARARs are divided into the three categories listed below:

Location-specific ARARs set restrictions upon the concentration of hazardous substances or the conduct of activities solely because they are in special locations (EPA, 1988). In determining the use of location-specific ARARs for selected remedial actions at CERCLA sites, one must investigate the jurisdictional prerequisites of each of the regulations. Basic definitions and exemptions must be analyzed on a site-specific basis to confirm the correct application of the requirements.

Chemical specific ARARs are usually health- or risk-based numerical values or methodologies that establish the acceptable amount or concentration of a chemical that may remain in, or be discharged to, the environment (EPA, 1988). They govern the extent of site remediation by providing either actual cleanup levels, or the basis for calculating such levels. For example, groundwater MCLs may provide the necessary cleanup goals for sites with contaminated groundwater. Chemical-specific ARARs may also be used to indicate acceptable levels of discharge in determining treatment and disposal requirements, and to assess the effectiveness of future remedial alternatives.

Action-specific ARARs are usually technology- or activity-based requirements or limitations on remedial actions taken (EPA, 1988). Selection of a particular response action at a site will invoke the appropriate action-specific ARARs that may specify particular performance standards or technologies, as well as specific environmental levels for discharged or residual chemicals.

Non-ARAR Standards

The Occupational Safety and Health Administration (OSHA) has promulgated standards for protection of workers who may be exposed to hazardous substances at RCRA or CERCLA sites (29 CFR Part 1910.120 and 1926.65). EPA requires compliance with the OSHA standards in the NCP (40 CFR 300.150), not through the ARAR process. Therefore, the OSHA standards are not considered as ARARs. Although the requirements, standards, and regulations of OSHA are not ARARs, they will be complied with during response activities.

2.2 Development of Remedial Action Objectives

RAOs consist of media-specific goals for protecting human health and the environment. The RAOs specify the media and contaminants of concern, exposure routes and receptors, and PRGs for each exposure route. By specifying both exposure pathways and PRGs, the RAOs permit the development of a range of alternatives that may achieve protection by reducing exposure to contaminated media.

The following sections present components of the RAO development process identification of the basis for taking action, principal threats evaluation, identification of media of concern, and identification of RAOs.

The RAOs are based on the HHRA and are intended to protect human health from overburden groundwater, vapors emanating from groundwater and soil in the Study Area. No RAOs are identified for the protection of the environment or recreational users of surface waters because the HHRA and SLERA concluded the unnamed stream does not pose a current or future risk. RAOs are used as the framework for developing remedial alternatives. The RAOs for the Site are summarized below and in Table 2-4.

2.2.1 Identification of Remedial Action Objectives

The following RAOs were developed to address human health risks posed by exposure to Study Area contaminants and to meet ARARs. These RAOs apply to the three media of concern identified for the Site: soil, groundwater and vapor inhalation.

Soil

- Prevent potential future residential exposure to contaminants in soil at 96 Commerce Street above background levels that would result in an excess cancer risk between 1 x 10^{-4} and 1 x 10^{-6}, or a non-carcinogenic risk greater than an HI of 1.

Site-Wide Overburden Groundwater

- Prevent ingestion and other household uses of groundwater containing levels of site-specific contamination in excess of federal MCLs, non-zero Maximum Contaminant

Level Goals (MCLGs), or the Primary Groundwater Quality Enforcement Standards of the Vermont Groundwater Rule and Strategy, Environmental Protection Rules, Chapter 12, whichever is lower or, in their absence, a level that is set at a non-cancer HQ of 1 or an excess cancer risk between 1×10^{-4} and 1×10^{-6}.

- Prevent construction worker exposure to shallow groundwater and volatiles in trench air at concentrations that would result in an excess cancer between 1×10^{-4} and 1×10^{-6}, or a non-carcinogenic risk greater than an HI of 1.

- Minimize the migration of contaminants beyond the Class IV/Site boundary.

- Minimize the migration of contaminants to the unnamed stream and the wetlands at the confluence of the unnamed stream and Tributary #4 to Muddy Brook.

Indoor Air

- Prevent inhalation of contaminants from vapors emanating from contaminated groundwater that would result in an excess cancer risk between 1×10^{-4} and 1×10^{-6}, or a non-carcinogenic risk greater than an HI of 1.

2.3 Contaminants of Concern

The COCs to be addressed under this FS were identified based on the human health risk assessment results and evaluation of RI data. The COC selection process is presented in this section.

An analyte was selected as a risk-based COC if it is identified as a primary contributor to risks (contributing 1×10^{-6} or greater carcinogenic risk to a total scenario cancer risk exceeding 1×10^{-4} or contributing an HQ of 1 or greater to an organ-specific HI exceeding 1).

The HHRA indicates that TCE is the only COC contributor to risks from exposures to shallow groundwater and volatiles in trench air during excavation activities (0 to 10 feet bgs) that exceed EPA's acceptable cancer risk level of 1×10^{-4} or non-cancer organ-specific HI of 1. Therefore, TCE is selected as the sole risk-based COC for this scenario.

The HHRA indicates that the following list of chemicals are primary contributors to potential future risks from exposures to groundwater as drinking water that exceed EPA's acceptable cancer risk level of 1 x 10^{-4} or non-cancer organ-specific HI of 1 for several exposure scenarios:

- VOCs (1,2-DCA, cis-1,2-DCE, methylene chloride, PCE, TCE and vinyl chloride); and
- Metals (arsenic, chromium, hexavalent chromium[1], cobalt, and iron).

Therefore, these contaminants are selected as risk-based COCs for potential future risks from exposures to groundwater as drinking water.

The soil evaluation identified chromium, arsenic and PAHs as potential risk-based COCs in soils at 96 Commerce Street based on detected concentrations exceeding risk-based screening levels and uncertainty about the form of chromium present (trivalent versus hexavalent).

EPA also conducted a vapor inhalation evaluation based on TCE data collected from the sump at 830 South Brownell Road that is reflective of groundwater that but for the sump system floods the basement. The TCE data exceeded EPA's acceptable risk levels for direct vapor inhalation.

2.4 Preliminary Remediation Goals

A PRG is a COC concentration that is protective for media exposures at *de-minimis* risk levels. PRGs are developed as part of the FS process to determine the allowable numeric chemical concentrations for COCs that are identified as primary contributors to human health risk. Candidate PRGs for each COC are first assembled and evaluated, and then PRGs are selected for use in the FS to determine the areas and volumes of contaminated media that will need to be addressed during the Remedial Action. Candidate PRGs include risk-based concentrations that are back-calculated from the site-specific exposure scenarios at a target Incremental Lifetime Cancer Risk of 1 x 10^{-6} and an HI of 1, ARARs, and background concentrations. The PRGs for the various scenarios and the development process are summarized in Tables 2-5 through 2-8.

[1] All samples were analyzed for total chromium. As a conservative measure for risk assessment, the chromium results were assumed to be hexavalent, the more toxic form.

The NCP stipulates that PRGs must initially be established as concentrations that correspond to an excess lifetime cancer risk greater than 1 x 10^{-6} or an HI of 1, but can be modified upwards in consideration of site-specific factors, ARARs, background, etc.

Based on the defined areas and media and the outcome of the HHRA and the SLERA, PRGs were developed for the following environmental media:

- Soil located in the former lagoon on 96 Commerce Street (former Mitec Systems property),
- Site-wide overburden groundwater (to protect from ingestion, dermal contact, and inhalation of vapors during household water use; and dermal contact and inhalation of vapors during construction activities), and
- Vapors emanating from contaminated groundwater into indoor air.

This section summarizes how PRGs were developed and selected for the groundwater, indoor air and soils.

Should ARARs or policies change in the future, potential impacts to the effectiveness and protectiveness of the selected remedy will be evaluated during the Five-Year Reviews.

2.4.1 ARARs-Based PRGs

The requirements of the federal and Vermont regulations and guidance were considered and addressed in developing candidate ARAR-based PRGs. Federal MCLs provide maximum allowable numeric concentrations of chemicals in water used as a drinking water source. The Primary Groundwater Quality Enforcement Standards of the Vermont Groundwater Rule and Strategy, Environmental Protection Rules, Chapter 12, also provide maximum allowable numeric concentrations of chemicals detected in groundwater used for a drinking water source. Table 2-5 lists the lowest of the three ARARs (the federal MCL in all cases) as the ARARs-based PRGs for the groundwater COCs. There are no federal or state ARARs applicable to soils or vapor intrusion.

2.4.2 Risk-Based PRGs

Candidate PRGs are also developed based on acceptable risks for carcinogens and non-carcinogens for the Site COCs. Risk-based PRGs are developed for cancer risk levels of 1×10^{-4}, 1×10^{-5}, and 1×10^{-6}, and for HI of 1 to allow for flexibility in risk management decisions. The *Risk Assessment Guidance for Superfund: Volume I, Human Health Evaluation Manual (Part B, Development of Risk-based Preliminary Remediation Goals)* (EPA, 1991) provides guidance on calculating risk-based PRGs.

The specific contaminated media, land-use assumptions, and the exposure assumptions behind pathways of individual exposure used in the site-specific HHRA were used to develop the chemical-specific risk-based PRGs. Risk-based PRGs for groundwater used as residential drinking water are presented in Table 2-5. Risk-based PRGs for shallow groundwater potentially contacted by construction workers during excavation (dermal contact and inhalation of vapors in trenches) are presented in Table 2-6. Risk-based PRGs for soil are presented in Table 2-7. Risk-based PRGs for vapor inhalation from COCs in vapors emanating from groundwater are presented in Table 2-8. Because soil COCs were identified through a screening level assessment and site-specific exposure assumptions were neither identified nor used in a calculation of risks in the HHRA, PRGs were developed using standard risk assessment assumptions. Although 96 Commerce Street is an industrial/commercial property, PRGs were developed to allow for future residential use, which are also protective for industrial/commercial uses. Supporting documentation for the calculation of groundwater risk-based PRGs is included in Appendix A. Supporting documentation for the calculation of soil risk-based PRGs is included in Appendix B. Supporting documentation for the calculation of vapor risk-based PRGs is included in Appendix C. The supporting documentation in these appendices presents the exposure assumptions, toxicity values, equations, and calculations of risk-based PRGs.

2.4.3 Background-Based PRGs

For CERCLA response actions, development of soil PRGs take into consideration natural and anthropogenic background chemical levels to ensure that remediation does not result in remediation of sites to concentrations below surrounding background levels. Background soil PRGs were not developed for use at this Site.

2.4.4 PRG Selection Process

The potential PRGs include ARARs (federal MCLs, Vermont Primary Groundwater Quality Enforcement Standards, and risk-based concentrations (for cancer risks = 1×10^{-6}, 1×10^{-5} and 1×10^{-4}; and a non-cancer HI of 1)), and the background concentrations (if available). For groundwater, soil and vapor intrusion PRGs, the hierarchy used in the selection of the recommended PRGs is as follows:

- If available, the ARAR is selected as the default recommended PRG.
- Based on site-specific conditions or considerations, an ARAR may not be designated as the recommended PRG if it is deemed insufficiently protective. In this case, a risk-based concentration may be selected as the recommended PRG. This case is generally applicable when 1) multiple contaminants or pathways contribute to risk and the cumulative risk based on ARARs would exceed EPA target levels or 2) updated toxicity information indicate the promulgated ARARs are no longer protective.
- If an ARAR is not available, a risk-based concentration (cancer risk of 1×10^{-6} or HI of 1) is selected as the recommended PRG.
- A background concentration is selected if it is higher than the ARAR or the risk-based value, consistent with EPA's policy that clean-up levels are not established below background conditions.

For overburden groundwater in the Study Area (Table 2-5), PRGs for 1,2-DCA, cis-1,2-DCE, methylene chloride, TCE, PCE, vinyl chloride, arsenic and chromium are based on ARARs (federal MCLs). PRGs for iron and cobalt are risk-based.

For shallow groundwater in the Study Area potentially contacted by construction workers during excavation (Table 2-6), the PRG for TCE is risk-based.

For soils at 96 Commerce Street (Table 2-7), PRGs for PAHs, hexavalent chromium and arsenic are the higher of risk-based concentrations, or background (to be determined during remedial design).

For vapor intrusion into indoor air in the Study Area (Table 2-8), the PRG for TCE is risk-based.

2.5 Estimated Volumes and Mass of Media Exceeding PRGs

The area, depth, and volume of contaminated media and the mass of contaminants requiring treatment are important considerations in the development of remedial alternatives and detailed cost evaluations. These values have been estimated for the Study Area using the results of source area investigations and cross-sectional data. The evaluation and results are summarized below.

The area and extent of the impacted soil is estimated based on soil borings and hand-auger soil borings performed in the Study Area between 2008 and 2014, in addition to the inferred former limits of the lagoon at the 96 Commerce Street property. The areal extent of each of impacted soil was estimated using GIS software and represent conservative estimates. The estimates were made based on the assumption that the soil concentrations exceeding PRGs extend evenly to the lateral limits shown of Figure 1-3 and vertically to the depths and thickness listed in Table 2-9.

The contaminant mass estimate for dissolved-phase TCE beneath the Study Area was calculated based on 2011 vertical profiling analytical data, the most comprehensive snapshot of aquifer conditions to date. The 26 vertical profile and eight Waterloo™ profile locations provide a robust data set capable of producing a refined estimate of the mass. The estimate was based on the following assumptions:

- The TCE plume extends over most of the Study Area. For evaluation and discussion purposes, the plume is referred to in two portions: the eastern portion beneath Commerce Street and the western portion beneath South Brownell Road and Kirby Lane (refer to Figure 1-4). The western portion is characterized by more shallow contamination in a mostly residential area while the eastern portion is deeper in nature and underlies a commercial/industrial area.

- Each portion's area is assumed to be the area within the 5 µg/L contour for dissolved-phase TCE, as shown on Figures 1-15 through 1-17.

- The unconsolidated materials in the overburden are heterogeneous and grade from a coarse to medium sand to fine sand and silt at depth. For purposes of this calculation, an average porosity for silty sand of 20-percent was assumed.

- TCE that may be present in unsaturated soil or as NAPL, and other detected VOCs were not included in this calculation.

Calculations were performed for by estimating the mass of 5-foot think vertical intervals and adding each of the intervals to obtain the total plume contaminant mass estimate (CME).

To perform the CME, the area of each 5-foot interval measured using Geographic Information System (GIS) software. These volumes were then multiplied by the assumed porosity of 20-percent to obtain the volume of groundwater in each of the zones (assuming full saturation). The groundwater volumes were multiplied by the median TCE dissolved phase concentration for each zone (shallow, intermediate, and deep as displayed on Figures 1-15, 1-16, and 1-17, respectively) to develop the CME. The CME for the area inside the 1,000 µg/L contour is 2,121 kg, and the CME for the outside of the 1,000 µg/L contour is 103 kg, equaling a total of 2,224 kg within the eastern portion of the plume. The western portion of the plume had an estimated mass for the area inside the 1,000 µg/L contour of 20 kg, and a CME for the area inside the 1,000 µg/L contour of 50 kg, for a total of 70 kg. The CME of the entire plume in the Study Area is 2,294 kg of TCE.

Inaccuracies in the above calculations result from the assumption that the median concentrations estimated for the inner and outer zones apply to the entire estimated area of each zone. The calculations do not consider the partitioning of contaminants in groundwater versus the contaminants adsorbed to the fraction of organic carbon in the aquifer matrix. The assumption is made for the purposes of the mass estimate that all contamination is in the dissolved phase. It is also acknowledged that heterogeneities in subsurface characteristics throughout the Study Area related to hydraulic conductivity and porosity may also contribute to certain inaccuracies.

The areas and volumes of impacted groundwater and soil are summarized in Table 2-9.

3.0 IDENTIFICATION AND SCREENING OF TECHNOLOGIES

This section is focused on the identification and screening of technologies that have the potential to be included in a remedial action alternative that, when assembled, will meet the RAOs for the Site. Prior to evaluating remedial technologies, the GRAs are evaluated based on the RAOs, COCs, and the areas and volumes of media exceeding the PRGs as described in Section 2.0. The GRAs are evaluated in Section 3.1 and the identification and screening of potentially applicable technologies is presented in Section 3.2.

3.1 General Response Actions

GRAs are broad categories consisting of remedial technologies and process options that can be selected individually or in combination in order to meet the RAOs. GRAs are included in the FS process to give a range of responses for consideration for site remediation. The GRAs for the Site are listed in Table 3-1 and include the following:

No Action

Under this response, no action would be taken to address impacted media. In accordance with the NCP and EPA's *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (EPA, 1988), a no-action response must be developed and evaluated to provide a baseline against which other response actions can be compared. The No Action response does not include environmental monitoring or actions to reduce the potential for exposure (e.g., fencing, deed restrictions). It does include conducting five-year reviews, as required by CERCLA.

Limited Action

The Limited Action response would consist of the implementation and maintenance of institutional and/or engineered controls aimed at limiting access to a particular area of concern or medium. Institutional controls are non-engineered, administrative or legal measures (e.g., land use restrictions such as restrictive covenants and zoning ordinances or informational/educational devices such as deed notices) that minimize the potential for exposure to contamination by limiting land or resource utilization. Engineered controls are physical structures (e.g., fencing or posted warnings) that serve to impede the potential for exposure to contamination.

Containment

Containment options are physical measures that are applied to the source(s) that aim to inhibit the migration of contaminants as well as prevent direct contact between contaminated media and potential receptors. Containment measures can include covers and/or perimeter controls to isolate waste material from water and/or oxygen.

Removal

For soil, this GRA involves a complete or partial removal of source material, followed by transportation to a permitted, off-site facility for disposal. Some type of treatment or dewatering may be required either prior to transport or prior to ultimate disposal, depending on the physical and chemical characterization of the material. Treatment of groundwater or stormwater from excavations may also be required if the dewatered fluids become contaminated.

Collection, Treatment and Discharge

For groundwater, this GRA involves the extraction and collection of groundwater via pumps, drainage trenches or other means. The water would then undergo on-site treatment and discharge or it would be transported to an off-site facility for treatment and discharge.

In Situ Treatment

In situ treatment technologies consist of those biological, physical, chemical and thermal processes that could be applied to treat impacted media without the need for removal. *In situ* treatment aims to reduce the overall toxicity, mobility and/or volume of the impacted media.

Ex Situ Treatment

Ex situ treatment technologies consist of those biological, physical, chemical and thermal processes that could be applied to treat impacted media after it has been removed from its current location. *Ex situ* treatment could result in the impacted media being returned to its original location and re-located to another location on or off-site. This treatment aims to reduce the overall toxicity, mobility and/or volume of the impacted media.

3.2 Identification and Screening of Technologies

The technology identification and screening process consists of the identification of GRAs that might be used, which consist of general categories of actions that can address the RAOs. The technology types associated with each GRA are then identified along with the specific process options for those response actions. Once technology types have been selected, specific process options are evaluated in greater detail in order to identify representative process options that may be selected for the formulation of remedial alternatives. The RI/FS guidance suggests that the evaluation focus on the effectiveness criterion with less of an emphasis on the implementability and relative costs of the technology/process option. A summary of the focus of each of the evaluation criterion is presented below:

- **Effectiveness –** The effectiveness criteria focuses on the potential success of candidate process options in managing the anticipated volume and mass of contaminants while achieving RAOs, given site-specific constraints. Additionally, the effectiveness criterion considers the potential impacts to human health and the environment during implementation and how proven or reliable the process may be with respect to site conditions or contaminants.

- **Implementability –** The implementability criterion consists of the technical and administrative feasibility of applying a candidate process option. The preliminary technology screening eliminates clearly unworkable or ineffective candidate process options based on technical limitations. The implementability evaluation also considers the institutional components such as: the availability of off-site treatment, storage, and disposal facilities, availability of equipment and vendors to implement the technology and the ability to obtain permits for off-site actions.

- **Relative Cost –** The relative cost evaluation criterion is not weighed heavily in this screening step. Relative capital and operations and maintenance (O&M) costs are used rather than detailed estimates. The analysis is based upon engineering judgment as to whether the relative costs are “High”, “Medium”, or “Low” when compared to similar process options or other candidate technologies.

The following sections present the identification and screening of general response actions, remedial technologies and process options to address the three identified media of concern for this FS: soil, groundwater and vapor.

3.2.1 Soil Remedial Technology Evaluation

In this section, potentially viable remedial technologies and process options are identified and evaluated according to their applicability to the contaminants in soil and the subsurface conditions, their technical and institutional implementability, and relative cost.

Identification and Screening of Soil Remedial Technologies and Process Options

PAHs and metals have been identified as the primary COCs in soil in the Study Area. Table 3-2 presents the GRAs, remedial technology types and process options that may be applicable to mitigating soil as a source of potential risk to human health and the environment. Technology types and process options that were retained for potential use are:

- No Action
- Limited Action
- Containment
- Removal
- *In Situ* Treatment

Evaluation and Selection of Technologies and Process Options

Table 3-2 provides the remedial technology screening of the candidate technologies and process options that may be applicable to soil contaminants. As a result of the screening evaluation, all of the *ex situ* treatment technologies were eliminated due to the spatial limitations and their degree of effectiveness compared to *in situ* treatment. Technology types and process options that were retained for potential use in the remedial alternatives for soil are:

- No Action
- Limited Action – Institutional Controls
    - Deed Restrictions, Land Use Restrictions, Town Ordinances

- Limited Action – Engineered Controls
    - Fencing
- Containment – Capping
    - Single-Layer Cap
- Removal – Soil Excavation
    - Off-Site Disposal
- *In Situ* Treatment – Physical Treatment
    - Solidification/Stabilization

3.2.2 Groundwater Remedial Technology Evaluation

In this section, potentially viable remedial technologies and process options are identified and evaluated according to their applicability to the contaminants in groundwater and the Study Area subsurface conditions, their technical and institutional implementability, and relative cost.

Identification and Screening of Groundwater Technologies and Process Options

TCE has been identified as the primary COC in groundwater in the Study Area. Selecting technologies and developing remedial alternatives that address the chlorinated VOC will address the majority of the human health risks. Table 3-3 presents the GRAs, remedial technology types, and process options that may be applicable to groundwater contaminants. Technology types and process options that were retained for potential use are:

- No Action
- Limited Action
- Containment
- Collection, Treatment and Discharge
- *In Situ* Treatment

Evaluation and Selection of Technologies and Process Options

Table 3-3 presents the screening of the technologies and process options that are potentially applicable for remediation of site groundwater. As a result of the screening evaluation, most technology types and process options were retained. The extensive subsurface utilities; the large aerial extent of the contaminated groundwater; the depth to bedrock; the irregular nature of the bedrock; and the Study Area's location within a heavily developed area are some of the main factors contributing to the elimination of some of the groundwater technology types and process options.

Technology types and process options that were retained for potential use in the remedial alternatives for groundwater are:

- No Action
- Limited Action – Long Term Monitoring
  - Groundwater Monitoring
- Limited Action – Monitored Natural Attenuation
  - MNA Processes
- Limited Action – Institutional Controls
  - Deed Restrictions, Land Use Restrictions, Town Ordinances
- Containment – Vertical Barriers
  - Grout Curtain
- Collection, Treatment and Discharge - Collection/Extraction
  - Extraction Wells
  - Extraction Trench
- Collection, Treatment and Discharge - Physical Treatment
  - Equalization
  - Dewatering
  - Sedimentation
  - Filtration
  - Air Stripping
  - Carbon Adsorption
- Collection, Treatment and Discharge - Chemical Treatment
  - Enhanced Oxidation
  - pH Adjustment
- Collection, Treatment and Discharge - Discharge
  - Direct Discharge to Surface Water
  - Subsurface Discharge
  - Off-Site Treatment – Publicly Owned Treatment Works (POTW)

- *In Situ* Treatment – Chemical Treatment
    - Chemical Oxidation
    - Chemical Reduction
- *In Situ* Treatment – Biological Treatment
    - Enhanced Biodegradation – Aerobic
    - Enhanced Biodegradation – Anaerobic

3.2.3 Vapor Mitigation Remedial Technology Evaluation

In this section, potentially viable remedial technologies and process options are identified and evaluated according to their applicability to the contaminants in vapors emanated from groundwater that could enter, and is below, the basement of 830 South Brownell Road, their technical and institutional Implementability, and relative cost.

Identification and Screening of Vapor Mitigation Technologies and Process Options

TCE has been identified as the primary COC with the potential to emanate from the groundwater in the Study Area. Table 3-4 presents the general response actions, remedial technology types, and process options that may be applicable to the vapor intrusion pathway.

- No Action
- Limited Action
- Barrier
- Soil Vapor Collection, Treatment and Discharge

Evaluation and Selection of Technologies and Process Options

Table 3-4 presents the screening of the technologies and process options that are potentially applicable for remediation of vapors in the Study Area. As a result of the screening evaluation, most technology types and process options were eliminated. The limited number of affected buildings, nature and extent of the contaminated vapor; and the construction of the building are some of the main factors contributing to the elimination of some of the vapor mitigation technology types and process options.

Technology types and process options that were retained for potential use in the remedial alternatives for vapor mitigation are:

- No Action
- Limited Action – Long-Term Monitoring
  - Indoor Air, Soil Vapor and Groundwater Monitoring
- Limited Action – Institutional Controls
  - Deed Restrictions, Land Use Restrictions, Town Ordinances
- Barrier – Soil Vapor Barriers
  - Spray Applied Membrane
  - Ceiling Vapor Entryways
- Soil Vapor Collection, Treatment and Discharge – Physical Treatment
  - Carbon Adsorption
  - Zeolite Adsorption
- Soil Vapor Collection, Treatment and Discharge – Discharge
  - Venting

4.0 DEVELOPMENT AND SCREENING OF ALTERNATIVES

In this section, alternatives are developed to meet the RAOs presented in Subsection 2.2, using the GRAs identified in Section 3.1, either individually or in combination. Remedial alternatives have been developed to address media based on the screening of technology types and process options. Remedial alternatives that have been developed are listed in Table 4-1. Developed remedial alternatives are then screened with respect to the criteria of effectiveness, implementability, and cost to meet the requirements of CERCLA and the NCP (40 CFR 300.430(e)(7)). Short- and long-term aspects shall be used to guide the development and screening of remedial alternatives. Retained alternatives will then be combined into alternatives with site-wide applicability for detailed evaluation in Section 5.0.

4.1 Alternative Screening Criteria

The objective of the alternative screening step is to eliminate impractical alternatives or higher cost alternatives (i.e., order of magnitude cost differences) that provide little or no increase in effectiveness or implementability over their lower-cost counterparts. The criteria used for screening remedial alternatives are effectiveness, implementability, and cost. These criteria are discussed in the paragraphs below.

Effectiveness

This criterion focuses on the degree to which an alternative: reduces toxicity, mobility or volume through treatment; minimizes residual risks and affords long-term protection; complies with ARARs; minimizes short-term impacts; and quickly achieves protection goals. The NCP indicates that, in addition to complying with ARARs and providing protection for human health and the environment, both the short- and long-term aspects of effectiveness should be considered when evaluating alternatives under this criterion. Short-term is considered to be the construction and implementation period, while long-term begins once the remedial action is complete and RAOs have been met (EPA, 1988). Short-term effectiveness considerations include the effects of the alternatives during the construction and implementation period, the alternative's ability to meet RAOs, and the relative time frame required to achieve RAOs. Long-term effectiveness considers the magnitude of the remaining residual risk because of residual contaminant sources, and the adequacy and reliability of specific technical components and control measures to maintain compliance with RAOs over the life of the remediation. Alternatives that do not provide adequate protection of human health and the environment or are significantly less effective than other, more promising alternatives, are eliminated from further consideration as required by the NCP.

Implementability

Each alternative is also evaluated in terms of technical and administrative implementability or feasibility. Much like the evaluation of effectiveness, the evaluation of technical feasibility can be broken into short- and long-term aspects. Short-term technical feasibility considers the availability of a technology for construction or mobilization and operation, as well as compliance with action-specific ARARs during the remedial action. Long-term technical feasibility considers the ease of operation and maintenance, technical reliability, the ease of undertaking additional RAs, and the necessary degree of monitoring for residuals and untreated wastes after employing specific technical controls. Meanwhile, administrative feasibility for implementing a given technology addresses the ability to obtain approvals from pertinent offices and agencies for off-site activities, the availability of treatment, storage, and disposal services, and the commercial availability of required services and trained specialists or operators. Alternatives that are technically or administratively infeasible or that would require equipment, specialists or facilities that are not available within a reasonable period of time may be eliminated from further consideration (NCP, 40 CFR 300.430(e)(7)).

Cost

This criterion considers the costs of construction and any long-term O&M costs associated with each alternative. As noted in EPA guidance, the overall goal of the remedy selection process is to remediate contaminated sites to the maximum extent practicable, which requires a co-equal mandate for remedies to be cost-effective (EPA, 1996). The NCP requires consideration of the use of engineering and institutional controls, as an alternative to treatment, when appropriate. Alternatives providing effectiveness and implementability similar to that of another alternative by employing a similar method of treatment or engineering control, but at greater cost, may be eliminated (NCP, 40 CFR 300.430(e)(7)(iii)). Costs that are grossly excessive compared to the overall effectiveness of alternatives may be considered as one of several factors used to eliminate alternatives (NCP, 40 CFR 300.430(e)(7)(iii)). As a result, a treatment alternative for such a site would likely be eliminated from consideration during the screening process.

It is important to note that the alternatives screening process does not formally evaluate costs. Rather, professional judgment is used to identify the relative cost-effectiveness of each alternative based on knowledge of relative costs. Detailed cost evaluations will be presented as part of the detailed evaluation of alternatives that passed the initial screening (see Section 5.0).

The No Action alternative is not evaluated according to the screening criteria; it will pass through screening to be evaluated during the detailed analysis as a baseline for other retained alternatives (EPA, 1988).

The five groundwater alternatives, five soil alternatives and three vapor mitigation alternatives developed and described below are evaluated relative to these criteria. Table 4-2 summarizes the alternatives screening results. Table 4-3 presents a summary of the key components of the alternatives retained for detailed analysis.

4.2 Identification and Description of Soil Alternatives

This subsection develops remedial alternatives for each of the two media. The alternatives consider the residual sources remaining in-place, the hydrogeologic system, affected media, and contaminant type and distribution. In assembling these alternatives, GRAs and process options chosen to represent the various technology types are combined to form alternatives for the Study Area as a whole. The RI did not identify any principal threat wastes in the Study Area. Alternatives are developed to provide a range of options consistent with EPA RI/FS guidance (EPA, 1988).

Due to the nature of the contaminated media and the physical limitations posed by the Study Area locale, only a limited range of options were identified based on the general response actions and process options that passed the technology screening in Section 3.0. The five remedial alternatives (including No Action) that have been identified to address RAOs for site-wide soil are listed below and described in more detail in subsequent subsections.

- SO1 – No Action
- SO2 – Limited Action – Institutional and Engineering Controls
- SO3 – Excavation and Off-Site Disposal
- SO4 – *In Situ* Treatment
- SO5 – Capping

4.2.1 Alternative SO1: No Action

Alternative SO1 includes no further action taken in the source areas. Any reduction in the risk at the Site will occur through natural attenuation processes. Alternative SO1 will not implement an environmental monitoring program to assess long-term changes in contaminant concentrations in soil in order to protect human health and the environment, but will include statutorily-required five-year reviews. CERCLA requires that the No Action alternative be evaluated to establish a baseline for comparison to other remedial alternatives.

Alternative SO1 will not be evaluated according to screening criteria, and will pass through screening to be evaluated during detailed analysis (EPA, 1988).

4.2.2 Alternative SO2: Limited Action – Institutional and Engineering Controls

Alternative SO2 was developed as a limited action to restrict access to the impacted soil within the Study Area through engineered controls (i.e., improved fencing) and institutional controls. Alternative SO2 will not implement an environmental monitoring program to assess long-term changes in contaminant concentrations in soil in order to protect human health and the environment but will include statutorily required five-year reviews.

Alternative SO2 has low effectiveness but is retained for further evaluation due to the ease of implementation and the low capital and O&M costs. Alternative SO2 consists of the following components:

- **Institutional Controls –** Institutional controls in the form of a deed restriction will be placed on the 96 Commerce Street property to prevent disturbance of the soil without protective measures during invasive subsurface activities (e.g. excavations, utility trenches) to prevent human exposures to contaminated soil.

- **Engineered Controls –** Engineered controls in the form of a fence restricting access to the former lagoon area will be installed surrounding impacted soil (Figure 4-1). The fence(s) will be constructed of chain-link mesh and surround the rear portion of the property with lockable access gates on the east and west corners of the property. Warning signs will be attached to the fence alerting visitors to the hazards associated with contact with the soil.

- **Five-Year Reviews –** Contaminants will remain in the Study Area soil and groundwater for an extended period of time after implementation of the alternative. Therefore, a review of Study Area conditions and risks will be conducted every five years, as required by CERCLA. The Five-Year Review will include evaluations of potential risks from exposure to VOCs, PAHs, and metals through contact and ingestion and evaluate the potential for vapor intrusion. Recommendations for improvements and follow-up actions will be made as necessary.

4.2.3 Alternative SO3: Excavation and Off-Site Disposal

Alternative SO3 uses removal of contaminated soil along with off-site disposal of the material at a licensed disposal facility. Included in the alternative is the removal of soil impacted with PAHs, arsenic and to be conservative, presumed hexavalent chromium in the former lagoon area at 96 Commerce Street (former Mitec Systems property).

A series of soil borings will be performed in the impacted zones in the Study Area to adequately delineate the vertical and horizontal extent of the impacted soil. Soils will be transported from the Site to an appropriate disposal facility. For cost estimating purposes the estimated excavation volume of soil to be removed from the 96 Commerce Street property is approximately 630 CY. Based on a total constituent analysis under EPA Method 1311 (Section 1.2 of EPA 1992) the waste stream will be treated as RCRA characteristic hazardous for off-site disposal unless determined to be non-hazardous during the pre-design investigation component described below.

Alternative SO3 has high effectiveness, is easily implemented, and has medium and low capital and O&M costs, respectively, and is retained for further evaluation. Figure 4-2 presents the locations of the key components of this alternative at 96 Commerce Street. The figure presents the locations of the soil borings and the presumed extent of the impacted soil, excavation, staging areas and travel routes. Alternative SO3 consists of the following components:

- **Pre-design Investigation –** Pre-design investigation (PDI) will be performed in the presumed impacted soil areas including the former lagoon area located on the 96 Commerce Street property. Soil sampling will be performed from the ground surface to a depth of up to 15 feet bgs at 2-foot intervals. The samples will be analyzed for total and hexavalent chromium and the results of the soil sample analysis will help delineate the intervals and spatial extent to be targeted for removal. Additional laboratory analysis for waste characterization will be performed. For costing purposes, it is assumed that up to 15 borings will be needed to determine the lateral and vertical extents of the soil impacts.

- **Soil Excavation Design –** Following the PDI, a soil removal design will be prepared to specify the vertical and horizontal extents of the removal actions along with the backfilling, compaction, and restoration plans; side-wall and building stabilization procedures, if necessary; destination disposal facility; and health and safety and loading protocols.

- **Soil Removal, Loading and Off-Site Disposal –** Prior to soil removal, 96 Commerce Street will be cleared of trees and brush to increase the area needed for construction activities. Soil will be physically removed to the extents indicated in the design plans by heavy machinery (e.g., excavator, backhoe) and loaded into roll-off dumpsters or onto trucks. The soil may be temporarily stockpiled on the property and covered by polyethylene sheeting, if necessary. The soil will be identified, characterized and disposed off-site in accordance with Vermont Hazardous Waste Regulations and RCRA at an approved disposal facility, as designated in the design plan for final disposal.

- **Site Restoration –** Following the soil removal and off-site disposal, the excavation area(s) will be backfilled with soil delivered to the Site from an off-site source and compacted to reduce settling. Topsoil will be used for the top of the backfill with grass seed to restore the area to previous conditions.

- **Five-Year Reviews –** Contaminants in soils above residential risk levels will be removed. Contaminants will remain, however, in Study Area groundwater for an extended period of time after implementation of the alternative. Therefore, a review of Study Area conditions and risks will be conducted every five years, as required by CERCLA. Five-Year Reviews will include evaluations of potential risks from exposure to contaminants in groundwater through contact and ingestion and through vapor inhalation. Recommendations for improvements and follow-up actions will be made as necessary.

4.2.4 Alternative SO4: *In Situ* Treatment

Alternative SO4 uses *in situ* treatment of contaminated soil to solidify or stabilize the impacted soil rendering it immobile or reducing it to a less toxic form, respectively.

A series of soil borings will be performed at 96 Commerce Street to delineate the vertical and horizontal extent of the impacted soil. Treatment will be performed with large diameter mixing augers or with excavator buckets to homogenize the material and blend Portland cement for solidification, or organic plant nutrients, organic matter, liming materials, and appropriate plant species and materials for stabilization to fixate contaminants to soil particles, rendering them immobile.

In addition to the engineered controls (fencing) described in SO2, Alternative SO4 will also include:

- **Institutional Controls –** Institutional controls in the form of a deed restriction will be placed on the 96 Commerce Street property to prevent disturbance of the soil without state/federal approval to protect the *in situ* treatment remedy and to prevent risk to human health.

- **Five-Year Reviews –** Contaminants will remain in the Study Area soil and groundwater for an extended period of time after implementation of the alternative. Therefore, a review of Study Area conditions and risks will be conducted every five years, as required by CERCLA. The Five-Year Review will include evaluations of potential risks from exposure to VOCs, PAHs, and metals through contact and ingestion and evaluate the potential for vapor intrusion. Recommendations for improvements and follow-up actions will be made as necessary

Alternative SO4 has medium effectiveness, is somewhat difficult to implement, and has medium and low capital and O&M costs, respectively, and has been eliminated from further evaluation.

4.2.5 Alternative SO5: Capping

Alternative SO5 uses capping of contaminated soil to isolate the contaminated soil from the potential for human contact.

A series of soil borings will be performed in the area of the former lagoon to adequately delineate the vertical and horizontal extent of the impacted soil. Soils on the 96 Commerce Street property will be left in place and capped with an impermeable barrier of asphalt to preserve the future use of the land by the occupants of the property. A surface water collection and diversion swale will be constructed around the cap to direct surface run-off to the eastern portion of the property where it will recharge into the overburden aquifer downgradient of the impacted soil mass. The clay surface would be covered with a sufficient vegetative support layer and topsoil to allow for the restoration of the existing grass lawn. The alternative will also include:

- **Institutional Controls –** Institutional controls in the form of a deed restriction will be placed on the 96 Commerce Street property to prevent disturbance of the soil without state/federal approval to protect the cap and to prevent risk to human health.

- **Five-Year Reviews –** Contaminants will remain in the Study Area soil and groundwater for an extended period of time after implementation of the alternative. Therefore, a review of Study Area conditions and risks will be conducted every five years, as required by CERCLA. The Five-Year Review will include evaluations of potential risks from exposure to VOCs, PAHs, and metals through contact and ingestion and evaluate the potential for vapor intrusion. Recommendations for improvements and follow-up actions will be made as necessary.

Alternative SO5 has medium effectiveness, is somewhat difficult to implement, and has high and medium capital and O&M costs, respectively, and has been eliminated from further evaluation.

4.3 Identification and Description of Groundwater Alternatives

This subsection develops remedial alternatives for overburden groundwater. The alternatives consider the residual sources remaining in-place, the hydrogeologic system, affected media, and contaminant type and distribution. In assembling these alternatives, GRAs and process options chosen to represent the various technology types are combined to form alternatives for the Study Area as a whole. The RI did not identify any principal threat wastes at the Site, however, chemicals adsorbed to the finer grained sand and silt in the unconsolidated materials in the overburden are an ongoing source of groundwater contamination. Alternatives are developed to provide a range of options consistent with EPA RI/FS guidance (EPA, 1988).

Due to the nature of the contaminated media and the physical limitations posed by the Study Area locale, only a limited range of options were identified based on the general response actions and process options that passed the technology screening in Section 3.0. The five remedial alternatives (including No Action) that have been identified to address RAOs for site-wide overburden groundwater are listed below and described in more detail in subsequent subsections.

- GW1 – No Action
- GW2 – Institutional Controls
- GW3 – Monitored Natural Attenuation (MNA) and Long-Term Monitoring
- GW4 – Groundwater Collection, Treatment and Discharge
- GW5 – *In Situ* Treatment and MNA

4.3.1 Alternative GW1: No Action

Alternative GW1 includes no further action taken in the source areas. Any reduction in the risk at the Site will occur through natural attenuation processes. Alternative GW1 will not implement an environmental monitoring program to assess long-term changes in contaminant concentrations in soil or groundwater in order to protect human health and the environment but will include statutorily-required five-year reviews. CERCLA requires that the No Action alternative be evaluated to establish a baseline for comparison to other remedial alternatives.

Alternative GW1 will not be evaluated according to screening criteria, and will pass through screening to be evaluated during detailed analysis (EPA, 1988).

4.3.2 Alternative GW2: Institutional Controls

Alternative GW2 was developed as a limited action to restrict access to the overburden groundwater. Alternative GW2 will not implement an environmental monitoring program to assess long-term changes in contaminant concentrations in groundwater in order to protect human health and the environment but will include statutorily required five-year reviews. Institutional controls would be implemented to prohibit use of existing wells for drinking and other household uses and the installation of any new wells for any purpose except as deemed necessary by EPA to implement the remedy; control inhalation and direct contact exposure to contaminated groundwater during excavation in saturated soils; and reclassify contaminated groundwater as Class IV (non-potable), restricting the installation of new wells or the modification of existing wells.

Alternative GW2 has low effectiveness but is retained for further evaluation due to the ease of implementation and the low capital and O&M costs. The properties where restrictions on groundwater use are likely to be needed are listed in Table 4-4 and shown on Figure 4-3.

Alternative GW2 consists of the following components:

- **Institutional Controls –** Institutional controls such as deed restrictions and/or a town ordinance would be implemented to prohibit use of existing wells for drinking and other household uses and the installation of any new wells for any purpose except as deemed necessary by EPA to implement the remedy. It will also require excavation control measures to protect construction workers and others performing invasive subsurface work (e.g., excavations, utility trenches) from potential inhalation of and direct contact with contaminated groundwater. As an additional institutional control, the State of Vermont will reclassify contaminated groundwater in the Study Area as Class IV per the Vermont Groundwater Protection statute at 10 VSA Chapter 48, designating it non-potable and restricting the use of drinking water supply wells on properties in the vicinity of the 70-acre plume and an appropriate buffer zone, as delineated by the State of Vermont.

- **Five-Year Reviews –** Contaminants will remain in the Study Area groundwater for an extended period of time after implementation of the alternative. Therefore, a review of Study Area conditions and risks will be conducted every five years, as required by CERCLA. The Five-Year Review will include evaluations of potential risks from exposure to VOCs through contact and ingestion and evaluate the potential for vapor intrusion. Recommendations for improvements and follow-up actions will be made as necessary.

4.3.3 Alternative GW3: Monitored Natural Attenuation and Long-Term Monitoring

Alternative GW3 uses monitored natural attenuation (MNA) to monitor the natural attenuation of contaminants in the overburden aquifer. Monitoring wells will be routinely sampled and evaluated for MNA parameters with annual reports documenting the data, evaluation and trends. The institutional controls described in Alternative GW2 will be implemented to protect human health during the MNA period until groundwater concentrations are reduced to below the PRGs.

Alternative GW3 has low effectiveness but is retained for further evaluation due to the ease of implementation and the low capital and O&M costs. The properties where restrictions on groundwater use are likely to be needed are listed in Table 4-4 and shown on Figure 4-3. The preliminary list of monitoring wells to be included in the long-term monitoring program is summarized in Table 4-5 and shown on Figure 4-4.

In addition to the institutional controls and five-year reviews described in GW2, Alternative GW3 consists of the following:

- **Monitored Natural Attenuation –** MNA will be implemented and evaluated based on EPA guidance documents including *An Approach for Evaluation the Progress of Natural*

Attenuation (EPA, 2011). Contaminated saturated soils in the groundwater plume core are continuing sources of groundwater contamination. Although no active remediation would occur under Alternative GW3, it is anticipated that contaminant concentrations in the aquifer will gradually diminish over time as the result of natural ongoing biotic and abiotic natural degradation processes over an extended period, until all groundwater concentrations are decreased to below PRGs. Unlike Alternatives GW1 and GW2, Alternative GW3 includes an annual MNA evaluation including a report documenting the monitoring performed, summarizing the analytical data, and analysis of data trends.

- **Long-Term Monitoring –** Groundwater would be sampled and analyzed on a biannual basis for the first five years, and annually thereafter, to monitor natural attenuation processes and to evaluate conditions in the overburden aquifer. Groundwater samples would be collected from the eastern and western plume hotspots and the peripheral portions of the plume. For costing purposes, it is assumed that the annual monitoring would continue for 30 years; however, the time needed for groundwater concentrations to attain the PRGs may exceed that period. Samples would be collected from approximately 27 existing monitoring wells. No additional monitoring wells are anticipated to be needed; however, monitoring well maintenance will be likely be required over the monitoring period. Samples will be analyzed for VOCs, PAHs, metals, and geochemical parameters (chloride, sulfate, sulfide, nitrate, nitrite, alkalinity, total organic carbon, ethene, ethane, methane, and hydrogen). The geochemical parameters assist with the evaluations to determine the effectiveness of MNA. The lateral and vertical contaminant migration in the overburden aquifer will be monitored. As necessary, a number of these wells may need to be redeveloped to remove siltation that typically occurs. Annual reports documenting the long-term monitoring procedures, observations, and analytical results will be submitted and will evaluate the effectiveness of the alternative with regards to plume migration, changes in plume geometry, and attainment of the RAOs.

4.3.4 Alternative GW4: Groundwater Collection, Treatment, and Discharge

Alternative GW4 uses collection of the most impacted portion of the plume on the eastern side of the Study Area, treatment of the collected water, and discharge of the treated water coupled with MNA in the remaining portions of the plume.

A series of groundwater extraction wells would be installed and spaced so that the radius of influence of each well overlaps the adjacent well. The wells would contain pumps, which would remove the contaminated groundwater and convey the water to a treatment system. Treatment of the extracted water would consist of equalization, particulate filtration, carbon adsorption and/or air stripping. The treated water would then be discharged to the unnamed brook near the eastern boundary of the Study Area. The PDI would be conducted to assess the extent of the currently identified source areas, and to determine the radius of influence of extraction wells. Institutional controls and long-term monitoring would be implemented to minimize exposure to contaminants and to monitor remedial progress and attainment of RAOs.

Alternative GW4 has medium effectiveness, is somewhat difficult to implement, and has high capital and O&M costs, and has been eliminated from further evaluation.

4.3.5 Alternative GW5: *In Situ* Treatment

Alternative GW5 includes *in situ* treatment in the form of *in situ* chemical oxidation (ISCO) and/or *in situ* bioremediation (ISB) to reduce the concentrations in the sections of the eastern and western portions of the plume with the highest concentrations and to dissolve any residual NAPL blobs or ganglia that may be present in the subsurface decreasing the ongoing contamination of the downgradient plume. MNA would be used in the remaining portions of the plume.

In situ treatment consists of performing injections into the aquifer using direct-push drilling techniques to advance to the target depths and directly injecting a chemical oxidant (ISCO) and/or amendments including bacteria (ISB) to promote reductive dechlorination, destroying the TCE plume *in situ*. It is anticipated that existing monitoring wells will be used for performance monitoring. *In situ* treatment generally does not include any permanent structures or buildings and does not include any trenching or excavation work. Piping and storage is all temporary and will be staged in areas where traffic is minimal and supply lines and hoses will be protected and shielded as necessary to prevent damage and traffic hazards. If ISCO is selected for the treatment, ISB may be used as a polishing step once the ISCO processes cease being effective. If ISB is selected for the treatment, no polishing step is anticipated.

Alternative GW5 has high effectiveness, is easy to implement, and has low and medium capital and O&M costs, respectively, and has been retained for further evaluation. The properties where restrictions on groundwater use are likely to be needed are listed in Table 4-4 and shown on Figure 4-3. Figure 4-5 displays the treatment areas and the potential locations of the linear treatment barriers/zones. The preliminary list of monitoring wells to be included in the long-term monitoring program is summarized in Table 4-5 and shown on Figure 4-4.

In addition to the institutional controls and five-year reviews described in GW2, Alternative GW5 consists of the following:

- **Pre-Design Investigation –** A PDI will be conducted to determine the specific course of action for *in situ* treatment. Bench-scale testing of chemical reagents and oxidants, and amendments and bacteria would be performed to maximize the effectiveness of the chemical treatment. The bench scale test will evaluate the characteristics of the aquifer water with respect to the acidity, oxidation-reduction potential, and aerobic versus anaerobic conditions. A microcosm study will be prepared to test several combinations of control, oxidant loading, bio stimulation, bioaugmentation, and testing of oxidant demand and nutrient sources.

  Once the bench scale tests are complete, the results will be used to perform pilot test(s) in the field. Implementation plans will be prepared documenting the design of the pilot tests prior to performance. The ISCO pilot test will be performed in the highest concentration area (greater than 50,000 µg/L). Oxidants will be injected based on the recommendations of the bench test using direct push drilling techniques. The ISB pilot scale test will be performed in the greater than 5,000 µg/L treatment area in both the eastern and western portions of the plume to evaluate the efficacy in both areas. Aerobic or anaerobic tests or both will be performed based on the results of the bench scale test. Performance monitoring for each pilot test will be performed during the test and approximately two months following the event to measure contaminant reduction and radius of influence as well as treatment efficacy. The performance monitoring will include sampling of the monitoring wells in the vicinity of the injections.

- ***In Situ* Treatment Design –** Based on the results of the PDI, a treatment design will be developed with the selected process option (i.e., ISCO, ISB, or both); delivery methods;

types and volumes of amendments to be applied; locations and arrangement of injections; duration and schedule of the applications; and the application and performance monitoring required to determine effectiveness of the technology.

- ***In Situ* Treatment –** *In situ* treatment would be performed in the identified areas of the plume with the highest concentrations. It is assumed that the oxidants and/or amendments would be introduced to the source area by means of direct push drilling techniques and injected into the aquifer at the targeted depth due to the soil stratigraphy. The targeted depths would be developed and reported in the treatment design. It should be noted that ISB alone may not be able to effectively reduce the area with concentrations over 50,000 µg/L. ISCO would likely be used in that zone to reduce the contamination to a level where ISB is more effective (e.g., less than 10,000 µg/L). The subsequent ISB implementation could be performed in a series of linear treatment barriers/zones. A large number of injections for the ISB portion of the alternative, if performed, would be required to treat the area with TCE greater than 5,000 µg/L; therefore, it is likely that treatment zones/barriers would be used to keep costs within a reasonable and feasible range. The zones/barriers would be linear arrangements of injection locations set perpendicular to the groundwater flow path, possibly spaced 30 to 50 feet on center depending on the results of the pilot test. The zones/barriers would intersect the groundwater flow and treat the plume as it passed through them.

  Performance monitoring would be performed to determine the effectiveness of the technology and to evaluate the trends and update the times to achieve PRGs and RAOs. The schedule and analytical requirements will depend on the specific technologies selected.

- **Monitored Natural Attenuation –** Contaminated saturated soils in the groundwater plume hotspots are continuing sources of groundwater contamination and are expected to be reduced in magnitude due to the *in situ* treatments; however, it is anticipated that contaminant concentrations in areas other than the hotspots will gradually diminish over time as the result of natural ongoing geochemical processes. Both biotic and abiotic natural degradation processes will gradually attenuate the VOC mass over an extended period, until all groundwater concentrations are decreased to below PRGs.

- **Long-Term Monitoring –** Groundwater would be sampled and analyzed on a biannual basis for the first five years after treatment, and every five years thereafter, to monitor natural attenuation processes and to evaluate conditions in the overburden aquifer. Groundwater samples would be collected from the eastern and western plume hotspots and the peripheral portions of the plume. For costing purposes, it is assumed that the annual monitoring would continue for 30 years; however, the time needed for groundwater concentrations to attain the PRGs may exceed that period. Samples would be collected from approximately 27 existing monitoring wells. No additional monitoring wells are anticipated to be needed; however, monitoring well maintenance will be likely be required over the monitoring period. Samples will be analyzed for VOCs, PAHs, metals, and geochemical parameters (chloride, sulfate, sulfide, nitrate, nitrite, alkalinity, total organic carbon, ethene, ethane, methane, and hydrogen). The lateral and vertical contaminant migration in the overburden aquifer will be monitored. As necessary, a number of these wells may need to be redeveloped to remove siltation that typically occurs. Annual reports documenting the long-term monitoring procedures, observations, and analytical results will be submitted and will evaluate the effectiveness of the alternative with regards to plume migration, changes in plume geometry, and attainment of the RAOs.

4.4 Identification and Description of Vapor Mitigation Alternatives

This subsection discusses three remedial alternatives for vapor intrusion. The alternatives consider the residual sources remaining in-place, the hydrogeologic system, affected media, and contaminant type and distribution. In assembling these alternatives, GRAs and process options chosen to represent the various technology types are combined to form alternatives for the Study Area as a whole. The RI did not identify any principal threat wastes in the Study Area; however, the dissolved-phase groundwater contamination located throughout the Study Area is a potential ongoing source of indoor air contamination. Alternatives are developed to provide a range of options consistent with EPA RI/FS guidance (EPA, 1988).

Due to the nature of the contaminated media and the physical limitations posed by the fact that the buildings already exist (versus new construction), only a limited range of options were identified based on the general response actions and process options that passed the technology screening in Section 3.0. The three remedial alternatives (including No Action) that have been identified to address RAOs for vapor mitigation are listed below.

- VM1 – No Action
- VM2 – Sump Pump, Vapor Venting, Treatment and Discharge
- VM3 – Enhanced Vapor Mitigation

The following subsections describe the alternatives developed for vapor mitigation.

4.4.1 Alternative VM1: No Action

Alternative VM1 includes no further action taken to prevent potential exposure to vapors in indoor air at 830 South Brownell Road from contaminated groundwater that could flood the basement and is below the basement. Any reduction in the risk in the Study Area relies on diminishing concentrations of VOCs in the groundwater. Alternative VM1 will not implement an environmental monitoring program to assess long-term changes in contaminant concentrations in vapors in order to protect human health and the environment but will include statutorily-required five-year reviews. CERCLA requires that the No Action alternative be evaluated to establish a baseline for comparison to other remedial alternatives.

Alternative VM1 will not be evaluated according to screening criteria, and will pass through screening to be evaluated during detailed analysis (EPA, 1988b).

4.4.2 Alternative VM2: Sump Pump, Vapor Venting, Treatment and Discharge

Alternative VM2 requires the continued operation of the sump pump, passive gas venting and sump water discharge system already installed by VT DEC, in consultation with EPA, to reduce the vapor inhalation risks to the residents of 830 South Brownell Road due to groundwater flooding in the basement. The alternative requires the installation of a granular activated carbon (GAC) treatment system for the sump water discharge to the ground surface and indirectly to groundwater per the requirement of 10 VSA Chapter 47, Water Pollution Control, Section 1259(a). The alternative will require an institutional control in the form of a deed restriction, requiring the continued operation of the already installed sump pump, passive gas venting and sump water discharge system, and, providing access to EPA and VT DEC for monitoring, maintenance of equipment and oversight. The alternative also requires evaluation of the system at 830 South Brownell Road within every Five-Year Review.

Alternative VM2 consists of the following components:

- **Long-Term Monitoring –** The performance of the existing system will be annually monitored to ensure that the remedy is protective of the residents. The sump will be visually inspected for leaks and proper operation; the basement air will be screened with an organic vapor meter; and water from the sump will be sampled and analyzed for VOCs.

- **Construction –** A GAC system, or similar, will be installed to treat collected groundwater prior to discharge to the ground surface. The system will be connected in line with the existing sump pump and discharge line.

- **Institutional Controls –** Institutional controls consisting of a deed restriction to require that residents of the property continue to operate the sump system in accordance with EPA and VT DEC direction to ensure the health and safety of the residents and to provide access to EPA and VT DEC for monitoring, maintenance of equipment and oversight.

- **Five-Year Reviews –** Contaminants will remain in the Study Area groundwater for an extended period of time after implementation of the alternative. Therefore, a review of Study Area conditions and risks will be conducted every five years, as required by CERCLA. The Five-Year Review will include evaluations of potential risks from exposure to contaminants through contact and ingestion and evaluate the potential for vapor intrusion. Recommendations for improvements and follow-up actions will be made as necessary.

4.4.3 Alternative VM3: Enhanced Vapor Mitigation

Alternative VM3 includes all elements described in Alternative VM2 to reduce the vapor inhalation risks of the residents of 830 South Brownell Road. Alternative VM3 also requires, as determined necessary based on a risk analysis of additional data collected during pre-design, additional measures to supplement or replace the already installed sump pump, passive venting, and sump water discharge system. Additional measures may include an active venting system, vapor barrier or other engineering controls. The alternative also includes a contingency to address other residential homes or commercial buildings in the vicinity of the plume if data collected during future sampling events for Five-Year Reviews or other reasons indicates a risk. The alternative will require an institutional control in the form of a deed restriction, requiring the continued operation and maintenance of the enhanced vapor mitigation system, if installed, and providing access to EPA and VT DEC for monitoring, maintenance of equipment and oversight. The alternative requires evaluation of the system at 830 South Brownell Road within every Five-Year Review.

In addition to the long-term monitoring, institutional controls, and five-year reviews described in VM2, Alternative VM3 consists of the following:

- **Construction –** A GAC system will be installed to treat collected groundwater prior to discharge to the ground surface. The system will be connected in line with the existing sump pump and discharge line. Additional measures will be constructed within the basement of the building to include the installation of an active venting system and/or a vapor barrier to keep potential vapors from the space.

5.0 DETAILED ANALYSIS OF ALTERNATIVES

The remedial alternatives retained from Section 4.0 are analyzed in detail in this section. The detailed analysis of the alternatives provides information necessary to facilitate the selection of a specific remedy or combination of remedies. The detailed analysis of alternatives was conducted in accordance with the NCP (40 CFR 200.430(e)) and the RI/FS Guidance (EPA, 1988).

The results of the detailed analyses of costs for each alternative is included in Tables 5-1 through 5-12. Detailed evaluations of each alternative's ability to comply with the chemical-specific, location-specific, and action-specific ARARs are presented in Tables 5-13 through Table 5-21.

5.1 Evaluation Criteria

The NCP requires that remedial alternatives be assessed against nine evaluation criteria, which are categorized as follows:

Threshold Criteria:

- **Overall Protection of Human Health and the Environment –** This criterion provides a final check to ensure that the alternative provides adequate protection of human health and the environment.

- **Compliance with ARARs –** This criterion is used to describe how each alternative will meet ARARs, or in cases where an ARAR(s) will not be met, the justification of any waiver shall be detailed.

Primary Balancing Criteria:

- **Long-Term Effectiveness and Permanence –** This criterion details the evaluation of the risks remaining after the remedial alternative has been enacted and the response objectives have been achieved. The primary focus of this evaluation is the evaluation of any procedures or controls that manage risks associated with treatment residuals and/or untreated wastes. Specifically, the magnitude of residual risks and the adequacy and reliability of controls for each alternative are examined.

- **Reduction of Toxicity, Mobility or Volume through Treatment –** This evaluation criterion addresses the statutory preference for selecting remedial alternatives that employ treatment technologies that permanently and significantly reduce the toxicity, mobility or volume of the hazardous substances.

- **Short-Term Effectiveness –** This criterion requires an evaluation of the impacts to human health (on-site workers and community) and the environment during construction and implementation of the remedial alternatives. Sustainability aspects of the alternatives are also evaluated under this criterion.

- **Implementability –** This criterion requires an evaluation of the technical and administrative implementability of the remedial actions, as well as an evaluation of the relative availability of services and materials. The evaluation of the technical implementability generally includes short-term difficulties in construction and operation, the reliability of the technology, the relative ease of undertaking additional remedial actions and monitoring considerations. Administrative implementability provides an evaluation of the administrative requirements needed to perform the remedy (such as securing rights of way and permits). The evaluation of the relative availability of services and materials is a determination of the ease of which specialized services, materials or equipment may be obtained.

- **Cost –** A detailed cost analysis is performed for each alternative to assess the net present worth cost to implement each alternative. The cost analyses include an estimation of the capital costs and annual operations and maintenance costs for the alternative, the development of costs that fall within a -30% to +50% estimation range, and a present worth analysis by discounting to a base year or current year using a 7% discount rate.

Modifying Criteria:

- **State Acceptance –** To the extent possible, the remedial alternatives have been assembled to assure compliance with State of Vermont ARARs, as they apply. Any additional concerns that the State of Vermont agencies may have will be communicated during the comment period after issuance of the Proposed Plan and taken into account in the ROD.

- **Community Acceptance –** In assembling the remedial alternatives, protection of the community and anticipation of any concerns the community may have associated with the remedies have been taken into account to the extent possible. Any additional comments or suggestions the community may have will be communicated during the comment period after issuance of the Proposed Plan and taken into account in the ROD.

In conformance with the NCP, the seven criteria included in the Threshold Criteria and the Primary Balancing Criteria noted above were used to evaluate each of the retained alternatives presented in Section 5.0 in the detailed analysis. The last two criteria, State and community acceptance, will be addressed following the public comment period.

5.2 Detailed Analysis of Alternatives

The following remedial action alternatives were retained for detailed analysis:

Soil Alternatives

- **SO1 – No Action:** Five-year reviews
- **SO2 – Limited Action – Institutional and Engineering Controls:** Fencing around impacted soil with institutional controls
- **SO3 – Excavation and Off-Site Disposal:** Excavation and off-site disposal of impacted soil

Groundwater Alternatives (Addressing Dissolved Contaminant Groundwater Plume)

- **GW1 – No Action:** Five-year reviews
- **GW2 – Institutional Controls:** Deed restrictions, land use restrictions and town ordinances
- **GW3** – **Monitored Natural Attenuation and Long-term Monitoring:** MNA and Long-term monitoring
- **GW5 – *In Situ* Treatment and MNA:** *In Situ* treatment (ISCO and/or ISB) and MNA

Vapor Mitigation Alternatives

- **VM1 – No Action:** Five-year reviews
- **VM2 – Sump Pump, Vapor Venting, Treatment and Discharge:** Institutional controls to maintain current system
- **VM3** – **Enhanced Vapor Mitigation:** Contingent upon risk analysis of additional data, enhancement or replacement of previously installed vapor mitigation system at 830 South Brownell Property; installation of vapor mitigation systems at other homes or businesses in vicinity of plume; and institutional controls.

5.3 Cost Estimation

Estimated costs for each remedial alternative are presented on Tables 5-1 through 5-12. Three variations of the estimated cost for Alternative GW5 have been developed and presented on Tables 5-7 through 5-9. The detailed cost estimate assumptions and calculations for present value and periodic costs are included in Appendix D. The detailed cost evaluations provided in the tables were prepared for each alternative in accordance with the *EPA Guide to Developing and*

Documenting Costs Estimates during the Feasibility Study (EPA, 2000). The guide states that cost estimates developed for an FS are for comparison purposes, only. In general, the FS stage of the remedial design may represent the 0-10% complete design, and as such, the anticipated accuracy range is -30% to +50%. As the remedial design is developed, the estimation accuracy is expected to be between -10% to +15%.

The cost estimates are prepared based on available information at the FS stage including the quantities or extent of contamination to be addressed, prices available from standard construction information sources and vendors, and assumptions used to develop the conceptual designs for the remedial alternatives. In addition, the time needed to complete the construction, or to achieve the RAOs is based on best estimates or professional judgment. The cost analyses developed at the FS stage are for order of magnitude and comparative analysis use in the remedy selection process, and do not represent actual costs needed to implement the remedy fully. As additional information becomes available during the pre-design investigation or the remedial design phase, estimated costs will become more refined and accurate.

A present value analysis (PVA) was prepared as part of the cost analysis for each alternative to normalize long-term expenditures to a base year value. The PVA represents the amount of monies that, if set aside at the initial point in time (base year), with outflows (payments) on an as-required basis, would be sufficient to pay for the remedial action over the anticipated duration of the remedy. A discount rate of seven was used, in accordance with EPA guidance.

In addition to capital and annual operations and maintenance costs, each alternative's cost estimate includes the following elements:

- Scope and Bid Contingencies that account for uncertainties that could be associated with incomplete site characterization, construction delays due to weather or unanticipated site conditions.

- Technical services, professional/specialist consulting and engineering costs as a percentage of capital costs.

- Administrative fees as a percentage of capital costs.

5.4 Identification of ARARs

Section 121(d)(2)(A) of CERCLA requires that Superfund remedial actions meet any federal standards, requirements, criteria, or limitations that are determined to be legally applicable or relevant and appropriate requirements. State ARARs must be met if they are more stringent than federal requirements and have been presented to EPA in a timely manner.

Section 121(d)(4) of CERCLA identifies six circumstances under which ARARs may be waived:

1. The remedial action selected is only a part of a total remedial action (interim remedy) and the final remedy will attain the ARAR upon its completion.

2. Compliance with the ARAR will result in a greater risk to human health and the environment than alternative options.

3. Compliance with the ARAR is technically impracticable from an engineering perspective.

4. An alternative remedial action will attain an equivalent standard of performance using another method or approach.

5. A State requirement that the State has not consistently applied (or demonstrated the intent to apply consistently) in similar circumstances.

6. For §104 Superfund-financed remedial actions, compliance with the ARAR will not provide a balance between protecting human health and the environment and the availability of Superfund money for response at other facilities.

Potential ARARs were identified for each of the remedial alternatives retained for detailed analysis. Each potential ARAR was reviewed to evaluate the applicability or relevancy and appropriateness according to the procedures identified in RI/FS Guidance (EPA, 1988) and the *CERCLA Compliance with Other Laws Manual, Part 1 and Part 2* (EPA, 1989). Evaluations of each alternative's ability to comply with the chemical-specific, location-specific, and action-specific ARARs are presented in Tables 5-13 through Table 5-21.

6.0 COMPARATIVE ANALYSIS OF REMEDIAL ALTERNATIVES

This section describes comparative analysis approach and presents the results of the comparative analysis of the remedial alternatives that were evaluated individually in Section 5.0.

6.1 Comparative Analysis Approach

The comparative analysis compares the relative performance of each alternative to the evaluation criteria specified in the NCP and described in Section 5.0. This comparison assists in the selection of a remedy for the Site by identifying the advantages and disadvantages of each alternative relative to the NCP evaluation criteria.

The approach to evaluating each alternative is specified in the NCP and further detailed in RI/FS Guidance (EPA, 1988). The selection of the preferred remedy must consider the major tradeoffs among the evaluation criteria. The NCP groups the evaluation criteria as described in Section 5.0 (Threshold Criteria, Primary Balancing Criteria, and Modifying Criteria).

6.2 Comparative Analysis

The subsections below present the comparative analysis of remedial alternatives relative for each of the two Threshold and five Primary Balancing criteria. Table 6-1 provides a summary of the comparative analysis results.

In order to make consistent comparisons among the three types of alternatives developed for the FS, the comparisons are made between alternatives with similar objectives. The soil alternatives are addressed together and the groundwater alternatives are addressed together. As there is only a single active vapor intrusion alternative, the criteria is discussed for that individual alternative without comparisons.

6.2.1 Overall Protection of Human Health and the Environment

Soil

Alternative SO1 does not meet this threshold criterion. Alternative SO1 provides the least amount of protection of human health and the environment of the soil alternatives because no actions would be taken to further reduce the ongoing risk presented by impacted soil.

Although Alternative SO2 and SO3 meet this criterion, Alternative SO3 is the most protective of human health and the environment. While Alternative SO2 restricts access to the impacted soil by the installation of a fence and includes institutional controls, the alternative does not include removal of the impacted material or the installation of a RCRA-compliant cap, and a fence is susceptible to damage, vandalism or trespass or other failure. Alternative SO3, removes the impacted soil and disposes of it at an off-site facility, effectively eliminating the potential for the soil to leach contaminants into the aquifer.

Groundwater

Alternative GW1 provides the least amount of protection of human health and the environment of the groundwater alternatives because no actions would be taken to further reduce the ongoing risk presented by impacted groundwater. Alternative GW1 would not meet the NCP threshold criterion of protection of human health and the environment.

Although GW2, GW3 and GW5 meet this threshold criterion, Alternative GW5 is the most protective of human health and the environment. Alternative GW2 applies institutional controls to restrict access to the groundwater (deed restriction and/or town zoning ordinance; state reclassification of the impacted groundwater to Class IV per the Vermont Groundwater Protection Statute at 10 VSA Chapter 48, designating it as non-potable) but the alternative does not remove or treat the impacted groundwater. Therefore, the potential for human contact or downgradient migration of the plume still exists. Additionally, Alternative GW2 does not allow for long-term monitoring to determine if the plume is changing in its geometry or is migrating toward new receptors. While Alternative GW3 adds a long-term monitoring program and annual evaluation of the natural attenuation processes, it still does not remove or treat the plume and relies only on the institutional controls to reduce the risk to human health. Alternatives GW1, GW2, and GW3 do nothing to protect the environment, as there is no hydraulic containment or treatment included in the alternatives to reduce the potential migration toward new receptors or non-impacted areas.

Alternative GW5 is a destructive technology that is also considered green and sustainable and will reduce and/or eliminate the contaminants in the hotspots of the plume, greatly reducing the amount of time that it will take to achieve the RAOs and PRGs.

Vapor

Alternative VM1 and VM2 do not meet this criterion. VM1 provides the least amount of protection of human health and the environment of the vapor alternatives because no actions would be taken to further reduce the ongoing risk presented by impacted vapors. The alternative does not require the continued operation of the existing vapor mitigation system (sump pump, passive venting and water discharge) at 830 South Brownell Road, nor require any additional engineering controls, contingent upon risk analysis of additional data to ensure protection of human health. Alternative VM2 better protects human health by limiting exposure to vapors emanating directly from groundwater that floods the basement and is below the basement, but still leaves the possibility of vapor intrusion risk at 830 South Brownell Road from vapors emanating from groundwater under the basement. Insufficient data currently exist to conclude that the existing vapor mitigation system at 830 South Brownell Road sufficiently mitigates vapor intrusion risk from vapors emanating from the groundwater under the basement. Alternative VM3 meets this criterion as it would fully protect human health by requiring the supplementation or replacement of the existing sump, venting and discharge system, as necessary, based on the collection and risk analysis of additional data during pre-design. Alternative VM3 also contains a contingency to treat other homes in the vicinity of the groundwater plume, if future data collection and analysis indicate an exceedance of risk.

6.2.2 Compliance with ARARs

Compliance with ARARs is summarized in Tables 5-13 through 5-21. A comparative evaluation of ARARs compliance is provided below.

LOCATION-SPECIFIC ARARS

Soil

Soil Alternative SO1 does not include any actions; therefore, this alternative does not trigger location-specific ARARs.

Alternative SO2 includes the installation of fencing around the impacted soil. Wetlands are present within the Study Area between Commerce Street and Kirby Lane and to the east of the unnamed stream located near the eastern boundary of the Study Area. Prior to soil removal activities, a confirmatory wetland, wetland buffer zone, and riparian buffer zone delineation will be performed; work will be performed to minimize impacts to wetlands and other resources, and any alterations to wetlands will be mitigated to restore ecological functions and values to comply with state and federal wetland rules. Erosion control measures will be implemented, if necessary, to minimize the sediment leaving the work areas as fence posts are installed. Measures will be used to minimize airborne dust.

Similar to Alternative SO2, Alternative SO3 will comply with state and federal wetlands and other land use rules. Prior to the soil removal activities, a confirmatory wetland, wetland buffer zone and riparian zone delineation will be performed; work will be performed to minimize impacts on wetlands and other resources, and any alterations to the existing wetlands and buffer zones will be mitigated appropriately. Erosion prevention and sediment control measures will be implemented, if necessary to prevent impacts to the work area and wetland and other resources areas that may be nearby. Measures will be used to minimize airborne dust.

The Vermont Division for Historic Preservation has informed EPA that in the area of potential effect, particularly in undisturbed soils between Commerce Street and Kirby Lane, there is a high probability of significant pre-contact archaeological sites. The area of excavation, however, has already been disturbed in the past by former owners and was subject to a removal action by the State of Vermont. Work will be completed in compliance with this ARAR, in consultation with the Vermont Division of Historic Preservation, as work areas are further delineated. No endangered species have been previously identified within the Study Area.

Groundwater

Groundwater Alternatives GW1, GW2 and GW3 do not include active remediation. All groundwater alternatives, therefore, trigger only minimal compliance requirements with location-specific ARARs. Such compliance requirements will relate to the installation of underground injection wells monitoring wells, and general site-work. Work will be completed to ensure compliance with wetlands protection, riparian buffer, historic preservation, erosion prevention requirements, on an as needed basis, upon further delineation of wetlands, wetland and riparian buffer zones, and archeological sites. Measures will be used to minimize airborne dust.

Vapor

Soil disturbance for the installation of the water treatment system or other engineering control is expected to be very minimal, but work will be performed to conform with state and federal archaeological and historic preservation laws and wetland laws, upon further delineation of work areas, wetlands, wetland buffer zones and riparian buffer zones. Measures will be used to minimize airborne dust.

CHEMICAL-SPECIFIC ARARS

Soil

No chemical-specific ARARs exist with respect to exposure to contaminants in soil. Instead, cleanup levels are based on risk.

Groundwater

Alternatives GW1, GW2 and GW3 will not achieve water quality chemical-specific ARARs until contaminants naturally attenuate - estimated to be 115 to 250 years. Alternative GW3 contains a long-term monitoring plan and MNA, but it would not improve the time period required to attain the chemical-specific ARARs.

Alternative GW5, which includes *in situ* treatment of the groundwater plume with MNA, is the only alternative to include an active treatment remedy to achieve ARARs in about 50 to 75 years, significantly faster than natural attenuation.

Vapor

No chemical-specific ARARs exist with respect to exposure to contaminants in vapor. Instead, cleanup levels are based on risk.

ACTION-SPECIFIC ARARS

Soil

Alternative SO1 does not require any actions, and Alternative SO2 requires minimal actions, namely fencing; as such they generally do not trigger action-specific ARARs. Based on a total constituent analysis under EPA Method 1311 (EPA, 1992), contaminated soils are believed to be RCRA characteristic waste. Alternative SO2 and SO1, which leave hazardous solid waste in place, however, do not comply with closure requirements that call for removal of all RCRA contaminants or a RCRA Subtitle C compliant cap under Vermont Hazardous Waste Management Regulations and RCRA.

Alternative SO3 involves construction activities; however, the soil removal areas are relatively small and do not exceed one acre in size, exempting the work from state and federal stormwater management requirements. Waste characterization and end facility approval will be performed prior to transport and disposal of the impacted soil off-site. The EPA Off-site Coordinator will be consulted to determine if the treatment, storage, and disposal facility (TSDF) is in compliance and is capable of accepting the contaminated soil. The construction and transportation of the material will be performed during normal business hours to keep noise levels within the acceptable range. Work will be performed to minimize airborne dust. If any dewatering of excavated soils occurs resulting in any discharge to the stream, state and federal water quality protection standards will be met. Measures will be implemented to minimize airborne dust.

Groundwater

GW1 involves no action and, therefore, triggers no ARARs. Alternatives GW2 and GW3, which do not involve any active remediation of groundwater, trigger no significant action specific ARARs. Any contaminated soil removed for the installation of new injection or monitoring wells with Alternatives GW2, GW3 or GW5 will be disposed of in compliance with Vermont Hazardous Waste Management Regulations and RCRA regulations. Work in these alternatives will be performed to minimize airborne dust.

Alternative GW5 is the only alternative for groundwater involving active treatment of groundwater. While this alternative triggers more action-specific ARARs than the other alternatives, its effectiveness at removing the impacted media and reducing the timeframe in which the PRGs and RAOs are achieved results in significant benefits. The *in situ* treatment through underground injections in Alternative GW5 will be completed in compliance with state and federal underground injection control regulations, and RCRA regulations specifically for chemical, physical and biological treatment.

Vapor

Alternative VM1 requires no action and therefore triggers no action-specific ARARs. Alternatives VM2 and VM3 require, at minimum, the continued operation of the existing sump pump, passive ventilation and sump water discharge system, and therefore trigger the requirement to treat sump pump water prior to discharge under 10 VSA Chapter 47, Water Pollution Control, Section 1259(a). VTDEC requires treatment to primary drinking water levels under Environmental Protection Rule Chapter 12 before discharge. Alternatives VM2 and VM3 will include the construction of a GAC or other treatment system to meet this ARAR.

6.2.3 Long-Term Effectiveness and Permanence

Soil

Alternative SO1 provides the least long-term effectiveness and permanence of the soil alternatives because no actions would be taken to control exposure over time or to permanently reduce the level of contaminants in the source area over the long term. Because SO2 requires a fence to be constructed around the impacted soil area to limit access to the area, it provides greater long-term protection, but a fence would be susceptible to vandalism, damage, and trespass, and would have to be maintained over time. Under Alternatives SO1 or SO2, little degradation or chemical reduction from the very toxic hexavalent chromium to the less toxic trivalent chromium would be expected over time in the former lagoon area. While natural degradation processes would likely eventually decrease the residual VOC mass and subsequently the amount of VOCs leaching into groundwater from the VOC impacted soil, the residual risk that remains would be significant over time.

Alternative SO3 provides excellent long-term effectiveness and permanence and is the most effective of the three retained alternatives. Alternative SO3 removes the impacted soil and disposes of the material at an approved off-site facility. There is no identified residual source beyond the impacted soil; therefore, once the soil is removed, the replacement fill is not expected to become impacted again. In addition, the facility operations that originally impacted the soil are no longer in place.

Groundwater

Alternatives GW1, GW2 and GW3 would provide the least long-term effectiveness and permanence of the soil alternatives. They leave the most residual risk because no actions would be taken to permanently reduce the level of contaminants in the plume in the long term. While natural degradation processes would likely eventually decrease the residual VOC mass, the risk that remains would be very significant over the long-term. Alternatives GW2 and GW3 are more effective than GW1 due to institutional controls that will prevent the withdrawal of groundwater, control excavation in soils saturated with contaminated groundwater, and reclassify groundwater to Class IV (non-potable).

Alternative GW5 would provide the highest level of long-term effectiveness and permanence because it relies on destructive *in situ* treatment to address the elevated contaminant concentrations. Reducing the highest concentrations is expected to reduce the treatment and monitoring time significantly with less potential rebound than other technologies.

If successfully implemented, Alternative GW5 would result in improved levels of dissolution of suspected NAPL blobs and ganglia to groundwater as well as the back-diffusion from the fine-grained silt. Alternative GW5 does not include permanent appurtenances, but rather is implemented in shorter duration injection events that allow the *in situ* technologies to operate in the subsurface over an extended period of time. *In situ* treatment under Alternative GW5 would accelerate the contaminant degradation processes and result in achieving PRGs more quickly than under the remaining alternatives.

Vapor

Alternative VM1 does not meet this criterion. Through the implementation of an institutional control, Alternative VM2 ensures the continued operation and maintenance of the existing vapor mitigation system at 830 South Brownell Road to help protect the residents in that home from harmful vapors until such time as groundwater concentrations are reduced and no longer pose a potential inhalation risk. Alternative VM3 provides the best long-term effectiveness and permanence because it will require the improvement of the existing vapor mitigation system, as determined necessary based on additional data sampling and risk assessment. Insufficient data currently exist to conclude that the existing vapor mitigation system at 830 South Brownell Road sufficiently mitigates vapor intrusion risk from vapors emanating from the groundwater under the basement. Alternative VM3 also includes a contingency to address additional homes surrounding the groundwater plume if future data and risk assessment determine it is necessary to address excessive risk.

6.2.4 Reduction of Toxicity, Mobility, or Volume through Treatment

Soil

Alternatives SO1 and SO2 provide no active treatment for soil and, therefore, would not satisfy CERCLA's statutory preference for treatment. Alternative SO3 will remove all of the accessible impacted soil from the Study Area. The alternative includes excavation of impacted soil with off-site disposal at an appropriate facility. By removing the soil, the toxicity, mobility, and volume of the material is nearly eliminated and the PRGs and RAOs will be achieved.

Groundwater

Alternatives GW1, GW2 and GW3 provide no active treatment for groundwater and, therefore, would not satisfy CERCLA's statutory preference for treatment. Natural processes may gradually degrade and decrease the contaminant mass over the long term. Lack of an MNA program in Alternatives GW1 and GW2 would prevent any determination of cleanup progress, although limited monitoring along the Class IV/Site boundary with GW2 would establish whether the plume in migrating into new areas. The MNA and long-term monitoring included in Alternative GW3 allows for the determination of cleanup progress and changes in the contaminant plume; however, there is still no active treatment involved.

Alternative GW5, the only alternative with active treatment, also includes the institutional controls and the MNA program included in Alternative GW3. Alternative GW5 includes the destructive *in situ* treatments that destroy the contaminants. The *in situ* treatments will either oxidize or reductively dechlorinate the chlorinated VOCs in the groundwater. Treatment residuals or daughter products associated with Alternative GW5 include primarily non-hazardous and non-toxic substances resulting from degradation of VOCs such as ethene, ethane, oxygen, carbon dioxide, hydrogen, and chlorides, and iron complexes (oxides, carbonates, sulfides). However, in some cases, vinyl chloride, which is a highly toxic substance, is a daughter product of the target contaminants, and may be produced as a result of treatment. Once the compounds are reduced to their ultimate daughter products they are permanently destroyed and the contaminant mass is reduced. Rebound can occur by ways of back-diffusion from the fine-grained silt matrix and dissolution from NAPL blobs and ganglia that may exist. By using a polishing step following the initial treatment of the hotspots, the rebounding will be minimized and the toxicity, mobility, and volume and mass will be further reduced.

Long-term monitoring of groundwater through an MNA program would provide the necessary data to determine the effectiveness and progress of the natural attenuation process in the remainder of the plume.

Vapor

Alternative VM1 does not meet this criterion. Alternatives VM2 and VM3 use engineering controls (rather than treatment) to reduce the toxicity, mobility and volume of vapors into 830 South Brownell Road. Per the requirement of an action-specific ARAR, however, the Vermont's Vermont Pollution Control, these alternatives do require treatment of groundwater collected from the sump in the basement at 830 South Brownell Road prior to discharge to groundwater.

6.2.5 Short-Term Effectiveness

Soil

No active remedial actions are associated with soil Alternatives SO1 and SO2; therefore, there would be no short-term risks to the community, site workers, or the environment from implementation of these alternatives.

Alternative SO3 will be effective in the short-term. Remedial actions for the soil alternative would include typical excavation and transportation of the soil removed to an off-site facility. Measures will be taken to mitigate dust emissions and the work will be performed during the typical working hours so noise and traffic issues will not be significant enough to require a mitigation plan. The work areas include residential and commercial/industrial areas with roadways that are in good condition and can handle the traffic that is anticipated for the alternative. The total estimated excavation volume is approximately 637 CY and would require approximately 21 truckloads over the period of excavation. The amount of replacement fill will be similar and could be delivered on the return trips to the Study Area. Exposure and safety risks to workers are easily controlled through engineered controls and personal protective equipment include typical OSHA Level D protection including gloves, safety glasses, and respirator cartridges, if necessary. Environmental monitoring will be performed to determine the appropriate level of protection. Erosion control, traffic control, loading plans, and proper off-site disposal of the material will reduce the short-term impacts to the environment.

Alternative SO1 would take no time to implement since it requires no action. Alternative SO2 would take under one year to implement. Both Alternative SO1 and SO2 would not achieve PRGs and RAOs. Alternative SO3 would take under one year to implement since it would only require a relatively small excavation and off-site disposal and would achieve the soil RAOs immediately following implementation.

Although, Alternatives SO1 and SO2 have a slightly better short-term effectiveness than Alternative SO3, only Alternative SO3 includes and active technology to treat or remove the material. There are no factors in short-term effectiveness of Alternative SO3 that would preclude the alternative from being chosen.

Groundwater

No active remedial actions are associated with groundwater Alternatives GW1, GW2, and GW3; therefore, there would be no short-term risks to the community, site workers, or the environment from implementation of these alternatives. Based on an analytical model (REMChlor) of groundwater contaminant transport and degradation. The REMChlor modeling assumptions are included in Appendix E. Alternatives GW1, GW2, and GW3 would not achieve groundwater PRGs for over 115 to 250 years.

Alternative GW5 is an active treatment alternative that would take place *in situ* in a heavily developed residential and commercial/industrial area. The pressurized injection of treatment reagents or amendments creates a risk to site workers from exposure to those substances. However, the risk of harm to the on-site worker can be mitigated through implementation of proper engineering controls and health and safety procedures. Administrative and engineering controls, and communication with local officials would ensure the safe transportation, storage, and injection of these materials and would be included as part of the remedial design and project planning. The potential risks to on-site workers and the community are expected to be minimal with proper controls.

Modification to the subsurface geochemistry would take place in Alternative GW5. However, once *in situ* treatment stops, the subsurface conditions are expected to gradually return to ambient conditions.

Alternatives GW1 and GW2 would take no time or minimal time to implement since they either require no action or only administrative action, but would not achieve RAOs for over 115 to 250 years. Alternative GW3 would implement MNA and long-term monitoring in addition to the institutional controls and would not achieve RAOs any faster than Alternative GW1 or GW2.

Alternative GW5 would take approximately 2 to 3 years to design and implement; however, each injection event is expected to be less than one month in length. By treating the highest concentrations only (greater than 50,000 µg/L) with ISCO which is expected to remove approximately 90-percent of that mass and subsequent ISB treatment, the time estimated to achieve RAOs is reduced to 50 to 75 years (based on analytical modeling).

Vapor

There are no short-term risks to the community, site-workers, or the environment from implementation of Alternatives VM1, VM2, or VM3.

Alternative VM2 will not take long to implement; the existing sump pump, passive venting and discharge system is in place, and all that is necessary is the construction of a GAC treatment shed for the discharge. Alternative VM3 will take longer to achieve than Alternative VM2 due to the need to collect additional data and perform a risk analysis, and contingent upon the results, augment or replace the existing system with an active vapor mitigation control system or other engineering control. Alternative VM3, however, is the only alternative that will fully address vapor inhalation at 830 South Brownell Road and at other homes in the vicinity of the plume in the Study Area, as deemed necessary based on risk.

6.2.6 Implementability

Soil

Each of the soil alternatives are easy to implement. Alternative SO1 requires no action and is, therefore, the easiest; however, Alternatives SO2 and SO3 require actions that are included in the general construction field. Fence installation and contaminated soil removal contractors are readily available and do not require specialized equipment or materials. The location of the excavation, near the building, add slightly to the complexity of Alternative SO3 but with proper engineering and design, these complexities can be managed without sacrificing the impacted soil volume.

Implementation of any of the soil alternatives would not inhibit or preclude performance of additional remedial actions, although it is not anticipated. The subsurface geochemistry and the physical characteristics would remain unaltered.

Technologies to be used with each of the soil alternatives have been implemented and demonstrated to be effective at other sites with similar contamination. There is no long-term monitoring required following implementation of each of the soil alternatives

Groundwater

Each of the groundwater alternatives are easy to implement. Alternative GW1 requires no action and is, therefore, the easiest. Alternative GW2 requires only administrative actions to enact institutional controls. Alternative GW3 requires a robust long-term monitoring plan; however, the locations have been monitored historically and are not likely to require significant effort beyond typical groundwater sampling activities. Alternative GW5 is the most difficult to implement because it requires several phases, designs, and mobilizations but the technology has been implemented and demonstrated to be effective at other Superfund sites with similar contamination and several contractors capable of performing the work are readily available.

Monitoring requirements for all groundwater alternatives are easily implemented. While the long-term monitoring and performance monitoring programs will be robust, there is no added difficulty in implementing them. The monitoring locations currently exist and are in good condition and access to the majority of the locations is uninhibited. Communication with stakeholders would occur during monitoring and other planned activities to the extent appropriate.

Once the *in situ* treatment element of Alternative GW5 is completed, no additional operations or maintenance would be required, but continued monitoring of the aquifer would be needed.

Each groundwater alternative includes institutional controls, which are relatively easy to implement. The natural attenuation process requires no implementation beyond long-term monitoring and reporting. Typically, there are administrative implementability issues associated with institutional controls due the requirement of obtaining third parties' signatures. However, none of these issues are significant and they would not prevent implementation of these actions. Implementation of the town zoning ordinances instead of deed restrictions would simplify the institutional control process even more.

Additional actions can be implemented under all alternatives because contaminants, at varying degrees remain in the aquifer for extended periods. Implementation of Alternatives GW1, GW2, and GW3 would not inhibit or preclude performance of additional remedial actions, as the subsurface geochemistry would remain unaltered. Alternative GW5 may cause temporary alterations in subsurface geochemistry that may deter additional remedial actions until subsurface conditions return to ambient conditions but this is expected and will be developed into the treatment train.

Technologies to be used with each of the groundwater alternatives have been implemented and demonstrated to be effective at other sites with similar contamination.

Vapor

Alternative VM1 is easy to implement as it requires no action other than Five-Year Reviews of the remedy. The system requirements under Alternatives VM2 and VM3 are easy to implement; contractors capable of designing and installing a sump discharge treatment system (e.g., running the discharge through GAC in a treatment shed on-site), and/or active venting or vapor barrier mitigation measures, if deemed necessary, are readily available. Institutional controls, required under Alternatives VM2 and VM3 are relatively easy to implement.

6.2.7 Cost

Detailed breakdowns of capital costs, operations and maintenance costs, and present value analyses for each groundwater alternative are provided in Appendix D and summarized in Table 6-1. Total present value costs for each alternative are also shown on Table 6-1.

Soil Alternative SO3 is the most expensive of the three alternatives; however, it is the only alternative that includes active remediation of the impacted soil. Alternative GW5 is also the most expensive alternative of the four due to the active remediation involved. Because of the size of the plume, additional options for the GW5 cost estimation were developed. The costs of the alternative vary greatly depending on the area of the treatment and the type of *in situ* treatment performed. Therefore, Table 6-2 lists several options with varying costs. Similarly, Alternative VM3 is the most expensive alternative of the three vapor mitigation remedies examined.

6.2.8 Green and Sustainable Technology Evaluation

The EPA Region 1's *Clean and Greener Policy for Contaminated Sites* (EPA, 2012) advocates strategies and practices to reduce the environmental footprint during remediation and restoration actions, to the extent feasible. This policy supports green remediation goals, where practical and appropriate, that include minimizing total energy use, minimizing air emissions and greenhouse gases, minimize water use and impacts to water resources, reduce, reuse and recycle materials and wastes, and support sustainable reuse of remediated land. As part of the evaluation of short-term effectiveness, including the potential environmental impacts of the remedial actions, sustainability aspects of the alternatives were considered.

Of the active soil alternatives, Alternative SO3 would use a relatively high amount of energy because of the number of truckloads required to transport the material to its off-site disposal facility and the heavy equipment required to remove the material from the ground and restore the properties. However, once the alternative is implemented, little to no energy will be used since there will be no on-going parts of the remedy (e.g., long-term monitoring). In order to control the amount of energy used and emissions emitted, local contractors and fuel-efficient trucks and equipment as well as disposal facilities that are relatively close to the Study Area will be sought. Additional sustainable measures will be evaluated using rail cars to transport waste material. No idling policies will be also instituted on-site.

Of the active groundwater alternatives, Alternative GW5 would use a relatively low amount of energy because the treatment processes do not require any additional energy. Once the reagents or amendments have been injected into the subsurface, the degradation of VOCs would occur through *in situ* chemical and/or biological processes. Energy would also be used during PDIs, performance of the injections (diesel or propane powered rigs), and transportation of materials and supplies, but total energy used would be low relative to that of other technologies. Other sustainable measures to be evaluated include the lack of permanent structures using electricity; the use of food-grade additives; and smaller drill rigs.

Of the vapor mitigation alternatives, Alternative VM3 has the greatest potential to require the most ongoing use of electricity for the operation of active venting system, and the sump pump discharge and treatment system. The wattage expected to run these systems (sump pumps), however, is relatively low, within the 500 watt range. Non-electrical engineering control options will be considered prior to implementation. VM3 is the only alternative that fully addresses vapor inhalation risk.

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TABLES

Table 1-1
Summary of Cancer Risks and Noncancer Hazard Indices
Commerce Street Plume Superfund Site
Williston, Vermont

Media	Exposure Area	Scenario Timeframe	Receptor	RME								CTE		
				CR>1E-04 or HI>1	Total CR[a]	Major Contributors to Total CR (Individual CR >1E-06)	Individual COPC CR	Total NC HI	Organ-Specific HI Above 1.0	Major Contributors to Total HI (Individual HQ > 1.0)	Individual COPC HQ	CR>1E-04 or HI>1	Total CR	Total NC HI
Sediment	Sediment unnamed stream	Current	Adult River Recreational Visitor	No	5.6E-07	---	---	0.0043	---	---	---	---	---	---
			Child River Recreational Visitor	No	5.1E-06	Dibenz(a,h)anthracene	1.4E-06	0.041	---	---	---	---	---	---
						Chromium	2.0E-06							
Surface Water	Surface Water Unnamed Stream	Current	Adult River Recreational Visitor	No	8.5E-07	---	---	0.0075	---	---	---	---	---	---
			Child River Recreational Visitor	No	8.6E-06	Vinyl chloride	8.5E-06	0.018	---	---	---	---	---	---
Groundwater	Shallow Groundater in Construction Trenches	Current	Construction Worker	Yes	2.0E-06	---	---	3.0	Immune System	Trichloroethylene	2.1	No	4.1E-07	0.59
	Site	Future	Age-Adjusted Resident	Yes	9.2E-02	1,2-Dichloroethane	6.5E-06	NE	---	---		Yes	3.6E-02	NE
						Methylene chloride	9.2E-04							
						Trichloroethylene	8.9E-02							
						Vinyl Chloride	1.9E-04							
						Arsenic	1.8E-04							
						Chromium	1.1E-03							
			Adult Resident	Yes	NE	---		2778	Liver	Methylene chloride	3.5	Yes	---	2478
										Vinyl Chloride	0.057			
									Kidney	cis-1,2-Dichloroethylene	4.9			
										1,2-Dichloroethylene	0.075			
									Immune System	Trichloroethylene	2765			
									Thyroid	Cobalt	0.96			
			Child Resident	Yes	NE	---		3181	Liver	Methylene chloride	5.5	Yes	---	2687
										Vinyl Chloride	0.082			
									Kidney	cis-1,2-Dichloroethylene	8.1			
										1,2-Dichloroethane	0.079			
									Immune System	Trichloroethylene	3159			
									Skin	Arsenic	1.5			
									Thyroid	Cobalt	1.6			
									Gastrointestinal	Iron	1.3			

Notes:
[a] Note that for conservatism, total chromium results are based on hexavalent chromium toxicity criteria.

COPC	Contaminant of Potential Concern
CR	Cancer Risk
CTE	Central Tendency Exposure
HI	Hazard Index
HQ	Hazard Quotient
NC	Noncancer
NE	Not Evaluated
RME	Reasonable Maximum Exposure
(dark gray shading)	Total Cancer Risks are above 1E-04 or Hazard Indices above 1.
(light blue shading)	Total Cancer Risks fall in the range of 1E-04 to 1E-06.

Table 2-1
Summary of Location-Specific ARARs
Commerce Street Plume Superfund Site
Williston, Vermont

REQUIREMENT	STATUS	REQUIREMENT SYNOPSIS
STATE ARARs and TO BE CONSIDERED GUIDANCES		
10 VSA Chapter 37, Vermont Wetlands Protection And Water Resources Management Act; Environmental Protection Rules, Chapter 30, Vermont Wetland Rules	Applicable	These standards establish criteria for delineating Class One and Class Two wetlands, which are considered significant wetlands, and sets forth allowed uses for these wetlands. Jurisdiction under the rules includes a 100-foot and 50-foot buffer zone to Class One and Class Two wetlands, respectively. The uses must not have undue adverse impacts on the significant functions of the wetland. Class Three wetlands are defined, but are not protected under these rules (they are addressed under Title 10 VSA Chapter 151, below). If any work occurs in wetlands or buffer zones, to be further delineated, it will comply with this ARAR.
10 VSA Chapter 151, Vermont's Land Use and Development Law (Act 250); Act 250 Rules (October 1, 2013)	Relevant and Appropriate	Issues to be addressed in assessing compliance with Act 250 include substantive environmental and facility siting requirements associated with: • any resulting undue water and air pollution, including construction-related dust and protection of headwaters (criterion 1) • compliance with all standards for disposal of wastes (criterion 1(B)); • impacts on floodways (criterion 1(D)); • impacts on streams (criterion 1(E)); • impact on state-regulated wetlands (Class One, Two, and Three); (criterion 1(G)); • any resulting undue erosion control or reduction in capacity of land to hold water (criterion 4); • impact on rare and natural areas, historic sites (criterion 8(A)); • impact on necessary wildlife habitat and endangered species (criterion 8(B)); • extraction of earth resources (criterion 9(D) and (E)); • energy conservation (criterion 9(F)); and • public investments (roads) (criterion 9(K)).
Vermont Historic Preservation Law, 22 VSA §§ 743(4), 761, 763, and 767.	Applicable	Places controls on actions conducted by the state that may impact historic, scientific, or archaeological sites and data.
Vermont ANR Guidance on Riparian Buffers (December 9, 2005)	To Be Considered	This guidance provides technical information on the functions and values of riparian buffers, as well as describing acceptable activities within buffer zones. It recommends the establishment of 100 foot buffer zones to streams under circumstances where there is an increased risk of erosion and/or potential for overland flow of pollutants. Where Class II wetlands are contiguous to a waterbody, buffer widths of greater than 50 feet may be recommended based on case-specific application of this Guidance. This Guidance will also be used to recommend buffers for Class III wetlands contiguous to waterbodies, as necessary to maintain the functions and values of the riparian area. This guidance will be a TBC if any work occurs in riparian buffer zones, as further delineated.
FEDERAL ARARs and TO BE CONSIDERED GUIDANCES		
National Historic Preservation Act (NHPA), Section 106, 16 USC 470 *et seq*., 36 CFR Part 800	Applicable	Section 106 of the NHPA of 1966 requires EPA to take into account the effect of all of its actions on historic properties. In consultation with the State Historic Preservation Officer (SHPO) EPA is to identify potential adverse effects on historic properties and seek ways to avoid, minimize or mitigate any such effects on historic properties.

Table 2-2
Summary of Chemical-Specific ARARs
Commerce Street Plume Superfund Site
Williston, Vermont

REQUIREMENT	STATUS	REQUIREMENT SYNOPSIS
STATE ARARs		
10 VSA Chapter 48, §1390-1394, Groundwater Protection; Environmental Protection Rule, Chapter 12, Groundwater Protection Rule and Strategy, sections 12-702 and Table 1 of Appendix One.	Applicable	Establishes groundwater classes and standards for groundwater quality. Management criteria for each groundwater class as well as primary standards for groundwater protection are established. Promulgated Groundwater Enforcement Standards are based on promulgated federal Maximum Contaminant Levels (MCL), and VT Department of Health Drinking Water Health Advisories if no federal MCL was adopted. Promulgated Groundwater Enforcement Standards are applicable, but Preventative Action Limits are not an ARAR. Will be used as cleanup standard if more stringent than federal MCL.
Vermont Department of Health Drinking Water Guidance (March 2015).	To Be Considered	Lists the Vermont Health Advisories (VHAs) for chemicals of concern in drinking water. VHAs are numeric guidelines researched and derived by the Health Department for chemicals in drinking water that do not have a federal MCL.
Vermont Department of Environmental Conservation Investigation and Remediation of Contaminated Properties Procedures (IRCPP), April 2012	To Be Considered	ICRPP includes numeric, health based soil and vapor remedial chemical concentration screening values for soil and vapor intrusion.
FEDERAL ARARs		
Federal Safe Drinking Water Act - Maximum Contaminant Levels (MCLs), National Primary Drinking Water Regulations, 40 CFR 141 Subparts B and G	Relevant and appropriate	These standards protect drinking water quality by limiting the levels of specific contaminants that can adversely affect public health and are known or anticipated to occur in public water systems. MCLs are the highest level of a contaminant that is allowed in drinking water and will be used as cleanup standards unless Vermont's Groundwater Enforcement Standard is more stringent.
Federal Safe Drinking Water Act - Maximum Contaminant Level Goals (MCLGs), National Primary Drinking Water Regulations, 40 CFR 141 Subpart F	Non-zero MCLGs are relevant and appropriate	MCLGs are the level of a contaminant in drinking water below which there is no known or expected risk to health. MCLs are set as close to MCLGs as feasible using the best available treatment technology and taking cost into consideration. Non-zero MCLGs will be used as cleanup standards unless Vermont's Groundwater Enforcement Standard is more stringent.
Oral Slope Factor (SF) for Cancer Ingestion Effects, EPA Integrated Risk Information System (IRIS)	To Be Considered	SFs are used to compute the incremental cancer risk from exposure to contaminants and represent the most up-to-date information on cancer risk from IRIS. An upper bound, approximating a 95% confidence limit, on the increased cancer risk from a lifetime exposure to an agent. Used for EPA risk assessments.
Inhalation Unit Risk (IUR) for Inhalation Cancer Effects, EPA IRIS	To Be Considered	IURs are used to compute the incremental cancer risk from exposure to contaminants and represent the most up-to-date information on cancer risk from IRIS. The upper bound excess lifetime cancer risk estimated to result from continuous exposure to an agent at a concentration of 1 $\mu g/m^3$ in air. Used for EPA risk assessments.
Oral Reference Dose (RfD) for Non-Cancer Ingestion Effects, EPA IRIS	To Be Considered	RfDs are used to compute the incremental non-cancer risk from exposure to contaminants and represent the most up-to-date information on cancer risk from IRIS. An estimate (with an uncertainty spanning perhaps an order of magnitude) of a daily oral exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. Used for EPA risk assessments.
Inhalation Reference Concentration (RfC) for Inhalation Non-Cancer Effects, EPA IRIS	To Be Considered	RfCs are used to compute the incremental non-cancer risk from exposure to contaminants and represent the most up-to-date information on cancer risk from IRIS. An estimate (with an uncertainty spanning perhaps an order of magnitude) of a continuous inhalation exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. Used for EPA risk assessments.
Health Advisories (EPA Office of Drinking Water)	To Be Considered	Health Advisories include estimates of risk due to consumption of contaminated drinking water; they consider non-carcinogenic effects only. To be considered in developing cleanup and monitoring standards in absence of other standards.
Guidelines for Carcinogen Risk Assessment EPA/630/P-03/001F (March 2005)	To Be Considered	These guidelines provide guidance on conducting risk assessments involving carcinogens.
Supplemental Guidance for Assessing Susceptibility from Early-Life Exposure to Carcinogens EPA/630/R-03/003F (March 2005)	To Be Considered	These guidelines provide guidance on conducting risk assessments involving carcinogens in children.
Technical Guide for Assessing and Mitigating the Vapor Intrusion Pathway from Subsurface Vapor Sources to Indoor Air, OSWER Publication 9200.2-154 (June 2015)	To Be Considered	This guidance will be followed to analyze and address any potential vapor intrusion at the Site.

Table 2-3
Summary of Action-Specific ARARs
Commerce Street Plume Superfund Site
Williston, Vermont

REQUIREMENT	STATUS	REQUIREMENT SYNOPSIS
STATE ARARs		
10 VSA Chapter 47, Vermont Water Pollution Control; Environmental Protection Rule, Chapter 29a, Vermont Water Quality Standards in Appendix C	Applicable	Establishes water quality standards for surface waters and applies to alternatives that call for monitoring surface water bodies on and off of the Site.
Environmental Protection Rule, Chapter 13, Water Pollution Control Permit Regulations (Vermont National Pollutant Discharge Elimination System (NPDES) Regulations)	Applicable	The regulations stipulate requirements for discharges to surface waters, compliance with NPDES standards, and meeting stormwater management requirements. If there is a discharge to a stream this ARAR will be met.
10 VSA Chapter 23; Vermont Air Pollution Control Act; Environmental Protection Rule Chapter 5, Air Pollution Control Regulations, including 5-231(4) and 5-241(1) for dust.	Applicable	Establishes authority for a coordinated statewide program of air pollution prevention, abatement and control. Lists prohibited activities and regulatory requirements affecting air quality and establishes primary and secondary ambient air quality standards.
10 VSA Chapter 47, Water Pollution Control § 1259(a)	Applicable	VTDEC requirement to treatment to primary groundwater standards in Environmental Protection Rule 12 for discharge to a water of the state.
Environmental Protection Rule, Chapter 11, Underground Injection Control Regulations	Relevant and Appropriate	Substantive requirements for injection of substances into groundwater for *in situ* groundwater treatment.
10 VSA Chapter 159, Vermont Waste Management Act; Environmental Protection Rule, Chapter 7, Vermont Hazardous Waste Management Regulations, Subchapter 2, Identification and Listing of Hazardous Waste	Applicable	Establishes requirements for the identification of hazardous waste based on characteristics and listing. Incorporates requirements of the federal Resource Conservation and Recovery Act regulations, 40 CFR 261.
10 VSA Chapter 159, Vermont Waste Management Act; Environmental Protection Rule, Chapter 7, Vermont Hazardous Waste Management Regulations, Subchapter 3, Hazardous Waste Generator Standards	Applicable	Establishes requirements for generators of hazardous wastes. Incorporates requirements of the federal Resource Conservation and Recovery Act regulations, 40 CFR 262.
10 VSA Chapter 159, Vermont Waste Management Act; Environmental Protection Rule, Chapter 7, Vermont Hazardous Waste Management Regulations, Subchapter 5, Requirements for Hazardous Waste Storage, Treatment and Disposal Facilities.	Relevant and Appropriate	Establishes requirements for the design, construction, operation, and maintenance of hazardous waste treatment, storage, and disposal facilities. Incorporates requirements of the federal Resource Conservation and Recovery Act regulations, 40 CFR 264, including 40 CFR 264 Subpart G, Closure and Post-Closure.

Table 2-3
Summary of Action-Specific ARARs
Commerce Street Plume Superfund Site
Williston, Vermont

REQUIREMENT	STATUS	REQUIREMENT SYNOPSIS
FEDERAL ARARs		
Resource Conservation and Recovery Act (RCRA), 42 U.S.C. §§ 6901, et seq., RCRA Regulations, 40 CFR Part 261, 262, 264, including 40 CFR 264 Subpart G Closure and Post Closure.	Applicable	Alternatives that result in the generation of hazardous waste will need to comply with these requirements. Vermont is delegated to implement these regulations through its Hazardous Waste Management Regulations (see above).
RCRA (40 CFR 265, Subpart Q - Chemical, Physical and Biological Treatment	Relevant and Appropriate	Standards apply to facilities where hazardous wastes are treated by chemical, physical, or biological methods.
Clean Water Act, Section 402 - National Pollution Discharge Elimination System (NPDES), 40 CFR 122-125, 131	Applicable	The CWA contains discharge limitation, monitoring requirements, and best management practices (BMPs) for discharges into navigable waters, i.e. surface waters. The regulations would be applicable to remedial strategies involving discharge to surface waters. If there is a discharge to a stream this ARAR will be met.
Clean Water Act, Section 304(a), National Recommended Water Quality Criteria (NRWQC), 40 CFR 131.11	Applicable	NRWQC are provided by EPA for chemicals for the protection of human health and the protection of aquatic life. If there is a discharge to a stream this ARAR will be met.
Underground Injection Control Program, 40 CFR 144, 146, 147.	Relevant and Appropriate	Substantive requirements for injection of substances into groundwater for *in situ* groundwater treatment. Vermont is delegated to implement these regulations through its Underground Injection Control regulations (see above).
Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites. Final OSWER Directive, Publication EPA/540/R-99/009. April 1999.	To Be Considered	Includes procedural requirements for the use of monitored natural attenuation as a remedial component.
Performance Monitoring of MNA Remedies for VOCs in Ground Water, EPA/600/R-04/027, April 2004.	To Be Considered	Includes procedural requirements for the use of monitored natural attenuation of VOCs as a remedial component.
An Approach for Evaluating the Progress of Natural Attenuation, EPA 600/R-11/204, December 2011	To Be Considered	Includes procedural requirements for evaluation of attenuation under monitored natural attenuation remedy.

Table 2-4
Remedial Action Objectives
Commerce Street Plume Superfund Site
Williston, Vermont

Media	Area of Impact	Remedial Action Objectives: Human Health	Remedial Action Objectives: Ecological and Environmental Protection	Historic Preservation Considerations
Soil	96 Commerce Street	Prevent potential future residential exposure to contaminants in soil above background levels that would result in an excess cancer risk between 1×10^{-4} and 1×10^{-6} or a non-carcinogenic risk greater than a HI of 1.	None	None
Groundwater	Site Wide	Prevent ingestion and other household uses of groundwater containing levels of site-specific contamination in excess of federal MCLs, non-zero MCLGs, or the Primary Groundwater Quality Enforcement Standards of the Vermont Groundwater Rule and Strategy, Environmental Protection Rules, Chapter 12, whichever is lower or, in their absence, a level that is set at a non-cancer HQ of 1 or an excess cancer risk between 1×10^{-4} and 1×10^{-6}.	Minimize the migration of contaminants to the unnamed stream and the wetlands at the confluence of the unnamed stream and Tributary #4 to Muddy Brook.	None
		Prevent construction worker exposure to shallow groundwater and volatiles in trench air at concentrations that would result in an excess cancer risk between 1×10^{-4} and 1×10^{-6} or a non-carcinogenic risk greater than a HI of 1.		
		Minimize the migration of contaminants beyond the Class IV/Site boundary.		
Indoor Air	Site Wide	Prevent inhalation of contaminants from vapors emanating from contaminated groundwater that would result in an excess cancer risk between 1×10^{-4} and 1×10^{-6} or a non-carcinogenic risk greater than a HI of 1.	None	None

Table 2-5
Groundwater Residential Preliminary Remediation Goals
Commerce Street Plume Superfund Site
Williston, Vermont

Analyte	Background Conc.	Risk-Based PRGs[1]				ARAR-based PRGs	Recommended Residential Groundwater PRGs[2]	
	(µg/L)	Res. 1 x 10^{-6} (µg/L)	Res. 1 x 10^{-5} (µg/L)	Res. 1 x 10^{-4} (µg/L)	Res. HQ=1 (µg/L)	MCL	Conc. (µg/L)	Basis
VOCs								
1,2-Dichloroethane	na	0.17	1.7	17	13	5	**5**	**ARAR**
cis-1,2-Dichloroethylene	na	na	na	na	37	70	**70**	**ARAR**
Methylene chloride	na	12.5	125	1250	110	5	**5**	**ARAR**
Tetrachloroethylene	na	na	na	na	na	5	**5**	**ARAR**
Trichloroethylene	na	0.6	6	60	2.8	5	**5**	**ARAR**
Vinyl chloride	na	0.02	0.2	2	45	2	**2**	**ARAR**
Metals								
Arsenic	na	0.052	0.52	5.2	6	10	**10**	**ARAR**
Total Chromium[3]	na	0.042	0.42	4.2	51	100	**100**	**ARAR**
Cobalt	na	na	na	na	6	na	**6**	**Risk-based**
Iron	na	na	na	na	14,000	na	**14,000**	**Risk-based**

Notes:

1. Risk-based PRG values development presented in FS Appendix A.
2. ARAR selected as PRG, if available. If no ARAR is available, the lower of the PRG based on 1 x 10^{-6} cancer risk or HQ=1, but not less than background, is selected as the PRG.
3. Samples analyzed for total chromium. Limited speciation data detected hexavalent chromium at former Mitec Systems property.

Res. - residential
ARAR - Applicable or Relevant and Appropriate Requirement
na - not applicable

Table 2-6
Groundwater Construction Worker Preliminary Remediation Goals
Commerce Street Plume Superfund Site
Williston, Vermont

Analyte	Background Conc.	Risk-Based PRGs[1]				ARAR-based PRGs	Recommended Construction Worker Groundwater PRGs[2]	
	(μg/L)	CW 1×10^{-6} (μg/L)	CW 1×10^{-5} (μg/L)	CW 1×10^{-4} (μg/L)	CW HQ=1 (μg/L)	MCL	Conc. (μg/L)	Basis
VOCs								
Trichloroethylene	na	13.5	135	1,350	2.3	5	**5**	**ARAR**

Notes:
1. Risk-based PRG values development presented in FS Appendix A.
2. ARAR selected as PRG, if available. If no ARAR is available, the lower of the PRG based on 1×10^{-6} cancer risk or HQ=1, but not less than background, is selected as the PRG.

CW - construction worker
ARAR - Applicable or Relevant and Appropriate Requirement
na - not applicable

Table 2-7
Soil Residential Preliminary Remediation Goals
Commerce Street Plume Superfund Site
Williston, Vermont

Analyte	Background Conc.[1]	Risk-Based PRGs[1]				ARAR-based PRGs	Recommended Residential Soil PRGs[2]	
	Soil (mg/Kg)	Res. 1 x 10^{-6} (mg/Kg)	Res. 1 x 10^{-5} (mg/Kg)	Res. 1 x 10^{-4} (mg/Kg)	Res. HQ=1 (mg/Kg)		Conc. (mg/Kg)	Basis
SVOCs								
cPAHs								
Benzo(a)anthracene	na	0.15	1.5	15	na	na	**0.15**	**Risk-based**
Benzo(a)pyrene	na	0.015	0.15	1.5	na	na	**0.015**	**Risk-based**
Benzo(b)fluoranthene	na	0.15	1.5	15	na	na	**0.15**	**Risk-based**
Metals								
Hexavalent Chromium	na	0.30	3.0	30	234	na	**0.3**	**Risk-based**
Arsenic	na	0.67	6.7	67	34.4	na	**0.67**	**Risk-based**

Notes:

1. Risk-based PRG values development presented in FS Appendix B.

2. ARAR selected as PRG, if available. If no ARAR is available, the lower of the PRG based on 1 x 10^{-6} cancer risk or HQ=1, but not less than background, is selected as the PRG.

Res. - residential

ARAR - Applicable or Relevant and Appropriate Requirement

na - not applicable

Table 2-8
Vapor Mitigation Preliminary Remediation Goals
Commerce Street Plume Superfund Site
Williston, Vermont

Analyte	Background Conc.	Risk-Based PRGs[1]				ARAR-based PRGs	Recommended Residential Vapor PRGs[2]	
	(µg/L)	Res. 1×10^{-6} (µg/L)	Res. 1×10^{-5} (µg/L)	Res. 1×10^{-4} (µg/L)	Res. HQ=1 (µg/L)		Conc. (µg/L)	Basis
VOCs								
Trichloroethylene	na	0.0018	0.018	0.18	0.0052	na	**0.0052**	**Risk-based**

Notes:

1. Risk-based PRG values development presented in FS Appendix C.
2. ARAR selected as PRG, if available. If no ARAR is available, the lower of the PRG based on 1×10^{-6} cancer risk or HQ=1, but not less than background, is selected as the PRG.

Res. - residential
ARAR - Applicable or Relevant and Appropriate Requirement
na - not applicable

Table 2-9
Estimated Areas and Volumes of Groundwater and Soil
Commerce Street Plume Superfund Site
Williston, Vermont

Overburden Groundwater					
	Average Thickness (ft)	**Area (ft^2)**	**Area (acres)**	**Volume (ft^3)**	**Volume (gal)**
Shallow	15	383,215	8.8	5,748,222	42,999,690
Intermediate	10	3,261,029	74.9	32,610,289	243,941,919
Deep	10	2,113,272	48.5	21,132,721	158,083,742
Soil					
	Average Thickness (ft)	**Length (ft)**	**Width (ft)**	**Volume (ft^3)**	**Volume (yd^3)**
96 Commerce Street	4.0	85.0	50.0	17,000	630

Notes:
1. Soil and groundwater depth and volume values calculated with ArcGIS and include approximately 10% factor of safety.

Table 3-1
Applicable General Response Actions
Commerce Street Plume Superfund Site
Williston, Vermont

General Response Action	Soil	Groundwater	Indoor Air
No-Action	x	x	x
Limited Action	x	x	x
Containment	x	x	x
Removal	x		
Collection, Treatment and Discharge		x	x
In Situ Treatment	x	x	
Ex Situ Treatment	x	x	

Notes:

"x" indicates that the General Technology is applicable to the media listed and will be selected for alternative screening.

Table 3-2
Remedial Technology Screening for Impacted Soil
Commerce Street Plume Superfund Site
Williston, Vermont

General Response Action	Remedial Technology Type	Process Option	Process Option Description	Effectiveness	Implementability	Relative Cost	Retained for Further Consideration	Screening Comments
No Action	No Action	Not applicable	No active source remediation conducted. No monitoring conducted.	Low effectiveness. The lack of action will not achieve RAOs.	Easily implemented.	Capital Costs: N/A O&M Costs: N/A	Retained	Baseline, as required by the NCP.
Limited Action	Institutional Controls	Deed Restrictions, Land Use Restrictions, Town Ordinances	No active remedial processes will be taken as part of this process option to address the contamination. These controls can include deed restrictions preventing certain activities on designated properties, land use restrictions, or Town ordinances that prevent certain activities within a designated area. May also be used to eliminate ability to install groundwater wells or require treatment of any groundwater recovered within the site boundaries.	Medium effectiveness. Frequently a component of a remedial alternative. Effective at minimizing risks to human health. Control areas are scalable with contaminated areas/volumes. Effective only if implemented, monitored, and enforced.	Administrative implementation is possible, but will require coordination between Local, State and Federal officials, and property owners. Must be monitored and enforced after implementation.	Capital Costs: Low O&M Costs: Low	Potentially applicable. Retained.	
	Engineered Controls	Fencing	A fence is installed around all areas that show impacts from contamination. This process will restrict access to the impacted soils and activities that would increase the likelihood of contact with contaminated media.	Low effectiveness. The lack of action will not achieve RAOs.	Easily implemented.	Capital Costs: Low O&M Costs: Low	Retained	
Containment	Capping	Single Layer Cap	Construct an impermeable or semi-permeable cap to minimize exposure on the surface, prevent or limit vertical infiltration of water, contain contamination, and create a usable land surface.	This technology may be able to achieve RAOs. This process option has been well demonstrated. Potential impacts to workers during construction. May have potential impacts from new asphalt pavement runoff to surface water, wetlands or stormwater quality.	Can be readily implemented at the Site. Services, materials, and contractors are readily available to perform installations.	Capital Costs: Low O&M Costs: Low	Retained	
		Multi-Layer Cap	Construct an impermeable or semi-permeable cap to minimize exposure on the surface, prevent or limit vertical infiltration of water, contain contamination, and create a usable land surface.	This technology may be able to achieve RAOs. This process option has been well demonstrated. Potential impacts to workers during construction. May have potential impacts from new asphalt pavement runoff to surface water, wetlands or stormwater quality.	Can be readily implemented at the Site. Services, materials, and specialized contractors are available to perform installations. Significant disruptions are anticipated during construction.	Capital Costs: Medium O&M Costs: Medium	Eliminated	Eliminated more protective than single layer to prevent direct exposure contacts.
Removal	Soil Excavation	Off-Site Disposal	Excavate the impacted soil and transport waste to a off-site location for disposal at an approved disposal facility. The alternative includes restoration of the natural grade and vegetation.	This technology may be able to achieve RAOs. Excavation of soil has been well demonstrated. Impacts to surrounding surface water and/or wetlands may occur; however, erosion control measures can be instituted. Standard construction hazards to workers are anticipated. Excavation activities may impact local workers/residents. Control measures can be used to mitigate these hazards.	Vendors are available to perform this process option. Permits (waste manifests/bills of lading) can be obtained for off-site transport and disposal and TSDFs are available to accept soil.	Capital Costs: Medium O&M Costs: Low	Retained	
In Situ Treatment	Physical Treatment	Solidification/ stabilization	A soil amendment is either injected or mixed in-situ (auger or caisson) to fixate contaminants to soil particles and thus rendering them immobile.	This technology may be able to achieve RAOs. A treatability study is generally required to confirm COCs are compatible with process. This process option is well demonstrated. Materials may "weather" and affect the ability to maintain immobilization of COCs. Standard construction hazards to workers are anticipated during materials handling.	This process option is readily available through specialty vendors. Some processes result in a significant increase in volume (up to double the original volume). The solidified material may hinder future site use.	Capital Costs: Medium O&M Costs: Low	Retained	
		Soil Vapor Extraction	Vacuum is applied through extraction wells to create a pressure/concentration gradient that induces gas-phase volatiles to be removed from soil through extraction wells.	This technology will not be able to achieve RAOs for Site COCs (chromium). This process is well demonstrated for the remediation of VOCs; however, it is not effective for Site COCs because of the low volatility of metals. Standard construction hazards to workers are anticipated.	Can be readily implemented at the Site. Services, materials, and contractors are readily available to perform installations.	Capital Costs: Medium O&M Costs: Medium	Eliminated	Eliminated. Ineffective for Site COCs in soil.
	Chemical Treatment	Chemical Oxidation	Injection of constituents into the subsurface to oxidize and destroy organic compounds.	This technology may be able to achieve RAOs for select COCs (chromium). This process option has been well demonstrated. However, presence of naturally occurring carbon and other oxidizable matter can limit treatment effectiveness. Potential impacts to workers/residents during materials handling and injections.	Can be readily implemented at the Site. Services, materials, and contractors are readily available to perform injections. no treatment residuals anticipated that warrant off-site disposal.	Capital Costs: Medium O&M Costs: Medium	Eliminated	Eliminated. Ineffective for Site COCs in soil.
		Chemical Reduction	Injection of constituents into the subsurface to chemically reduce inorganic compounds to less mobile and less toxic compounds.	This technology may be able to achieve RAOs for select COCs (metals); however, this process option is not well demonstrated for soil contamination. Difficult to accurately evaluate effectiveness.	Specialty contractors that offer geochemical analysis, reagent, and injection services are available. no treatment residuals anticipated that warrant off-site disposal.	Capital Costs: Medium O&M Costs: Low	Eliminated	Eliminated. Not a demonstrated technology.

General Response Action	Remedial Technology Type	Process Option	Process Option Description	Effectiveness	Implementability	Relative Cost	Retained for Further Consideration	Screening Comments
In Situ Treatment	Biological Treatment	Enhanced Biodegradation	Aerobic or anaerobic degradation of organic contaminants through the addition of nutrient or indigenous/engineered microorganisms.	This technology may be able to achieve RAOs for select COCs (chromium). not well demonstrated for in-situ treatment of unsaturated soils.	Specialty contractors that offer the bioaugmentation and stimulation materials and injection services are available. no treatment residuals anticipated that warrant off-site disposal.	Capital Costs: Medium O&M Costs: Low	Eliminated	Eliminated. Not a demonstrated technology.
		Phytoremediation	Phytoremediation is a process that uses plants to remove, transfer, stabilize, and destroy organic and inorganic contaminants in soil.	This technology may be able to achieve RAOs for select COCs (chromium); however this process is not well demonstrated. This process option may be seasonal.	Contractors that offer the materials are available. no treatment residuals anticipated that warrant off-site disposal.	Capital Costs: Low O&M Costs: Low	Eliminated	Eliminated. Not a demonstrated technology.
	Thermal Treatment	Electrical Resistance Heating	Using an electrical current, soil is heated so that water and contaminants trapped are vaporized and ready for vacuum extraction.	This technology is ineffective for metals. In addition, the recovery/control of extremely hot gases presents a serious safety issues. Short-term impacts to workers/residents include potentially high gas temperatures, extensive period needed to cool down treatment zone. Control measures can be implemented to protect workers and residents.	Specialty contractors are available to perform this process option. Specialty equipment, construction materials, and personnel are required. Permits can be obtained and TSDFs are available for the off-site disposal of recovered wastes. Significant disruptions are anticipated during construction, operation, and demobilization.	Capital Costs: High O&M Costs: High	Eliminated	Eliminated. Ineffective for Site COCs in soil.
		Thermal desorption	Using high temperature thermal desorption, soil is heated in-situ to 320 to 600°C volatilizing PAHs and PCBs.	This technology is ineffective for metal. In addition, the recovery/control of extremely hot gases presents a serious safety issues. Short-term impacts to workers/residents include potentially high gas temperatures, extensive period needed to cool down treatment zone. Control measures can be implemented to protect workers and residents.	Specialty contractors are available to perform this process option. Specialty equipment, construction materials, and personnel are required. Permits can be obtained and TSDFs are available for the off-site disposal of recovered wastes. Significant disruptions are anticipated during construction, operation, and demobilization.	Capital Costs: High O&M Costs: High	Eliminated	Eliminated. Ineffective for Site COCs in soil.
		Vitrification	Soil is heated in-situ to form a glass, thereby destroying the organic compounds and immobilizing most inorganic contaminants. Off-gases need to be captured, condensed, and treated before discharging to the ambient air.	This technology may be able to achieve RAOs. However, process option is not well demonstrated at full-scale due to implementation problems in the past associated with recovery/control of extremely hot gases. Short-term impacts to workers include potentially high gas temperatures, extensive period needed to cool down treatment zone.	There are no current vendors that market this process option. Specialty equipment, construction materials, and personnel are required. Permits can be obtained and TSDFs are available for the off-site disposal of recovered wastes.	Capital Costs: High O&M Costs: High	Eliminated	Eliminated. Not well demonstrated at full-scale, no current vendor for process option.
Ex Situ Treatment	Physical Treatment	Solidification/ Stabilization	Soil is excavated and a soil amendment is mixed ex-situ to fixate contaminants to soil particles and thus rendering them immobile.	This technology may be able to achieve RAOs. A treatability study is generally required to confirm COCs are compatible with process. This process option is well demonstrated. Materials may "weather" and affect the ability to maintain immobilization of COCs. Standard construction hazards to workers are anticipated during materials handling. Potential impacts to workers and may occur during performance; however, measures can be implemented to control fugitive dust emissions.	This process option is readily available through specialty vendors. Some processes result in a significant increase in volume (up to double the original volume). Permits can be obtained and TSDFs are available for the off-site disposal of solidified material. Onsite disposal of solidified material may significantly hinder future site use because of alteration to local topography.	Capital Costs: High O&M Costs: N/A	Eliminated	Eliminated. Capital costs are high and onsite space is limited for increase in volume.
		Soil Washing	Soil is excavated and contaminants are removed from soil by concentrating them into a smaller volume of soil through particle size separation, gravity separation, and attrition scrubbing.	This technology may be able to achieve RAOs. This process option has been well demonstrated for coarser sized particles. Standard construction hazards to workers are anticipated during materials handling and ex-situ treatment. Potential impacts to workers and nearby residents may occur during ex-situ treatment; however, measures can be implemented to control fugitive dust emissions.	This process option is readily available through specialty vendors. Permits can be obtained and TSDFs are available for the off-site disposal of treated material. Significant disruptions are anticipated during construction.	Capital Costs: High O&M Costs: N/A	Eliminated	Eliminated. May be effective for fines, which will be difficult to separate.
	Chemical Treatment	Chemical Oxidation	Soil is excavated and oxidants are mixed ex-situ to oxidize and destroy organic compounds.	This technology may be able to achieve RAOs for select COCs (PAHs and PCBs). This process option has been well demonstrated. Standard construction hazards to workers are anticipated during materials handling and ex-situ treatment. Potential impacts to workers and nearby residents may occur during ex-situ treatment; however, measures can be implemented to control fugitive dust emissions.	Can be readily implemented at the Site. Services, materials, and contractors are readily available to perform injections. Once treated, soils can be used to fill excavations. Significant disruptions are anticipated during construction.	Capital Costs: High O&M Costs: N/A	Eliminated	Eliminated. More protective than in-situ chemical oxidation; however, more effort will be needed to excavate, treat, and manage soil.
		Chemical Reduction	Soil is excavated and reducing constituents are mixed ex-situ to reduce inorganic compounds to less mobile and less toxic compounds.	This technology may be able to achieve RAOs for select COCs (hexavalent chromium); however, this process option is not well demonstrated for soil contamination. Difficult to accurately evaluate effectiveness. Standard construction hazards to workers are anticipated during materials handling and ex-situ treatment. Potential impacts to workers and nearby residents may occur during ex-situ treatment; however, measures can be implemented to control fugitive dust emissions.	Specialty contractors that offer geochemical analysis, reagent, and injection services are available. Once treated, soils can be used to fill excavations. Significant disruptions are anticipated during construction.	Capital Costs: High O&M Costs: N/A	Eliminated	Eliminated. More protective than in-situ chemical reduction but impacts to safety are great due to the necessity to leave the excavation open while treating the soil ex situ.
		Dehalogenation	Soil is excavated, reagents are added, and mixture is heated, decomposing or volatilizing the contaminants.	This technology is ineffective for metals. This process option has been well demonstrated for chlorinated compounds. Standard construction hazards to workers are anticipated during materials handling and potential impacts to workers and nearby residents may occur during ex-situ treatment; however, measures can be implemented to control fugitive dust emissions.	Specialty contractors are available. Once treated, soils can be used to fill excavations. Significant disruptions are anticipated during construction.	Capital Costs: High O&M Costs: N/A	Eliminated	Eliminated. This process is for halogenated compound, which are not Site COCs in the soil unit.

Table 3-2
Remedial Technology Screening for Impacted Soil
Commerce Street Plume Superfund Site
Williston, Vermont

General Response Action	Remedial Technology Type	Process Option	Process Option Description	Effectiveness	Implementability	Relative Cost	Retained for Further Consideration	Screening Comments
Ex Situ Treatment	Biological Treatment	Enhanced Biodegradation\	Soil is excavated, placed into bioreactors, and undergo aerobic or anaerobic degradation of organic contaminants through the addition of nutrient or indigenous/engineered microorganisms.	This technology is ineffective for metals. This process option has been demonstrated. Standard construction hazards to workers are anticipated during ex-situ treatment. Potential impacts to workers and nearby residents may occur during ex-situ treatment; however, measures can be implemented to control fugitive dust emissions.	Specialty contractors that offer the bioaugmentation and stimulation materials are available. Once treated, soils can be used to fill excavations. Significant disruptions are anticipated during construction.	Capital Costs: High O&M Costs: Low	Eliminated	Eliminated. This process is for halogenated compound, which are not Site COCs in the soil unit.
	Thermal Treatment	Thermal Desorption	Soil is excavated then heated using medium temperature thermal desorption (low temperature is ineffective for Site COCs) to 320 to 600°C volatilizing PAHs and PCBs.	This technology can be effective for PAHs and PCBs, and is ineffective for Site metal COCs. In addition, the recovery/control of extremely hot gases presents a serious safety issues. Standard construction hazards to workers are anticipated during ex-situ treatment. In addition, short-term impacts to workers/residents include potentially high gas temperatures, extensive period needed to cool down treatment zone. Control measures can be implemented to protect workers and residents.	Specialty contractors are available to perform this process option. Specialty equipment, construction materials, and personnel are required. Permits can be obtained and TSDFs are available for the off-site disposal of recovered wastes. Once treated, soils can be used to fill excavations. Significant disruptions are anticipated during construction, operation, and demobilization.	Capital Costs: High O&M Costs: High	Eliminated	Eliminated. No more protective than in-situ thermal desorption.
		Vitrification	Soil is excavated then heated to form a glass, thereby destroying the organic compounds and immobilizing most inorganic contaminants. Off-gases need to be captured, condensed, and treated before discharging to the ambient air.	This technology may be able to achieve RAOs. However, process option is not well demonstrated at full-scale due to implementation problems in the past associated with recovery/control of extremely hot gases. Standard construction hazards to workers are anticipated during ex-situ treatment. In addition, short-term impacts to workers include potentially high gas temperatures, extensive period needed to cool down treatment zone. Control measures can be implemented to protect workers and residents.	There are no current vendors that market this process option. Specialty equipment, construction materials, and personnel are required. Permits can be obtained and TSDFs are available for the off-site disposal of recovered wastes. Significant disruptions are anticipated during construction, operation, and demobilization.	Capital Costs: High O&M Costs: High	Eliminated	Eliminated. Not well demonstrated at full-scale, no current vendor for process option.
		Incineration	Soil is excavated then heated using high temperatures (870 to 1,200°C), volatilizing and oxidizing contaminants.	This technology is ineffective for metals. In addition, the recovery/control of extremely hot gases presents a serious safety issues. Standard construction hazards to workers are anticipated during ex-situ treatment. In addition, short-term impacts to workers/residents include potentially high gas temperatures, extensive period needed to cool down treatment zone. Control measures can be implemented to protect workers and residents.	There are no current vendors that market this process option. Specialty equipment, construction materials, and personnel are required. Permits can be obtained and TSDFs are available for the off-site disposal of recovered wastes. Significant disruptions are anticipated during construction, operation, and demobilization.	Capital Costs: High O&M Costs: N/A	Eliminated	Eliminated. Ineffective for Site COCs in soil.

Notes:
1. The process technologies cited above will likely require some level of bench-scale testing, field-scale pilot testing, and design prior to full-scale implementation.
2. Shaded process options have been eliminated from further consideration.

Table 3-3
Remedial Technology Screening for Impacted Groundwater
Commerce Street Plume Superfund Site
Williston, Vermont

General Response Action	Remedial Technology Type	Process Option	Process Option Description	Effectiveness	Implementability	Relative Cost	Retained for Further Consideration	Screening Comments
No Action	No Action	Not applicable	No active source remediation conducted. No monitoring conducted.	Low effectiveness. The lack of action will not achieve RAOs.	Easily implemented.	Capital Costs: None O&M Costs: None	Retained	Baseline, as required by the NCP. Retained.
Limited Action	Long-term monitoring	Groundwater Monitoring	No active remedial processes will be taken to address the contamination. Monitoring will be performed to assess whether natural attenuation is occurring.	Low effectiveness. Provides data to determine if natural attenuation processes are effective. Monitoring network is scalable with area and volume. TCE not expected to degrade naturally over an acceptable remedial timeframe given the concentrations in the plume core.	Can be readily implemented. Qualified contractors are numerous. Stakeholder approval of the monitoring program is required. Minimal impacts to human health and the environment.	Capital Costs: None O&M Costs: Low	Retained	May be included as an element a treatment alternative.
	Monitored Natural Attenuation	Advection	Advection is the transport of a contaminant due to the bulk movement of groundwater. This is the primary mechanism for contaminant transport.	Medium effectiveness. Currently naturally on-going at the Site. If ongoing source of groundwater contamination at the Site is eliminated or isolated, could eventually assist in achieving clean-up goals, given sufficient time. Well demonstrated at many sites.	Easily implemented.	Capital Costs: None O&M Costs: None	Retained	May be included as an element a treatment alternative.
		Dispersion	Mechanical dispersion is the heterogeneous flow of a contaminant through aquifer materials caused by variations in pore size, tortuosity in flow paths and friction in the pore throats between soil particles.	Medium effectiveness. Currently naturally on-going at the Site. If ongoing source of groundwater contamination at the Site is eliminated or isolated, could eventually assist in achieving clean-up goals, given sufficient time. Well demonstrated at many sites.	Easily implemented.	Capital Costs: None O&M Costs: None	Retained	May be included as an element a treatment alternative.
		Diffusion	Molecular diffusion occurs when chemicals move from zones of higher concentration to zones of lower concentration.	Medium effectiveness. Currently naturally on-going at the Site. If ongoing source of groundwater contamination at the Site is eliminated or isolated, could eventually assist in achieving clean-up goals, given sufficient time. Well demonstrated at many sites.	Easily implemented.	Capital Costs: None O&M Costs: None	Retained	May be included as an element a treatment alternative.
		Sorption	Sorption is the lessening of a chemical's presence within a groundwater plume due to the affinity of the chemical to aquifer materials. In this process hydrophobic organic chemicals bind to organic carbon or clay particles and are thus removed from the plume.	Medium effectiveness. Currently naturally on-going at the Site. If ongoing source of groundwater contamination at the Site is eliminated or isolated, could eventually assist in achieving clean-up goals, given sufficient time. Well demonstrated at many sites.	Easily implemented.	Capital Costs: None O&M Costs: None	Retained	May be included as an element a treatment alternative.
		Hydrolysis	Hydrolysis is a chemical reaction in which a halogen ion from a chlorinated VOC is substituted with a hydroxyl ion from a water molecule.	Medium effectiveness. Currently naturally on-going at the Site. If ongoing source of groundwater contamination at the Site is eliminated or isolated, could eventually assist in achieving clean-up goals, given sufficient time. Well demonstrated at many sites.	Easily implemented.	Capital Costs: None O&M Costs: None	Retained	May be included as an element a treatment alternative.
		Abiotic Reductive Dechlorination	Degradation of the chlorinated VOC occurs when a chlorine ion is replaced by a hydrogen ion. Examples of abiotic reductive dechlorination include hydrogenolysis and dihaloelimination. In hydrogenolysis, a chlorine ion is replaced by a hydrogen ion. In dihaloelimination, two chlorine ions are replaced, creating a double bond.	Medium effectiveness. Currently naturally on-going at the Site. If ongoing source of groundwater contamination at the Site is eliminated or isolated, could eventually assist in achieving clean-up goals, given sufficient time. Well demonstrated at many sites.	Easily implemented.	Capital Costs: None O&M Costs: None	Retained	May be included as an element a treatment alternative.
		Aerobic Biodegradation	Aerobic biodegradation refers to the process by which native microorganisms in the subsurface degrade the contaminants within the groundwater in the presence of oxygen.	Medium effectiveness. Aerobic degradation is applicable for vinyl chloride. Aerobic conditions can exist in the portions of the aquifer near the vadose zone. Process has been demonstrated to be effective for treating Site contaminants through cometabolism. Ineffective for metals and in some cases may mobilize some metals.	Easily implemented.	Capital Costs: None O&M Costs: None	Retained	May be included as an element a treatment alternative.
		Anaerobic Biodegradation	Anaerobic biodegradation refers to the process by which native microorganisms in the subsurface degrade the contaminants within the groundwater in the absence of oxygen.	Medium effectiveness. May be naturally occurring at the Site. It is likely that anaerobic conditions are present in the central portion of the plume. Anaerobic degradation (reductive dechlorination) is the primary biological degradation pathway for Site contaminants. If ongoing source of groundwater contamination at the Site is eliminated or isolated, could eventually achieve clean-up goals, given sufficient time.	Easily implemented.	Capital Costs: None O&M Costs: None	Retained	May be included as an element a treatment alternative.
	Institutional Controls	Deed Restrictions, Land Use Restrictions, Town Ordinances	No active remedial processes will be taken as part of this process option to address the contamination. These controls can include deed restrictions preventing certain activities on designated properties, land use restrictions, or Town ordinances that prevent certain activities within a designated area. May also be used to eliminate ability to install groundwater wells or require treatment of any groundwater recovered within the site boundaries.	Medium effectiveness. Frequently a component of a remedial alternative. Effective at minimizing risks to human health. Control areas are scalable with contaminated areas/volumes. Effective only if implemented, monitored, and enforced.	Administrative implementation is possible, but will require coordination between Local, State and Federal officials, and property owners. Must be monitored and enforced after implementation.	Capital Costs: Low O&M Costs: Low	Retained	May be included as an element a treatment alternative.

Table 3-3
Remedial Technology Screening for Impacted Groundwater
Commerce Street Plume Superfund Site
Williston, Vermont

General Response Action	Remedial Technology Type	Process Option	Process Option Description	Effectiveness	Implementability	Relative Cost	Retained for Further Consideration	Screening Comments
Containment	Vertical Barriers	Slurry Wall	A trench is excavated along the perimeter of (or a portion of) the contaminated groundwater plume and is filled with a low-permeability slurry to prevent migration of contaminated groundwater.	Low effectiveness. Irregular and deep impermeable and semi-permeable surfaces at the site may prevent proper key-in of slurry wall into an aquitard If the slurry wall is not properly keyed in, bedrock or clay/till fractures may allow groundwater to circumvent the wall. Limited impacts to human health and the environment during construction and implementation.	This process option has been implemented on a large scale remediation project where the slurry wall was keyed into a confining layer of hard till. However, deep clay, till, and bedrock surfaces at the site will make implementation more difficult in this case. Implementation would be made difficult by extensive subsurface utilities. Some areas may require extensive construction due to bedrock depth. Implemented using standard excavation and construction techniques. A number of companies can provide this service.	Capital Costs: High O&M Costs: Low	Eliminated	Potentially limited effectiveness due to irregular and deep impermeable and semi-permeable surfaces. Difficult to implement due to utilities and deep impermeable and semi-permeable surfaces.
		Sheet-pile wall	Vertical steel sheet piles are driven into the subsurface (usually to bedrock or an aquitard such as the clay or till layers) along the perimeter (or a portion of) the contaminated groundwater plume to prevent the further migration of contaminated groundwater. Individual sheets are interlocking, and the knuckles are filled with grout or similar low-permeability material, creating an low-permeability or impermeable barrier.	Low effectiveness. Irregular and deep permeable and semi-permeable surfaces may prevent proper key-in of sheet-pile wall into a sufficient aquitard. If sheet-pile wall is not properly keyed in, fractures may allow groundwater to circumvent the wall. Limited impacts to human health and the environment during construction and implementation. Shown to be effective on a large scale remediation project.	Readily implementable using standard pile installation and construction techniques, although difficult to implement in areas with extensive subsurface utilities. A number of companies can provide this service. Impermeable and semi-permeable surfaces may be too deep in certain areas for this method to be constructible.	Capital Costs: High O&M Costs: Low	Eliminated	Potentially limited effectiveness due to irregular and deep impermeable and semi-permeable surfaces. Difficult to implement due to utilities and bedrock depth
		Grout Curtain	Grout is injected into soil pore spaces to prevent groundwater from migrating through the pores. The injection locations are set such that the resulting grout injections provide a barrier to continued groundwater migration.	More effective in addressing irregular and deep impermeable and semi-permeable surfaces. Minimal effects on human health and the environment during construction and implementation.	Easier to implement in areas with extensive subsurface utilities. Implemented using common drilling, grout injection and construction techniques. A number of companies can provide this service.	Capital Costs: Medium O&M Costs: Low	Retained	Most effective and implementable barrier technology.
Collection, Treatment and Discharge	Collection / Extraction	Extraction Wells	Extraction wells are installed to capture groundwater to prevent or minimize contaminant migration. This technology is typically associated with an ex-situ treatment system.	Medium effectiveness. Has been shown to be successful at capturing contaminated groundwater. Capable of being scaled to accommodate a variety of areas/volumes. Minimal impact on human health/environment during construction. Can achieve RAOs, given sufficient time.	Readily available using conventional drilling techniques. Treatment system required to treat recovered groundwater prior to discharge. Numerous companies available to design and construct extraction and treatment systems. Large volume of contaminated groundwater would require a large number of extraction wells and a large treatment plant to address site-wide groundwater contamination.	Capital Costs: Medium O&M Costs: Medium-High	Retained	Medium effectiveness, readily implementable.
		Extraction Trench	A trench and recovery system can be installed to capture contaminated groundwater for ex-situ treatment. This technology is typically associated with an ex-situ treatment system.	Medium effectiveness. Effective means for containing overburden contaminant migration and collecting groundwater for treatment.	Depth to bedrock would make implementation difficult in some areas using standard excavation techniques. Treatment system required to treat recovered groundwater prior to discharge. Difficult to implement in areas with extensive subsurface utilities. Trench excavation would be very difficult due to deep impermeable and semi-permeable surfaces.	Capital Costs: Medium O&M Costs: Medium-High	Retained	Medium effectiveness.
	Physical Treatment	Equalization	Groundwater extraction flow dampening and/or contaminant concentration variation in a vessel to promote constant discharge rate and water quality. Generally this technology is a pretreatment process incorporated into a treatment train.	Medium effectiveness. Component of a ex-situ treatment train. Effective method for normalizing contaminant concentrations volumes and flows. Minimal impact on human health and the environment during construction/implementation. Scalable with anticipated volumes.	Easily implemented. Qualified contractors are numerous.	Capital Costs: Low O&M Costs: Low	Retained	May be included as an element a treatment alternative.
		Dewatering	Mechanical removal of free water from treatment residuals reducing the residuals volume and mass. Generally this technology is post-treatment process incorporated into a treatment train.	Medium effectiveness. Component of a treatment train. Very effective at reducing the mass of solid residuals (sludge, etc.) associated with ex-situ groundwater treatment. Scalable with anticipated volumes.	Easily implemented. Materials and equipment are readily available. TSDF available for waste material deposition.	Capital Costs: Medium O&M Costs: Medium	Retained	May be included as an element a treatment alternative.
		Sedimentation	Gravity separation of suspended solids in a vessel. Generally this technology is a pretreatment process that is incorporated into a treatment train.	Medium effectiveness. Component of a treatment train. Effective in conjunction with flocculation and coagulation to remove suspended solids (including metals) from an aqueous waste stream. Scalable with anticipated volumes.	Easily implemented. Materials and equipment are readily available. TSDF available for waste material deposition.	Capital Costs: Low O&M Costs: Low	Retained	May be included as an element a treatment alternative.
		Oil/Water Separation	Separation of immiscible liquids from water using forces of gravity. Generally this technology is incorporated as part of a treatment train.	High effectiveness. Component of a treatment train. This process option does not treat dissolved contaminants, but is effective at removing non-aqueous phase liquids, notably petroleum-based contaminants. Scalable with anticipated volumes.	Easily implemented. Materials and equipment are readily available. TSDF available for waste material deposition.	Capital Costs: Low O&M Costs: Low	Eliminated	Non-aqueous phase liquids are not assumed present at the Site.

General Response Action	Remedial Technology Type	Process Option	Process Option Description	Effectiveness	Implementability	Relative Cost	Retained for Further Consideration	Screening Comments
Collection, Treatment and Discharge	Physical Treatment	Filtration	Separation of particles from water using entrapment technologies. Typically this is a pre-treatment technology implemented as part of a treatment train.	High effectiveness. Often a critical component of a treatment train. Very effective at capturing suspended solids in an aqueous waste stream. Scalable with anticipated volumes.	Easily implemented. Materials and equipment are readily available. TSDF available for waste material deposition.	Capital Costs: Low O&M Costs: Low	Retained	May be included as an element a treatment alternative.
		Reverse Osmosis	Use of high pressure and membranes to separate dissolved materials from water.	Low effectiveness. This method has been shown to be effective at treating Site COCs. Highly susceptible to inorganic fouling. Anticipated maintenance requirements could limit its effectiveness. Scalable with anticipated volumes, but generally most-successful with small volumes.	Implementable. Offered by numerous specialty contractors.	Capital Costs: Medium O&M Costs: High	Eliminated	Efficiency and effectiveness are questionable.
		Air Stripping	Extracted groundwater is sprayed on packing within air stripping columns or discharged to shallow stacked trays. A counter current of air is passed through the water desorbing contaminants into the vapor phase, which are captured and treated subsequently.	Medium effectiveness. Well-demonstrated technology for treating Site COCs. Effectiveness of the process can be limited by high inorganic content in the waste stream. Minimal impact on human health and the environment during construction/implementation.	Components of the system are easily obtainable and constructible. Rigorous pre-treatment and ongoing maintenance may be required to keep the system operational.	Capital Costs: Low O&M Costs: Medium	Retained	May be included as an element a treatment alternative.
		Carbon Adsorption	Extracted groundwater is pumped through granular activated carbon causing dissolved contaminants to adsorb onto the carbon. This can also be applied to a contaminated airstream (as in the case of an air-stripping technology).	Medium effectiveness. Well-demonstrated technology for treating Site COCs. Scalable with anticipated treatment volumes. Limited effectiveness at treating vinyl chloride. Minimal impact on human health & environment during construction or implementation.	Easily implemented. Materials and equipment are readily available. TSDF available for waste material deposition.	Capital Costs: Low O&M Costs: Medium/High	Retained	May be included as an element a treatment alternative.
		Distillation	Vaporization and subsequent condensation of extracted groundwater.	Low effectiveness. This process option is not effective at treating waste streams containing dilute mixtures of contaminants.	Readily implementable. Materials required are easily obtained.	Capital Costs: Medium O&M Costs: Medium/High	Eliminated	This process option is not effective on the Site contaminants.
		Irrigation / Evaporation	Combined treatment and discharge technology that sprays extracted groundwater onto the ground surface to enhance vaporization of contaminants into the atmosphere.	Low effectiveness. Not effective during cold months. Potential for human health and environmental impacts during implementation.	It is not likely that this treatment technique would be a viable process at the Site. A large expanse of land will be required to manage the waste stream.	Capital Costs: Low O&M Costs: Low	Eliminated	This process option is not implementable.
	Chemical Treatment	Ion Exchange	Ion exchange removes ions from the aqueous phase by the exchange of cations or anions between the contaminants and the exchange medium. Ion exchange materials may consist of resins made from synthetic organic materials that contain ionic functional groups to which exchangeable ions are attached.	Low effectiveness. Component of a treatment train. Effective at reducing the inorganic contents in a waste stream prior to additional treatment but does not address the primary contaminants at the Site. Scalable with anticipated volumes.	Materials are available from a variety of vendors. TSDFs available.	Capital Costs: Medium O&M Costs: Medium	Eliminated	This process option is not implementable.
		Enhanced Oxidation	Extracted groundwater is pretreated to decrease turbidity, mixed with a strong oxidizer (such as hydrogen peroxide or ozone), may include exposed to UV light. UV light with oxidizers form free radicals that destroy the organic contaminants.	High effectiveness. Effective at oxidizing Site COCs. Use of hydrogen peroxide or other oxidant with UV light could increase risk to process operators. Minimal impact on the environment. Scalable with anticipated volumes. O&M may pose hazards to workers due to chemicals, UV, and electricity.	This process option is available through several specialty contractors. May require arrangements with local electrical utilities to supply a significant amount of electricity.	Capital Costs: Medium O&M Costs: Medium/High	Retained	May be included as an element a treatment alternative.
		pH Adjustment	Addition of acid or caustic material to recovered groundwater and reduce the solubility of dissolved metals and facilitate their removal. Generally this technology is incorporated as part of a treatment train.	Medium effectiveness. Component of a treatment train. Adjustment of pH has been show to be effective at minimizing inorganics in a waste stream. Handling of acids/bases could increase the risk to human health during implementation. Scalable with anticipated volume.	This process option is easily implemented using typical installation techniques. Replacement reagents are easily obtained through a variety of chemical vendors.	Capital Costs: Low O&M Costs: Low	Retained	May be included as an element a treatment alternative.
		Flocculation / Precipitation	Amendments are added to the extracted groundwater to neutralize surface charges and promote agglomeration of colloidal particles to enhance settling.	Medium effectiveness. Component of a treatment train. Has been shown to be effective at reducing suspended solids in a waste stream. Scalable with anticipated volume. Minimal risk to human health and the environment during construction or implementation.	This process option is easily implemented using typical installation techniques. Replacement reagents are easily obtained through a variety of chemical vendors.	Capital Costs: Low O&M Costs: Low	Eliminated	This process option is not effective for Site COCs.

Table 3-3
Remedial Technology Screening for Impacted Groundwater
Commerce Street Plume Superfund Site
Williston, Vermont

General Response Action	Remedial Technology Type	Process Option	Process Option Description	Effectiveness	Implementability	Relative Cost	Retained for Further Consideration	Screening Comments
Collection, Treatment, and Discharge	Biological Treatment	Aerobic Degradation / Bioreactor	Groundwater is stored in a vessel or pond for treatment. Suspended growth or attached film using aerobic microbes degrade organic matter and chemicals.	Low effectiveness. Process not commonly utilized at environmental cleanups. Minimal effectiveness on treating Site COCs. Requires large treatment reactors and lengthy treatment times.	Implementable using typical construction technologies. Typically requires a moderate to high degree of maintenance.	Capital Costs: Medium O&M Costs: Medium	Eliminated	Not effective; limited implementability.
		Anaerobic biodegradation	Groundwater is stored in a vessel. Suspended growth or attached film using anaerobic microbes degrade organic matter and chemicals.	Low effectiveness. Would require a large treatment reactor volume. Anaerobic treatment systems can be prone to upsets resulting in reduced treatment efficiency and erratic operation. Anticipate an extended treatment duration.	Implementable using typical construction technologies. Typically requires a moderate to high degree of maintenance.	Capital Costs: Medium O&M Costs: Medium	Eliminated	Questionable effectiveness and implementability.
	Discharge	Beneficial re-use / Surface Discharge	If treated water is of sufficient quality it may be used as an irrigation source.	Medium effectiveness. This method has been used successfully at other sites. Site topography and hydrogeology would limit the effectiveness of this discharge method. Scalable with anticipated treatment volumes, but large areas are required.	Treatment standards are very low and may not be cost effective to achieve. Components available, easily built using typical construction methods. Reuse may include steam generation, landscaping use and manufacturing. Limited space available on site to locate large treatment vessels.	Capital Costs: Medium O&M Costs: Low	Eliminated	Questionable cost effectiveness.
		Direct Discharge to Surface Water	Treated water is discharged to the unnamed brook or other suitable receiving water.	High effectiveness. Has been used successfully at numerous sites. Discharge limitations are protective of human health and the environment. Scalable with anticipated volumes, but not easily modified once installed.	Implementable using widely-available construction methods.	Capital Costs: Medium O&M Costs: Low	Retained	May be included as an element a treatment alternative.
		Subsurface Discharge	Treated water is injected below ground through a reinjection gallery.	Low effectiveness. This method has been used successfully at other sites, but insufficient infiltration capacity would limit the effectiveness of this discharge method at this site. Contamination below the water table may be mobilized if mounding is not properly managed. Scalable with anticipated treatment volumes, but large areas are required.	Discharge standards are very low. Difficult to implement due to requirement to dispose of large quantities of water into an area of limited unsaturated thickness in portions of site and dense populations in other portions of site. Easily-obtainable components, and easily constructible using typical construction methods.	Capital Costs: Medium O&M Costs: Medium	Retained	May be included as an element a treatment alternative.
		Off-Site Treatment POTW	Pre-treated water is discharged to a publicly-owned treatment system.	High effectiveness. This method has been used successfully at numerous other sites. Minimal impact on human health and the environment. Scalable with anticipated volume. Very difficult to modify once installed.	Discharge must meet VT NPDES General Permit Standards for Discharge of Groundwater Remediation Wastewater to a Sanitary Sewer. Town sewer is available near the Site.	Capital Costs: Low O&M Costs: Low	Retained	May be included as an element a treatment alternative.
In Situ Treatment	Physical Treatment	Air-Sparge Wells/Barrier with Vapor Extraction	Wells are installed to pump air into the overburden aquifer to volatilize VOC from groundwater. Air and VOCs are extracted through the vadose zone by an SVE system. The vapors are then directed to a treatment system such as vapor phase carbon adsorption.	Medium effectiveness. Has been shown effective at treating COCs in a saturated environment; however, the technology requires highly permeable soils. The clay and till layers at the Site will limit the effectiveness. May immobilize metals by creating an oxidizing environment. Minimal impact on human health/environment during construction or implementation. Portions of OU are capped increasing effectiveness. Scalable with increased treatment volume/area.	Heterogeneity in soil will result in difficulties recovering sparge vapors. Large treatment area will require a large number of wells, which is not possible in an urban, developed setting. Constructed using conventional drilling and construction methods. Sparge/vapor extraction system available through many vendors. Contaminated knockout water will require management.	Capital Costs: Medium O&M Costs: Medium	Eliminated	Very difficult to implement.
		Circulating Wells/Vapor Extraction	Air is injected into a double screened well, lifting the water in the well and forcing it out the upper screen. Simultaneously, additional water is drawn in the lower screen. Once in the well, some of the VOCs in the contaminated ground water are transferred from the dissolved phase to the vapor phase by air bubbles. The contaminated air rises in the well to the water surface where vapors are drawn off and treated by an SVE system.	Low effectiveness. Projects have shown successful treatment of some Site COCs using this method. Limited effectiveness in a moderately-permeable heterogeneous aquifer. Small area of influences would require a large number of wells the plume area. Minimal damage to human health or environmental receptors. Scalable with anticipated volumes and areas.	Constructible using conventional drilling and wells installation techniques. TSDFs available for VOCs disposal. Large treatment area will require a large number of wells, which is difficult in an urban, developed setting.	Capital Costs: High O&M Costs: Medium	Eliminated	Large number of wells make it very difficult to implement.

General Response Action	Remedial Technology Type	Process Option	Process Option Description	Effectiveness	Implementability	Relative Cost	Retained for Further Consideration	Screening Comments
In Situ Treatment	Thermal Treatment	Steam heating and vapor recovery	Forces steam into the aquifer to vaporize organic chemicals. The vaporized chemicals are recovered using an SVE system, which are treated in a vapor-phase carbon treatment system and discharged into the air.	Medium effectiveness. The technology may not be effective for desorb VOCs from saturated contaminated soils. Cold groundwater entering treatment zone will cause decline in subsurface temperature, reducing VOCs extraction. Large impacted area and thickness of unsaturated zone will result in high energy requirements. Good vapor control or recovery in some areas of the Site will be problematic. Potential short-term impacts to onsite receptors involving exposure to high temperatures and high pressure, high temperature contaminated fluids. Also, technology considered to have limited technical feasibility considering the large volume of saturated soil to be treated.	This process option is offered by a limited number of vendors. Difficult to implement in areas with extensive subsurface utilities. Large treatment area will require a large number of wells, which is not possible in an urban, developed setting. Specialty equipment and personnel are required. TSDFs are available to receive captured VOCs.	Capital Costs: High O&M Costs: High	Eliminated	Limited effectiveness due to extensive subsurface utilities, process option will not be cost effective due to large volume of groundwater to be treated.
	Thermal Treatment (cont.)	Conductive or electrical resistance heating and vapor recovery	Heating elements or electrodes installed within the contaminated zones are electrified and slowly heat the soil and groundwater, and volatilized VOCs and vapor are captured in SVE system, condensed, and treated prior to discharge.	Medium effectiveness. This technology can potentially achieve RAOs for VOCs. Effectiveness is not dependent upon soil permeability or homogeneity. Colder groundwater entering treatment zone would not affect thermal treatment and VOCs desorption as with steam heating. Large impacted area and thickness of unsaturated zone will result in high energy requirements. Potential short-term impacts to on-site receptors including high temperatures and electrical arcing, which can be controlled. Has been implemented at full-scale on several sites.	This process option is available with specialty subcontractors. Difficult to implement in areas with extensive subsurface utilities. Large and deep treatment area would require large number of heaters/electrodes and extraction wells which is not possible in an urban, developed setting. TSDFs are available to receive captured VOCs.	Capital Costs: High O&M Costs: High	Eliminated	Limited effectiveness due to extensive subsurface utilities, process option will not be cost effective due to large volume of groundwater to be treated.
		Vitrification	Aquifer materials are heated to high temperatures, forming a glass, thereby destroying the VOCs. Off-gases need to be captured, condensed, and treated before discharging to the ambient air.	Medium effectiveness. Process option is not well demonstrated due to implementation problems in the past associated with recovery/control of extremely hot gases. Destructive interactions with underground utilities. Short-term impacts to receptors include potentially high gas temperatures, extensive period needed to cool down treatment zone.	There are no current vendors that market this process option. Difficult to implement in areas with extensive subsurface utilities. Specialty equipment and personnel are required. TSDFs are available to receive captured VOCs.	Capital Costs: High O&M Costs: High	Eliminated	Vitrification not well demonstrated at full-scale, limited effectiveness due to extensive subsurface utilities, no current vendor for process option.
	Chemical Treatment	Permeable reactive barrier	A trench is excavated and a permeable reaction wall is installed across the flow path of a contaminant plume, allowing the water portion of the plume to passively move through the wall. These barriers allow the passage of water while prohibiting the movement of contaminants by employing such agents as zero-valent metals, chelators (ligands selected for their specificity for a given metal), sorbents, microbes, biomass, and others.	Low effectiveness. Effective technology at treating Site COCs. Irregular and deep impermeable and semi-permeable surfaces and large saturated thickness may limit extent of treatment in overburden.	This technology is readily available using specialty contractors. Difficult to implement in areas with extensive subsurface utilities. Deep impermeable and semi-permeable surfaces may make implementation difficult in some areas.	Capital Costs: High O&M Costs: Medium	Eliminated	Low effectiveness.
		Chemical Oxidation	Vertical or horizontal wells are drilled into the saturated zone for the purpose of injecting a specified chemical oxidant into the subsurface. The contaminants are destroyed or converted to less-toxic substances through a series of oxidation reactions.	High effectiveness. This process option has been shown to be effective in treating Site COCs. Subsurface heterogeneities may limit distribution of oxidant. Limited effectiveness in areas with high organic content soil (peat). Potential hazards to workers during implementation.	Several specialty contractors offer the product and injection services. Difficult to implement in areas with extensive subsurface utilities. Utilities may provide preferential flow pathways. Materials are obtainable from suppliers. Oxidant quantities that can be stored on site may be limited by U.S. Dept. of Homeland Security.	Capital Costs: High O&M Costs: Low	Retained	High effectiveness.
		Chemical Reduction	Wells or injection points are advanced into the subsurface to inject reducing substances such as a zero-valent iron solution into the subsurface. Contaminants are destroyed by reduction reactions, which also promote natural reductive dechlorination in the subsurface. ZVI, alone or in conjunction with other amendments, can also be used to address metals.	High effectiveness. This process option has been shown to be effective in treating Site COCs. Subsurface heterogeneities may limit distribution of reductant. Scalable to any treatment area or volume. Enhances biological activity in the subsurface. Minimally-invasive injection strategy. Has been demonstrated at a number of sites.	Several specialty contractors offer the reagents and injection services. Difficult to implement in areas with extensive subsurface utilities. Utilities may provide preferential flow pathways. Some reductant quantities that can be stored on site may be limited by U.S. Dept. of Homeland Security.	Capital Costs: High O&M Costs: Low	Retained	High effectiveness.
		Nano-particle zero-valent iron	Wells are drilled into the saturated zone for the purpose of injecting a nano-scale slurry containing zero-valent iron into the subsurface. The iron in the fluid causes reductive dechlorination, and also serves to enhance any natural reductive dechlorination processes.	High effectiveness. Few project have selected this remedy. Has been shown to be successful in full-scale applications.	Very specialized with few specialty contractors available. Difficult to implement in areas with extensive subsurface utilities. Utilities may provide preferential flow pathways.	Capital Costs: Medium O&M Costs: Low	Eliminated	Questionable implementability due to contractor availability, subsurface utilities.

Table 3-3
Remedial Technology Screening for Impacted Groundwater
Commerce Street Plume Superfund Site
Williston, Vermont

General Response Action	Remedial Technology Type	Process Option	Process Option Description	Effectiveness	Implementability	Relative Cost	Retained for Further Consideration	Screening Comments
In Situ Treatment	Biological Treatment	Enhanced Biodegradation-Aerobic	Injections are performed to stimulate or supplement the on-going in-place aerobic natural attenuation processes. Wells are drilled into the saturated zone to deploy biostimulants, carbon sources, nutrients, and possibly inject of naturally-occurring or bio-engineered bacteria into the subsurface.	Medium effectiveness. Applicable for vinyl chloride, only under oxic/aerobic conditions. Not the primary Site-related contaminant (chlorinated VOCs) degradation pathway. Could eventually achieve clean-up goals, given sufficient time. Not effective for groundwater at depth due to anaerobic conditions. Process has been demonstrated for Site contaminants.	Several specialty contractors offer the reagents and injection services. Difficult to implement in areas with extensive subsurface utilities. Utilities may provide preferential flow pathways.	Capital Costs: Medium O&M Costs: Medium	Retained	May be included as an element a treatment alternative.
		Enhanced Biodegradation-Anaerobic	Injections are performed to stimulate or supplement the on-going in-place anaerobic natural attenuation processes. Wells are drilled into the saturated zone to deploy biostimulants, carbon sources, nutrients, and possibly inject of naturally-occurring or bio-engineered bacteria into the subsurface.	High effectiveness. Primary degradation pathway for some Site contaminants (reductive dechlorination). Degradation is known to stall at vinyl chloride. Could eventually achieve clean-up goals given sufficient time. May mobilize some metals at the Site.	Several specialty contractors offer the reagents and injection services. Difficult to implement in areas with extensive subsurface utilities. Utilities may provide preferential flow pathways.	Capital Costs: Medium O&M Costs: Medium	Retained	May be included as an element a treatment alternative. Retained.

Notes:
1. The process technologies cited above will likely require some level of bench-scale testing, field-scale pilot testing, and design prior to full-scale implementation.
2. Shaded process options have been eliminated from further consideration.

Table 3-4
Remedial Technology Screening for Impacted Vapor
Commerce Street Plume Superfund Site
Williston, Vermont

General Response Action	Remedial Technology Type	Process Option	Process Option Description	Effectiveness	Implementability	Relative Cost	Retained for Further Consideration	Screening Comments
No Action	No Action	Not applicable	No active source remediation conducted. No monitoring conducted.	Low effectiveness. The lack of action will not achieve RAOs.	Easily implemented.	Capital Costs: None O&M Costs: None	Retained	Baseline, as required by the NCP.
Monitored Natural Attenuation	Physical Processes	Dispersion	Mechanical dispersion is the heterogeneous flow of a contaminant through aquifer materials caused by variations in pore size, tortuosity in flow paths and friction in the pore throats between soil particles.	Limited dispersion of contaminants in soil gas because of shallow depth to contaminated groundwater. Difficult to accurately evaluate effectiveness. Process dependent on decrease of contaminants in groundwater.	Easily implemented.	Capital Costs: Low O&M Costs: Low	Eliminated	Not effective for soil gas without contaminant decrease in groundwater.
		Diffusion	Molecular diffusion occurs when chemicals move from zones of higher concentration to zones of lower concentration.	Limited diffusion of contaminants in soil gas because of shallow depth to contaminated groundwater. Difficult to accurately evaluate effectiveness. Process dependent on decrease of contaminants in groundwater.	Easily implemented.	Capital Costs: Low O&M Costs: Low	Eliminated	Not effective for soil gas without contaminant decrease in groundwater.
		Sorption	Sorption is the lessening of a chemical's presence within the vadose zone due to the affinity of the chemical to vadose zone soils. In this process hydrophobic organic chemicals bind to organic carbon or clay particles which prevents the chemicals from being released to the air.	Limited sorption of contaminants in soil gas because of shallow depth to contaminated groundwater. Difficult to accurately evaluate effectiveness. Process dependent on decrease of contaminants in groundwater.	Easily implemented.	Capital Costs: Low O&M Costs: Low	Eliminated	Not effective for soil gas without contaminant decrease in groundwater.
	Chemical Processes	Abiotic Reductive Dechlorination	Examples of this type of chemical reaction are hydrogenolysis and dehaloelimination. In hydrogenolysis, a chlorine ion is replaced by a hydrogen ion. In dihaloelimination, two chlorine ions are replaced, creating a double bond.	Not effective for soil gas in shallow vadose zone.	Easily implemented.	Capital Costs: Low O&M Costs: Low	Eliminated	Not effective for vapor in living spaces.
	Biological Processes	Aerobic Biodegradation	Aerobic biodegradation refers to the process by which native microorganisms in the subsurface degrade the contaminants within the vadose zone in the presence of oxygen.	Not well demonstrated for COCs in soil gas. Process dependent on decrease of contaminants in groundwater.	Easily implemented.	Capital Costs: Low O&M Costs: Low	Eliminated	Not effective for soil gas without contaminant decrease in groundwater.
		Anaerobic Biodegradation	Anaerobic biodegradation refers to the process by which native microorganisms in the subsurface degrade the contaminants within the vadose zone in the absence of oxygen.	Not well demonstrated for soil gas. Difficult to accurately evaluate effectiveness. Process dependent on decrease of contaminants in groundwater.	Easily implemented.	Capital Costs: Low O&M Costs: Low	Eliminated	Not effective for soil gas without contaminant decrease in groundwater.
Limited Action	Long-Term Monitoring	Indoor Air, Soil Vapor and Groundwater Monitoring	No active remedial processes will be taken to address the contamination. Indoor air, soil vapor, and groundwater samples will be collected to monitor the plume and vapor intrusion status for changes in conditions or concentrations.	Frequently a component of a remedial alternative. Provides data to determine if remedial actions are effective. Monitoring network is scalable with area and volume. No impact to human health and the environment.	Easily implemented. Qualified contractors are numerous. Stakeholder approval of the monitoring program is required.	Capital Costs: Low O&M Costs: Low	Retained	May be retained as part of a treatment train.
	Institutional Controls	Deed Restrictions, Land Use Restrictions, Town Ordinances	No active remedial processes will be taken to address the contamination. These controls can include deed restrictions preventing certain activities on designated properties, land use restrictions, or Town ordinances that prevent certain activities within a designated area. May also be used to require soil vapor infiltration mitigation in new construction.	Frequently a component of a remedial alternative. Effective at minimizing risks to human health. Control areas are scalable with contaminated areas/volumes. Effective only if implemented, monitored, and enforced.	Administrative implementation is possible, but will require coordination between Local, State and Federal officials, and property owners. Must be monitored and enforced after implementation.	Capital Costs: Low O&M Costs: Low	Retained	May be retained as part of a treatment train.
Barrier	Soil Vapor Barriers	Rigid Membranes	Membrane sheets are installed beneath new construction to prevent advective and diffusive migration of VOC vapors into buildings. All membrane seams are sealed and utility penetrations are constructed to eliminate vapor migration pathways. QA/QC processes are utilized to ensure soil gas entry routes are eliminated.	Demonstrated effective for vapor migration control. Not commonly used for residential applications. Effective for new construction only.	Process option is available through specialty subcontractors. Most cost effective for large commercial/industrial sites and new construction. Sealing utility penetrations can be time consuming. Third party QA/QC inspection services available. No residual handling required.	Capital Costs: Medium O&M Costs: Low	Eliminated	Not implementable on existing properties.
		Spray Applied Membranes	Membrane material is spray applied to area of concern. It is not necessary to seal seams between membrane sheets and utility penetrations are more easily managed. QA/QC processes are utilized to ensure gas entry routes are eliminated.	Demonstrated effective for vapor migration control. Field applied and as a result may not be uniformly applied and may be less effective than rigid membranes. Better suited for new construction than existing buildings.	More easily implemented than rigid membranes. Specialty subcontractors available to install. Applicable for some existing construction. QA/QC testing available. No residual handling required.	Capital Costs: Medium O&M Costs: Low	Retained	May be retained as part of a treatment train.
		Sealing Vapor Entryways	Caulking or other flexible material used to seal soil vapor migration pathways into structures.	Only applicable to accessible locations. Unlikely to address all possible entryways. Effective in new structures, limited effectiveness in existing structures.	Easily constructible using conventional methods with a large number of available subcontractors. Easily applicable to existing structures. No residual handling required.	Capital Costs: Low O&M Costs: Low	Retained	May be retained as part of a treatment train.

General Response Action	Remedial Technology Type	Process Option	Process Option Description	Effectiveness	Implementability	Relative Cost	Retained for Further Consideration	Screening Comments
Soil Vapor Collection, Treatment, and Discharge	Passive Venting	Sub-slab Venting	Mitigates soil vapor intrusion by creating a preferential pathway for vapors to migrate to the exterior a structure. Usually consists of perforated PVC piping in a permeable bedding material. Can be used in conjunction with membranes. Relies on atmospheric pressure changes to remove soil gas.	May not reliably mitigate soil vapor intrusion during a variety of weather conditions, occupant activities and/or appliance usage. Difficult to assure effectiveness in existing structures. Most effective in new structures.	Easy to implement for new construction. More difficult to implement for existing construction. Will not be implemented on existing structures that will be addressed by this Feasibility Study. Subcontractors readily available. No residual handling required.	Capital Costs: Low O&M Costs: Low	Eliminated	Uncertain effectiveness and difficult to implement in existing structures.
	Passive Venting (cont.)	Interior Venting	Increase the amount of air exchange with the outdoors and enhance dilution of indoor contaminants. Heat exchangers can be used to reduce heating/air conditioning costs.	Demonstrated effective for dilution of VOC contamination in indoor air. Can be effective in both new and existing structures.	The additional cost of heating or air conditioning makes this process option cost prohibitive over the long term. Easy to implement. No residual handling required.	Capital Costs: Low/Medium O&M Costs: High	Eliminated	Operation is cost prohibitive as a long term alternative.
	Pressurization	Building Pressurization/HVAC Modification	Modify or supplement existing HVAC systems to create positive pressure in the lower level of the structure to mitigate vapor intrusion. Positive pressure must be consistently maintained to prevent advective flow of soil gas into the structure.	Most effective as an interim measure. Long-term operation of HVAC system is likely to damage equipment. Could be effective in new structures, not effective for existing structures. More effective in warm climates where winter heating is not necessary.	Requires specialized HVAC subcontractor and equipment modification to implement. Not implementable with all HVAC systems. No residual handling required.	Capital Costs: Medium O&M Costs: Medium	Eliminated	Not effective as long term solution. Not applicable to all HVAC systems.
		Sub-slab Pressurization	Mitigates soil vapor intrusion by using a fan to create positive pressure below the building slab. The positive pressure below the building slab creates a barrier to soil gas. May be appropriate when sub-slab material is too permeable to allow depressurization.	Demonstrated effective for vapor migration control. Effectiveness is dependent on the extent to which the pressurization system can influence the entire floor area of concern. If pressurization system is limited in areal extent, effectiveness would be limited.	Specialty subcontractors are available to install this equipment. May cause disruption if implemented in existing construction. More easily implemented in new construction.	Capital Costs: Medium O&M Costs: Medium	Eliminated	Not effective for existing structures.
		Block Wall Pressurization	Depressurizing concrete block foundation to mitigate vapor intrusion through porous concrete block walls. Depressurization pipe is installed horizontally within the void space of a foundation wall. Limits stack effect. Can be used to augment sub-slab pressurization.	Effective if block wall is identified as a soil gas entry route. May be possible to pressurize entire basement with proper configuration. Effective for new structures with block foundations. Not effective in existing buildings without concrete block foundations.	Specialty subcontractors are available to install this equipment. In some cases may be easier to implement then subslab pressurization.	Capital Costs: Medium O&M Costs: Medium	Eliminated	Not effective for existing structures.
	Active Collection/ Extraction	Active Sub-slab Depressurization	Mitigate soil vapor intrusion by creating a negative pressure beneath a structure. Removes soil VOC vapors by advective flow of soil vapor from beneath structures. May require horizontal extraction points beneath structure's foundation.	Demonstrated effective for vapor migration control. Effective mitigation requires depressurization beneath the slab that is strong enough to overcome depressurizations within the house caused by appliances, bathroom fans, stove vents, occupant activities, weather effects etc. Effective for both new and existing structures.	Not implementable in areas with high water tables. Specialty subcontractors are available to install this equipment. Fan should be installed in area where vented gasses will not be drawn back into the building. Presence of sumps or major utility penetrations in the basement may cause short circuiting. May cause problems with back drafting of combustion appliances.	Capital Costs: Medium O&M Costs: Medium	Eliminated	Not effective in areas with high water.
		Active Tile Drain Depressurization	Depressurizes existing foundation drains and/or drain tiles (if present) by connecting vacuum lines and a blower to recover soil vapor in the area near the foundation. Interior drains are located inside of the footings while exterior tiles are located on the side of the footings outside of the structure.	May not be effective in buildings in tight soils where connection between tile drain and the slab is poor or in buildings with exterior drain networks. Most effective with a drain tile network that extends around the entire perimeter of the structure. Effective for new structures and some types of existing structures.	Not implementable in areas with high water tables. Specialty subcontractors are available to install this equipment. Presence of dry well or topographic low must be taken into account in design. May cause problems with back drafting of combustion appliances.	Capital Costs: Medium O&M Costs: Medium	Eliminated	Not effective in areas with high water.
		Active Block Wall Depressurization	Depressurizing concrete block foundation to mitigate vapor intrusion through porous concrete block walls. Depressurization pipe is installed horizontally within the void space of a foundation wall. Limits stack effect. Can be used to augment sub-slab pressurization.	Effective if block wall is identified as a soil gas entry route or to augment subslab depressurization. May be possible to depressurize entire basement with proper configuration. Effective for new structures, or existing structures with concrete block foundations.	Specialty subcontractors are available to install this equipment. In some cases may be easier to implement then subslab pressurization. May cause problems with back drafting of combustion appliances.	Capital Costs: Medium O&M Costs: Medium	Eliminated	Not effective in non-block wall structures.
		Active Sub-Membrane Depressurization	Used in buildings with dirt floor basements. Includes an impermeable membrane with soil vapor extraction points installed vertically through the membrane.	If properly designed and installed, this process option is effective in intercepting soil vapors. Proper sealing of membrane to perimeter walls and membrane seam sealing is critical in effectiveness. Membranes must be protected from physical damage and puncturing by overlying material that is compatible with the membrane. Effective for existing structures with dirt basements, not likely to be effective for new structures.	Difficult to implement in areas with high water tables. Specialty subcontractors are available to install this equipment. May cause problems with back drafting of combustion appliances.	Capital Costs: Medium O&M Costs: Medium	Eliminated	Not effective in areas with high water.
	Physical Treatment	Carbon Adsorption	Extracted soil vapor is discharged through granular activated carbon causing contaminants to sorb onto the carbon.	Well-demonstrated technology for treating some Site COCs. Scalable with anticipated treatment volumes. Limited effectiveness at treating vinyl chloride.	Readily implementable. Replacement carbon and replacement parts are easily obtainable. TSDF available to received spent carbon.	Capital Costs: Low O&M Costs: Medium/High	Retained	May be retained as part of a treatment train.
		Zeolite Adsorption	Extracted soil vapor is discharged through zeolites causing contaminants to sorb onto the carbon.	Well-demonstrated technology for treating Site COCs. Scalable with anticipated treatment volumes. In some cases may be more effective at treating vinyl chloride then activated carbon.	Readily implementable. Replacement zeolite and replacement parts are easily obtainable. TSDF available to receive spent zeolite.	Capital Costs: Low O&M Costs: Medium/High	Retained	If soil gas treatment is required prior to venting, O&M costs will vary with contaminant loading and the effectiveness of pretreatment steps.

Table 3-4
Remedial Technology Screening for Impacted Vapor
Commerce Street Plume Superfund Site
Williston, Vermont
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General Response Action	Remedial Technology Type	Process Option	Process Option Description	Effectiveness	Implementability	Relative Cost	Retained for Further Consideration	Screening Comments
Soil Vapor Collection, Treatment, and Discharge (cont.)	Chemical Treatment	Photo-Catalytic Oxidation	The photocatalytic oxidation of high levels of CVOCs in gas phase has been demonstrated using a specially designed photoreactor that includes a titanium catalyst. Treatment efficiency was strongly affected by the presence of water in the air stream. Treatment efficiencies are highest at room temperature, low initial contaminant concentrations, low flow rates and high light intensities.	May be effective in treating COCs. Commercial units are available utilizing this technology but their efficiencies with the anticipated vapor stream would have to be pilot tested and would be expected to vary with ambient conditions.	Not readily implementable. Some commercial units available.	Capital Costs: Medium O&M Costs: Medium/High	Eliminated	Not a demonstrated technology.
	Biological Treatment	Aerobic Biodegradation	Soil vapor is discharged to a vessel for treatment. Attached film aerobic microbes degrade organic matter and chemicals.	Process not commonly utilized as part of an environmental remediation treatment train. Minimal effectiveness on treating Site COCs. May require large treatment reactors.	Implementable using typical construction technologies. Typically requires a moderate to high degree of maintenance.	Capital Costs: Medium O&M Costs: Medium	Eliminated	Not effective; limited implementability.
		Anaerobic Biodegradation	Soil vapor is discharged to a vessel for treatment. Attached film anaerobic microbes degrade organic matter and chemicals.	Process not commonly utilized at environmental cleanups. Minimal effectiveness on treating Site COCs. May require large treatment reactors.	Implementable using typical construction technologies. Typically requires a moderate to high degree of maintenance.	Capital Costs: Medium O&M Costs: Medium	Eliminated	Questionable effectiveness and implementability.
	Discharge	Venting	Treated or untreated soil vapor is vented to the atmosphere.	Has been successfully used at numerous sites. Discharge limitations are protective of human health and the environment. Scalable with anticipated volumes.	Implementable using widely available construction methods.	Capital Costs: Medium O&M Costs: Low	Retained	May be retained as part of a treatment train.

Notes:
1. The process technologies cited above will likely require some level of bench-scale testing, field-scale pilot testing, and design prior to full-scale implementation.
2. Shaded process options have been eliminated from further consideration.

Table 4-1
Alternatives Developed for Screening
Commerce Street Plume Superfund Site
Williston, Vermont

Media	Remedial Alternative	Alternative Description
Soil	SO1 – No Action	Required to be evaluated per CERCLA. The No Action alternative does not treat, remove or routinely monitor soil, but does require 5-year reviews.
	SO2 – Limited Action-Institutional and Engineering Controls	The Limited Action alternative does not treat, remove or routinely monitor impacted soil. Institutional controls in the form of deed restrictions will be placed on the property that contains the impacted soil. Stipulations will be added requiring protective measures during invasive subsurface activities (e.g., excavations, utility trenches) to prevent human exposure to contaminated soil. Additionally, a fence will be erected around the portion of the property that contains the impacted soil.
	SO3 – Excavation and Off-Site Disposal	Impacted soil is excavated and loaded into trucks for off-site disposal at a licensed waste disposal facility. The alternative includes restoration of the natural grade and vegetation.
	SO4 – *In Situ* Treatment	A soil amendment consisting of Portland cement for solidification or organic plant nutrients, organic matter, liming materials, pesticides, and appropriate plant species and materials for stabilization is either injected into or mixed with impacted soil to fixate contaminants to soil particles in place rendering them immobile. This alternative includes the institutional and engineered controls described in Alternative SO2.
	SO5 – Capping	Impacted soil is covered with a non-permeable cap constructed of clay, asphalt or a synthetic material to prevent human contact and water (rain, snow) percolation through the impacted soil. This alternative includes institutional controls similar to those described in Alternative SO2 with additional requirements for long-term operation and maintenance of the cap. Engineering control (i.e., fence) likely would not be needed.
Groundwater	GW1 – No Action	Required to be evaluated per CERCLA. The No Action alternative does not treat, remove or routinely monitor groundwater, but does require 5-year reviews.
	GW2 – Institutional Controls	The Limited Action alternative does not treat or remove contaminated groundwater. The groundwater within the impacted boundary will be reclassified as Class IV per the Vermont Groundwater Protection Rule, designating the water as non-potable and restricting the installation of water supply wells on any property within the boundary. Institutional controls will also require protective measures during invasive subsurface activities (e.g., excavations, utility trenches) to prevent direct human contact to and inhalation of vapors emanating from shallow contaminated groundwater. Requires limited monitoring to ensure that contaminants are not migrating beyond the new Class IV boundary.
	GW3 – Monitored Natural Attenuation and Long-term Monitoring	No active remedial processes will be taken to address the contamination. Monitoring will be performed across the entire plume to assess whether natural attenuation is occurring. Monitoring wells will be selected, and routinely sampled and evaluated for MNA parameters with annual reports documenting the data and evaluating the trends. This alternative includes the institutional controls and Class IV boundary monitoring described in Alternative GW2.
	GW4 – Collection, Treatment and Discharge	Use of extraction wells to collect impacted groundwater, conveyance of the water to on-site treatment plant, and treatment of the water using sedimentation, filtration, air stripping, and/or carbon adsorption. Treated water to be discharged back to the aquifer, unnamed stream, or publicly owned wastewater treatment plant (POTW). This alternative includes the institutional controls and Class IV monitoring described in Alternative GW2.
	GW5 – *In Situ* Treatment and MNA	This alternative addresses the site-wide dissolved-phase plume with MNA and institutional controls, as described in Alternative GW3. In addition, portions of the plume with the highest concentrations ("hotspots") will receive targeted chemical and/or biological treatment through wells drilled into the saturated zone. Chemical oxidant injected into the subsurface either destroys compounds or converts them to less-toxic substances through a series of oxidation reactions. Injection of biostimulants, carbon sources, nutrients and naturally-occurring or bio-engineered bacteria into the subsurface stimulates or supplements natural attenuation processes. This alternative will require bench- and pilot-scale tests during remedial design to determine design parameters, which oxidants are suitable and whether on-going biodegradation is aerobic or anaerobic biodegradation. Either treatment may be used alone, or together in a treatment train.
Vapor Mitigation	VM1 – No Action	Required to be evaluated per CERCLA. The No Action alternative does not treat, remove or routinely monitor vapors, but does require 5-year reviews.
	VM2 - Sump Pump, Vapor Venting, Treatment and Discharge	Institutional controls in the form of a deed restriction would be implemented to require the continued operation of and allow access to the sump pump, passive gas venting, and sump water discharge system already installed in 2014 by VT DEC at the 830 South Brownell Road location, in consultation with EPA. A treatment system will be installed (e.g., GAC in treatment shed on the property) for the treatment of sump water prior to discharge to groundwater.
	VM3 - Enhanced Vapor Mitigation	Includes all elements described in Alternative VM2, but also requires, as determined necessary based on a risk analysis of additional data collected during pre-design, additional measures (e.g., active venting, vapor barrier) to supplement or replace the already installed sump pump, vapor venting, and sump water discharge system at the 830 South Brownell Road location. The alternative also includes a contingency to address other residential homes in the vicinity of the plume if risk analysis of data collected during future sampling events for Five-Year Reviews or other reasons indicate a risk. The alternative will require an institutional control in the form of a deed restriction, requiring the continued operation of and access to the enhanced vapor mitigation system. Five-Year Reviews would be performed to evaluate the ongoing protectiveness of the remedy.

Table 4-2
Screening of Alternatives
Commerce Street Plume Superfund Site
Williston, Vermont

Media	Remedial Alternative	Alternative Description	Effectiveness	Implementability	Relative Cost	Screening Comments
Soil	SO1 – No Action	Required to be evaluated per CERCLA. The No Action alternative does not treat, remove or routinely monitor soil, but does require 5-year reviews.	Not effective. The lack of action will not achieve the remedial action objectives (RAOs).	Easily implemented. Requires no action.	Capital Costs: None O&M Costs: None	Retained as required by NCP
	SO2 – Limited Action-Institutional and Engineering Controls	The Limited Action alternative does not treat, remove or routinely monitor impacted soil. Institutional controls in the form of deed restrictions will be placed on the property that contains the impacted soil. Stipulations will be added requiring protective measures during invasive subsurface activities (e.g., excavations, utility trenches) to prevent human exposure to contaminated soil. Additionally, a fence will be erected around the portion of the property that contains the impacted soil.	Low effectiveness. Only limits the potential risk of contact with the impacted soil, but does not remove or treat the impacted soil.	Easily implemented. Installation of the fence is easy and O&M includes regular inspections to determine if damage has been caused and the subsequent repairs, if necessary.	Capital Costs: Low O&M Costs: Low	Retained
	SO3 – Excavation and Off-Site Disposal	Impacted soil is excavated and loaded into trucks for off-site disposal at a licensed waste disposal facility. The alternative includes restoration of the natural grade and vegetation.	High effectiveness. Would remove the impacted soil from the Site and dispose of/treat the material at an off-site location, eliminated the risk of human contact and leaching into groundwater.	Easily implemented. Impacted soil is relatively shallow. Access for trucks and equipment is limited but manageable.	Capital Costs: Medium O&M Costs: Low	Retained
	SO4 – *In Situ* Treatment	A soil amendment consisting of Portland cement for solidification or organic plant nutrients, organic matter, liming materials, pesticides, and appropriate plant species and materials for stabilization is either injected into or mixed with impacted soil to fixate contaminants to soil particles in place rendering them immobile. This alternative includes the engineered controls described in Alternative SO2.	Medium effectiveness. The impacted soil mass would be stabilized and solidified, reducing the toxicity of the contaminated soil. However, the mass remains on site and the potential for future contact and/or leaching into the groundwater exists, although unlikely at high concentrations.	Somewhat difficult to implement. The implementation of the alternative is not specifically challenging given the relatively shallow depth of contamination; however, the addition of bench-scale tests, limited working space, and long-term monitoring make this alternative more difficult.	Capital Costs: Medium O&M Costs: Low	Eliminated
	SO5 – Capping	Impacted soil is covered with a non-permeable cap constructed of clay, asphalt or a synthetic material to prevent human contact and water (rain, snow) percolation through the impacted soil. This alternative includes institutional controls similar to those described in Alternative SO2 with additional requirements for long-term operation and maintenance of the cap. Engineering control (i.e., fence) likely would not be needed.	Medium effectiveness. The cap would eliminate surface recharge and percolation of water through the impacted soil mass to prevent future leaching into groundwater; however, groundwater contact may still occur when the water table rises and saturates the contaminated soil left in place. Relies on frequent monitoring to ensure cap has not been compromised (e.g., animal disturbance, vandalism), and requires long-term maintenance.	Somewhat difficult to implement. The implementation of the alternative is not specifically challenging; however, space required for staging, moving equipment, and the construction of surface water diversion and leachate collection is limited without demolition of existing structures.	Capital Costs: High O&M Costs: Medium	Eliminated
Groundwater	GW1 – No Action	Required to be evaluated per CERCLA. The No Action alternative does not treat, remove or routinely monitor groundwater, but does require 5-year reviews.	Not effective. The lack of action will not achieve the RAOs.	Easily implemented. Requires no action.	Capital Costs: None O&M Costs: None	Retained as required by NCP
	GW2 – Institutional Controls	The Limited Action alternative does not treat or remove contaminated groundwater. The groundwater within the impacted boundary will be reclassified as Class IV per the Vermont Groundwater Protection Rule, designating the water as non-potable and restricting the installation of water supply wells on any property within the boundary. Institutional controls will also require protective measures during invasive subsurface activities (e.g., excavations, utility trenches) to prevent direct human contact to and inhalation of vapors emanating from shallow contaminated groundwater. Requires limited monitoring to ensure that contaminants are not migrating beyond the new Class IV boundary.	Low effectiveness. Only effective for limiting human exposure to impacted groundwater. Does not actively reduce toxicity or volume of dissolved-phase plume or contaminant mass. Ineffective at preventing dissolved-phase plume and/or source material from migrating.	Easily implemented. Potential for migration outside the new Class IV boundary can be evaluated using existing monitoring well network. Monitoring wells will require long-term O&M.	Capital Costs: None O&M Costs: Low	Retained
	GW3 – Monitored Natural Attenuation and Long-term Monitoring	No active remedial processes will be taken to address the contamination. Monitoring will be performed across the entire plume to assess whether natural attenuation is occurring. Monitoring wells will be selected, and routinely sampled and evaluated for MNA parameters with annual reports documenting the data and evaluating the trends. This alternative includes the institutional controls and Class IV boundary monitoring described in Alternative GW2.	Low effectiveness. Only effective for the dissolved-phase contamination over a relatively long period of time. Does not actively reduce toxicity of contaminant mass. Ineffective at preventing dissolved-phase plume and/or source material from migrating.	Easily implemented. Natural attenuation can be evaluated using existing monitoring wells and historical data to determine trends. Monitoring wells will require long-term O&M.	Capital Costs: Low O&M Costs: Low	Retained
	GW4 – Collection, Treatment and Discharge	Use of extraction wells to collect impacted groundwater, conveyance of the water to on-site treatment plant, and treatment of the water using sedimentation, filtration, air stripping, and/or carbon adsorption. Treated water to be discharged back to the aquifer, unnamed stream, or publicly owned wastewater treatment plant (POTW). This alternative includes the institutional controls and Class IV monitoring described in Alternative GW2.	Medium effectiveness. Would significantly limit future migration of contaminated groundwater, therefore, significantly decreasing further contamination of the downgradient plume. Technology would require a long time and potentially other remedial actions to achieve RAOs.	Somewhat difficult to implement. Extraction wells will require pre-packed screens to eliminate the running sands issue during installation. Subsurface utilities, developed properties and densely populated residential area will make citing treatment system enclosure/building and the underground piping difficult. O&M for alternative is intensive including monitoring, routine maintenance, operating activities, troubleshooting, etc.	Capital Costs: High O&M Costs: High	Eliminated

Table 4-2
Screening of Alternatives
Commerce Street Plume Superfund Site
Williston, Vermont

Media	Remedial Alternative	Alternative Description	Effectiveness	Implementability	Relative Cost	Screening Comments
Groundwater	GW5 – *In Situ* Treatment and MNA	This alternative addresses the site-wide dissolved-phase plume with MNA and institutional controls, as described in Alternative GW3. In addition, portions of the plume with the highest concentrations ("hotspots") will receive targeted chemical and/or biological treatment through wells drilled into the saturated zone. Chemical oxidant injected into the subsurface either destroys compounds or converts them to less-toxic substances through a series of oxidation reactions. Injection of biostimulants, carbon sources, nutrients and naturally-occurring or bio-engineered bacteria into the subsurface stimulates or supplements natural attenuation processes. This alternative will require bench- and pilot-scale tests during remedial design to determine design parameters, which oxidants are suitable and whether on-going biodegradation is aerobic or anaerobic biodegradation. Either treatment may be used alone, or together in a treatment train.	High effectiveness. Chemical treatment would reductively dechlorinate contaminants and biological treatment would oxidize contaminants in the target areas. By targeting active treatment in hotspot areas, toxicity is reduced significantly and more quickly than MNA alone. Also reduces the potential for contamination to migrate beyond the new Class IV boundary. High long term effectiveness as the technology is "destructive".	Easily implemented. Additional injection/extraction wells will be required and will require pre-packed screens to deal with running sands; however, no permanent piping or infrastructure is needed. Implementation may include extraction, batching of amendments and oxidants, and injection. Piping, pumps, storage, etc. are temporary appurtenances and will be removed from the Site once the application is completed. O&M includes performance monitoring.	Capital Costs: Low O&M Costs: Medium	Retained
Vapor Mitigation	VM1 – No Action	Required to be evaluated per CERCLA. The No Action alternative does not treat, remove or routinely monitor vapors, but does require 5-year reviews.	Not effective. The lack of action will not achieve the RAOs.	Easily implemented. Requires no action.	Capital Costs: None O&M Costs: None	Retained as required by NCP
	VM2 - Sump Pump, Vapor Venting, Treatment and Discharge	Institutional controls in the form of a deed restriction would be implemented to require the continued operation of an allow access to the sump pump, passive gas venting, and sump water discharge system already installed in 2014 by VT DEC at the 830 South Brownell Road location, in consultation with EPA. A treatment system will be installed (e.g., GAC in treatment shed on the property) for the treatment of sump water prior to discharge to groundwater.	Low long-term effectiveness. The current system has high short-term effectiveness; however, it was not constructed for permanence and will likely require additional sealing, venting, and discharge efforts in the future.	Easily implemented. The system is currently operational at the property and would only require the construction of the treatment shed/system and implementation of the institutional controls.	Capital Costs: Low O&M Costs: Medium	Retained
	VM3 - Enhanced Vapor Mitigation	Includes all elements described in Alternative VM2, but also requires, as determined necessary based on a risk analysis of additional data collected during pre-design, additional measures (e.g., active venting, vapor barrier) to supplement or replace the already installed sump pump, vapor venting, and sump water discharge system at the 830 South Brownell Road location. The alternative also includes a contingency to address other residential homes in the vicinity of the plume if risk analysis of data collected during future sampling events for Five-Year Reviews or other reasons indicate a risk. The alternative will require an institutional control in the form of a deed restriction, requiring the continued operation of and allow access to the enhanced vapor mitigation system. Five-Year Reviews would be performed to evaluate the ongoing protectiveness of the remedy.	High effectiveness. The current system has high short-term effectiveness and the alternative provides for additional measures to supplement or replace the already installed system at 830 South Brownell Road , in addition to other residential properties, if necessary, to improve the long-term effectiveness.	Easily implemented. Technologies are readily available and can be installed or constructed using local contractors and supplies.	Capital Costs: Medium O&M Costs: Medium	Retained

Table 4-3
Key Components of Remedial Alternatives Retained For Detailed Analysis
Commerce Street Plume Superfund Site
Williston, Vermont

Remedial Alternative	Key Components													
	Pre-Design Investigation	Bench/ Pilot Testing	Design	Extraction/Injection/ Monitoring Well Installation	*in situ* Chemical Treatment	*in situ* Biological Treatment	Construction	Removal and Off-Site Disposal	Site Restoration	Monitored Natural Attenuation	Long-Term Monitoring Program	Engineered Controls	Institutional Controls	Five-Year Reviews
Soil Alternatives														
SO1 – No Action														✓
SO2 – Limited Action-Institutional and Engineering Controls												✓	✓	✓
SO3 – Excavation and Off-Site Disposal	✓		✓					✓	✓					✓
SO4 – *In Situ* Treatment	✓	✓	✓		✓		✓		✓		✓		✓	✓
SO5 – Capping	✓		✓				✓		✓		✓		✓	✓
Groundwater Alternatives														
GW1 – No Action														✓
GW2 – Institutional Controls													✓	✓
GW3 – Monitored Natural Attenuation and Long-Term Monitoring										✓	✓		✓	✓
GW4 – Collection, Treatment and Discharge	✓	✓	✓	✓			✓			✓	✓		✓	✓
GW5 – *In Situ* Treatment and MNA	✓	✓	✓	✓	✓	✓				✓	✓		✓	✓
Vapor Alternatives														
VM1 – No Action														✓
VM2 - Sump Pump, Vapor Venting, Treatment and Discharge							✓				✓		✓	✓
VM3 - Enhanced Vapor Mitigation							✓				✓		✓	✓

Table 4-4
Preliminary List of Properties Requiring Land Use Restrictions
Commerce Street Plume Superfund Site
Williston, Vermont

Properties Requiring Land Use Restrictions			
Groundwater Restrictions			**Vapor Mitigation Restrictions**
7:3:10	7:16:10	7:65:10	7:3:23
7:3:12	7:16:12	7:65:11	
7:3:14	7:16:14	7:65:12	
7:3:15	8:19:2	7:65:15	
7:3:16	7:19:5	7:65:17	
7:3:18	7:19:11	7:65:19	
7:3:20	8:19:12	7:65:21	
7:3:21	7:19:14	7:65:23	
7:3:23	7:19:17	7:69:12	
7:3:24	7:19:19	7:69:13	
7:3:26	COM-31 7:19:20	7:69:72A	
7:3:27	7:19:23	7:73:1	
7:3:30	7:19:25	7:73:2	
7:3:31	7:19:29	7:73:6	
7:3:32	7:19:30	7:105:35	
7:3:35	7:19:31	8:105:19	
7:3:36	7:19:32	8:106:1	
7:3:37	7:19:36	8:106:5	
7:3:38	7:19:37	7:107:1	
7:3:48	7:19:38	COM-32 7:19:28	
7:3:50	7:65:2	COM-33 7:19:33	
7:3:52	7:65:4	COM-34 7:19:35	
7:3:53	7:65:6	COM-40 7:107:2	
7:3:54	7:65:8	COM-63 7:3:64	
7:3:60	7:65:9	COM-70 7:69:74	
7:3:68			

Properties are identified by City of Williston Assessors Map and Lot Number (e.g., 3-18).

Table 4-5
Monitoring Locations Included in Monitored Natural Attenuation and Long-Term Monitoring Programs
Commerce Street Plume Superfund Site
Williston, Vermont

Well ID	Aquifer Zone	Northing	Easting
AIP-01	DOB	712371.5783	1478407.3054
AL-1	IOB	712114.7865	1477632.9172
AL-15	SOB	711925.3000	1478263.1000
ASI-02S	SOB	711162.6920	1477998.1107
ASI-03D2	IOB	711055.8400	1477912.7200
ASI-04D2	DOB	710971.5001	1478239.6000
ASI-04S	SOB	710973.5562	1478236.8678
ASI-05D2	DOB	711258.3000	1478330.8000
ASI-05S	SOB	711259.7767	1478328.9184
ASI-08S	SOB	710775.0717	1478095.1958
ASI-14D2	IOB	711346.2001	1477595.3999
ASI-15D2	DOB	711789.3000	1477798.9999
ASI-16D2	DOB	711944.5752	1477546.1421
ASI-23D2	IOB	711457.5001	1477218.4000
BM-3D	IOB	711892.2099	1478212.1299
MI-2	SOB	712197.0400	1478145.7000
MW-02M	IOB	712140.7320	1478536.0328
MW-03D	DOB	712188.9150	1478145.5359
MW-04D	DOB	711717.1544	1478068.5873
MW-05D	DOB	711510.7592	1477996.6724
MW-06D	DOB	711242.5173	1478250.5314
MW-06M	IOB	711250.4280	1478253.4081
MW-07M	IOB	710810.3098	1477806.8178
MW-08M	IOB	712011.9061	1477134.1669
MW-08S	SOB	712021.6715	1477127.6564
MW-09M	IOB	711678.5390	1477422.8540
MW-10D	DOB	711128.6595	1477098.3595

SOB wells in MNA/LTM:	7
IOB wells in MNA/LTM:	10
DOB wells in MNA/LTM:	10
Total wells in MNA/LTM:	27

Notes:
SOB = shallow overburden, screened 0 - 20 feet below ground surface (bgs).
IOB = intermediate overburden, screened 20 - 30 feet bgs.
DOB = deep overburden, screened greater than 30 feet bgs.
Northing and easting shown are in 1983 North American Datum, State Plane Feet, Vermont

Table 5-1
Cost Detail
Alternative SO1: No Action
Commerce Street Plume Superfund Site
Williston, Vermont

ALTERNATIVE SO1: NO ACTION

Site: Commerce Street Plume Superfund Site
Location: Williston, Vermont
Phase: Feasibility Study (-30% to +50%)
Base Year: 2015
Date: April 2015

Description: The No Action Alternative is required to be evaluated per CERCLA. The No Action alternative does not treat, remove or routinely monitor soil, but does require 5-year reviews.

Description	Qty.	Units	Unit Cost	Cost	Notes
Capital Costs					
Institutional Controls	0	ea	$ 6,000	$ -	
(Deed Restrictions and/or Activity Use Restrictions)					
Total Before Contingency and other factors				**$ -**	
Contingency (30%)	0%			$ -	
				$ -	
Engineering Design	0%			$ -	
Project Management	0%			$ -	
Construction Management (Field Oversight and Reporting)	0%			$ -	
Total Capital Costs:				**$ -**	
Annualized O&M Costs					**Notes:**
Groundwater Monitoring				$ -	Annual O&M Costs shown are average annualized costs over
Analytical Costs				$ -	the period 0-30 years. See Appendix C for yearly O&M cost detail.
Routine Maintenance				$ -	
Site Inspections				$ -	
Annual Reporting				$ -	
Five-Year Review Cost				$ 5,000	
Contingency (10%)				$ 500	
Project Management (5%)				$ 250	
Total Annual O&M Cost				**$ 5,750**	
Subtotal					
Cost type	**Year**	**Total Non-Discounted Cost**	**Total Annual O&M Cost**	**Discount Rate**	**PRESENT VALUE**
Present Value Analysis					
Capital Cost	0	$ -			$ -
Annual O&M Cost	1-30	$ 172,500	$ 5,750	7%	$ 62,037
					$ 62,037

From O&M Cost Sheets in Appendix C

Table 5-2
Cost Detail
Alternative SO2: Limited Action/Institutional and Engineered Controls
Commerce Street Plume Superfund Site
Williston, Vermont

ALTERNATIVE SO2: LIMITED ACTION - INSTITUTIONAL AND ENGINEERED CONTROLS

Site: Commerce Street Plume Superfund Site
Location: Williston, Vermont
Phase: Feasibility Study (-30% to +50%)
Base Year: 2015
Date: April 2015

Description: The Limited Action alternative does not treat, remove or routinely monitor impacted soil. Institutional controls in the form of deed restrictions will be placed on the property that contains the impacted soil. Stipulations will be added requiring protective measures during invasive subsurface activities (e.g., excavations, utility trenches) to prevent human exposure to contaminated soil. Additionally, a fence will be erected around the portion of the property that contains the impacted soil.

Description	Qty.	Units	Unit Cost	Cost	Notes
Capital Costs					
Mobilization / Demobilization	1	ls	$ 1,000	$ 1,000	
Clearing and Grubbing of trees for fence line	1	ls	$ 8,500	$ 8,500	
Temporary Facilities	1	ls	$ 500	$ 500	
Fencing	600	ft	$ 25	$ 15,000	
Institutional Controls	1	ea	$ 8,000	$ 8,000	
(Deed Restrictions and/or Activity Use Restrictions)					
Total Before Contingency and other factors				**$ 33,000**	
Contingency (30%)	30%			$ 9,900	
				$ 42,900	
Engineering Design	9%			$ 3,861	
Project Management	8%			$ 3,432	
Construction Management (Field Oversight and Reporting)	12%			$ 5,148	
Total Capital Costs:				**$ 55,341**	
Annualized O&M Costs					**Notes:**
Groundwater Monitoring				$ -	Annual O&M Costs shown are average annualized costs over
Analytical Costs				$ -	the period 0-30 years. See Appendix C for yearly O&M cost detail.
Routine Maintenance				$ 700	
Site Inspections				$ 2,533	
Annual Reporting				$ 1,500	
Five-Year Review Cost				$ 5,000	
Contingency (10%)				$ 973	
Project Management (5%)				$ 487	
Total Annual O&M Cost				**$ 11,193**	

Cost type	Year	Subtotal	Total Non-Discounted Cost	Total Annual O&M Cost	Discount Rate	PRESENT VALUE	
Present Value Analysis							
Capital Cost	0	$	55,341			$ 55,341	
Annual O&M Cost	1-30	$	335,800	$ 11,193	7%	$ 128,844	From O&M Cost Sheets in Appendix C
						$	

Table 5-3
Cost Detail
Alternative SO3: Excavation and Off-Site Disposal
Commerce Street Plume Superfund Site
Williston, Vermont

ALTERNATIVE SO3: EXCAVATION AND OFF-SITE DISPOSAL

Site: Commerce Street Plume Superfund Site
Location: Williston, Vermont
Phase: Feasibility Study (-30% to +50%)
Base Year: 2015
Date: April 2015

Description: The Soil Excavation and Off-Site Disposal action includes the excavation, loading, transport, and off-site disposal of contaminated soil from 96 Commerce Street (former Mitec Systems property). The soil is presumed to contain RCRA characteristic hazardous waste. This action includes re-grading with clean fill and restoring vegetation.

Description	Qty.	Units	Unit Cost	Cost	Notes
Capital Costs					
Soil Excavation and Off-Site Disposal (former Mitec Systems property)					
Pre-Design Soil Confirmation Sampling	1.5	day	$ 3,500	$ 5,250	(15 borings over 1.5 days with Geoprobe)
Analytical sampling (Total and Hexavalent Chromium)	45	ea	$ 65	$ 2,925	3 samples per boring
Mobilization / Demobilization	1	ls	$ 5,000	$ 5,000	
Clearing and Grubbing of excavation area	1	ls	$ 6,500	$ 6,500	
Temporary Facilities	1	ls	$ 1,000	$ 1,000	
Erosion and Sediment Control	440	ft	$ 12	$ 5,280	
Soil Excavation	1	day	$ 12,500	$ 12,500	
Transportation and Disposal	945	tons	$ 325	$ 307,125	Assumes 630 CY as hazardous waste (Chromium)
Clean Fill	945	tons	$ 25	$ 23,625	
Institutional Controls	0	ea	$ 8,000	$ -	
(Deed Restrictions and/or Activity Use Restrictions)					
Total Before Contingency and other factors				**$ 369,205**	

Table 5-3
Cost Detail
Alternative SO3: Excavation and Off-Site Disposal
Commerce Street Plume Superfund Site
Williston, Vermont

Description	Qty.	Units	Unit Cost	Cost	Notes
Contingency (30%)	30%			$ 110,762	
				$ 479,967	
Engineering Design	10%			$ 47,997	
Project Management	6%			$ 28,798	
Construction Management (Field Oversight and Reporting)	8%			$ 38,397	
			Total Capital Costs:	**$ 595,158**	
Annualized O&M Costs					
Groundwater Monitoring				$ -	
Analytical Costs				$ -	
Routine Maintenance				$ -	**Notes:** Annual O&M Costs shown are average annualized costs over the period 0-30 years. See Appendix C for yearly O&M cost detail.
Site Inspections				$ -	
Annual Reporting				$ -	
Five-Year Review Cost				$ 5,000	
Contingency (10%)				$ 500	
Project Management (5%)				$ 250	
			Total Annual O&M Cost	**$ 5,750**	

Cost type	Subtotal Year	Total Non-Discounted Cost	Total Annual O&M Cost	Discount Rate	PRESENT VALUE	
Present Value Analysis						
Capital Cost	0	$ 595,158			$ 595,158	
Annual O&M Cost	1-30	$ 172,500	$ 5,750	7%	$ 62,037	From O&M Cost Sheets in Appendix C
					$ 657,196	

Table 5-4
Cost Detail
Alternative GW1: No Action
Commerce Street Plume Superfund Site
Williston, Vermont

ALTERNATIVE GW1: NO ACTION

Site: Commerce Street Plume Superfund Site
Location: Williston, Vermont
Phase: Feasibility Study (-30% to +50%)
Base Year: 2015
Date: April 2015

Description: The No Action Alternative is required to be evaluated per CERCLA. The No Action alternative does not treat, remove or routinely monitor groundwater but does require 5-year reviews.

Description	Qty.	Units	Unit Cost	Cost	Notes
Capital Costs					
Institutional Controls	0	ea	$ 8,000	$ -	
(Deed Restrictions and/or Activity Use Restrictions)					
Total Before Contingency and other factors				**$ -**	
Contingency (30%)	0%			$ -	
				$ -	
Engineering Design	0%			$ -	
Project Management	0%			$ -	
Construction Management (Field Oversight and Reporting)	0%			$ -	
Total Capital Costs:				**$ -**	
Annualized O&M Costs					**Notes:**
Groundwater Monitoring				$ -	Annual O&M Costs shown are average annualized costs over
Analytical Costs				$ -	the period 0-30 years. See Appendix C for yearly O&M cost detail.
Routine Maintenance				$ -	
Site Inspections				$ -	
Annual Reporting				$ -	
Five-Year Review Cost				$ 5,000	
Contingency (10%)				$ 500	
Project Management (5%)				$ 250	
Subtotal			**Total Annual O&M Cost**	**$ 5,750**	

Cost type	Year	Total Non-Discounted Cost	Total Annual O&M Cost	Discount Rate	PRESENT VALUE	
Present Value Analysis						
Capital Cost	0	$ -			$ -	
Annual O&M Cost	1-30	$ 172,500	$ 5,750	7%	$ 62,037	From O&M Cost Sheets in Appendix C
					$	

Table 5-5
Cost Detail
Alternative GW2: Limited Action - Institutional Controls
Commerce Street Plume Superfund Site
Williston, Vermont

ALTERNATIVE GW2: LIMITED ACTION - INSTITUTIONAL CONTROLS

Site: Commerce Street Plume Superfund Site
Location: Williston, Vermont
Phase: Feasibility Study (-30% to +50%)
Base Year: 2015
Date: April 2015

Description: The Limited Action alternative does not treat or remove contaminated groundwater. The groundwater within the impacted boundary will be reclassified as Class IV per the Vermont Groundwater Protection Rule, designating the water as non-potable and restricting the installation of new water supply wells on any property within the boundary. Institutional controls will also require protective measures during invasive subsurface activities (e.g., excavations, utility trenches) to prevent direct human contact to and inhalation of vapors emanating from shallow contaminated groundwater. Requires limited monitoring to ensure that contaminants are not migrating beyond the new Class IV boundary.

Description	Qty.	Units	Unit Cost	Cost	Notes
Capital Costs					
Groundwater Sampling - Compliance Wells	1	wk	$ 24,625	$ 24,625	Assumes 6 compliance wells. Includes labor, travel and ODCs
Analytical Costs	6	ea	$ 125	$ 750	VOCs only
Temporary Facilities	1	ls	$ 500	$ 500	
IDW	2	dr	$ 500	$ 1,000	
Data Summary Report	1	ls	$ 8,500	$ 8,500	
Institutional Controls	1	ea	$ 8,000	$ 8,000	
(Deed Restrictions and/or Activity Use Restrictions)					
Total Before Contingency and other factors				**$ 43,375**	
Contingency (20%)	20%			$ 8,675	
				$ 52,050	
Engineering Design	9%			$ 4,685	
Project Management	8%			$ 4,164	
Construction Management (Field Oversight and Reporting)	12%			$ 562	
Total Capital Costs:				**$ 61,461**	
Annualized O&M Costs					**Notes:**
Groundwater Monitoring				$ 5,500	Annual O&M Costs shown are average annualized costs over
Analytical Costs				$ 375	the period 0-30 years. See Appendix C for yearly O&M cost detail.
Routine Maintenance				$ 933	
Site Inspections				$ -	
Annual Reporting				$ 2,250	
Five-Year Review Cost				$ 5,000	
Contingency (10%)				$ 1,406	
Project Management (5%)				$ 703	
Total Annual O&M Cost				**$ 16,167**	

Subtotal

Table 5-5
Cost Detail
Alternative GW2: Limited Action - Institutional Controls
Commerce Street Plume Superfund Site
Williston, Vermont

Description	Qty.	Units	Unit Cost	Cost	Notes
Cost type	**Year**	**Total Non-Discounted Cost**	**Total Annual O&M Cost**	**Discount Rate**	**PRESENT VALUE**	
Present Value Analysis						
Capital Cost	0	$ 61,461			$ 61,461	
Annual O&M Cost	1-30	$ 485,013	$ 16,167	7%	$ 184,178	From O&M Cost Sheets in Appendix C
					$ 245,639	

Table 5-6
Cost Detail
Alternative GW3: Limited Action - Monitored Natural Attenuation and Long-Term Monitoring
Commerce Street Plume Superfund Site
Williston, Vermont

ALTERNATIVE GW3: LIMITED ACTION - MONITORED NATURAL ATTENUATION AND LONG-TERM MONITORING

Site: Commerce Street Plume Superfund Site
Location: Williston, Vermont
Phase: Feasibility Study (-30% to +50%)
Base Year: 2015
Date: April 2015

Description: The Limited Action with MNA Alternative does not include active treatment to address the contamination. Monitoring will be performed across the entire plume to assess whether natural attenuation is occurring. Monitoring wells will be selected, and routinely sampled and evaluated for MNA parameters with annual reports documenting the data and evaluating the trends. This alternative includes the institutional controls and Class IV boundary monitoring described in Alternative GW2.

Description	Qty.	Units	Unit Cost	Cost	Notes
Capital Costs					
Groundwater Sampling (2 rounds in Year 1)	2	wk	$ 38,500	$ 77,000	Assumes 27 wells to be sampled as part of MNA
Analytical Costs	54	ea	$ 815	$ 44,010	
Temporary Facilities	2	ls	$ 1,000	$ 2,000	
IDW	4	dr	$ 500	$ 2,000	
Data Summary Report	1	ls	$ 12,500	$ 12,500	
Institutional Controls	1	ea	$ 8,000	$ 8,000	
Total Before Contingency and other factors				**$ 145,510**	
Contingency (30%)	30%			$ 43,653.00	
				$ 189,163	
Engineering Design	8%			$ 15,133	
Project Management	8%			$ 15,133	
Construction Management (Field Oversight and Reporting)	10%			$ 18,916	
Total Capital Costs:				**$ 238,345**	
Annualized O&M Costs					**Notes:**
Groundwater Monitoring				$ 44,917	Annual O&M Costs shown are average annualized costs over
Analytical Costs				$ 25,710	the period 0-30 years. See Appendix C for yearly O&M cost detail.
Routine Maintenance				$ 400	
Site Inspections				$ -	
Annual Reporting				$ 8,667	
Five-Year Review Cost				$ 5,000	
Contingency (10%)				$ 8,469	
Project Management (5%)				$ 4,235	
Total Annual O&M Cost				**$ 97,397**	

Cost type	SUBTOTAL Year	Total Non-Discounted Cost	Total Annual O&M Cost	Discount Rate	PRESENT VALUE	
Present Value Analysis						
Capital Cost	0	$ 238,345			$ 238,345	
Annual O&M Cost	1-30	$ 2,921,920	$ 97,397	7%	$ 1,349,179	From O&M Cost Sheets in Appendix C
					$ 1,587,524	

ALTERNATIVE GW5: IN SITU TREATMENT (ISCO) AND MONITORED NATURAL ATTENUATION

Site: Commerce Street Plume Superfund Site
Location: Williston, Vermont
Phase: Feasibility Study (-30% to +50%)
Base Year: 2015
Date: April 2015

Description: This alternative addresses the site-wide dissolved-phase plume with MNA and institutional controls, as described in Alternative GW3. In addition, portions of the plume with TCE concentrations >50,000 ppb will receive targeted chemical treatment through wells drilled into the saturated zone. Chemical oxidant injected into the subsurface either destroys compounds or converts them to less-toxic substances through a series of oxidation reactions. This alternative will require bench and pilot-scale tests during remedial design to determine design parameters, which oxidants are suitable and whether on-going biodegradation is occurring.

Description	Qty.	Units	Unit Cost	Cost	Notes
ISCO Portion - Eastern Area >50,000 µg/L: 12 foot thickness over 54,000 SF Area					
Capital Costs					
ISCO Bench Scale					
- Sample Collection	1	ea	$ 7,500	$ 7,500	
- Oxidant Studies	1	ea	$ 20,000	$ 20,000	
- Reporting	1	ea	$ 12,000	$ 12,000	
ISCO Pilot Study					
- Sample/Water Collection	1	ea	$ 7,500	$ 7,500	
- Mobilization and Site Prep.	1	ea	$ 10,000	$ 10,000	
- Installation of Injection Points	1	wk	$ 15,000	$ 15,000	
- Batching, Injection, and Monitoring	1	wk	$ 26,625	$ 26,625	
- Sample Analysis	25	ea	$ 1,000	$ 25,000	
- Decon and Site Restoration	1	ea	$ 15,000	$ 15,000	
- Reporting	1	ls	$ 25,000	$ 25,000	
				$ 163,625	Bench and Pilot Studies Subtotal
ISCO Treatment					
Mobilization	2	ea	$ 15,000	$ 30,000	
Temporary Facilities and Work Area Setup	2	ea	$ 10,000	$ 20,000	
ISCO Injection Points (Direct Inject with Geoprobe)	6	wk	$ 30,000	$ 180,000	2 events, 3 weeks each, 2 rigs
Oxidant	450,000	lbs	$ 2.50	$ 1,125,000	Includes Shipping
pH Amendments	960,000	lbs	$ 0.30	$ 288,000	Includes Shipping
Batching of Oxidant	2	wk	$ 26,625	$ 53,250	
Treatment Monitoring and Sample Collection During Injections	6	wk	$ 26,625	$ 159,750	
Sample Analysis	50	ea	$ 1,000	$ 50,000	
Site Restoration	2	ea	$ 10,000	$ 20,000	
Decon and Demobilization	2	ea	$ 15,000	$ 30,000	
IDW Disposal	2	ea	$ 10,000	$ 20,000	
Post Injection Sample Collection (2 rounds)	2	wk	$ 37,800	$ 75,600	
Post Injection Sample Analysis (2 rounds)	100	ea	$ 1,000	$ 100,000	
				$ 2,151,600	

Table 5-7
Cost Detail
Alternative GW5: *In Situ* Treatment (ISCO) and Monitored Natural Attenuation
Commerce Street Plume Superfund Site
Williston, Vermont

Description	Qty.	Units	Unit Cost	Cost	Notes
Institutional Controls	1	ls	$ 8,000	$ 8,000	
Total Before Contingency and other factors				**$ 2,323,225**	
Contingency (30%)	30%			$ 696,967.50	
				$ 3,020,193	
Engineering Design	8%			$ 241,615	
Project Management	4%			$ 120,808	
Construction Management (Field Oversight and Reporting)	5%			$ 151,010	
Total Capital Costs:				**$ 3,533,625**	
Annualized O&M Costs					**Notes:**
Groundwater Monitoring				$ 19,250	Annual O&M Costs shown are average
Analytical Costs				$ 11,010	annualized costs over the period 0-30 years.
Routine Maintenance				$ 400	See Appendix B for yearly O&M cost detail.
Site Inspections				$ -	
Annual Reporting				$ 3,333	
Five-Year Review Cost				$ 5,000	
Contingency (10%)				$ 3,899	
Project Management (5%)				$ 1,950	
Total Annual O&M Cost				**$ 44,842**	

Cost type	Year Subtotal	Total Non-Discounted Cost	Total Annual O&M Cost	Discount Rate	PRESENT VALUE
Present Value Analysis					
Capital Cost	0	$ 3,533,625			$ 3,533,625
Annual O&M Cost	1-30	$ 1,345,270	$ 44,842	7%	$ 767,042
					$ 4,300,667

Table 5-8
Cost Detail
Alternative GW5: *In Situ* Treatment (ISB) and Monitored Natural Attenuation
Commerce Street Plume Superfund Site
Williston, Vermont

ALTERNATIVE GW5: IN SITU TREATMENT (ISB) AND MONITORED NATURAL ATTENUATION

Site: Commerce Street Plume Superfund Site
Location: Williston, Vermont
Phase: Feasibility Study (-30% to +50%)
Base Year: 2015
Date: April 2015

Description: This alternative addresses the site-wide dissolved-phase plume with MNA and institutional controls, as described in Alternative GW3. In addition, portions of the plume with TCE concentrations > 5,000 ppb will receive targeted biological treatment through wells drilled into the saturated zone. Injection of biostimulants, carbon sources, nutrients and naturally-occurring or bio-engineered bacteria into the subsurface stimulates or supplements natural attenuation processes. This alternative will require bench and pilot-scale tests during remedial design to determine design parameters, which oxidants are suitable, and whether on-going biodegradation is aerobic or anaerobic.

Description	Qty.	Units	Unit Cost	Cost	Notes
ISB Portion - Eastern and Western Areas >5,000 µg/L: 15 foot thickness over 400,000 SF Area					
Capital Costs					
ISB Bench Scale					
- Sample Collection	1	ea	$ 7,500	$ 7,500	
- Microcosm Studies	1	ea	$ 35,000	$ 35,000	
- Reporting	1	ea	$ 12,000	$ 12,000	
ISB Pilot Study					
- Sample/Water Collection	1	ea	$ 7,500	$ 7,500	
- Mobilization and Site Prep.	1	ea	$ 10,000	$ 10,000	
- Creation of Cultures	1	ea	$ 25,000	$ 25,000	
- Installation of Injection Points	1	wk	$ 15,000	$ 15,000	
- Batching, Injection, and Monitoring	1	wk	$ 37,800	$ 37,800	
- Sample Analysis	25	ea	$ 1,000	$ 25,000	
- Decon and Site Restoration	1	ea	$ 15,000	$ 15,000	
- Reporting	1	ls	$ 35,000	$ 35,000	
				$ 224,800	Bench and Pilot Studies Subtotal
ISB Treatment					
Mobilization (East and West Areas)	4	ea	$ 15,000	$ 60,000	4 Mobilizations
Temporary Facilities and Work Area Setup	4	ea	$ 10,000	$ 40,000	
Aquifer Amendments to adjust pH, DO, and ORP	500	gal	$ 100	$ 50,000	Includes Shipping
Cultures/Bacteria	1,200	L	$ 210	$ 252,000	Includes Shipping
Electron Donor - Sodium Lactate	120,000	lbs	$ 3.0	$ 360,000	Includes Shipping
Electron Donor - LactOil	330,000	lbs	$ 3.5	$ 1,155,000	Includes Shipping
On Site Batching and Preparation	6	wk	$ 37,800	$ 226,800	
ISB Injection Points (Direct Inject with Geoprobe)	12	wk	$ 45,000	$ 540,000	4 events, 3 weeks each, 3 Rigs
Treatment Monitoring and Sample Collection During Injections	12	wk	$ 37,800	$ 453,600	
Sample Analysis	50	ea	$ 1,000	$ 50,000	
Site Restoration	4	ea	$ 10,000	$ 40,000	

Table 5-8
Cost Detail
Alternative GW5: *In Situ* Treatment (ISB) and Monitored Natural Attenuation
Commerce Street Plume Superfund Site
Williston, Vermont

Description	Qty.	Units	Unit Cost	Cost	Notes
Decon and Demobilization	4	ea	$ 15,000	$ 60,000	
IDW Disposal	4	ea	$ 10,000	$ 40,000	
Post Injection Sample Collection (2 rounds)	2	wk	$ 37,800	$ 75,600	
Post Injection Sample Analysis (2 rounds)	100	ea	$ 1,000	$ 100,000	
				$ 3,503,000	Treatment Subtotal
Institutional Controls	1	ls	$ 8,000	$ 8,000	
	Total Before Contingency and other factors			**$ 3,735,800**	
Contingency (30%)	30%			$ 1,120,740	
			Subtotal	**$ 4,856,540**	
Engineering Design	8%			$ 388,523	
Project Management	5%			$ 242,827	
Construction Management (Field Oversight and Reporting)	7%			$ 339,958	
			Total Capital Costs:	**$ 5,827,848**	
					Notes:
Annualized O&M Costs					Annual O&M Costs shown are average
Groundwater Monitoring				$ 19,250	annualized costs over the period 0-30 years.
Analytical Costs				$ 11,010	See Appendix B for yearly O&M cost detail.
Routine Maintenance				$ 400	
Site Inspections				$ -	
Annual Reporting				$ 3,333	
Five-Year Review Cost				$ 5,000	
Contingency (10%)				$ 3,899	
Project Management (5%)				$ 1,950	
			Total Annual O&M Cost	**$ 44,842**	

Cost type	Year	Total Non-Discounted Cost	Total Annual O&M Cost	Discount Rate	PRESENT VALUE
Present Value Analysis					
Capital Cost	0	$ 5,827,848			$ 5,827,848
Annual O&M Cost	1-30	$ 1,345,270	$ 44,842	7%	$ 767,042
					$ 6,594,890

Table 5-9
Cost Detail
Alternative GW5: *In Situ* Treatment (ISCO and ISB Barriers) and Monitored Natural Attenuation
Commerce Street Plume Superfund Site
Williston, Vermont

ALTERNATIVE GW5: IN SITU GROUNDWATER TREATMENT (ISCO, ISB ZONES) AND MONITORED NATURAL ATTENUATION

Site: Commerce Street Plume Superfund Site
Location: Williston, Vermont
Phase: Feasibility Study (-30% to +50%)
Base Year: 2015
Date: April 2015

Description: This alternative addresses the site-wide dissolved-phase plume with MNA and institutional controls, as described in Alternative GW3. In addition, portions of the plume with TCE concentrations > 50,000 ppb will receive targeted chemical treatment and TCE > 500 ppb will receive targeted biological treatment through wells drilled into the saturated zone. Chemical oxidant injected into the subsurface either destroys compounds or converts them to less-toxic substances through a series of oxidation reactions. Injection of biostimulants, carbon sources, nutrients and naturally-occurring or bio-engineered bacteria into the subsurface stimulates or supplements natural attenuation processes. This alternative will require bench- and pilot-scale tests during remedial design to determine design parameters, which oxidants are suitable and whether on-going biodegradation is aerobic or anaerobic. Either treatment may be used alone, or together in a treatment train.

Description	Qty.	Units	Unit Cost	Cost	Notes
ISCO Portion - Eastern Area with TCE >50,000 µg/L: 12 foot thickness over 54,000 SF Area and ISB Treatment Barriers of TCE >500 µg/L (120,000 SF for East and West Areas)					
ISB Bench Scale					
- Sample Collection	1	ea	$ 7,500	$ 7,500	
- Microcosm Studies	1	ea	$ 35,000	$ 35,000	
- Reporting	1	ea	$ 12,000	$ 12,000	
ISB Pilot Study					
- Sample/Water Collection	1	ea	$ 7,500	$ 7,500	
- Mobilization and Site Prep.	1	ea	$ 10,000	$ 10,000	
- Creation of Cultures	1	ea	$ 25,000	$ 25,000	
- Installation of Injection Points	1	wk	$ 15,000	$ 15,000	
- Batching, Injection, and Monitoring	1	wk	$ 37,800	$ 37,800	
- Sample Analysis	25	ea	$ 1,000	$ 25,000	
- Decon and Site Restoration	1	ea	$ 15,000	$ 15,000	
- Reporting	1	ls	$ 35,000	$ 35,000	
				$ 224,800	**Bench and Pilot Studies Subtotal**
ISB Treatment					
Mobilization (East and West Areas)	2	ea	$ 15,000	$ 30,000	2 Mobilizations
Temporary Facilities and Work Area Setup	2	ea	$ 10,000	$ 20,000	
Aquifer Amendments to adjust pH, DO, and ORP	250	gal	$ 100	$ 25,000	Includes Shipping
Cultures/Bacteria	600	L	$ 210	$ 126,000	Includes Shipping
Electron Donor - Sodium Lactate	60,000	lbs	$ 3.0	$ 180,000	Includes Shipping
Electron Donor - LactOil	165,000	lbs	$ 3.5	$ 577,500	Includes Shipping
On Site Batching and Preparation	3	wk	$ 37,800	$ 113,400	
ISB Injection Points (Direct Inject with Geoprobe)	6	wk	$ 45,000	$ 270,000	2 events, 3 weeks each, 3 Rigs
Treatment Monitoring and Sample Collection During Injections	6	wk	$ 37,800	$ 226,800	
Sample Analysis	50	ea	$ 1,000	$ 50,000	
Site Restoration	2	ea	$ 10,000	$ 20,000	

Table 5-9
Cost Detail
Alternative GW5: *In Situ* Treatment (ISCO and ISB Barriers) and Monitored Natural Attenuation
Commerce Street Plume Superfund Site
Williston, Vermont

Description	Qty.	Units	Unit Cost	Cost	Notes
Decon and Demobilization	2	ea	$ 15,000	$ 30,000	
IDW Disposal	2	ea	$ 10,000	$ 20,000	
Post Injection Sample Collection (2 rounds)	2	wk	$ 37,800	$ 75,600	
Post Injection Sample Analysis (2 rounds)	100	ea	$ 1,000	$ 100,000	
				$ 1,864,300	**Bio Treatment Zone Subtotal**
Institutional Controls	1	ls	$ 8,000	$ 8,000	
	Total Before Contingency and other factors			**$ 2,097,100**	
Contingency (30%)	30%			$ 629,130	
			Subtotal	**$ 2,726,230**	
Engineering Design	8%			$ 218,098	
Project Management	5%			$ 136,312	
Construction Management (Field Oversight and Reporting)	7%			$ 190,836	
	Total ISB Barrier Capitol Costs			**$ 3,271,476**	
	Total ISCO Capital Costs			**$ 3,533,625**	**Refer to Table 5-7**
	ISCO and ISB Barrier Capital Costs			**$ 6,805,101**	
					Notes:
Annualized O&M Costs					Annual O&M Costs shown are average
Groundwater Monitoring				$ 19,250	annualized costs over the period 0-30 years.
Analytical Costs				$ 11,010	See Appendix B for yearly O&M cost detail.
Routine Maintenance				$ 400	
Site Inspections				$ -	
Annual Reporting				$ 3,333	
Five-Year Review Cost				$ 5,000	
Contingency (10%)				$ 3,899	
Project Management (5%)				$ 1,950	
			Total Annual O&M Cost	**$ 44,842**	

Cost type	Year	Total Non-Discounted Cost	Total Annual O&M Cost	Discount Rate	PRESENT VALUE
Present Value Analysis					
Capital Cost	0	$ 6,805,101			$ 6,805,101
Annual O&M Cost	1-30	$ 1,345,270	$ 44,842	7%	$ 767,042
					$ 7,572,143

Table 5-10
Cost Detail
Alternative VM1: No Action
Commerce Street Plume Superfund Site
Williston, Vermont

ALTERNATIVE VM1: NO ACTION

Site: Commerce Street Plume Superfund Site
Location: Williston, Vermont
Phase: Feasibility Study (-30% to +50%)
Base Year: 2015
Date: April 2015

Description: The No Action Alternative is required to be evaluated per CERCLA. The No Action alternative does not treat, or routinely monitor indoor air, but does require 5-year reviews.

Description	Qty.	Units	Unit Cost	Cost	Notes
Capital Costs					
Institutional Controls	0	ea	$ 6,000	$ -	
(Deed Restrictions and/or Activity Use Restrictions)					
Total Before Contingency and other factors				**$ -**	
Contingency (30%)	0%			$ -	
				$ -	
Engineering Design	0%			$ -	
Project Management	0%			$ -	
Construction Management (Field Oversight and Reporting)	0%			$ -	
Total Capital Costs:				**$ -**	
Annualized O&M Costs					**Notes:**
Groundwater Monitoring				$ -	Annual O&M Costs shown are average annualized costs over
Analytical Costs				$ -	the period 0-30 years. See Appendix C for yearly O&M cost detail.
Routine Maintenance				$ -	
Site Inspections				$ -	
Annual Reporting				$ -	
Five-Year Review Cost				$ 5,000	
Contingency (10%)				$ 500	
Project Management (5%)				$ 250	
Total Annual O&M Cost				**$ 5,750**	

Subtotal

Cost type	Year	Total Non-Discounted Cost	Total Annual O&M Cost	Discount Rate	PRESENT VALUE	Notes
Present Value Analysis						
Capital Cost	0	$ -			$ -	
Annual O&M Cost	1-30	$ 172,500	$ 5,750	7%	$ 62,037	From O&M Cost Sheets in Appendix C
					$ 62,037	

Table 5-11
Cost Detail
Alternative VM2: Sump Pump, Vapor Venting, Treatment and Discharge
Commerce Street Plume Superfund Site
Williston, Vermont

ALTERNATIVE VM2: SUMP PUMP, VAPOR VENTING, TREATMENT AND DISCHARGE

Site: Commerce Street Plume Superfund Site
Location: Williston, Vermont
Phase: Feasibility Study (-30% to +50%)
Base Year: 2015
Date: April 2015

Description: This alternative includes the continued operation of the sump pump, passive gas venting and sump water discharge system already installed in 2014 by VTDEC. In addition, a system will be installed on the property (carbon filters in a treatment shed) for the treatment of sump water prior to discharge to the ground surface and indirectly to groundwater.

Description	Qty.	Units	Unit Cost	Cost	Notes
Capital Costs					
Carbon System and Shed	1	ls	$ 1,200	$ 1,200	
Institutional Controls	1	ea	$ 8,000	$ 8,000	
(Deed Restrictions and/or Activity Use Restrictions)					
Total Before Contingency and other factors				**$ 9,200**	
Contingency (30%)	30%			$ 2,760	
				$ 11,960	
Engineering Design	9%			$ 1,076.00	
Project Management	8%			$ 956.80	
Construction Management (Field Oversight and Reporting)	12%			$ 1,435.00	
Total Capital Costs:				**$ 15,428**	
Annualized O&M Costs					**Notes:**
Groundwater Monitoring				$ -	Annual O&M Costs shown are average annualized costs over
Analytical Costs				$ -	the period 0-30 years. See Appendix C for yearly O&M cost detail.
Routine Maintenance				$ 1,500	
Site Inspections				$ 1,000	
Annual Reporting				$ -	
Five-Year Review Cost				$ 5,000	
Contingency (10%)				$ 750	
Project Management (5%)				$ 375	
Total Annual O&M Cost				**$ 8,625**	

Cost type	Year Subtotal	Total Non-Discounted Cost	Total Annual O&M Cost	Discount Rate	PRESENT VALUE	
Present Value Analysis						
Capital Cost	0	$ 15,428			$ 15,428	
Annual O&M Cost	1-30	$ 258,750	$ 8,625	7%	$ 97,713	From O&M Cost Sheets in Appendix C
					$	

Table 5-12
Cost Detail
Alternative VM3: Enhanced Vapor Mitigation
Commerce Street Plume Superfund Site
Williston, Vermont

ALTERNATIVE VM3: ENHANCED VAPOR MITIGATION

Site: Commerce Street Plume Superfund Site
Location: Williston, Vermont
Phase: Feasibility Study (-30% to +50%)
Base Year: 2015
Date: April 2015

Description: This alternative includes all the elements of Alternative VM2 and the installation of additional vapor mitigation to supplement or replace the existing system at 830 So. Brownell Road. This alternative also includes the installation of vapor mitigation or engineering controls at other properties if warranted based on samples collected in conjunction with future 5-year reviews. For estimating purposes, costs for one active system at 830 So. Brownell Road was assumed for this evaluation.

Description	Qty.	Units	Unit Cost	Cost	Notes
Capital Costs					
Carbon System	1	ls	$ 1,200	$ 1,200	
Pre-design investigation and risk analysis	1	ls	$ 12,000	$ 12,000	
Vapor barrier	1	ls	$ 3,500	$ 3,500	
Active venting system	1	ls	$ 3,500	$ 3,500	
Institutional Controls	1	ea	$ 8,000	$ 8,000	
(Deed Restrictions and/or Activity Use Restrictions)					
Total Before Contingency and other factors				**$ 28,200**	
Contingency (30%)	30%			$ 8,460	
				$ 36,660	
Engineering Design	9%			$ 3,299	
Project Management	8%			$ 2,933	
Construction Management (Field Oversight and Reporting)	12%			$ 4,399	
Total Capital Costs:				**$ 47,291**	
Annualized O&M Costs					**Notes:**
Groundwater Monitoring				$ 1,000	Annual O&M Costs shown are average annualized costs over
Analytical Costs				$ -	the period 0-30 years. See Appendix C for yearly O&M cost detail.
Routine Maintenance				$ 1,500	
Site Inspections				$ 1,000	
Annual Reporting				$ -	
Five-Year Review Cost				$ 5,000	
Contingency (10%)				$ 850	
Project Management (5%)				$ 425	
Total Annual O&M Cost				**$ 9,775**	

Cost type	Year Subtotal	Total Non-Discounted Cost	Total Annual O&M Cost	Discount Rate	PRESENT VALUE	
Present Value Analysis						
Capital Cost	0	$ 47,291			$ 47,291	
Annual O&M Cost	1-30	$ 293,250	$ 9,775	7%	$ 110,121	From O&M Cost Sheets in Appendix C
					$	

Table 5-13
Location-Specific ARARs for Soil Alternatives
Commerce Street Plume Superfund Site
Williston, Vermont

REQUIREMENT	STATUS	REQUIREMENT SYNOPSIS	ACTION TAKEN TO COMPLY WITH ARARs		
			SO1	SO2	SO3
STATE ARARs and TO BE CONSIDERED GUIDANCES					
10 VSA Chapter 37, Vermont Wetlands Protection And Water Resources Management Act; Environmental Protection Rules, Chapter 30, Vermont Wetland Rules	Applicable	These standards establish criteria for delineating Class One and Class Two wetlands, which are considered significant wetlands, and sets forth allowed uses for these wetlands. Jurisdiction under the rules includes a 100-foot and 50-foot buffer zone to Class One and Class Two wetlands, respectively. The uses must not have undue adverse impacts on the significant functions of the wetland. Class Three wetlands are defined, but are not protected under these rules (they are addressed under Title 10 VSA Chapter 151, below). If any work occurs in wetlands or buffer zones, to be further delineated, it will comply with this ARAR.	Alternative SO1 requires no action and, therefore, will have no impact on wetlands.	No Class I wetlands occur on-site and Class II wetlands are limited to the area between Commerce Street and Kirby Lane and to the east of the unnamed stream. A confirmatory wetland and buffer zone delineation will be performed prior to work in the vicinity. Alteration of any Class II wetlands will be mitigated, as required, to restore ecological functions and values.	No Class I wetlands occur on-site and Class II wetlands are limited to the area between Commerce Street and Kirby Lane and to the east of the unnamed stream. A confirmatory wetland and buffer zone delineation will be performed prior to work in the vicinity. Alteration of any Class II wetlands will be mitigated, as required, to restore ecological functions and values.
10 VSA Chapter 151, Vermont's Land Use and Development Law (Act 250); Act 250 Rules (October 1, 2013)	Relevant and Appropriate	Issues to be addressed in assessing compliance with Act 250 include substantive environmental and facility siting requirements associated with: • any resulting undue water and air pollution, including construction-related dust and protection of headwaters (criterion 1) • compliance with all standards for disposal of wastes (criterion 1(B)); • impacts on floodways (criterion 1(D)); • impacts on streams (criterion 1(E)); • impact on state-regulated wetlands (Class One, Two, and Three); (criterion 1(G)); • any resulting undue erosion control or reduction in capacity of land to hold water (criterion 4); • impact on rare and natural areas, historic sites (criterion 8(A)); • impact on necessary wildlife habitat and endangered species (criterion 8(B)); • extraction of earth resources (criterion 9(D) and (E)); • energy conservation (criterion 9(F)); and • public investments (roads) (criterion 9(K)).	Alternative SO1 requires no action and, therefore, will have no impact relative to land use and development.	Alternative SO2 requires fence construction. Erosion control measures will be implemented to prevent impacts to streams, floodways, wetlands, etc. Measures will be used to limit airborne dust. Impacts on habitats, resources, and public investments will be minimized through engineered controls.	Alternative SO3 requires soil removal. Erosion control measures will be implemented to prevent impacts to streams, floodways, wetlands, etc. Measures will be used to limit airborne dust. Impacts on habitats, resources, and public investments will be minimized through engineered controls.
Vermont Historic Preservation Law, 22 VSA §§ 743(4), 761, 763, and 767.	Applicable	Places controls on actions conducted by the state that may impact historic, scientific, or archaeological sites and data.	Alternative SO1 requires no action and, therefore, will have no impact on potential historic, scientific, or archaeological sites and data.	Alternative SO2 requires very minimal soil disturbance to install a fence. Work will be completed in compliance with this ARAR, as work is further delineated, in consultation with the Vermont Division of Historic Preservation.	Alternative SO3 requires soil removal. The area of excavation has already been disturbed by former owners and subject to a removal action by the State of Vermont. Work will be completed in compliance with this ARAR, as work is further delineated, in consultation with the Vermont Division of Historic Preservation.
Vermont ANR Guidance on Riparian Buffers (December 9, 2005)	To Be Considered	This guidance provides technical information on the functions and values of riparian buffers, as well as describing acceptable activities within buffer zones. It recommends the establishment of 100 foot buffer zones to streams under circumstances where there is an increased risk of erosion and/or potential for overland flow of pollutants. Where Class II wetlands are contiguous to a waterbody, buffer widths of greater than 50 feet may be recommended based on case-specific application of this Guidance. This Guidance will also be used to recommend buffers for Class III wetlands contiguous to waterbodies, as necessary to maintain the functions and values of the riparian area. This guidance will be a TBC if any work occurs in riparian buffer zones, as further delineated.	Alternative SO1 requires no action and, therefore, will have no impact on riparian buffers.	An unnamed stream with riparian buffer zone exists on-site, which will be further delineated before work begins. Work within the riparian buffer zone will be implemented to protect the water quality of the adjacent waterway.	An unnamed stream with riparian buffer zone exists on-site, which will be further delineated before work begins. Work within the riparian buffer zone will be implemented to protect the water quality of the adjacent waterway.
FEDERAL ARARs and TO BE CONSIDERED GUIDANCES					
National Historic Preservation Act (NHPA), Section 106, 16 USC 470 *et seq*., 36 CFR Part 800	Applicable	Section 106 of the NHPA of 1966 requires EPA to take into account the effect of all of its actions on historic properties. In consultation with the State Historic Preservation Officer (SHPO) EPA is to identify potential adverse effects on historic properties and seek ways to avoid, minimize or mitigate any such effects on historic properties.	Alternative SO1 requires no action and, therefore, will have no impact on potential historic, scientific, or archaeological sites and data.	Alternative SO2 requires very minimal soil disturbance to install a fence. Work will be completed in compliance with this ARAR, as work is further delineated, in consultation with the Vermont Division of Historic Preservation.	Alternative SO3 requires soil removal. The area of excavation has already been disturbed by former owners and subject to removal action by the State of Vermont. Work will be completed in compliance with this ARAR, as work is further delineated, in consultation with the Vermont Division of Historic Preservation.

Table 5-14
Location-Specific ARARs for Groundwater Alternatives
Commerce Street Plume Superfund Site
Williston, Vermont

REQUIREMENT	STATUS	REQUIREMENT SYNOPSIS	ACTION TAKEN TO COMPLY WITH ARARs			
			GW1	GW2	GW3	GW5
STATE ARARs and TO BE CONSIDERED GUIDANCES						
10 VSA Chapter 37, Vermont Wetlands Protection And Water Resources Management Act; Environmental Protection Rules, Chapter 30, Vermont Wetland Rules	Applicable	These standards establish criteria for delineating Class One and Class Two wetlands, which are considered significant wetlands, and sets forth allowed uses for these wetlands. Jurisdiction under the rules includes a 100-foot and 50-foot buffer zone to Class One and Class Two wetlands, respectively. The uses must not have undue adverse impacts on the significant functions of the wetland. Class Three wetlands are defined, but are not protected under these rules (they are addressed under Title 10 VSA Chapter 151, below). If any work occurs in wetlands or buffer zones, to be further delineated, it will comply with this ARAR.	Alternative GW1 requires no action and, therefore, will have no impact on the Class II wetlands within the Study Area.	Alternative GW2 requires no action beyond institutional controls. Wetlands and buffer zones are to be further delineated at the Site. Any incidental work, such as the installation of new wells, within the buffer zone or wetlands, will be implemented to protect wetlands, mitigate any loss, and restore ecological functions and values.	Alternative GW3 requires no action beyond institutional controls and MNA. Wetlands and buffer zones are to be further delineated at the Site. Any incidental work, such as the installation of new wells, within the buffer zone or wetlands, will be implemented to protect wetlands, mitigate any loss, and restore ecological functions and values.	Alternative GW2 includes *in situ* treatment of the impacted groundwater. Wetlands and buffer zones are to be further delineated at the Site. Any incidental work, such as the installation of new wells, within the buffer zone or wetlands, will be implemented to protect wetlands, mitigate any loss, and restore ecological functions and values.
10 VSA Chapter 151, Vermont's Land Use and Development Law (Act 250); Act 250 Rules (October 1, 2013)	Relevant and Appropriate	Issues to be addressed in assessing compliance with Act 250 include substantive environmental and facility siting requirements associated with: • any resulting undue water and air pollution, including construction-related dust and protection of headwaters (criterion 1) • compliance with all standards for disposal of wastes (criterion 1(B)); • impacts on floodways (criterion 1(D)); • impacts on streams (criterion 1(E)); • impact on state-regulated wetlands (Class One, Two, and Three); (criterion 1(G)); • any resulting undue erosion control or reduction in capacity of land to hold water (criterion 4); • impact on rare and natural areas, historic sites (criterion 8(A)); • impact on necessary wildlife habitat and endangered species (criterion 8(B)); • extraction of earth resources (criterion 9(D) and (E)); • energy conservation (criterion 9(F)); and • public investments (roads) (criterion 9(K)).	Alternative GW1 requires no action and, therefore, will have no impact relative to land use and development.	Alternative GW2 requires no action beyond institutional controls. Any incidental work, such as the installation of new wells, will be done in compliance with this ARAR; As necessary, erosion control measures will be implemented to prevent impacts to streams, floodways, wetlands, etc. Measures will be used to limit airborne dust. Impacts on habitats, resources, and public investments will be minimized through engineered controls.	Alternative GW3 requires no action beyond institutional controls and MNA. Any incidental work, such as the installation of new wells, will be done in compliance with this ARAR; As necessary, erosion control measures will be implemented to prevent impacts to streams, floodways, wetlands, etc. Measures will be used to limit airborne dust. Impacts on habitats, resources, and public investments will be minimized through engineered controls.	Alternative GW5 includes *in situ* treatment of the impacted groundwater. Installation of new monitoring and injection wills will be done in compliance with this ARAR; As necessary, erosion control measures will be implemented to prevent impacts to streams, floodways, wetlands, etc. Measures will be used to limit airborne dust. Impacts on habitats, resources, and public investments will be minimized through engineered controls.
Vermont Historic Preservation Law, 22 VSA §§ 743(4), 761, 763, and 767.	Applicable	Places controls on actions conducted by the state that may impact historic, scientific, or archaeological sites and data.	Alternative GW1 requires no action and, therefore, will have no impact on potential historic, scientific, or archaeological sites and data.	Alternative GW2 requires no action beyond institutional controls. Incidental work, such as the installation of new wells, will be completed in compliance with this ARAR as work is further delineated in consultation with the Vermont Division of Historic Preservation.	Alternative GW2 requires no action beyond institutional controls and MNA. Incidental work, such as the installation of new wells, will be completed in compliance with this ARAR as work is further delineated in consultation with the Vermont Division of Historic Preservation.	Alternative GW3 includes in situ treatment of the impacted groundwater. Installation of new monitoring wells, will be completed in compliance with this ARAR, as work is further delineated, in consultation with the Vermont Division of Historic Preservation.
Vermont ANR Guidance on Riparian Buffers (December 9, 2005)	To Be Considered	This guidance provides technical information on the functions and values of riparian buffers, as well as describing acceptable activities within buffer zones. It recommends the establishment of 100 foot buffer zones to streams under circumstances where there is an increased risk of erosion and/or potential for overland flow of pollutants. Where Class II wetlands are contiguous to a waterbody, buffer widths of greater than 50 feet may be recommended based on case-specific application of this Guidance. This Guidance will also be used to recommend buffers for Class III wetlands contiguous to waterbodies, as necessary to maintain the functions and values of the riparian area. This guidance will be a TBC if any work occurs in riparian buffer zones, as further delineated.	Alternative GW1 requires no action and, therefore, will have no impact on riparian buffers.	Alternative GW2 requires no action beyond institutional controls. Wetlands and buffer zones are to be further delineated at the Site. Any incidental work in the riparian buffer zone, such as the installation of new wells, will be done in compliance with this ARAR.	An unnamed stream with riparian buffer zone exists on-site, which will be further delineated before work begins. Any incidental work within the riparian buffer zone, such as the installation of new wells, will be implemented to protect the water quality of the adjacent waterway.	An unnamed stream with riparian buffer zone exists on-site, which will be further delineated before work begins. Any incidental work in the riparian buffer zone, such as the installation of new monitoring or injection wells, will be implemented to protect the water quality of the adjacent waterway.
FEDERAL ARARs and TO BE CONSIDERED GUIDANCES						
National Historic Preservation Act (NHPA), Section 106, 16 USC 470 *et seq*., 36 CFR Part 800	Applicable	Section 106 of the NHPA of 1966 requires EPA to take into account the effect of all of its actions on historic properties. In consultation with the State Historic Preservation Officer (SHPO) EPA is to identify potential adverse effects on historic properties and seek ways to avoid, minimize or mitigate any such effects on historic properties.	Alternative GW1 requires no action and, therefore, will have no impact on potential historic, scientific, or archaeological sites and data.	Alternative GW2 requires no action beyond institutional controls. Incidental work, such as the installation of new wells, will be completed in compliance with this ARAR as work is further delineated in consultation with the Vermont Division of Historic Preservation.	Alternative GW2 requires no action beyond institutional controls and MNA. Incidental work, such as the installation of new wells, will be completed in compliance with this ARAR as work is further delineated in consultation with the Vermont Division of Historic Preservation.	Alternative GW3 includes in situ treatment of the impacted groundwater. Installation of new monitoring wells, will be completed in compliance with this ARAR, as work is further delineated, in consultation with the Vermont Division of Historic Preservation.

Table 5-15
Location-Specific ARARs for Vapor Mitigation Alternatives
Commerce Street Plume Superfund Site
Williston, Vermont

REQUIREMENT	STATUS	REQUIREMENT SYNOPSIS	ACTION TAKEN TO COMPLY WITH ARARs		
			VM1	VM2	VM3
STATE ARARs and TO BE CONSIDERED GUIDANCES					
10 VSA Chapter 37, Vermont Wetlands Protection And Water Resources Management Act; Environmental Protection Rules, Chapter 30, Vermont Wetland Rules	Applicable	These standards establish criteria for delineating Class One and Class Two wetlands, which are considered significant wetlands, and sets forth allowed uses for these wetlands. Jurisdiction under the rules includes a 100-foot and 50-foot buffer zone to Class One and Class Two wetlands, respectively. The uses must not have undue adverse impacts on the significant functions of the wetland. Class Three wetlands are defined, but are not protected under these rules (they are addressed under Title 10 VSA Chapter 151, below). If any work occurs in wetlands or buffer zones, to be further delineated, it will comply with this ARAR.	Alternative VM1 requires no action and, therefore, will have no impact on wetlands.	No Class I wetlands occur on-site and Class II wetlands are limited to the area between Commerce Street and Kirby Lane and to the east of the unnamed stream. Wetlands will be further delineated before work begins. Although unexpected, if an work is within the buffer zone or wetlands, work will be implemented to protect wetlands, mitigate any loss, and restore ecological functions and values.	No Class I wetlands occur on-site and Class II wetlands are limited to the area between Commerce Street and Kirby Lane and to the east of the unnamed stream. Wetlands will be further delineated before work begins. Although unexpected, if an work is within the buffer zone or wetlands, work will be implemented to protect wetlands, mitigate any loss, and restore ecological functions and values.
10 VSA Chapter 151, Vermont's Land Use and Development Law (Act 250); Act 250 Rules (October 1, 2013)	Relevant and Appropriate	Issues to be addressed in assessing compliance with Act 250 include substantive environmental and facility siting requirements associated with: • any resulting undue water and air pollution, including construction-related dust and protection of headwaters (criterion 1) • compliance with all standards for disposal of wastes (criterion 1(B)); • impacts on floodways (criterion 1(D)); • impacts on streams (criterion 1(E)); • impact on state-regulated wetlands (Class One, Two, and Three); (criterion 1(G)); • any resulting undue erosion control or reduction in capacity of land to hold water (criterion 4); • impact on rare and natural areas, historic sites (criterion 8(A)); • impact on necessary wildlife habitat and endangered species (criterion 8(B)); • extraction of earth resources (criterion 9(D) and (E)); • energy conservation (criterion 9(F)); and • public investments (roads) (criterion 9(K)).	Alternative VM1 requires no action and, therefore, will have no impact relative to land use and development.	Alternative VM2 requires only minimal soil disturbance to build a water discharge treatment system. As necessary, erosion control measures will be implemented to prevent impacts to streams, floodways, wetlands, etc. Measures will be used to limit airborne dust. Impacts on habitats, resources, and public investments will be minimized through engineered controls.	Alternative VM3 requires only minimal soil disturbance to build a water discharge treatment system. As necessary, erosion control measures will be implemented to prevent impacts to streams, floodways, wetlands, etc. Measures will be used to limit airborne dust. Impacts on habitats, resources, and public investments will be minimized through engineered controls.
Vermont Historic Preservation Law, 22 VSA §§ 743(4), 761, 763, and 767.	Applicable	Places controls on actions conducted by the state that may impact historic, scientific, or archaeological sites and data.	Alternative VM1 requires no action and, therefore, will have no impact on potential historic, scientific, or archaeological sites and data.	Alternative VM2 requires very minimal soil disturbance to build a water discharge treatment system. Work will be completed in compliance with this ARAR, as work is further delineated, in consultation with the Vermont Division of Historic Preservation.	Alternative VM3 requires very minimal soil disturbance to build a water discharge treatment system. Work will be completed in compliance with this ARAR, as work is further delineated, in consultation with the Vermont Division of Historic Preservation.
Vermont ANR Guidance on Riparian Buffers (December 9, 2005)	To Be Considered	This guidance provides technical information on the functions and values of riparian buffers, as well as describing acceptable activities within buffer zones. It recommends the establishment of 100 foot buffer zones to streams under circumstances where there is an increased risk of erosion and/or potential for overland flow of pollutants. Where Class II wetlands are contiguous to a waterbody, buffer widths of greater than 50 feet may be recommended based on case-specific application of this Guidance. This Guidance will also be used to recommend buffers for Class III wetlands contiguous to waterbodies, as necessary to maintain the functions and values of the riparian area. This guidance will be a TBC if any work occurs in riparian buffer zones, as further delineated.	Alternative VM1 requires no action and, therefore, will have no impact on riparian buffers.	An unnamed stream with riparian buffer zone exists on-site, which will be further delineated before work begins. Work within the riparian buffer zone will be implemented to protect the water quality of the adjacent waterway.	An unnamed stream with riparian buffer zone exists on-site, which will be further delineated before work begins. Work within the riparian buffer zone will be implemented to protect the water quality of the adjacent waterway.
FEDERAL ARARs and TO BE CONSIDERED GUIDANCES					
National Historic Preservation Act (NHPA), Section 106, 16 USC 470 *et seq*., 36 CFR Part 800	Applicable	Section 106 of the NHPA of 1966 requires EPA to take into account the effect of all of its actions on historic properties. In consultation with the State Historic Preservation Officer (SHPO) EPA is to identify potential adverse effects on historic properties and seek ways to avoid, minimize or mitigate any such effects on historic properties.	Alternative VM1 requires no action and, therefore, will have no impact on potential historic, scientific, or archaeological sites and data.	Alternative VM2 requires very minimal soil disturbance to build a water discharge treatment system. Work will be completed in compliance with this ARAR, as work is further delineated, in consultation with the Vermont Division of Historic Preservation.	Alternative VM3 requires very minimal soil disturbance to build a water discharge treatment system. Work will be completed in compliance with this ARAR, as work is further delineated, in consultation with the Vermont Division of Historic Preservation.

Table 5-16
Chemical-Specific ARARs for Soil Alternatives
Commerce Street Plume Superfund Site
Williston, Vermont

REQUIREMENT	STATUS	REQUIREMENT SYNOPSIS	ACTION TAKEN TO COMPLY WITH ARARs		
			SO1	SO2	SO3
STATE ARARs					
10 VSA Chapter 48, §1390-1394, Groundwater Protection; Environmental Protection Rule, Chapter 12, Groundwater Protection Rule and Strategy, sections 12-702 and Table 1 of Appendix One.	Applicable	Establishes groundwater classes and standards for groundwater quality. Management criteria for each groundwater class as well as primary standards for groundwater protection are established. Promulgated Groundwater Enforcement Standards are based on promulgated federal Maximum Contaminant Levels (MCL), and VT Department of Health Drinking Water Health Advisories if no federal MCL was adopted. Promulgated Groundwater Enforcement Standards are applicable, but Preventative Action Limits are not an ARAR. Will be used as cleanup standard if more stringent than federal MCL.	Applicable to groundwater, not soil	Applicable to groundwater, not soil.	Applicable to groundwater, not soil
Vermont Department of Health Drinking Water Guidance (March 2015).	To Be Considered	Lists the Vermont Health Advisories (VHAs) for chemicals of concern in drinking water. VHAs are numeric guidelines researched and derived by the Health Department for chemicals in drinking water that do not have a federal MCL.	TBC for groundwater, not soil	TBC for groundwater, not soil	TBC for groundwater, not soil
VT Department of Environmental Conservation Investigation and Remediation of Contaminated Properties Procedures (IRCPP), April 2012	To Be Considered	ICRPP includes numeric, health based soil and vapor remedial chemical concentration screening values for soil and vapor intrusion.	No chemical-specific ARAR exists with respect to exposure to contaminants in soil. PRGs are based on EPA risk assessment. ICRPP screening values will serve as additional TBC.	No chemical-specific ARAR exists with respect to exposure to contaminants in soil. PRGs are based on EPA risk assessment. ICRPP screening values will serve as additional TBC.	No chemical-specific ARAR exists with respect to exposure to contaminants in soil. PRGs are based on EPA risk assessment. ICRPP screening values will serve as additional TBC.
FEDERAL ARARs					
Federal Safe Drinking Water Act - Maximum Contaminant Levels (MCLs), National Primary Drinking Water Regulations, 40 CFR 141 Subparts B and G	Relevant and appropriate	These standards protect drinking water quality by limiting the levels of specific contaminants that can adversely affect public health and are known or anticipated to occur in public water systems. MCLs are the highest level of a contaminant that is allowed in drinking water and will be used as cleanup standards unless Vermont's Groundwater Enforcement Standard is more stringent.	Relevant and appropriate for groundwater, not soil	Relevant and appropriate for groundwater, not soil	Relevant and appropriate for groundwater, not soil
Federal Safe Drinking Water Act - Maximum Contaminant Level Goals (MCLGs), National Primary Drinking Water Regulations, 40 CFR 141 Subpart F	Non-zero MCLGs are relevant and appropriate	MCLGs are the level of a contaminant in drinking water below which there is no known or expected risk to health. MCLs are set as close to MCLGs as feasible using the best available treatment technology and taking cost into consideration. Non-zero MCLGs will be used as cleanup standards unless Vermont's Groundwater Enforcement Standard is more stringent.	Relevant and appropriate for groundwater, not soil	Relevant and appropriate for groundwater, not soil	Relevant and appropriate for groundwater, not soil
Oral Slope Factor (SF) for Cancer Ingestion Effects, EPA Integrated Risk Information System (IRIS)	To Be Considered	SFs are used to compute the incremental cancer risk from exposure to contaminants and represent the most up-to-date information on cancer risk from IRIS. An upper bound, approximating a 95% confidence limit, on the increased cancer risk from a lifetime exposure to an agent. Used for EPA risk assessments.	SFs were used to evaluate carcinogenic health risks associated with site-related contaminants, and were used to develop PRGs.	SFs were used to evaluate carcinogenic health risks associated with site-related contaminants, and were used to develop PRGs.	SFs were used to evaluate carcinogenic health risks associated with site-related contaminants, and were used to develop PRGs.
Inhalation Unit Risk (IUR) for Inhalation Cancer Effects, EPA IRIS	To Be Considered	IURs are used to compute the incremental cancer risk from exposure to contaminants and represent the most up-to-date information on cancer risk from IRIS. The upper bound excess lifetime cancer risk estimated to result from continuous exposure to an agent at a concentration of 1 $\mu g/m^3$ in air. Used for EPA risk assessments.	IURs were used to evaluate carcinogenic health risks associated with site-related contaminants, and were used to develop PRGs.	IURs were used to evaluate carcinogenic health risks associated with site-related contaminants, and were used to develop PRGs.	IURs were used to evaluate carcinogenic health risks associated with site-related contaminants, and were used to develop PRGs.
Oral Reference Dose (RfD) for Non-Cancer Ingestion Effects, EPA IRIS	To Be Considered	RfDs are used to compute the incremental non-cancer risk from exposure to contaminants and represent the most up-to-date information on cancer risk from IRIS. An estimate (with an uncertainty spanning perhaps an order of magnitude) of a daily oral exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. Used for EPA risk assessments.	RfDs were used to evaluate non-carcinogenic health risks associated with site-related contaminants, and were used to develop PRGs.	RfDs were used to evaluate non-carcinogenic health risks associated with site-related contaminants, and were used to develop PRGs.	RfDs were used to evaluate non-carcinogenic health risks associated with site-related contaminants, and were used to develop PRGs.
Inhalation Reference Concentration (RfC) for Inhalation Non-Cancer Effects, EPA IRIS	To Be Considered	RfCs are used to compute the incremental non-cancer risk from exposure to contaminants and represent the most up-to-date information on cancer risk from IRIS. An estimate (with an uncertainty spanning perhaps an order of magnitude) of a continuous inhalation exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. Used for EPA risk assessments.	RfCs were used to evaluate non-carcinogenic health risks associated with site-related contaminants, and were used to develop PRGs.	RfCs were used to evaluate non-carcinogenic health risks associated with site-related contaminants, and were used to develop PRGs.	RfCs were used to evaluate non-carcinogenic health risks associated with site-related contaminants, and were used to develop PRGs.
Health Advisories (EPA Office of Drinking Water)	To Be Considered	Health Advisories include estimates of risk due to consumption of contaminated drinking water; they consider non-carcinogenic effects only. To be considered in developing cleanup and monitoring standards in absence of other standards.	TBC for groundwater, not soil	TBC for groundwater, not soil	TBC for groundwater, not soil
Guidelines for Carcinogen Risk Assessment EPA/630/P-03/001F (March 2005)	To Be Considered	These guidelines provide guidance on conducting risk assessments involving carcinogens.	These guidelines for assessing cancer risks were also used to develop PRGs.	These guidelines for assessing cancer risks were also used to develop PRGs.	These guidelines for assessing cancer risks were also used to develop PRGs.
Supplemental Guidance for Assessing Susceptibility from Early-Life Exposure to Carcinogens EPA/630/R-03/003F (March 2005)	To Be Considered	These guidelines provide guidance on conducting risk assessments involving carcinogens in children.	These guidelines for evaluating cancer risks in children were also used to develop PRGs for carcinogens.	These guidelines for evaluating cancer risks in children were also used to develop PRGs for carcinogens.	These guidelines for evaluating cancer risks in children were also used to develop PRGs for carcinogens.
Technical Guide for Assessing and Mitigating the Vapor Intrusion Pathway from Subsurface Vapor Sources to Indoor Air, OSWER Publication 9200.2-154 (June 2015)	To Be Considered	This guidance will be followed to analyze and address any potential vapor intrusion at the Site.	TBC for vapor, not soil.	TBC for vapor, not soil.	TBC for vapor, not soil.

REQUIREMENT	STATUS	REQUIREMENT SYNOPSIS	ACTION TAKEN TO COMPLY WITH ARARs			
			GW1	GW2	GW3	GW5
STATE ARARs						
10 VSA Chapter 48, §1390-1394, Groundwater Protection; Environmental Protection Rule, Chapter 12, Groundwater Protection Rule and Strategy, sections 12-702 and Table 1 of Appendix One.	Applicable	Establishes groundwater classes and standards for groundwater quality. Management criteria for each groundwater class as well as primary standards for groundwater protection are established. Promulgated Groundwater Enforcement Standards are based on promulgated federal Maximum Contaminant Levels (MCL), and VT Department of Health Drinking Water Health Advisories if no federal MCL was adopted. Promulgated Groundwater Enforcement Standards are applicable, but Preventative Action Limits are not an ARAR. Will be used as cleanup standard if more stringent than federal MCL.	Used to determine PRGs, which were based on MCL or risk-based levels. Alternative GW1 requires no action and, therefore, will not improve the time to reach PRGs before natural attenuation.	Used to determine PRGs, which were based on MCL or risk-based levels. Alternative GW2 requires no action beyond institutional controls and, therefore, will not improve groundwater quality to meet PRGS before natural attenuation.	Used to determine PRGs, which were based on MCL or risk-based levels. Alternative GW2 requires no action beyond MNA and institutional controls and, therefore, will not improve groundwater quality to meet PRGS before natural attenuation.	Used to determine PRGs, which were based on MCL or risk-based levels. Alternative GW5 includes *in situ* treatment of the impacted groundwater to achieve PRGs (based on MCLs and risk-based levels) within 50 to 75 years.
Vermont Department of Health Drinking Water Guidance (March 2015).	To Be Considered	Lists the Vermont Health Advisories (VHAs) for chemicals of concern in drinking water. VHAs are numeric guidelines researched and derived by the Health Department for chemicals in drinking water that do not have a federal MCL.	Included as basis of some promulgated VT Groundwater Enforcement Standards under VT Environmental Protection Rule Chapter 12, which were used to determine PRGs. Alternative GW1 requires no action and, therefore, will not improve the time to reach PRGs before natural attenuation.	Included as basis of some promulgated VT Groundwater Enforcement Standards under VT Environmental Protection Rule Chapter 12, which were used to determine PRGs. Alternative GW2 requires no action beyond institutional controls and, therefore, will not improve groundwater quality to meet PRGS before natural attenuation.	Included as basis of some promulgated VT Groundwater Enforcement Standards under VT Environmental Protection Rule Chapter 12, which were used to determine PRGs. Alternative GW2 requires no action beyond MNA and institutional controls and, therefore, will not improve groundwater quality to meet PRGS before natural attenuation.	Included as basis of some promulgated VT Groundwater Enforcement Standards under VT Environmental Protection Rule Chapter 12, which were used to determine PRGs. Alternative GW5 includes in situ treatment of the impacted groundwater to achieve PRGs (based on MCLs and risk-based levels) within 50 to 75 years.
VT Department of Environmental Conservation Investigation and Remediation of Contaminated Properties Procedures (IRCPP), April 2012	To Be Considered	ICRPP includes numeric, health based soil and vapor remedial chemical concentration screening values for soil and vapor intrusion.	TBC for soil and vapor, but not groundwater.	TBC for soil and vapor, but not groundwater.	TBC for soil and vapor, but not groundwater.	TBC for soil and vapor, but not groundwater.
FEDERAL ARARs						
Federal Safe Drinking Water Act - Maximum Contaminant Levels (MCLs), National Primary Drinking Water Regulations, 40 CFR 141 Subparts B and G	Relevant and appropriate	These standards protect drinking water quality by limiting the levels of specific contaminants that can adversely affect public health and are known or anticipated to occur in public water systems. MCLs are the highest level of a contaminant that is allowed in drinking water and will be used as cleanup standards unless Vermont's Groundwater Enforcement Standard is more stringent.	Used to determine PRGs, which were based on MCL or risk-based levels. Alternative GW1 requires no action and, therefore, will not improve the time to reach PRGs before natural attenuation.	Used to determine PRGs, which were based on MCL or risk-based levels. Alternative GW2 requires no action beyond institutional controls and, therefore, will not improve groundwater quality to meet PRGS before natural attenuation.	Used to determine PRGs, which were based on MCL or risk-based levels. Alternative GW2 requires no action beyond MNA and institutional controls and, therefore, will not improve groundwater quality to meet PRGS before natural attenuation.	Used to determine PRGs, which were based on MCL or risk-based levels. Alternative GW5 includes *in situ* treatment of the impacted groundwater to achieve PRGs (based on MCLs and risk-based levels) within 50 to 75 years.
Federal Safe Drinking Water Act - Maximum Contaminant Level Goals (MCLGs), National Primary Drinking Water Regulations, 40 CFR 141 Subpart F	Non-zero MCLGs are relevant and appropriate	MCLGs are the level of a contaminant in drinking water below which there is no known or expected risk to health. MCLs are set as close to MCLGs as feasible using the best available treatment technology and taking cost into consideration. Non-zero MCLGs will be used as cleanup standards unless Vermont's Groundwater Enforcement Standard is more stringent.	Used to determine PRGs, which were based on MCL or risk-based levels. Alternative GW1 requires no action and, therefore, will not improve the time to reach PRGs before natural attenuation.	Used to determine PRGs, which were based on MCL or risk-based levels. Alternative GW2 requires no action beyond institutional controls and, therefore, will not improve groundwater quality to meet PRGS before natural attenuation.	Used to determine PRGs, which were based on MCL or risk-based levels. Alternative GW2 requires no action beyond MNA and institutional controls and, therefore, will not improve groundwater quality to meet PRGS before natural attenuation.	Used to determine PRGs, which were based on MCL or risk-based levels. Alternative GW5 includes *in situ* treatment of the impacted groundwater to achieve PRGs (based on MCLs and risk-based levels) within 50 to 75 years.
Oral Slope Factor (SF) for Cancer Ingestion Effects, EPA Integrated Risk Information System (IRIS)	To Be Considered	SFs are used to compute the incremental cancer risk from exposure to contaminants and represent the most up-to-date information on cancer risk from IRIS. An upper bound, approximating a 95% confidence limit, on the increased cancer risk from a lifetime exposure to an agent. Used for EPA risk assessments.	SFs were used to evaluate carcinogenic health risks associated with site-related contaminants, and were used to develop PRGs.	SFs were used to evaluate carcinogenic health risks associated with site-related contaminants, and were used to develop PRGs.	SFs were used to evaluate carcinogenic health risks associated with site-related contaminants, and were used to develop PRGs.	SFs were used to evaluate carcinogenic health risks associated with site-related contaminants, and were used to develop PRGs.
Inhalation Unit Risk (IUR) for Inhalation Cancer Effects, EPA IRIS	To Be Considered	IURs are used to compute the incremental cancer risk from exposure to contaminants and represent the most up-to-date information on cancer risk from IRIS. The upper bound excess lifetime cancer risk estimated to result from continuous exposure to an agent at a concentration of 1 $\mu g/m^3$ in air. Used for EPA risk assessments.	IURs were used to evaluate carcinogenic health risks associated with site-related contaminants, and were used to develop PRGs.	IURs were used to evaluate carcinogenic health risks associated with site-related contaminants, and were used to develop PRGs.	IURs were used to evaluate carcinogenic health risks associated with site-related contaminants, and were used to develop PRGs.	IURs were used to evaluate carcinogenic health risks associated with site-related contaminants, and were used to develop PRGs.
Oral Reference Dose (RfD) for Non-Cancer Ingestion Effects, EPA IRIS	To Be Considered	RfDs are used to compute the incremental non-cancer risk from exposure to contaminants and represent the most up-to-date information on cancer risk from IRIS. An estimate (with an uncertainty spanning perhaps an order of magnitude) of a daily oral exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. Used for EPA risk assessments.	RfDs were used to evaluate non-carcinogenic health risks associated with site-related contaminants, and were used to develop PRGs.	RfDs were used to evaluate non-carcinogenic health risks associated with site-related contaminants, and were used to develop PRGs.	RfDs were used to evaluate non-carcinogenic health risks associated with site-related contaminants, and were used to develop PRGs.	RfDs were used to evaluate non-carcinogenic health risks associated with site-related contaminants, and were used to develop PRGs.

Table 5-17
Chemical-Specific ARARs for Groundwater Alternatives
Commerce Street Plume Superfund Site
Williston, Vermont

REQUIREMENT	STATUS	REQUIREMENT SYNOPSIS	ACTION TAKEN TO COMPLY WITH ARARs			
			GW1	GW2	GW3	GW5
Inhalation Reference Concentration (RfC) for Inhalation Non-Cancer Effects, EPA IRIS	To Be Considered	RfCs are used to compute the incremental non-cancer risk from exposure to contaminants and represent the most up-to-date information on cancer risk from IRIS. An estimate (with an uncertainty spanning perhaps an order of magnitude) of a continuous inhalation exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. Used for EPA risk assessments.	RfCs were used to evaluate non-carcinogenic health risks associated with site-related contaminants, and were used to develop PRGs.	RfCs were used to evaluate non-carcinogenic health risks associated with site-related contaminants, and were used to develop PRGs.	RfCs were used to evaluate non-carcinogenic health risks associated with site-related contaminants, and were used to develop PRGs.	RfCs were used to evaluate non-carcinogenic health risks associated with site-related contaminants, and were used to develop PRGs.
Health Advisories (EPA Office of Drinking Water)	To Be Considered	Health Advisories include estimates of risk due to consumption of contaminated drinking water; they consider non-carcinogenic effects only. To be considered in developing cleanup and monitoring standards in absence of other standards.	Used to help establish PRGs in absence of other standards. PRGs established based on MCL and risk-based levels.	Used to help establish PRGs in absence of other standards. PRGs established based on MCL and risk-based levels.	Used to help establish PRGs in absence of other standards. PRGs established based on MCL and risk-based levels.	Used to help establish PRGs in absence of other standards. PRGs established based on MCL and risk-based levels.
Guidelines for Carcinogen Risk Assessment EPA/630/P-03/001F (March 2005)	To Be Considered	These guidelines provide guidance on conducting risk assessments involving carcinogens.	These guidelines for assessing cancer risks were also used to develop PRGs.	These guidelines for assessing cancer risks were also used to develop PRGs.	These guidelines for assessing cancer risks were also used to develop PRGs.	These guidelines for assessing cancer risks were also used to develop PRGs.
Supplemental Guidance for Assessing Susceptibility from Early-Life Exposure to Carcinogens EPA/630/R-03/003F (March 2005)	To Be Considered	These guidelines provide guidance on conducting risk assessments involving carcinogens in children.	These guidelines for evaluating cancer risks in children were also used to develop PRGs for carcinogens.	These guidelines for evaluating cancer risks in children were also used to develop PRGs for carcinogens.	These guidelines for evaluating cancer risks in children were also used to develop PRGs for carcinogens.	These guidelines for evaluating cancer risks in children were also used to develop PRGs for carcinogens.
Technical Guide for Assessing and Mitigating the Vapor Intrusion Pathway from Subsurface Vapor Sources to Indoor Air, OSWER Publication 9200.2-154 (June 2015)	To Be Considered	This guidance will be followed to analyze and address any potential vapor intrusion at the Site.	TBC for vapor, not groundwater.	TBC for vapor, not groundwater.	TBC for vapor, not groundwater.	TBC for vapor, not groundwater.

Table 5-18
Chemical-Specific ARARs for Vapor Mitigation Alternatives
Commerce Street Plume Superfund Site
Williston, Vermont

REQUIREMENT	STATUS	REQUIREMENT SYNOPSIS	ACTION TAKEN TO COMPLY WITH ARARs		
			VM1	VM2	VM3
STATE ARARs					
10 VSA Chapter 48, §1390-1394, Groundwater Protection; Environmental Protection Rule, Chapter 12, Groundwater Protection Rule and Strategy, sections 12-702 and Table 1 of Appendix One.	Applicable	Establishes groundwater classes and standards for groundwater quality. Management criteria for each groundwater class as well as primary standards for groundwater protection are established. Promulgated Groundwater Enforcement Standards are based on promulgated federal Maximum Contaminant Levels (MCL), and VT Department of Health Drinking Water Health Advisories if no federal MCL was adopted. Promulgated Groundwater Enforcement Standards are applicable, but Preventative Action Limits are not an ARAR. Will be used as cleanup standard if more stringent than federal MCL.	Applicable to groundwater, not vapor	Applicable to groundwater, not vapor	Applicable to groundwater, not vapor
Vermont Department of Health Drinking Water Guidance (March 2015).	To Be Considered	Lists the Vermont Health Advisories (VHAs) for chemicals of concern in drinking water. VHAs are numeric guidelines researched and derived by the Health Department for chemicals in drinking water that do not have a federal MCL.	TBC for groundwater, not vapor	TBC for groundwater, not vapor	TBC for groundwater, not vapor
VT Department of Environmental Conservation Investigation and Remediation of Contaminated Properties Procedures (IRCPP), April 2012	To Be Considered	ICRPP includes numeric, health based soil and vapor remedial chemical concentration screening values for soil and vapor intrusion.	No chemical-specific ARAR exists with respect to exposure to vapor mitigation. Cleanup levels are based on EPA risk assessment. ICRPP vapor screening values will serve as additional TBC.	No chemical-specific ARAR exists with respect to exposure to vapor mitigation. Cleanup levels are based on EPA risk assessment. ICRPP vapor screening values will serve as additional TBC.	No chemical-specific ARAR exists with respect to exposure to vapor mitigation. Cleanup levels are based on EPA risk assessment. ICRPP vapor screening values will serve as additional TBC.
FEDERAL ARARs					
Federal Safe Drinking Water Act - Maximum Contaminant Levels (MCLs), National Primary Drinking Water Regulations, 40 CFR 141 Subparts B and G	Relevant and appropriate	These standards protect drinking water quality by limiting the levels of specific contaminants that can adversely affect public health and are known or anticipated to occur in public water systems. MCLs are the highest level of a contaminant that is allowed in drinking water and will be used as cleanup standards unless Vermont's Groundwater Enforcement Standard is more stringent.	Relevant and appropriate for groundwater, not vapor.	Relevant and appropriate for groundwater, not vapor.	Relevant and appropriate for groundwater, not vapor.
Federal Safe Drinking Water Act - Maximum Contaminant Level Goals (MCLGs), National Primary Drinking Water Regulations, 40 CFR 141 Subpart F	Non-zero MCLGs are relevant and appropriate	MCLGs are the level of a contaminant in drinking water below which there is no known or expected risk to health. MCLs are set as close to MCLGs as feasible using the best available treatment technology and taking cost into consideration. Non-zero MCLGs will be used as cleanup standards unless Vermont's Groundwater Enforcement Standard is more stringent.	Relevant and appropriate for groundwater, not vapor.	Relevant and appropriate for groundwater, not vapor.	Relevant and appropriate for groundwater, not vapor.
Oral Slope Factor (SF) for Cancer Ingestion Effects, EPA Integrated Risk Information System (IRIS)	To Be Considered	SFs are used to compute the incremental cancer risk from exposure to contaminants and represent the most up-to-date information on cancer risk from IRIS. An upper bound, approximating a 95% confidence limit, on the increased cancer risk from a lifetime exposure to an agent. Used for EPA risk assessments.	SFs were used to evaluate carcinogenic health risks associated with site-related contaminants, and were used to develop PRGs.	SFs were used to evaluate carcinogenic health risks associated with site-related contaminants, and were used to develop PRGs.	SFs were used to evaluate carcinogenic health risks associated with site-related contaminants, and were used to develop PRGs.
Inhalation Unit Risk (IUR) for Inhalation Cancer Effects, EPA IRIS	To Be Considered	IURs are used to compute the incremental cancer risk from exposure to contaminants and represent the most up-to-date information on cancer risk from IRIS. The upper bound excess lifetime cancer risk estimated to result from continuous exposure to an agent at a concentration of 1 $\mu g/m^3$ in air. Used for EPA risk assessments.	IURs were used to evaluate carcinogenic health risks associated with site-related contaminants, and were used to develop PRGs.	IURs were used to evaluate carcinogenic health risks associated with site-related contaminants, and were used to develop PRGs.	IURs were used to evaluate carcinogenic health risks associated with site-related contaminants, and were used to develop PRGs.
Oral Reference Dose (RfD) for Non-Cancer Ingestion Effects, EPA IRIS	To Be Considered	RfDs are used to compute the incremental non-cancer risk from exposure to contaminants and represent the most up-to-date information on cancer risk from IRIS. An estimate (with an uncertainty spanning perhaps an order of magnitude) of a daily oral exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. Used for EPA risk assessments.	RfDs were used to evaluate non-carcinogenic health risks associated with site-related contaminants, and were used to develop PRGs.	RfDs were used to evaluate non-carcinogenic health risks associated with site-related contaminants, and were used to develop PRGs.	RfDs were used to evaluate non-carcinogenic health risks associated with site-related contaminants, and were used to develop PRGs.
Inhalation Reference Concentration (RfC) for Inhalation Non-Cancer Effects, EPA IRIS	To Be Considered	RfCs are used to compute the incremental non-cancer risk from exposure to contaminants and represent the most up-to-date information on cancer risk from IRIS. An estimate (with an uncertainty spanning perhaps an order of magnitude) of a continuous inhalation exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. Used for EPA risk assessments.	RfCs were used to evaluate non-carcinogenic health risks associated with site-related contaminants, and were used to develop PRGs.	RfCs were used to evaluate non-carcinogenic health risks associated with site-related contaminants, and were used to develop PRGs.	RfCs were used to evaluate non-carcinogenic health risks associated with site-related contaminants, and were used to develop PRGs.
Health Advisories (EPA Office of Drinking Water)	To Be Considered	Health Advisories include estimates of risk due to consumption of contaminated drinking water; they consider non-carcinogenic effects only. To be considered in developing cleanup and monitoring standards in absence of other standards.	TBC for groundwater, not vapor.	TBC for groundwater, not vapor.	TBC for groundwater, not vapor.
Guidelines for Carcinogen Risk Assessment EPA/630/P-03/001F (March 2005)	To Be Considered	These guidelines provide guidance on conducting risk assessments involving carcinogens.	These guidelines for assessing cancer risks were also used to develop PRGs.	These guidelines for assessing cancer risks were also used to develop PRGs.	These guidelines for assessing cancer risks were also used to develop PRGs.
Supplemental Guidance for Assessing Susceptibility from Early-Life Exposure to Carcinogens EPA/630/R-03/003F (March 2005)	To Be Considered	These guidelines provide guidance on conducting risk assessments involving carcinogens in children.	These guidelines for evaluating cancer risks in children were also used to develop PRGs for carcinogens.	These guidelines for evaluating cancer risks in children were also used to develop PRGs for carcinogens.	These guidelines for evaluating cancer risks in children were also used to develop PRGs for carcinogens.
Technical Guide for Assessing and Mitigating the Vapor Intrusion Pathway from Subsurface Vapor Sources to Indoor Air, OSWER Publication 9200.2-154 (June 2015)	To Be Considered	This guidance will be followed to assess and mitigate risk from vapor intrusion at the Site.	No chemical-specific ARAR exists with respect to exposure to vapor. Vapor PRG based on EPA risk assessment. Guidance on assessment and mitigation of vapor intrusion to serve as TBC.	No chemical-specific ARAR exists with respect to exposure to vapor. Vapor PRG based on EPA risk assessment. Guidance on assessment and mitigation of vapor intrusion to serve as TBC.	No chemical-specific ARAR exists with respect to exposure to vapor. Vapor PRG based on EPA risk assessment. Guidance on assessment and mitigation of vapor intrusion to serve as TBC.

Table 5-19
Action-Specific ARARs for Soil Alternatives
Commerce Street Plume Superfund Site
Williston, Vermont

REQUIREMENT	STATUS	REQUIREMENT SYNOPSIS	ACTION TAKEN TO COMPLY WITH ARARs		
			SO1	SO2	SO3
STATE ARARs					
10 VSA Chapter 47, Vermont Water Pollution Control; Environmental Protection Rule, Chapter 29a, Vermont Water Quality Standards in Appendix C	Applicable	Establishes water quality standards for surface waters and applies to alternatives that call for monitoring surface water bodies on and off of the Site.	Alternative SO1 requires no action and therefore will not trigger this action-specific ARAR.	Alternative SO2 requires only fencing and ICs and does not involve any discharges to streams. Therefore this ARAR is not applicable.	Alternative SO3 includes soil removal and off-site disposal. Any dewatering will be filtered and treated appropriately prior to discharge, or disposed of off-site.
Environmental Protection Rule, Chapter 13, Water Pollution Control Permit Regulations (Vermont National Pollutant Discharge Elimination System (NPDES) Regulations)	Applicable	The regulations stipulate requirements for discharges to surface waters, compliance with NPDES standards, and meeting stormwater management requirements. If there is a discharge to a stream this ARAR will be met.	Alternative SO1 requires no action and therefore will not trigger this action-specific ARAR.	Alternative SO2 requires only fencing and ICs and does not involve any discharges to streams. Therefore this ARAR is not applicable.	Alternative SO3 includes soil removal and off-site disposal. Any dewatering will be filtered and treated appropriately prior to discharge, or disposed of off-site.
10 VSA Chapter 23; Vermont Air Pollution Control Act; Environmental Protection Rule Chapter 5, Air Pollution Control Regulations, including 5-231(4) and 5-241(1) for dust.	Applicable	Establishes authority for a coordinated statewide program of air pollution prevention, abatement and control. Lists prohibited activities and regulatory requirements affecting air quality and establishes primary and secondary ambient air quality standards.	Alternative SO1 requires no action and therefore will not trigger this action-specific ARAR.	Alternative SO2 requires only fencing and ICs. No idling policies will be instituted during the work days. Work to construct fencing will be conducted to limit airborne dust.	Alternative SO3 includes soil removal using heavy equipment and trucks for transportation of the material. No idling policies will be instituted during the work days. Methods will be used to limit airborne dust.
10 VSA Chapter 47, Water Pollution Control § 1259(a)	Applicable	VTDEC requirement to treatment to primary groundwater standards in Environmental Protection Rule 12 for discharge to a water of the state.	Alternative SO1 requires no action and therefore will not trigger this action-specific ARAR.	Alternative SO2 requires only fencing and ICs and does not involve any discharges. Therefore this ARAR is not applicable.	Alternative SO3 includes soil removal and off-site disposal. Any dewatering will be filtered and treated appropriately prior to discharge, or disposed of off-site.
Environmental Protection Rule, Chapter 11, Underground Injection Control Regulations	Relevant and Appropriate	Substantive requirements for injection of substances into groundwater for *in situ* groundwater treatment.	Alternative SO1 requires no action and therefore will not trigger this action-specific ARAR.	Alternative SO2 requires only fencing and ICs and does not involve any underground injections. Therefore this ARAR is not relevant and appropriate.	Alternative SO3 includes soil removal and off-site disposal, without any underground injections. Therefore this ARAR is not relevant and appropriate.
10 VSA Chapter 159, Vermont Waste Management Act; Environmental Protection Rule, Chapter 7, Vermont Hazardous Waste Management Regulations, Subchapter 2, Identification and Listing of Hazardous Waste	Applicable	Establishes requirements for the identification of hazardous waste based on characteristics and listing. Incorporates requirements of the federal Resource Conservation and Recovery Act regulations, 40 CFR 261.	Alternative SO1 requires no action and therefore will not trigger this action-specific ARAR.	Alternative SO2 requires only fencing and ICs, leaving waste in place. Therefore this ARAR is not applicable.	Alternative SO3 includes soil removal and off-site disposal. Prior to transportation and disposal, waste will be identified and characterized in accordance with this ARAR.
10 VSA Chapter 159, Vermont Waste Management Act; Environmental Protection Rule, Chapter 7, Vermont Hazardous Waste Management Regulations, Subchapter 3, Hazardous Waste Generator Standards	Applicable	Establishes requirements for generators of hazardous wastes. Incorporates requirements of the federal Resource Conservation and Recovery Act regulations, 40 CFR 262.	Alternative SO1 requires no action and therefore will not trigger this action-specific ARAR.	Alternative SO2 requires only fencing and ICs, leaving waste in place. Therefore this ARAR is not applicable.	Alternative SO3 includes soil removal and off-site disposal. The substantive requirements of these generator rules will be followed.
10 VSA Chapter 159, Vermont Waste Management Act; Environmental Protection Rule, Chapter 7, Vermont Hazardous Waste Management Regulations, Subchapter 5, Requirements for Hazardous Waste Storage, Treatment and Disposal Facilities.	Applicable	Establishes requirements for the design, construction, operation, and maintenance of hazardous waste treatment, storage, and disposal facilities. Incorporates requirements of the federal Resource Conservation and Recovery Act regulations, 40 CFR 264, including 40 CFR 264 Subpart G, Closure and Post-Closure.	Alternative SO1 requires no action, leaving waste in place. Chromium contaminant levels at 96 Commerce Street, however, trigger this ARAR, requiring a RCRA C compliant cap or removal of all RCRA contaminants. Therefore this alternative fails to meet this ARAR.	Alternative SO2 requires ICs and fencing, leaving waste in place. Chromium contaminant levels at 96 Commerce Street, however, trigger this ARAR, requiring a RCRA C compliant cap or removal of all RCRA contaminants. Therefore this alternative fails to meet this ARAR.	Alternative SO3 includes soil removal and off-site disposal. The alternative will comply with closure requirements of this ARAR through the removal of all RCRA contaminants at 96 Commerce Street.
FEDERAL ARARs					
Resource Conservation and Recovery Act (RCRA), 42 U.S.C. §§ 6901, et seq., RCRA Regulations, 40 CFR Part 261, 262, 264, including 40 CFR 264 Subpart G Closure and Post Closure.	Applicable	Alternatives that result in the generation of hazardous waste will need to comply with these requirements. Vermont is delegated to implement these regulations through its Hazardous Waste Management Regulations (see above).	Alternative SO1 requires no action and therefore will not trigger this action-specific ARAR.	Alternative SO2 requires ICs and fencing, leaving waste in place. Chromium contaminant levels at 96 Commerce Street, however, trigger this ARAR, requiring a RCRA C compliant cap or removal of all RCRA contaminants. Therefore this alternative fails to meet this ARAR.	Alternative SO3 includes soil removal and off-site disposal. Waste will be identified and characterized as prescribed; generator rules will be followed; all contaminated soil will be removed under closure requirements.
RCRA (40 CFR 265, Subpart Q - Chemical, Physical and Biological Treatment	Relevant and Appropriate	Standards apply to facilities where hazardous wastes are treated by chemical, physical, or biological methods.	Alternative SO1 requires no action and therefore will not trigger this action-specific ARAR.	Alternative SO2 requires only fencing and ICs and does not involve any chemical, physical or biological treatment. Therefore this ARAR is not relevant and appropriate.	Alternative SO2 requires only fencing and ICs and does not involve any chemical, physical or biological treatment. Therefore this ARAR is not relevant and appropriate.
Clean Water Act, Section 402 - National Pollution Discharge Elimination System (NPDES), 40 CFR 122-125, 131	Applicable	The CWA contains discharge limitation, monitoring requirements, and best management practices (BMPs) for discharges into navigable waters, i.e. surface waters. The regulations would be applicable to remedial strategies involving discharge to surface waters. If there is a discharge to a stream this ARAR will be met.	Alternative SO1 requires no action and therefore will not trigger this action-specific ARAR.	Alternative SO2 requires only fencing and ICs and does not involve any discharges to streams. Therefore this ARAR is not applicable.	Alternative SO3 includes soil removal and off-site disposal. Any dewatering will be filtered and treated appropriately prior to discharge, or disposed of off-site.
Clean Water Act, Section 304(a), National Recommended Water Quality Criteria (NRWQC), 40 CFR 131.11	Applicable	NRWQC are provided by EPA for chemicals for the protection of human health and the protection of aquatic life. If there is a discharge to a stream this ARAR will be met.	Alternative SO1 requires no action and therefore will not trigger this action-specific ARAR.	Alternative SO2 requires only fencing and ICs and does not involve any discharges to streams. Therefore this ARAR is not applicable.	Alternative SO3 includes soil removal and off-site disposal. Any dewatering will be filtered and treated appropriately prior to discharge, or disposed of off-site.

REQUIREMENT	STATUS	REQUIREMENT SYNOPSIS	ACTION TAKEN TO COMPLY WITH ARARs		
			SO1	SO2	SO3
Underground Injection Control Program, 40 CFR 144, 146, 147.	Relevant and Appropriate	Substantive requirements for injection of substances into groundwater for *in situ* groundwater treatment. Vermont is delegated to implement these regulations through its Underground Injection Control regulations (see above).	Alternative SO1 requires no action and therefore will not trigger this action-specific ARAR.	Alternative SO2 requires only fencing and ICs and does not involve any underground injections. Therefore this ARAR is not relevant and appropriate.	Alternative SO3 includes soil removal and off-site disposal, without any underground injections. Therefore this ARAR is not relevant and appropriate.
Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites. Final OSWER Directive, Publication EPA/540/R-99/009. April 1999.	To Be Considered	Includes procedural requirements for the use of monitored natural attenuation as a remedial component.	Alternative SO1 requires no action and therefore will not trigger this action-specific ARAR.	This ARAR is applicable to groundwater, not soil.	This ARAR is applicable to groundwater, not soil.
Performance Monitoring of MNA Remedies for VOCs in Ground Water, EPA/600/R-04/027, April 2004.	To Be Considered	Includes procedural requirements for the use of monitored natural attenuation of VOCs as a remedial component.	Alternative SO1 requires no action and therefore will not trigger this action-specific ARAR.	This ARAR is applicable to groundwater, not soil.	This ARAR is applicable to groundwater, not soil.
An Approach for Evaluating the Progress of Natural Attenuation, EPA 600/R-11/204, December 2011	To Be Considered	Includes procedural requirements for evaluation of attenuation under monitored natural attenuation remedy.	Alternative SO1 requires no action and therefore will not trigger this action-specific ARAR.	This ARAR is applicable to groundwater, not soil.	This ARAR is applicable to groundwater, not soil.

REQUIREMENT	STATUS	REQUIREMENT SYNOPSIS	ACTION TAKEN TO COMPLY WITH ARARs			
			GW1	GW2	GW3	GW5
STATE ARARs						
10 VSA Chapter 47, Vermont Water Pollution Control; Environmental Protection Rule, Chapter 29a, Vermont Water Quality Standards in Appendix C	Applicable	Establishes water quality standards for surface waters and applies to alternatives that call for monitoring surface water bodies on and off of the Site.	Alternative GW1 requires no action and therefore will not trigger this action-specific ARAR.	Alternative GW2 requires no action beyond institutional controls and does not involve any discharges to streams. Therefore, this ARAR is not applicable.	Alternative GW3 requires no action beyond institutional controls and does not involve any discharges to streams. Therefore, this ARAR is not applicable.	Alternative GW5 involves *in situ* treatment through underground injections, but does not involve discharges to surface waters or streams. Water brought to the surface will be batched and reinjected, treated, or disposed of off-site, in compliance with ARARs.
Environmental Protection Rule, Chapter 13, Water Pollution Control Permit Regulations (Vermont National Pollutant Discharge Elimination System (NPDES) Regulations)	Applicable	The regulations stipulate requirements for discharges to surface waters, compliance with NPDES standards, and meeting stormwater management requirements. If there is a discharge to a stream this ARAR will be met.	Alternative GW1 requires no action and therefore will not trigger this action-specific ARAR.	Alternative GW2 requires no action beyond institutional controls and does not involve any discharges to streams. Therefore, this ARAR is not applicable.	Alternative GW3 requires no action beyond institutional controls and does not involve any discharges to streams. Therefore, this ARAR is not applicable.	Alternative GW5 involves *in situ* treatment through underground injections, but does not involve discharges to surface waters or streams. Water brought to the surface will be batched and reinjected, treated, or disposed of off-site, in compliance with ARARs.
10 VSA Chapter 23; Vermont Air Pollution Control Act; Environmental Protection Rule Chapter 5, Air Pollution Control Regulations, including 5-231(4) and 5-241(1) for dust.	Applicable	Establishes authority for a coordinated statewide program of air pollution prevention, abatement and control. Lists prohibited activities and regulatory requirements affecting air quality and establishes primary and secondary ambient air quality standards.	Alternative GW1 requires no action and therefore will not trigger this action-specific ARAR.	Alternative GW2 requires no action beyond institutional controls. Procedures will be implemented to minimize airborne dust if new wells are installed.	Alternative GW3 requires no action beyond institutional controls and MNA. Procedures will be implemented to minimize airborne dust if new wells are installed.	Alternative GW5 requires *in situ* treatment and MNA through underground water injection wells and monitoring wells. Procedures will be implemented to minimize airborne dust if new wells are installed.
10 VSA Chapter 47, Water Pollution Control § 1259(a)	Applicable	VT DEC requires treatment to primary groundwater standards in Environmental Protection Rule 12 for discharge to a water of the state.	Alternative GW1 requires no action and therefore will not trigger this action-specific ARAR.	Alternative GW2 requires no action beyond institutional controls and does not involve any discharges to waters of the state. Therefore, this ARAR is not applicable.	Alternative GW3 requires no action beyond institutional controls and MNA and does not involve any discharges waters of the state. Therefore, this ARAR is not applicable.	Alternative GW5 includes *in situ* treatment through underground injections to groundwater, but for the purpose of remediation with concurrence of VTDEC.
Environmental Protection Rule, Chapter 11, Underground Injection Control Regulations	Relevant and Appropriate	Substantive requirements for injection of substances into groundwater for *in situ* groundwater treatment.	Alternative GW1 requires no action and therefore will not trigger this action-specific ARAR.	Alternative GW2 requires no action beyond institutional controls and does not involve and underground injections. Therefore, this ARAR is not relevant and appropriate.	Alternative GW2 requires no action beyond institutional controls and MNA and does not involve and underground injections. Therefore, this ARAR is not relevant and appropriate.	Alternative GW5 includes *in situ* treatment through underground injections. Therefore,, this Alternative will be completed in compliance with the substantive requirements of this ARAR.
10 VSA Chapter 159, Vermont Waste Management Act; Environmental Protection Rule, Chapter 7, Vermont Hazardous Waste Management Regulations, Subchapter 2, Identification and Listing of Hazardous Waste	Applicable	Establishes requirements for the identification of hazardous waste based on characteristics and listing. Incorporates requirements of the federal Resource Conservation and Recovery Act regulations, 40 CFR 261.	Alternative GW1 requires no action and therefore will not trigger this action-specific ARAR.	Only minimal RCRA waste is expected to be generated. Investigation and monitoring derived waste (e.g. purge water, contaminated soils from new wells, etc.) will be collected, characterized, prior to transportation and disposal at an approved facility.	Only minimal RCRA waste is expected to be generated. Investigation and monitoring derived waste (e.g. purge water, contaminated soils from new wells, etc.) will be collected and characterized prior to transportation and disposal at an approved facility.	Only minimal RCRA waste is expected to be generated. Investigation, monitoring and injection well derived waste (e.g. purge water, contaminated soils from new wells, etc.) will be collected and characterized prior to transportation and disposal at an approved facility.
10 VSA Chapter 159, Vermont Waste Management Act; Environmental Protection Rule, Chapter 7, Vermont Hazardous Waste Management Regulations, Subchapter 3, Hazardous Waste Generator Standards	Applicable	Establishes requirements for generators of hazardous wastes. Incorporates requirements of the federal Resource Conservation and Recovery Act regulations, 40 CFR 262.	Alternative GW1 requires no action and therefore will not trigger this action-specific ARAR.	Only minimal RCRA waste is expected to be generated (investigation and monitoring derived waste (e.g., purge water, contaminated soils from new wells)). If RCRA waste is generated, the substantive requirements of these generator rules will be followed.	Only minimal RCRA waste is expected to be generated (investigation and monitoring derived waste (e.g., purge water, contaminated soils from new wells)). If RCRA waste is generated, the substantive requirements of these generator rules will be followed.	Only minimal RCRA waste is expected to be generated (investigation, monitoring and injection well derived waste (e.g., purge water, contaminated soils from new wells)). If RCRA waste is generated, the substantive requirements of these generator rules will be followed.
10 VSA Chapter 159, Vermont Waste Management Act; Environmental Protection Rule, Chapter 7, Vermont Hazardous Waste Management Regulations, Subchapter 5, Requirements for Hazardous Waste Storage, Treatment and Disposal Facilities.	Applicable	Establishes requirements for the design, construction, operation, and maintenance of hazardous waste treatment, storage, and disposal facilities. Incorporates requirements of the federal Resource Conservation and Recovery Act regulations, 40 CFR 264, including 40 CFR 264 Subpart G, Closure and Post-Closure.	Alternative GW1 requires no action and therefore will not trigger this action-specific ARAR.	Only minimal RCRA waste is expected to be generated (investigation and monitoring derived waste (e.g., purge water, contaminated soils from new wells)). If RCRA waste is generated, waste storage, treatment and disposal requirements will be followed.	Only minimal RCRA waste is expected to be generated (investigation and monitoring derived waste (e.g., purge water, contaminated soils from new wells)). If RCRA waste is generated, waste storage, treatment and disposal requirements will be followed.	Only minimal RCRA waste is expected to be generated (investigation, monitoring and injection well derived waste (e.g., purge water, contaminated soils from new wells)). If RCRA waste is generated, waste storage, treatment and disposal requirements will be followed.
FEDERAL ARARs						
Resource Conservation and Recovery Act (RCRA), 42 U.S.C. §§ 6901, et seq., RCRA Regulations, 40 CFR Part 261, 262, 264, including 40 CFR 264 Subpart G Closure and Post Closure.	Applicable	Alternatives that result in the generation of hazardous waste will need to comply with these requirements. Vermont is delegated to implement these regulations through its Hazardous Waste Management Regulations (see above).	Alternative GW1 requires no action and therefore will not trigger this action-specific ARAR.	Only minimal RCRA waste is expected to be generated (investigation and monitoring derived waste (e.g., purge water, contaminated soils from new wells)). RCRA waste will be identified and characterized as prescribed; generator and waste storage, treatment and disposal requirements will be followed.	Only minimal RCRA waste is expected to be generated (investigation and monitoring derived waste (e.g., purge water, contaminated soils from new wells)). RCRA waste will be identified and characterized as prescribed; generator and waste storage, treatment and disposal requirements will be followed.	Only minimal RCRA waste is expected to be generated (investigation, monitoring and injection well derived waste (e.g., purge water, contaminated soils from new wells)). RCRA waste will be identified and characterized as prescribed; generator and waste storage, treatment and disposal requirements will be followed.

Table 5-20
Action-Specific ARARs for Groundwater Alternatives
Commerce Street Plume Superfund Site
Williston, Vermont

REQUIREMENT	STATUS	REQUIREMENT SYNOPSIS	ACTION TAKEN TO COMPLY WITH ARARs			
			GW1	GW2	GW3	GW5
RCRA (40 CFR 265, Subpart Q - Chemical, Physical and Biological Treatment	Relevant and Appropriate	Standards apply to facilities where hazardous wastes are treated by chemical, physical, or biological methods.	Alternative GW1 requires no action and therefore will not trigger this action-specific ARAR.	ARAR applicable only to Alternative GW5.	ARAR applicable only to Alternative GW5.	Alternative GW5 includes *in situ* treatment through underground injections. Therefore, this Alternative will be completed in compliance with the substantive requirements of this ARAR for chemical, physical and biological treatment.
Clean Water Act, Section 402 - National Pollution Discharge Elimination System (NPDES), 40 CFR 122-125, 131	Applicable	The CWA contains discharge limitation, monitoring requirements, and best management practices (BMPs) for discharges into navigable waters, i.e. surface waters. The regulations would be applicable to remedial strategies involving discharge to surface waters. If there is a discharge to a stream this ARAR will be met.	Alternative GW1 requires no action and therefore will not trigger this action-specific ARAR.	Alternative GW2 requires no action beyond institutional controls and does not involve any discharges to waters of the state. Therefore, this ARAR is not applicable.	Alternative GW3 requires no action beyond institutional controls and does not involve any discharges to waters of the state. Therefore, this ARAR is not applicable.	Alternative GW5 involves *in situ* treatment through underground injections, but does not involve discharges to surface waters or streams. Water brought to the surface will be batched and reinjected, treated, or disposed of off-site, in compliance with ARARs
Clean Water Act, Section 304(a), National Recommended Water Quality Criteria (NRWQC), 40 CFR 131.11	Applicable	NRWQC are provided by EPA for chemicals for the protection of human health and the protection of aquatic life. If there is a discharge to a stream this ARAR will be met.	Alternative GW1 requires no action and therefore will not trigger this action-specific ARAR.	Alternative GW2 requires no action beyond institutional controls and does not involve any discharges to waters of the state. Therefore, this ARAR is not applicable.	Alternative GW3 requires no action beyond institutional controls and does not involve any discharges to waters of the state. Therefore, this ARAR is not applicable.	Alternative GW5 involves *in situ* treatment through underground injections, but does not involve discharges to surface waters or streams. Water brought to the surface will be batched and reinjected, treated, or disposed of off-site, in compliance with ARARs.
Underground Injection Control Program, 40 CFR 144, 146, 147.	Relevant and Appropriate	Substantive requirements for injection of substances into groundwater for *in situ* groundwater treatment. Vermont is delegated to implement these regulations through its Underground Injection Control regulations (see above).	Alternative GW1 requires no action and therefore will not trigger this action-specific ARAR.	Alternative GW2 requires no action beyond institutional controls and does not involve any underground injections. Therefore, this ARAR is not relevant and appropriate.	Alternative GW3 requires no action beyond institutional controls and does not involve any underground injections. Therefore, this ARAR is not relevant and appropriate.	Alternative GW5 includes *in situ* treatment through underground injections. Therefore, this Alternative will be completed in compliance with the substantive requirements of this ARAR.
Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites. Final OSWER Directive, Publication EPA/540/R-99/009. April 1999.	To Be Considered	Includes procedural requirements for the use of monitored natural attenuation as a remedial component.	Alternative GW1 requires no action and therefore will not trigger this action-specific ARAR.	Alternative GW2 requires no action beyond institutional controls. Monitoring will occur, but not in accordance with MNA standards described in this TBC.	Alternative GW3 requires institutional controls with MNA. This guidance will be used to guide the MNA program under this alternative.	Alternative GW5 requires *in situ* remediation coupled with MNA. This guidance will be used to guide the MNA program under this alternative.
Performance Monitoring of MNA Remedies for VOCs in Ground Water, EPA/600/R-04/027, April 2004.	To Be Considered	Includes procedural requirements for the use of monitored natural attenuation of VOCs as a remedial component.	Alternative GW1 requires no action and therefore will not trigger this action-specific ARAR.	Alternative GW2 requires no action beyond institutional controls. Monitoring will occur, but not in accordance with MNA standards described in this TBC.	Alternative GW3 requires institutional controls with MNA. This guidance will be used to guide the MNA program under this alternative.	Alternative GW5 requires *in situ* remediation coupled with MNA. This guidance will be used to guide the MNA program under this alternative.
An Approach for Evaluating the Progress of Natural Attenuation, EPA 600/R-11/204, December 2011	To Be Considered	Includes procedural requirements for evaluation of attenuation under monitored natural attenuation remedy.	Alternative GW1 requires no action and therefore will not trigger this action-specific ARAR.	Alternative GW2 requires no action beyond institutional controls. Monitoring will occur, but not in accordance with MNA standards described in this TBC.	Alternative GW3 requires institutional controls with MNA. This guidance will be used to guide the MNA program under this alternative.	Alternative GW5 requires *in situ* remediation coupled with MNA. This guidance will be used to guide the MNA program under this alternative.

Table 5-21
Action-Specific ARARs for Vapor Mitigation Alternatives
Commerce Street Plume Superfund Site
Williston, Vermont

REQUIREMENT	STATUS	REQUIREMENT SYNOPSIS	ACTION TAKEN TO COMPLY WITH ARARs		
			VM1	VM2	VM3
STATE ARARs					
10 VSA Chapter 47, Vermont Water Pollution Control; Environmental Protection Rule, Chapter 29a, Vermont Water Quality Standards in Appendix C	Applicable	Establishes water quality standards for surface waters and applies to alternatives that call for monitoring surface water bodies on and off of the Site.	Alternative VM1 requires no action and therefore will not trigger this action-specific ARAR.	Alternative VM2 does not involve any discharges to streams. Therefore, this ARAR is not applicable.	Alternative VM3 does not involve any discharges to streams. Therefore, this ARAR is not applicable.
Environmental Protection Rule, Chapter 13, Water Pollution Control Permit Regulations (Vermont National Pollutant Discharge Elimination System (NPDES) Regulations)	Applicable	The regulations stipulate requirements for discharges to surface waters, compliance with NPDES standards, and meeting stormwater management requirements. If there is a discharge to a stream this ARAR will be met.	Alternative VM1 requires no action and therefore will not trigger this action-specific ARAR.	Alternative VM2 does not involve any discharges to streams. Therefore, this ARAR is not applicable.	Alternative VM3 does not involve any discharges to streams. Therefore, this ARAR is not applicable.
10 VSA Chapter 23; Vermont Air Pollution Control Act; Environmental Protection Rule Chapter 5, Air Pollution Control Regulations, including 5-231(4) and 5-241(1) for dust.	Applicable	Establishes authority for a coordinated statewide program of air pollution prevention, abatement and control. Lists prohibited activities and regulatory requirements affecting air quality and establishes primary and secondary ambient air quality standards.	Alternative VM1 requires no action and therefore will not trigger this action-specific ARAR.	Installation of the water treatment system building will use methods to limit airborne dust.	Installation of the water treatment system building or other engineering controls, as deemed necessary based on further risk analysis, will use methods to limit airborne dust.
10 VSA Chapter 47, Water Pollution Control § 1259(a)	Applicable	VTDEC requirement to treatment to primary groundwater standards in Environmental Protection Rule 12 for discharge to a water of the state.	Alternative VM1 requires no action and therefore will not trigger this action-specific ARAR.	Alternative VM2 will comply with this ARAR through a water discharge treatment system for continued use of sump system.	Alternative VM3 will comply with this ARAR through a water discharge treatment system for continued use of sump system.
Environmental Protection Rule, Chapter 11, Underground Injection Control Regulations	Relevant and Appropriate	Substantive requirements for injection of substances into groundwater for *in situ* groundwater treatment.	Alternative VM1 requires no action and therefore will not trigger this action-specific ARAR.	Alternative VM2 does not involve any underground injections. Therefore, this ARAR is not relevant and appropriate.	Alternative VM3 does not involve any underground injections. Therefore, this ARAR is not relevant and appropriate.
10 VSA Chapter 159, Vermont Waste Management Act; Environmental Protection Rule, Chapter 7, Vermont Hazardous Waste Management Regulations, Subchapter 2, Identification and Listing of Hazardous Waste	Applicable	Establishes requirements for the identification of hazardous waste based on characteristics and listing. Incorporates requirements of the federal Resource Conservation and Recovery Act regulations, 40 CFR 261.	Alternative VM1 requires no action and therefore will not trigger this action-specific ARAR.	Alternative VM2 involves vapor mitigation and is not anticipated to involve RCRA waste. However, any incidental RCRA waste generated, if any, will be collected, characterized, prior to shipment and disposal at an approved facility.	Alternative VM3 involves vapor mitigation and is not anticipated to involve RCRA waste. However, any incidental RCRA waste generated, if any, will be collected, characterized, prior to shipment and disposal at an approved facility.
10 VSA Chapter 159, Vermont Waste Management Act; Environmental Protection Rule, Chapter 7, Vermont Hazardous Waste Management Regulations, Subchapter 3, Hazardous Waste Generator Standards	Applicable	Establishes requirements for generators of hazardous wastes. Incorporates requirements of the federal Resource Conservation and Recovery Act regulations, 40 CFR 262.	Alternative VM1 requires no action and therefore will not trigger this action-specific ARAR.	Alternative VM2 involves vapor mitigation and is not anticipated to involve RCRA waste. However, if any incidental RCRA waste is generated, the substantive requirements of these generator rules will be followed.	Alternative VM3 involves vapor mitigation and is not anticipated to involve RCRA waste. However, if any incidental RCRA waste is generated, the substantive requirements of these generator rules will be followed.
10 VSA Chapter 159, Vermont Waste Management Act; Environmental Protection Rule, Chapter 7, Vermont Hazardous Waste Management Regulations, Subchapter 5, Requirements for Hazardous Waste Storage, Treatment and Disposal Facilities.	Applicable	Establishes requirements for the design, construction, operation, and maintenance of hazardous waste treatment, storage, and disposal facilities. Incorporates requirements of the federal Resource Conservation and Recovery Act regulations, 40 CFR 264, including 40 CFR 264 Subpart G, Closure and Post-Closure.	Alternative VM1 requires no action and therefore will not trigger this action-specific ARAR.	Alternative VM2 involves vapor mitigation and is not anticipated to involve RCRA waste. However, if any incidental RCRA waste is generated, waste storage, treatment and disposal requirements will be followed.	Alternative VM3 involves vapor mitigation and is not anticipated to involve RCRA waste. However, if any incidental RCRA waste is generated, waste storage, treatment and disposal requirements will be followed.
FEDERAL ARARs					
Resource Conservation and Recovery Act (RCRA), 42 U.S.C. §§ 6901, et seq., RCRA Regulations, 40 CFR Part 261, 262, 264, including 40 CFR 264 Subpart G Closure and Post Closure.	Applicable	Alternatives that result in the generation of hazardous waste will need to comply with these requirements. Vermont is delegated to implement these regulations through its Hazardous Waste Management Regulations (see above).	Alternative VM1 requires no action and, therefore, will not trigger this action-specific ARAR.	Alternative VM2 involves vapor mitigation and is not anticipated to involve RCRA waste. However, if any incidental RCRA waste is generated, waste will be identified and characterized as prescribed; generator, and waste storage, treatment and disposal requirements will be followed.	Alternative VM3 involves vapor mitigation and is not anticipated to involve RCRA waste. However, if any incidental RCRA waste is generated, waste will be identified and characterized as prescribed; generator, and waste storage, treatment and disposal requirements will be followed.
RCRA (40 CFR 265, Subpart Q - Chemical, Physical and Biological Treatment	Relevant and Appropriate	Standards apply to facilities where hazardous wastes are treated by chemical, physical, or biological methods.	Alternative VM1 requires no action and, therefore, will not trigger this action-specific ARAR.	Alternative VM2 does not involve any underground injections for chemical, physical or biological treatment. Therefore, this ARAR is not relevant and appropriate.	Alternative VM3 does not involve any underground injections for chemical, physical or biological treatment. Therefore, this ARAR is not relevant and applicable.
Clean Water Act, Section 402 - National Pollution Discharge Elimination System (NPDES), 40 CFR 122-125, 131	Applicable	The CWA contains discharge limitation, monitoring requirements, and best management practices (BMPs) for discharges into navigable waters, i.e. surface waters. The regulations would be applicable to remedial strategies involving discharge to surface waters. If there is a discharge to a stream this ARAR will be met.	Alternative VM1 requires no action and, therefore, will not trigger this action-specific ARAR.	Alternative VM2 does not involve any discharges to streams. Therefore, this ARAR is not applicable.	Alternative VM3 does not involve any discharges to streams. Therefore, this ARAR is not applicable.
Clean Water Act, Section 304(a), National Recommended Water Quality Criteria (NRWQC), 40 CFR 131.11	Applicable	NRWQC are provided by EPA for chemicals for the protection of human health and the protection of aquatic life. If there is a discharge to a stream this ARAR will be met.	Alternative VM1 requires no action and, therefore, will not trigger this action-specific ARAR.	Alternative VM2 does not involve any discharges to streams. Therefore, this ARAR is not relevant and appropriate.	Alternative VM3 does not involve any discharges to streams. Therefore, this ARAR is not applicable.

Underground Injection Control Program, 40 CFR 144, 146, 147.	Relevant and Appropriate	Substantive requirements for injection of substances into groundwater for *in situ* groundwater treatment. Vermont is delegated to implement these regulations through its Underground Injection Control regulations (see above).	Alternative VM1 requires no action and, therefore, will not trigger this action-specific ARAR.	Alternative VM2 does not involve any underground injections. Therefore, this ARAR is not applicable.	Alternative VM3 does not involve any underground injections. Therefore, this ARAR is not relevant and appropriate.
Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites. Final OSWER Directive, Publication EPA/540/R-99/009. April 1999.	To Be Considered	Includes procedural requirements for the use of monitored natural attenuation as a remedial component.	Alternative VM1 requires no action and, therefore, will not trigger this action-specific ARAR.	This ARAR is applicable to groundwater, not vapor.	This ARAR is applicable to groundwater, not vapor.
Performance Monitoring of MNA Remedies for VOCs in Ground Water, EPA/600/R-04/027, April 2004.	To Be Considered	Includes procedural requirements for the use of monitored natural attenuation of VOCs as a remedial component.	Alternative VM1 requires no action and, therefore, will not trigger this action-specific ARAR.	This ARAR is applicable to groundwater, not vapor.	This ARAR is applicable to groundwater, not vapor.
An Approach for Evaluating the Progress of Natural Attenuation, EPA 600/R-11/204, December 2011	To Be Considered	Includes procedural requirements for evaluation of attenuation under monitored natural attenuation remedy.	Alternative VM1 requires no action and, therefore, will not trigger this action-specific ARAR.	This ARAR is applicable to groundwater, not vapor.	This ARAR is applicable to groundwater, not vapor.

Table 6-1
Comparison Analysis of Alternatives
Commerce Street Plume Superfund Site
Williston, Vermont
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Evaluation Criteria	Soil Alternatives			Groundwater Alternatives			
	Alternative SO1	**Alternative SO2**	**Alternative S03**	**Alternative GW1**	**Alternative GW2**	**Alternative GW3**	**Alternative GW5**
Overall Protection of Human Health and the Environment	Does not meet the criterion. Would not eliminate, reduce, or control source areas or potential future exposure to contaminants exceeding PRGs and would not meet remedial action objectives.	Good Would limit the exposure to the impacted soil by creating a physically barrier around the area to prevent entry, protecting human health. Although there are no significant environmental risks, the alternative would do nothing to assist in the restoration of the subsurface material.	Excellent Would be protective of human health and the environment. Would remove the impacted soil from the Site and dispose of it properly in a licensed treatment or disposal facility removing the risk to human health and the environment. SO3 is more protective than SO2 because of the greater long-term effectiveness afforded by removing the material rather than leaving it in place and restricting access.	Does not meet the criterion. Would not eliminate, reduce, or control source areas or potential future exposure to contaminants exceeding PRGs and would not meet remedial action objectives.	Poor Would limit the consumption of the groundwater and protect construction workers. While there are currently no ecological risks, the alternative does not monitor or control the migration of the plume to future receptors. Alternative GW2 would not eliminate, reduce, or control the current contaminants exceeding PRGs and would not meet the RAOs.	Good Would limit the consumption of the groundwater and protect construction workers. Alternative GW3 is slightly better than Alternative GW2 since it implements a monitoring program to detect contaminant trends, natural attenuation effectiveness, and plume migration.	Excellent Would limit the consumption of the groundwater and protect construction workers. Alternative GW3 would implement irreversible *in situ* technologies that destroy the contaminants and result in benign byproducts; therefore, the alternative would eliminate, reduce, and control the current contaminants exceeding PRGs and is expected to meet the RAOs. Alternative GW5 is significantly better at the overall protection of human health and the environment than the remaining groundwater alternatives.
Compliance with ARARs	Does not meet the criterion. RCRA characteristic hazardous waste was disposed in the lagoon at 96 Commerce Street, thus requiring either full removal or a RCRA Subtitle C cap.	Does not meet the criterion. RCRA characteristic hazardous waste was disposed in the lagoon at 96 Commerce Street, thus requiring either full removal or a RCRA Subtitle C cap.	Excellent Would be designed to attain ARARs pertaining to RCRA, wetlands, stormwater runoff, and erosion and sediment control. The TSDF will be approved by the EPA Off-site Coordinator prior to disposal to ensure that the facility is in full compliance before receiving the material.	Does not meet the criterion. Would not attain protective concentrations for contaminants in groundwater based on chemical-specific ARARs and TBCs.	Poor Meets the criterion. Would attain protective concentrations for contaminants in groundwater based on chemical-specific ARARs and TBCs. Does not include monitoring to evaluate plume changes, but would implement institutional controls to reclassify impacted groundwater as non-potable and limit the withdrawal of groundwater to prevent other uses that could cause the plume to migrate until cleanup standards are met.	Good Meets the criterion. Would attain protective concentrations for contaminants in groundwater based on chemical-specific ARARs and TBCs, and includes monitoring to evaluate plume changes and monitor natural attenuation of the plume. Would implement institutional controls to reclassify impacted groundwater as non-potable and limit the withdrawal of groundwater to prevent other uses that could cause the plume to migrate until cleanup standards are met.	Excellent Would use active *in situ* treatment to attain protective concentrations for contaminants in groundwater based on chemical-specific ARARs and TBCs and includes monitoring to evaluate plume changes and monitor natural attenuation of the plume. Would implement institutional controls to reclassify impacted groundwater as non-potable and limit the withdrawal of groundwater to prevent other uses that could cause the plume to migrate until cleanup standards are met.
Long-term Effectiveness and Permanence	Does not meet the criterion Would not eliminate, reduce, or control source areas or potential future exposure to contaminants exceeding PRGs and would not provide long-term effectiveness at protecting human health and the environment.	Good Would isolate the impacted soil from human contact by means of a fence; however, the fence would be susceptible to vandalism, wear and tear, and weather-related damage. It is anticipated that the fence would need to be repaired or replace several times during the 30 year period. Restricting access would not be effective in the long-term at achieving the PRGs or RAOs.	Excellent Removal of the impacted soil and disposal or treatment at an off-site facility would have excellent long-term effectiveness. There is no identified residual source of the soil impacts; therefore, once the soil is removed the replacement fill is not expected to become impacted again. SO3 is more effective and permanent that SO2.	Does not meet the criterion Would not eliminate, reduce, or control source areas or potential future exposure to contaminants exceeding PRGs and would not provide long-term effectiveness at protecting human health and the environment.	Poor Would limit the consumption of the groundwater and protect construction workers by reclassifying the impacted groundwater within the Study Area as non-potable and limit the withdrawal of groundwater to prevent other uses that could cause the plume to migrate until cleanup standards are met in one to two hundred years.-Institutional controls would be needed in perpetuity.	Poor Would limit the consumption of the groundwater and protect construction workers by reclassifying the impacted groundwater within the Study Area as non-potable and limit the withdrawal of groundwater to prevent other uses that could cause the plume to migrate until cleanup standards are met in one to two hundred years. Institutional controls would be needed in perpetuity. Alternative GW3 is slightly more effective than GW2 because it implements a long-term monitoring program to detect contaminant trends, natural attenuation effectiveness, and plume migration~~.~~	Better In addition to the institutional controls in Alternatives GW2 and GW3, Alternative GW5 implements irreversible *in situ* treatments that destroy the contaminants and result in benign byproducts. The destruction of the contaminants, along with the long-term monitoring program to detect contaminant trends, natural attenuation effectiveness, and plume migration, will reduce the time required to eliminate, reduce or control the current contaminants exceeding PRGs and would ultimately meet the RAOs in decades. Alternative GW5 is significantly better in long-term effectiveness and permanence than the remaining groundwater alternatives.
Reduction of Toxicity, Mobility, and Volume through Treatment	Would not use treatment to accomplish the reduction of toxicity, mobility, and volume.	Would not use treatment to accomplish the reduction of toxicity, mobility, and volume.	Excellent SO3 would use removal and off-site disposal to reduce the toxicity, mobility, and volume of the impacted soil. Removal of the soil and off-site disposal is expected to eliminate the volume of soil that is above the PRGs.	Poor Would not use treatment to accomplish the reduction of toxicity, mobility, and volume.	Poor Would not use treatment to accomplish the reduction of toxicity, mobility, and volume.	Poor Would not use treatment to accomplish the reduction of toxicity, mobility, and volume.	Excellent Alternative GW5 implements irreversible *in situ* treatments that destroy the contaminants and result in benign byproducts. The destruction of the contaminants, along with the long-term monitoring program to detect contaminant trends, natural attenuation effectiveness, and plume migration, will reduce the time required to eliminate, reduce, or control the current contaminants exceeding PRGs and would ultimately meet the RAOs. Alternative GW5 is significantly better at the reduction of toxicity, mobility, and volume than the remaining groundwater alternatives.

Evaluation Criteria	Soil Alternatives			Groundwater Alternatives			
	Alternative SO1	**Alternative SO2**	**Alternative S03**	**Alternative GW1**	**Alternative GW2**	**Alternative GW3**	**Alternative GW5**
Short-term Effectiveness	Poor Does not reduce risk from exposure to contaminated soil. No action taken so there are no short-term effects to the community, Site workers or the environment.	Good Would be no risks to the community, site workers, or the environment from implementation. The construction of the fence would be performed quickly and would be minimally intrusive since no active remedial actions are associated with alternative. Achieves protectiveness-through the use of land use restrictions.	Better Would be minimal risks to the community, site workers, and the environment from implementation. The excavation work would be completed in one to two weeks. The volume of the material to be excavated would result in several truck loads of material travelling over the road; however, the Site is located in or adjacent to commercial and industrial areas and the roads are capable of handling the traffic. Work would be expected to be performed during normal business hours. Risks to on-site workers is easily mitigated through engineered controls and personal protective equipment. Erosion control, traffic control and loading plans, and proper disposal of removed soil would reduce the impacts to the environment.	Poor Does not reduce risk from exposure to contaminated groundwater. No action taken so there are in no short-term effects to the community, Site workers or the environment.	Excellent Short-term risks from incidental work such as the installation of new monitoring wells are minimal and do not pose a great risk to the community or Site workers. Human health is protected by institutional controls.	Excellent Short-term risks from incidental work such as the installation of new monitoring wells are minimal and do not pose a great risk to the community or Site workers. Human health is protected by institutional controls.	Good Alternative GW5 implements irreversible *in situ* treatments that destroy the contaminants and result in benign byproducts. The technologies require minimal exposure to contaminants since it is performed in the subsurface. Some materials will be brought to the Site in the form of ISCO reagents and/or biological amendments in addition to the performance of injection may require engineered controls and personal protective equipment for the site workers. Administrative and engineering controls and communication with local officials and the community would ensure safe transport, storage and injection of these materials.
Implementability	Excellent Does not include any actions, other than Five-Year Reviews, and, therefore, would be technically easy to implement.	Excellent Construction of the fence is easily implementable. Contractors capable of performing the work are readily available and the construction time is expected to be less than one week. O&M of the alternative includes seasonal inspections and maintenance, as needed. Deed restrictions can be difficult to implement as EPA cannot record them unilaterally and needs the cooperation and assistance of third parties (e.g., property owners, mortgage holders, town officials).	Excellent Excavation of the impacted material is easily implementable. Contractors capable of performing the work are readily available and the construction time is expected to be one to two weeks. Once the excavation work is complete there is no O&M needed.	Excellent Does not include any actions, other than Five-Year Reviews, and, therefore, would be technically easy to implement.	Excellent Includes Five-Year Reviews and limited groundwater monitoring at the Site boundary which are technically easy to implement. Institutional controls such as deed restrictions or municipal ordinances can be difficult to implement as EPA cannot record them unilaterally and needs the cooperation and assistance of third parties (e.g., property owners, mortgage holders, town officials).	Excellent Includes Five-Year Reviews and groundwater monitoring throughout the groundwater plume and at the Site boundary which are technically easy to implement. Institutional controls such as deed restrictions or municipal ordinances can be difficult to implement as EPA cannot record them unilaterally and needs the cooperation and assistance of third parties (e.g., property owners, mortgage holders, town officials).	Good The technology is typically easy to implement; however, the size of the plume and the development of the area contribute to the complexities of this alternative. The *in situ* treatment will focus on the hotspots of the plume which are located in heavily developed commercial/industrial and residential locations. Therefore, care will have to be taken to adequately identify subsurface utilities and to control daylighting of additives in residential basements. Contractors capable to performing the work and the reagents and amendments required are readily available. While Alternative GW5 is not as easily implementable as the remaining alternatives, there are no obvious significant impediments to the implementation.
Cost	Excellent $62,037 - Total Present Worth (30 yrs)	Better $184,185 - Total Present Worth (30 yrs)	Good $657,196 - Total Present Worth (30 yrs)	Excellent $62,037 - Total Present Worth (30 yrs)	Better $245,639 - Total Present Worth (30 yrs)	Good $1,587,524 - Total Present Worth (30 yrs)	Poor $4,300,667 to $7,572,143 - Total Present Worth (30 yrs) depending on the combination of technology and area treated

Evaluation Criteria	Vapor Mitigation Alternatives		
	Alternative VM1	**Alternative VM2**	**Alternative VM3**
Overall Protection of Human Health and the Environment	Does not meet the criterion. Would not eliminate, reduce, or control source areas or potential future exposure to contaminants exceeding PRGs and would not meet remedial action objectives.	Good Would limit the exposure of vapors emanating from contaminated groundwater but still leaves the possibility of vapor intrusion risk at 830 South Brownell Road from vapors emanating from groundwater under the basement.	Excellent Would fully protect human health by requiring the supplementation or replacement of the existing sump, venting and discharge system, as necessary, based on the collection and risk analysis of additional data during pre-design. Alternative VM3 also contains a contingency to treat other homes in the vicinity of the groundwater plume, if future data collection and analysis indicate an exceedance of risk.
Compliance with ARARs	No chemical-specific ARAR exists with respect to exposure to contaminants in vapor.	Excellent Sump water will be treated before discharge to the ground surface and indirectly to groundwater in conformance with Vermont's Water Pollution Control law.	Excellent Sump water will be treated before discharge to the ground surface and indirectly to groundwater in conformance with Vermont's Water Pollution Control law. Soil disturbance for the installation of additional vapor mitigation system or other engineering controls will conform with state and federal laws pertaining to historic preservation laws and wetland laws, as applicable.
Long-term Effectiveness and Permanence	Does not meet the criterion. Would not eliminate, reduce, or control source areas or potential future exposure to contaminants exceeding PRGs and would not provide long-term effectiveness at protecting human health and the environment.	Good Ensures the continued operation and maintenance of the existing vapor mitigation system at 830 South Brownell Road to help protect the residents in that home from harmful vapors until such time as groundwater concentrations are reduced and no longer pose a potential inhalation risk.	Excellent Requires the improvement of the existing vapor mitigation system, as determined necessary based on additional data sampling and risk assessment and also includes a contingency to address additional homes or businesses surrounding the groundwater plume if future data and risk assessment determine it is necessary to address excessive risk.
Reduction of Toxicity, Mobility, and Volume through Treatment	Does not meet this criterion. Would not use treatment to accomplish the reduction of toxicity, mobility, and volume.	Poor Uses engineering controls rather than treatment to reduce toxicity, mobility, or volume with respect to vapors but does require treatment of sump discharge.	Poor Uses engineering controls rather than treatment to reduce toxicity, mobility, or volume with respect to vapors but does require treatment of sump discharge.

Evaluation Criteria	Vapor Mitigation Alternatives		
	Alternative VM1	**Alternative VM2**	**Alternative VM3**
Short-term Effectiveness	Good There are no short-term risks to the community, Site workers or the environment.	Good There are no short-term risks to the community, Site workers or the environment. Will not take long to implement; the existing sump pump, passive venting and discharge system is in place, and all that is necessary is the construction of a GAC treatment shed for the discharge.	Excellent There are no short-term risks to the community, Site workers or the environment. Will take longer to achieve than Alternative VM2 due to the need to collect additional data and perform a risk analysis, and contingent upon the results, augment or replace the existing system with an active vapor mitigation control system or other engineering control.
Implementability	Excellent Does not include any actions, other than Five-Year Reviews, and, therefore, would be technically easy to implement.	Excellent Contractors capable of designing and installing a sump discharge treatment system (e.g., running the discharge through GAC in a treatment shed on-site), and/or active venting or vapor barrier mitigation measures, if deemed necessary, are readily available.	Excellent Contractors capable of designing and installing a sump discharge treatment system (e.g., running the discharge through GAC in a treatment shed on-site), and/or active venting or vapor barrier mitigation measures, if deemed necessary, are readily available.
Cost	Excellent $62,037 - Total Present Worth (30 yrs)	Better $113,141 - Total Present Worth (30 yrs)	Good $157,412 - Total Present Worth (30 yrs)

Table 6-2
Cost Summary
Alternative GW5: *In Situ* Treatment Cost Summary
Commerce Street Plume Superfund Site
Williston, Vermont

In-Situ Treatment Options									
Treatment Alternative	**Treatment Area**	**Area (SF)**	**Effective Treatment Area (SF)**	**Average Thickness of Contaminated Zone**	**Volume (Cubic Feet)**	**Volume (Cubic Yards)**	**Estimated Average Cost per CY**	**Total Estimated Remedial Capitol Costs**	**Comments**
ISCO Only	**Eastern Area > 50,000 ppb TCE**	54,000	54,000	12	648,000	24,000	$147	**$3,533,625**	
ISCO Only	**Eastern Area > 5,000 ppb TCE**	400,000	300,000	15	4,500,000	166,667	$130	**$21,666,667**	
ISB Only	**Eastern Area >5,000 ppb TCE**	400,000	300,000	15	4,500,000	166,667	$26	**$4,333,333**	ISB not likely effective for TCE area > 50,000 ppb, so would need to be combined with ISCO in Eastern Area
ISB Only	**Eastern and Western Areas > 5,000 ppb TCE**	540,000	405,000	15	6,075,000	225,000	$26	**$5,827,848**	ISB not likely effective for TCE area > 50,000 ppb, so would need to be combined with ISCO in Eastern Area
ISB Only	**Eastern and Western Areas > 500 ppb TCE**	1,400,000	700,000	15	10,500,000	388,889	$24	**$9,333,333**	ISB not likely effective for TCE area > 50,000 ppb, so would need to be combined with ISCO in Eastern Area
ISB Only	**Eastern and Western Areas > 5 ppb TCE**	3,300,000	1,650,000	20	33,000,000	1,222,222	$24	**$29,333,333**	ISB not likely effective for TCE area > 50,000 ppb, so would need to be combined with ISCO in Eastern Area

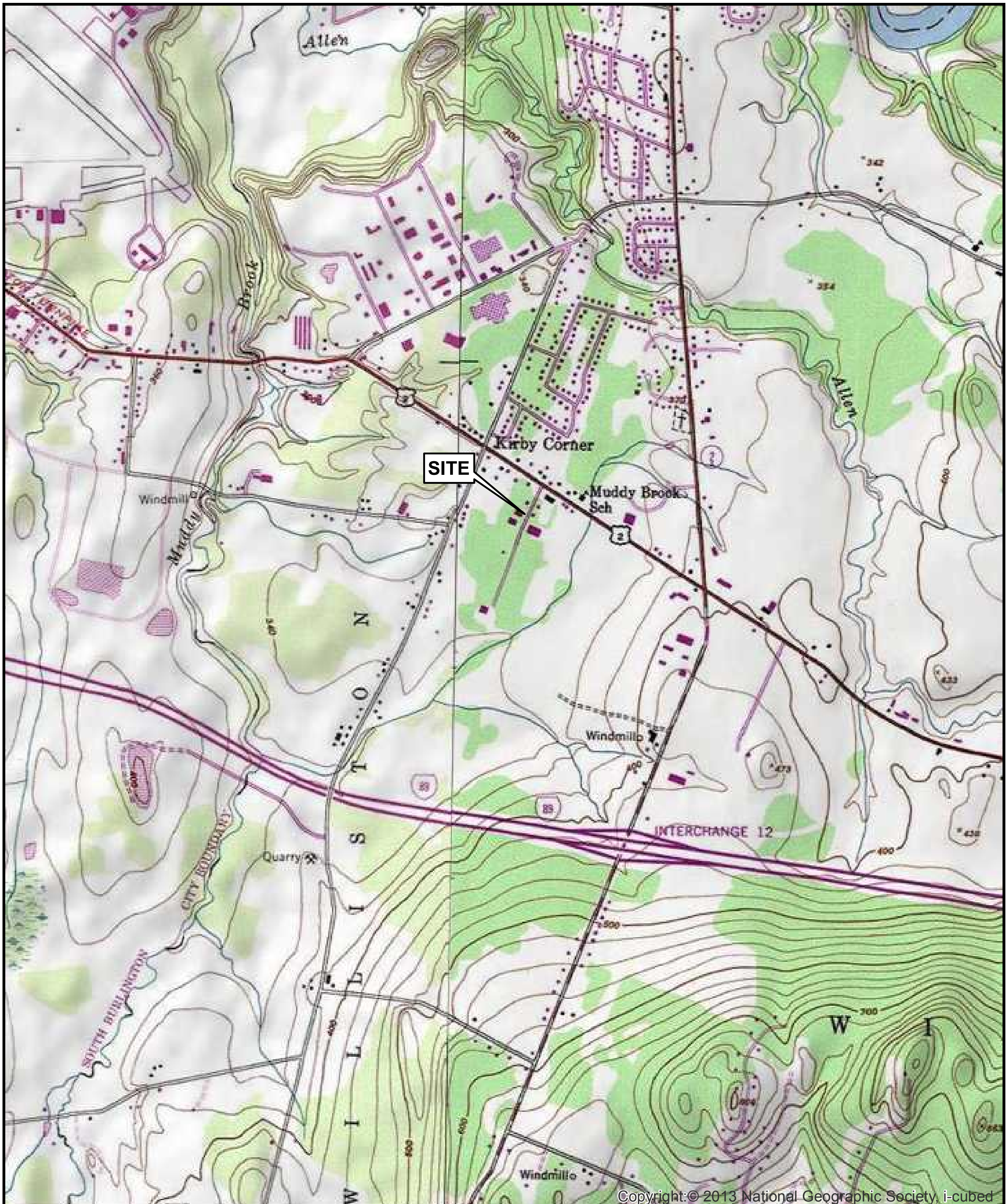
In-Situ Treatment Train Options									
Treatment Alternative	**Treatment Area**	**Area (SF)**	**Effective Treatment Area (SF)**	**Average Thickness of Contaminated Zone**	**Volume (Cubic Feet)**	**Volume (Cubic Yards)**	**Estimated Average Cost per CY**	**Total Estimated Remedial Costs**	**Comments**
ISCO with ISB	**Eastern Area > 50,000 ppb TCE**	54,000	54,000	12	648,000	24,000	$147	**$3,533,625**	ISCO Portion
	Eastern Area > 5,000 ppb TCE	400,000	300,000	15	4,500,000	166,667	$26	**$4,316,924**	ISB Portion
							Total	**$7,850,550**	
ISCO with ISB	**Eastern Hot Spot > 50,000 ppb TCE**	54,000	54,000	12	648,000	24,000	$147	**$3,533,625**	ISCO Portion
	Eastern and Western Hot Spots > 5,000 ppb TCE	540,000	405,000	15	6,075,000	225,000	$26	**$5,827,848**	ISB Portion
							Total	**$9,361,473**	
ISCO with ISB	**Eastern Area > 50,000 ppb TCE**	54,000	54,000	12	648,000	24,000	$147	**$3,533,625**	ISCO Portion
	Eastern and Western Areas > 500 ppb TCE	1,400,000	700,000	15	10,500,000	388,889	$24	**$9,333,333**	ISB Portion
							Total	**$12,866,959**	

Table 6-2
Cost Summary
Alternative GW5: *In Situ* Treatment Cost Summary
Commerce Street Plume Superfund Site
Williston, Vermont

Treatment Trains using ISB "Barrier" Approach									
Treatment Alternative	**Treatment Area**	**Area (SF)**	**Effective Treatment Area (SF)**	**Average Thickness of Contaminated Zone**	**Volume (Cubic Feet)**	**Volume (Cubic Yards)**	**Estimated Average Cost per CY**	**Total Estimated Remedial Costs**	**Comments**
ISCO with ISB "Barrier"	**Eastern Area >50,000 ppb TCE**	54,000	54,000	12	648,000	24,000	$147	**$3,533,625**	**ISCO Portion**
	Eastern Area >5,000 ppb TCE	60,000	60,000	15	900,000	33,333	$50	**$1,666,667**	**ISB Portion (2 Transects)**
							Total	**$5,200,292**	
ISCO with ISB "Barrier"	**Eastern Area >50,000 ppb TCE**	54,000	54,000	12	648,000	24,000	$147	**$3,533,625**	**ISCO Portion**
	Eastern and Western Areas > 5,000 ppb TCE	90,000	90,000	15	1,350,000	50,000	$50	**$2,500,000**	**ISB Portion (3 Transects)**
							Total	**$6,033,625**	
ISCO with ISB "Barrier"	**Eastern Area >50,000 ppb TCE**	54,000	54,000	12	648,000	24,000	$147	**$3,533,625**	**ISCO Portion**
	Eastern and Western Areas > 500 ppb TCE	120,000	120,000	15	1,800,000	66,667	$50	**$3,271,476**	**ISB Portion (4 Transects)**
							Total	**$6,805,101**	
ISCO with ISB "Barrier"	**Eastern Area >50,000 ppb TCE**	54,000	54,000	12	648,000	24,000	$147	**$3,533,625**	**ISCO Portion**
	Eastern and Western Areas > 5 ppb TCE	150,000	150,000	20	3,000,000	111,111	$50	**$5,555,556**	**ISB Portion (5 Transects)**
							Total	**$9,089,181**	

Notes
1) Shaded rows depict treatment alternatives that are further developed with detailed costs in Tables 5-7, 5-8 and 5-9

FIGURES



USGS Topographic Map
Essex Junction, Vermont
Burlington, Vermont
Revised 1987

0 600 1,200 2,400
Feet
1 inch = 2,000 feet

N

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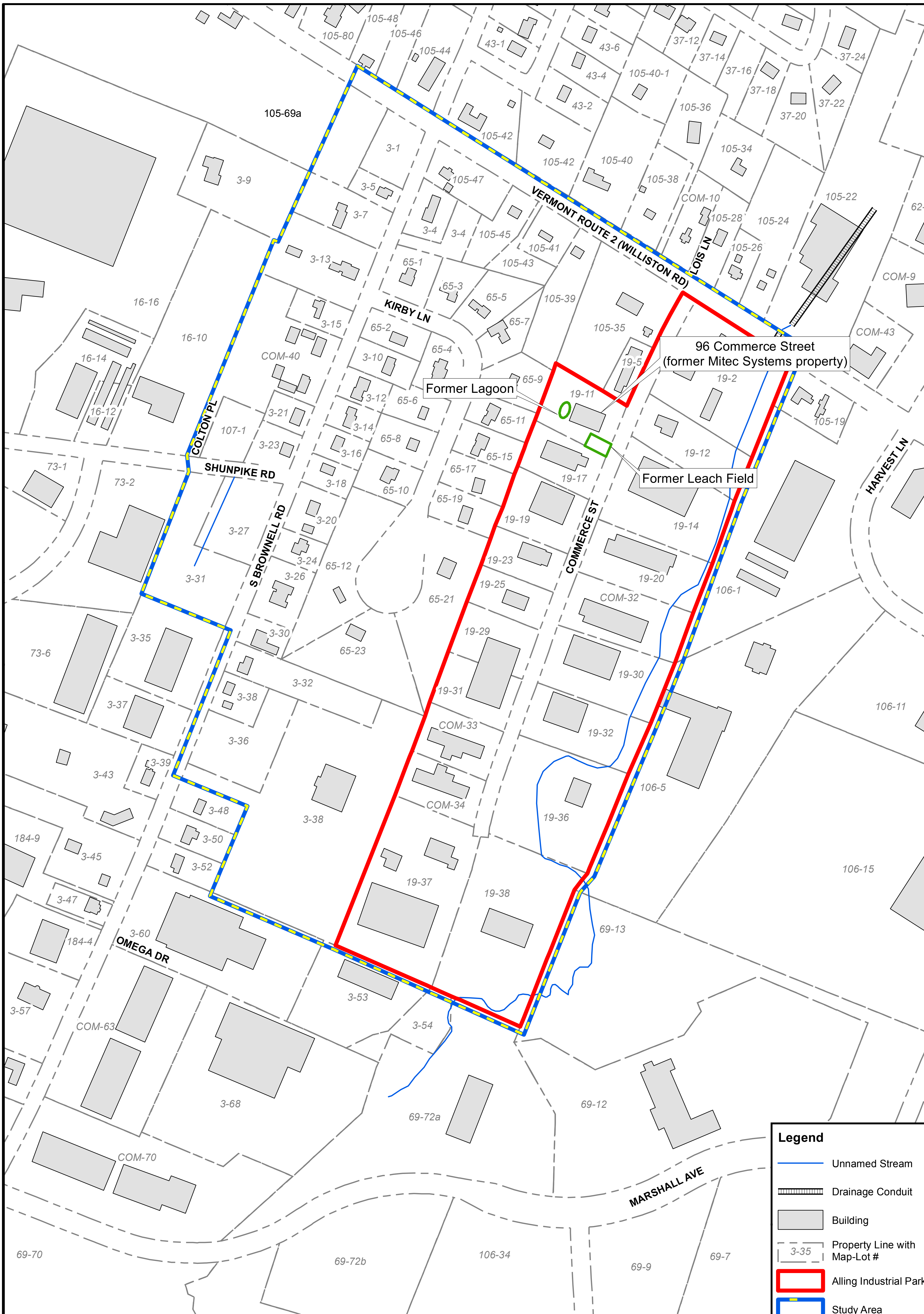
FIGURE 1-1

LOCUS MAP
COMMERCE STREET PLUME
SUPERFUND SITE
WILLISTON, VERMONT

PREPARED BY: JH	CHECKED BY: JL
PROJECT NO. 80036	DATE: JULY 2015



Notes:

1. Site features are depicted for display purposes only.

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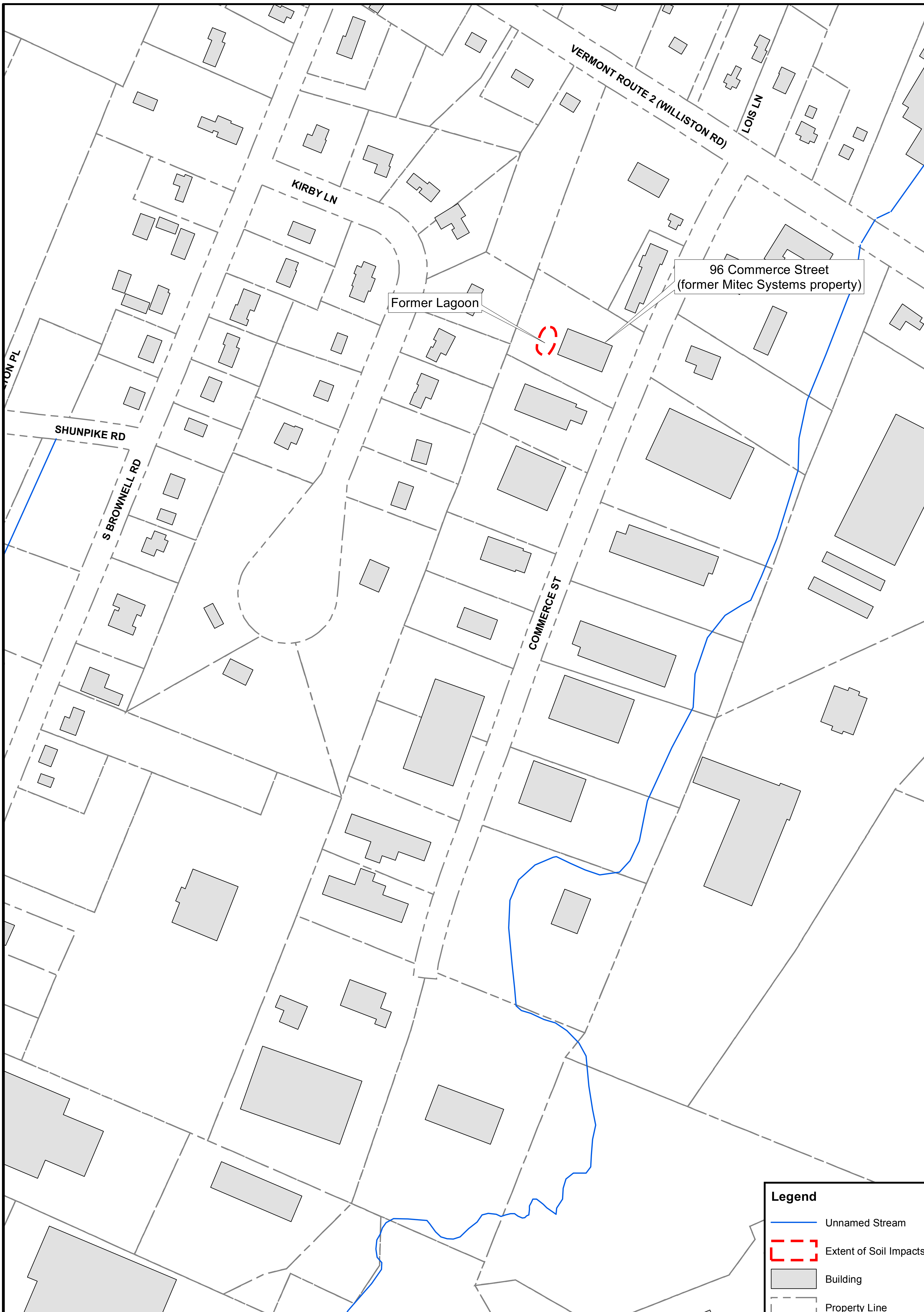
FIGURE 1-2

STUDY AREA
COMMERCE STREET PLUME
SUPERFUND SITE
WILLISTON, VERMONT

PREPARED BY: DG	CHECKED BY: SH
PROJECT NO. 80036	DATE: JULY 2015



Notes:

1. Site features are depicted for display purposes only.

0 100 200 400

Feet

1 inch = 200 feet

N

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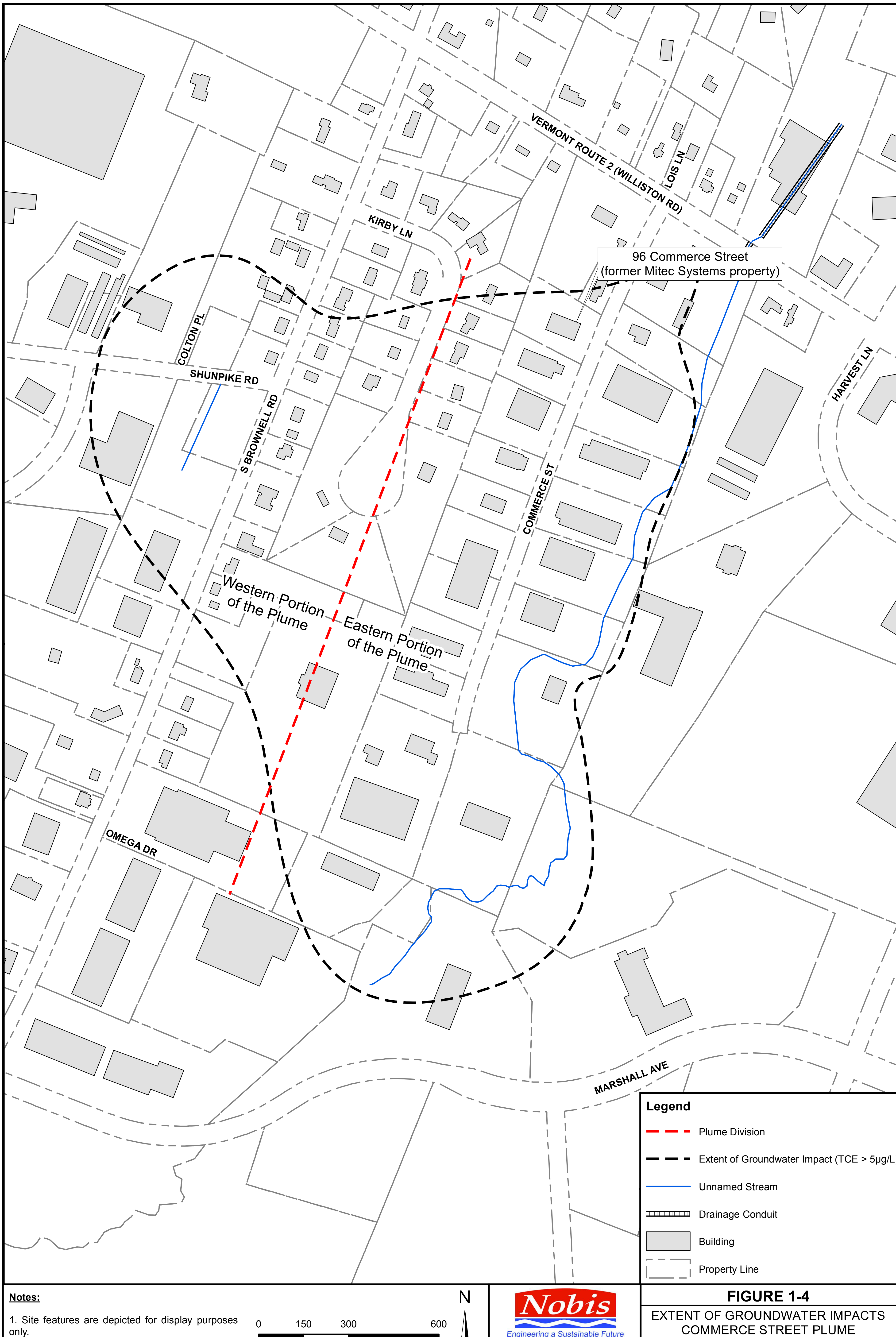
FIGURE 1-3

EXTENT OF SOIL IMPACTS
COMMERCE STREET PLUME
SUPERFUND SITE
WILLISTON, VERMONT

PREPARED BY: NZ	CHECKED BY: SH
PROJECT NO. 80036	DATE: JULY 2015



Notes:

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FIGURE 1-4

EXTENT OF GROUNDWATER IMPACTS
COMMERCE STREET PLUME
SUPERFUND SITE
WILLISTON, VERMONT

PREPARED BY: NZ	CHECKED BY: SH
PROJECT NO. 80036	DATE: JULY 2015

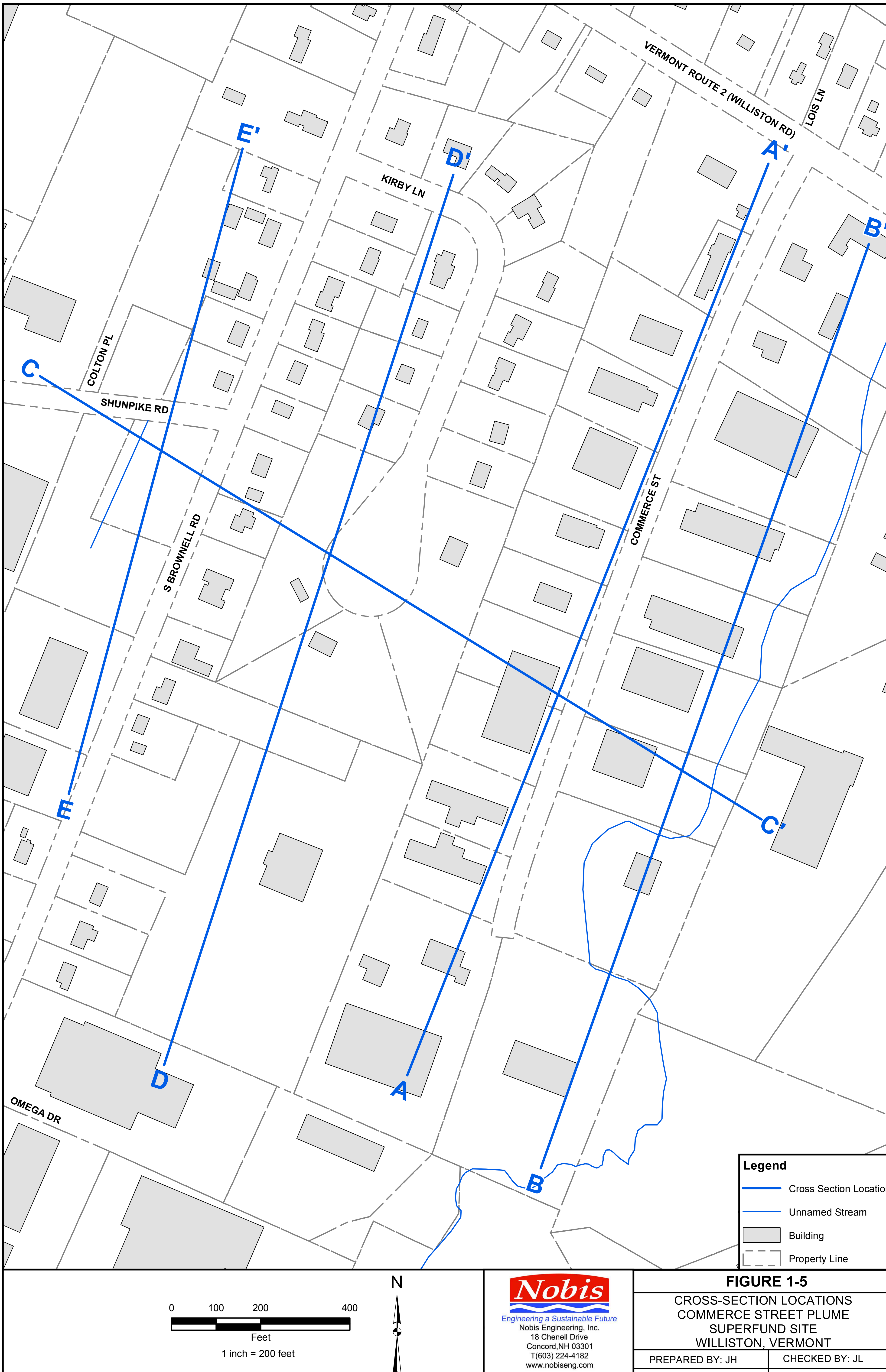

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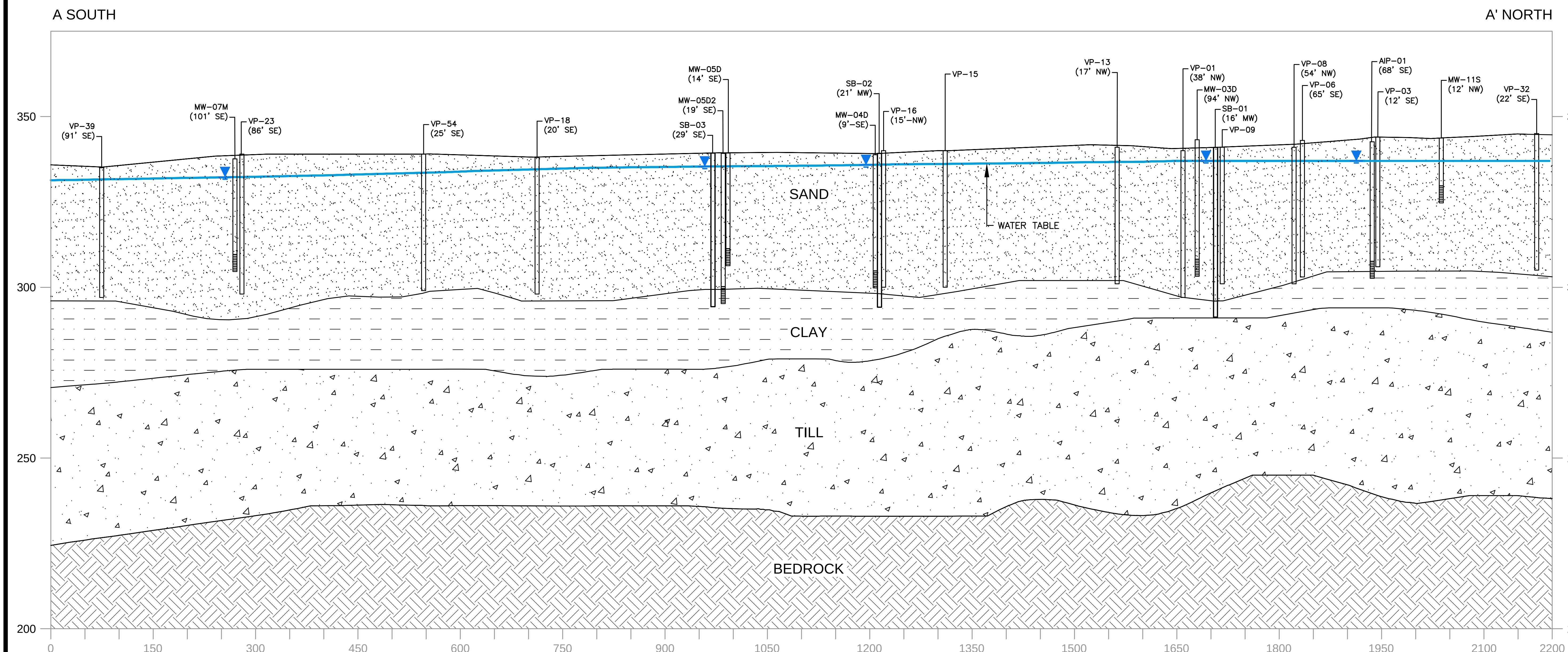
FIGURE 1-5

CROSS-SECTION LOCATIONS
COMMERCE STREET PLUME
SUPERFUND SITE
WILLISTON, VERMONT

PREPARED BY: JH	CHECKED BY: JL
PROJECT NO. 80036	DATE: JULY 2015



HORIZONTAL

150 0 150 300

30 0 30 60

VERTICAL
SCALE IN FEET

MONITORING WELL

WELL I.D.
(BASELINE OFFSET DISTANCE & DIRECTION)

GROUNDWATER ELEVATION
(OCTOBER 2011)

PVC RISER OR STEEL RISER

SCREEN

VERTICAL PROFILE

PROFILE I.D.
(BASELINE OFFSET DISTANCE & DIRECTION)

LEGEND

SAND

CLAY

TILL

BEDROCK

NOTES

1. STRATA SURFACES ARE MAPPED BASED ON THE 2010 GEOPHYSICAL MAPPING HAGER GEOSCIENCE, INC. (HGI), AND OBSERVATIONS MADE DURING SOIL BORINGS AND VERTICAL PROFILING.
2. THE VERTICAL SCALE OF THE CROSS-SECTION HAS BEEN EXAGGERATED FOR ILLUSTRATIVE PURPOSES AND SHOWS THE APPROXIMATE MSL (MEAN SEA LEVEL) ELEVATION.

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FIGURE 1-6

A-A' CROSS-SECTION
COMMERCE STREET PLUME
SUPERFUND SITE
WILLISTON, VERMONT

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PROJECT NO.	80036	DATE:	JULY 2015

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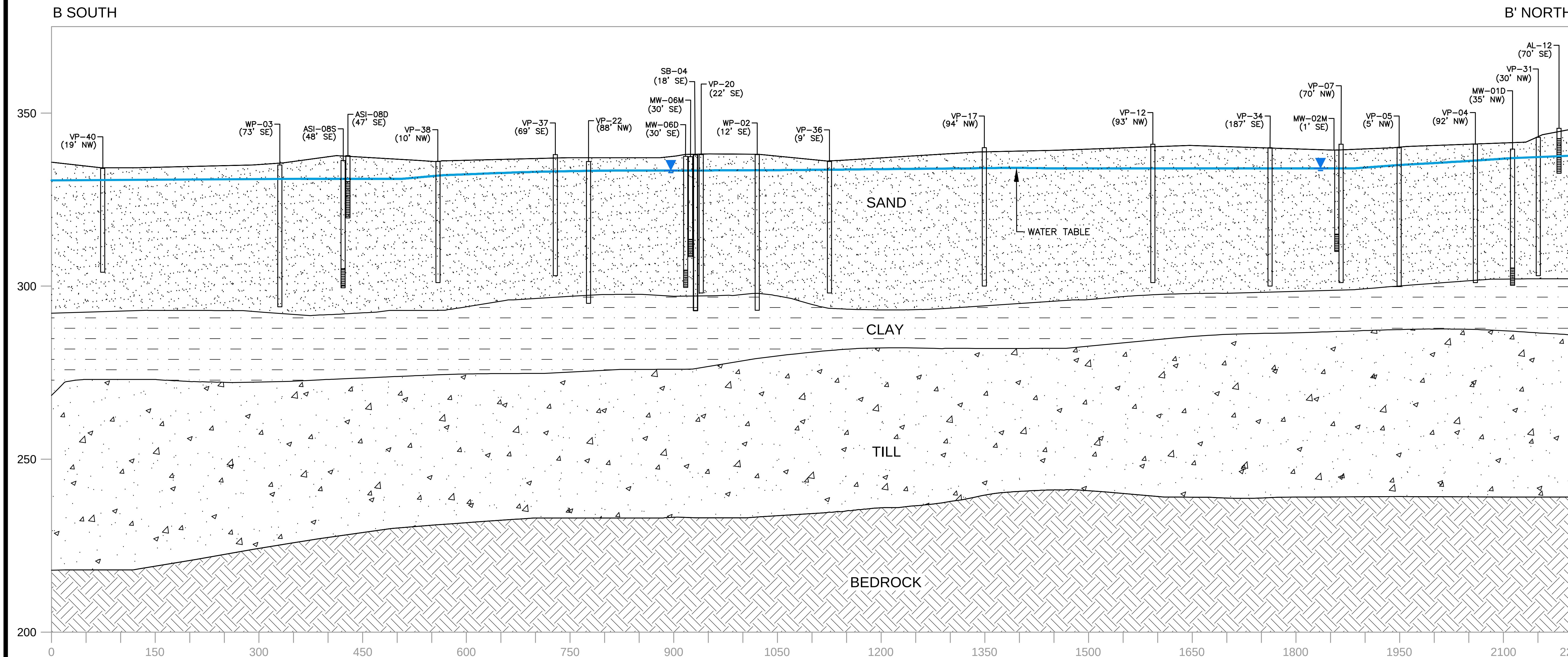

HORIZONTAL

150 0 150 300

30 0 30 60

VERTICAL
SCALE IN FEET

MONITORING WELL

- WELL I.D. (BASELINE OFFSET DISTANCE & DIRECTION)
- GROUNDWATER ELEVATION (OCTOBER 2011)
- PVC RISER OR STEEL RISER
- SCREEN

VERTICAL PROFILE

- PROFILE I.D. (BASELINE OFFSET DISTANCE & DIRECTION)

LEGEND

- SAND
- CLAY
- TILL
- BEDROCK

NOTES

1. STRATA SURFACES ARE MAPPED BASED ON THE 2010 GEOPHYSICAL MAPPING HAGER GEOSCIENCE, INC. (HGI), AND OBSERVATIONS MADE DURING SOIL BORINGS AND VERTICAL PROFILING.
2. THE VERTICAL SCALE OF THE CROSS-SECTION HAS BEEN EXAGGERATED FOR ILLUSTRATIVE PURPOSES AND SHOWS THE APPROXIMATE MSL (MEAN SEA LEVEL) ELEVATION.

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FIGURE 1-7

B-B' CROSS-SECTION
COMMERCE STREET PLUME
SUPERFUND SITE
WILLISTON, VERMONT

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PROJECT NO.	80036	DATE:	JULY 2015

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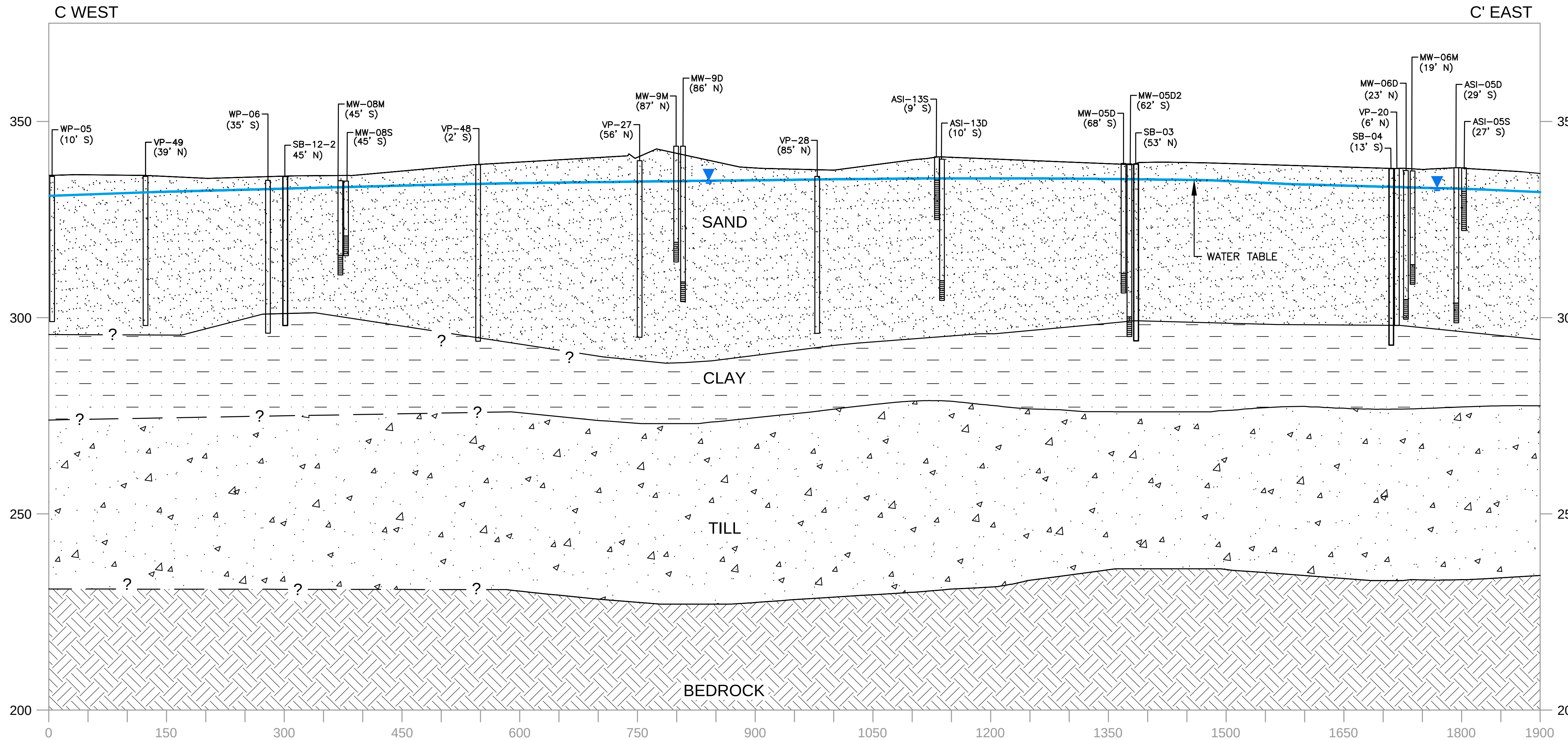

HORIZONTAL

150 0 150 300

30 0 30 60

VERTICAL
SCALE IN FEET

K:\Technical Data (TD)\CAD\dwg\80036-CROSS-SECTIONS.dwg

MONITORING WELL

WELL I.D.
(BASELINE OFFSET DISTANCE & DIRECTION)

GROUNDWATER ELEVATION
(OCTOBER 2011)

PVC RISER OR STEEL RISER

SCREEN

VERTICAL PROFILE

PROFILE I.D.
(BASELINE OFFSET DISTANCE & DIRECTION)

LEGEND

SAND

CLAY

TILL

BEDROCK

— ? — STRATA LOCATION UNKNOWN; BOUNDARY HAS BEEN INTERPRETED

NOTES

1. STRATA SURFACES ARE MAPPED BASED ON THE 2010 GEOPHYSICAL MAPPING HAGER GEOSCIENCE, INC. (HGI), AND OBSERVATIONS MADE DURING SOIL BORINGS AND VERTICAL PROFILING.

2. THE VERTICAL SCALE OF THE CROSS-SECTION HAS BEEN EXAGGERATED FOR ILLUSTRATIVE PURPOSES AND SHOWS THE APPROXIMATE MSL (MEAN SEA LEVEL) ELEVATION.

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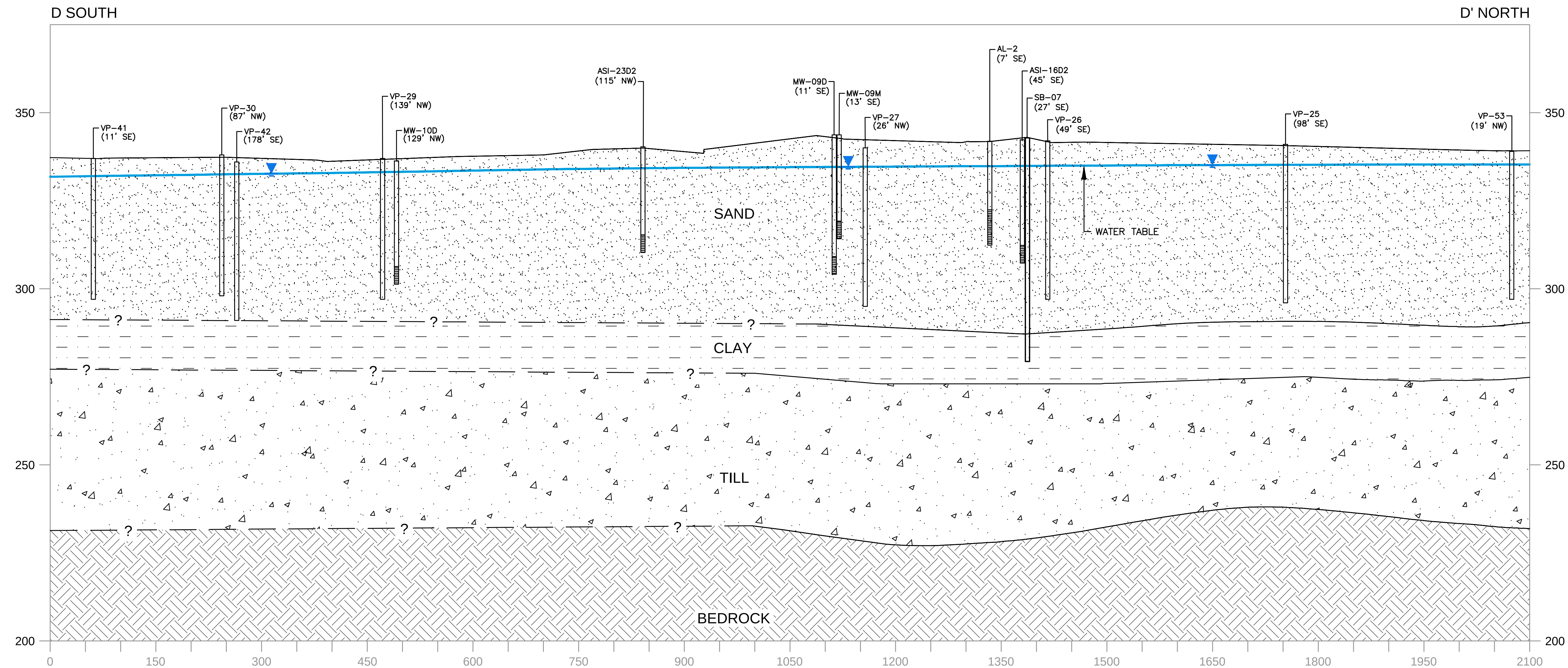
FIGURE 1-8

C-C' CROSS-SECTION
COMMERCE STREET PLUME
SUPERFUND SITE
WILLISTON, VERMONT

DRAWN BY:	ML/AKP	APPROVED BY:	SH
PROJECT NO.	80036	DATE:	JULY 2015



HORIZONTAL

150 0 150 300

30 0 30 60

VERTICAL
SCALE IN FEET

MONITORING WELL

WELL I.D.
(BASELINE OFFSET DISTANCE & DIRECTION)

GROUNDWATER ELEVATION
(OCTOBER 2011)

PVC RISER OR STEEL RISER

SCREEN

VERTICAL PROFILE

PROFILE I.D.
(BASELINE OFFSET DISTANCE & DIRECTION)

LEGEND

SAND

CLAY

TILL

BEDROCK

— ? — STRATA LOCATION UNKNOWN; BOUNDARY HAS BEEN INTERPRETED

NOTES

1. STRATA SURFACES ARE MAPPED BASED ON THE 2010 GEOPHYSICAL MAPPING HAGER GEOSCIENCE, INC. (HGI), AND OBSERVATIONS MADE DURING SOIL BORINGS AND VERTICAL PROFILING.

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FIGURE 1-9

D-D' CROSS-SECTION
COMMERCE STREET PLUME
SUPERFUND SITE
WILLISTON, VERMONT

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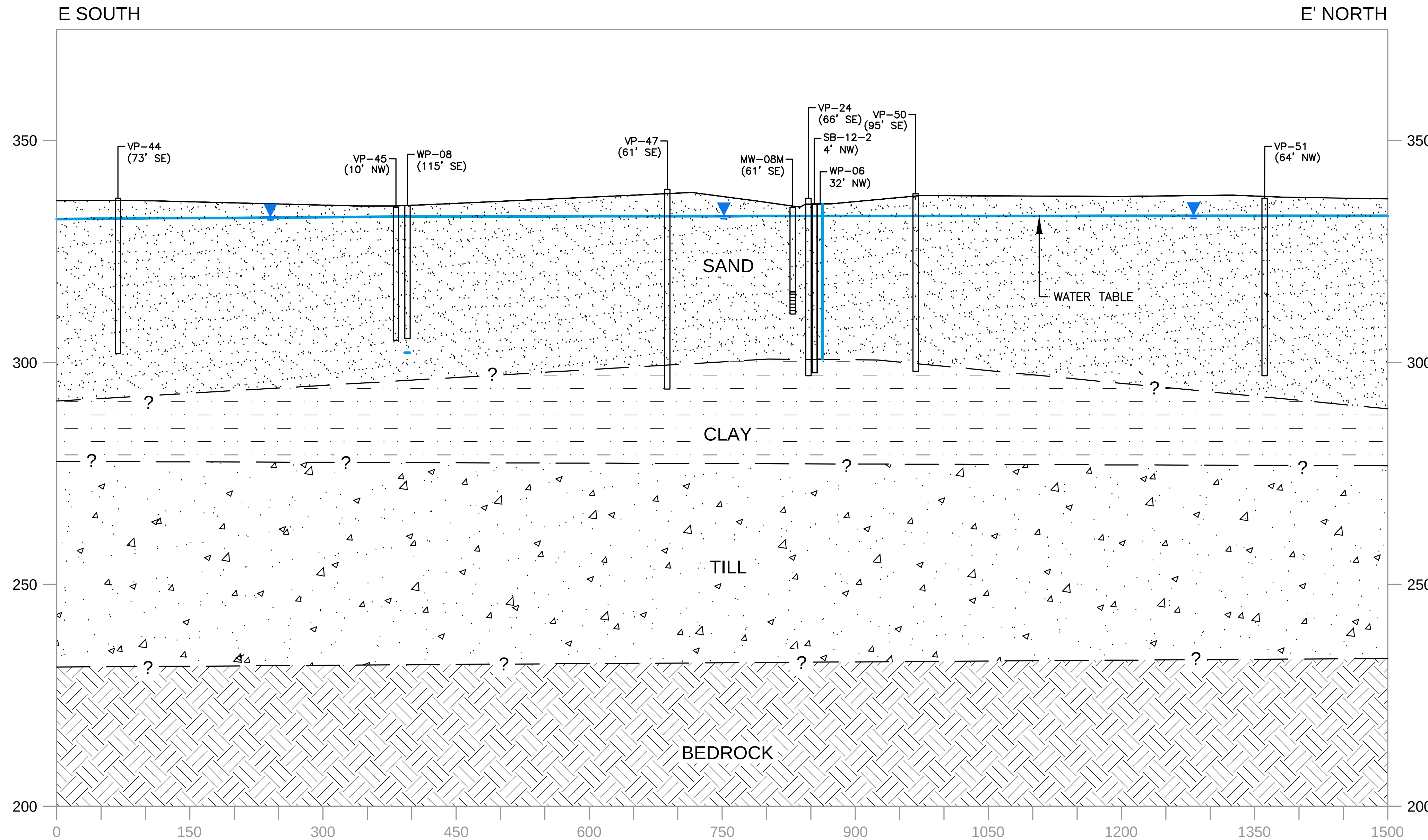
PROJECT NO.	80036	DATE:	JULY 2015



HORIZONTAL
150 0 150 300
30 0 30 60
VERTICAL
SCALE IN FEET

MONITORING WELL

WELL I.D.
(BASELINE OFFSET DISTANCE & DIRECTION)

GROUNDWATER ELEVATION
(OCTOBER 2011)

PVC RISER OR STEEL RISER

SCREEN

VERTICAL PROFILE

PROFILE I.D.
(BASELINE OFFSET DISTANCE & DIRECTION)

LEGEND

SAND

CLAY

TILL

BEDROCK

— ? — STRATA LOCATION UNKNOWN; BOUNDARY HAS BEEN INTERPRETED

NOTES

1. STRATA SURFACES ARE MAPPED BASED ON THE 2010 GEOPHYSICAL MAPPING HAGER GEOSCIENCE, INC. (HGI), AND OBSERVATIONS MADE DURING SOIL BORINGS AND VERTICAL PROFILING.

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FIGURE 1-10

E-E' CROSS-SECTION
COMMERCE STREET PLUME
SUPERFUND SITE
WILLISTON, VERMONT

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PROJECT NO.	80036	DATE:	JULY 2015

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Notes:

1. Location of all features is approximate. Map is for reference purposes only. Nobis Engineering, Inc. makes no claims, warranties, representations, expressed or implied, relating to the completeness, accuracy, or reliability of the data shown.

2. Groundwater contours are based on groundwater elevation data obtained in November 2010 and were contoured using the natural neighbor interpolation method. This is one interpretation of the data; other interpretations are possible.

0 100 200 400

Feet

1 inch = 200 feet

N

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FIGURE 1-11

NOVEMBER 2010 (LOW WATER) SHALLOW OVERBURDEN GROUNDWATER CONTOURS
COMMERCE STREET PLUME
SUPERFUND SITE
WILLISTON, VERMONT

PREPARED BY: JH	CHECKED BY: JL
PROJECT NO. 80036	DATE: JULY 2015

Notes:

1. Location of all features is approximate. Map is for reference purposes only. Nobis Engineering, Inc. makes no claims, warranties, representations, expressed or implied, relating to the completeness, accuracy, or reliability of the data shown.

2. Groundwater contours are based on groundwater elevation data obtained in October 2011 and were contoured using the natural neighbor interpolation method. This is one interpretation of the data; other interpretations are possible.

0 100 200 400

Feet

1 inch = 200 feet

N

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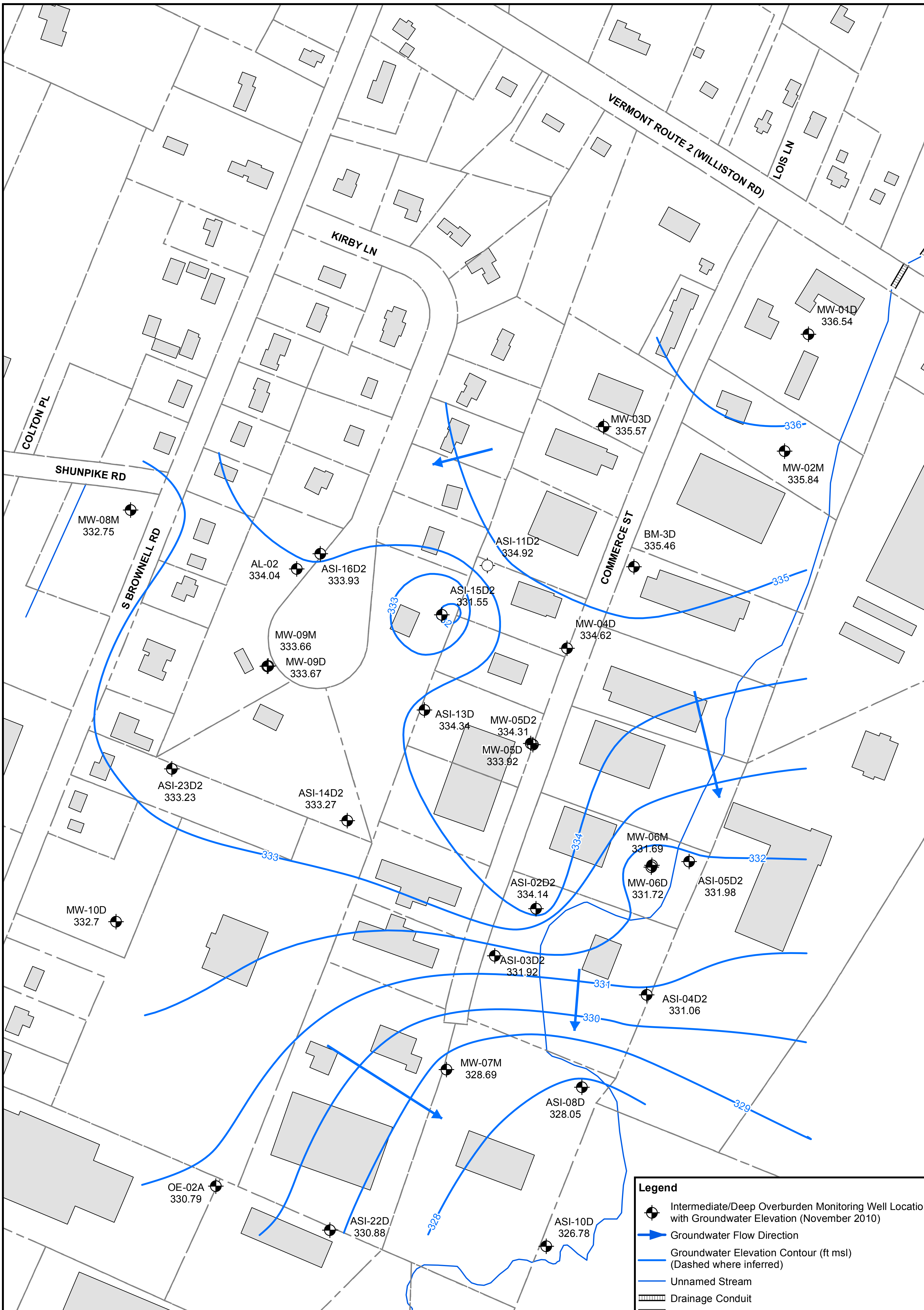
FIGURE 1-12

OCTOBER 2011 (HIGH WATER) SHALLOW OVERBURDEN GROUNDWATER CONTOURS
COMMERCE STREET PLUME
SUPERFUND SITE
WILLISTON, VERMONT

PREPARED BY: JH	CHECKED BY: JL
PROJECT NO. 80036	DATE: JULY 2015



Notes:

1. Location of all features is approximate. Map is for reference purposes only. Nobis Engineering, Inc. makes no claims, warranties, representations, expressed or implied, relating to the completeness, accuracy, or reliability of the data shown.

2. Groundwater contours are based on groundwater elevation data obtained in November 2010 and were contoured using the natural neighbor interpolation method. This is one interpretation of the data; other interpretations are possible.

0 100 200 400

Feet

1 inch = 200 feet

N

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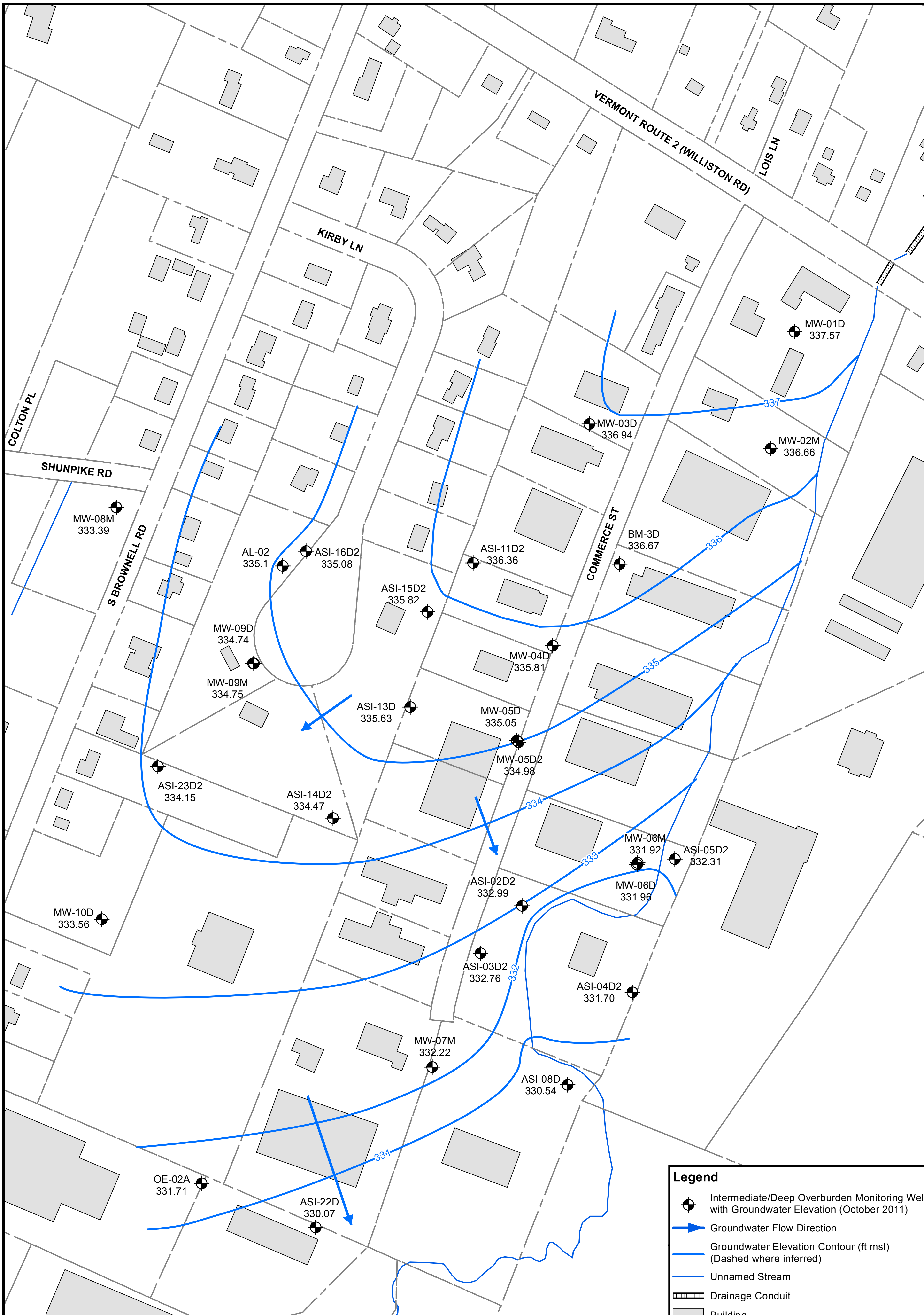
FIGURE 1-13

NOVEMBER 2010 (LOW WATER) INTERMEDIATE/ DEEP OVERBURDEN GROUNDWATER CONTOURS
COMMERCE STREET PLUME
SUPERFUND SITE
WILLISTON, VERMONT

PREPARED BY: JH	CHECKED BY: JL
PROJECT NO. 80036	DATE: JULY 2015



Notes:

1. Location of all features is approximate. Map is for reference purposes only. Nobis Engineering, Inc. makes no claims, warranties, representations, expressed or implied, relating to the completeness, accuracy, or reliability of the data shown.

2. Groundwater contours are based on groundwater elevation data obtained in October 2011 and were contoured using the natural neighbor interpolation method. This is one interpretation of the data; other interpretations are possible.

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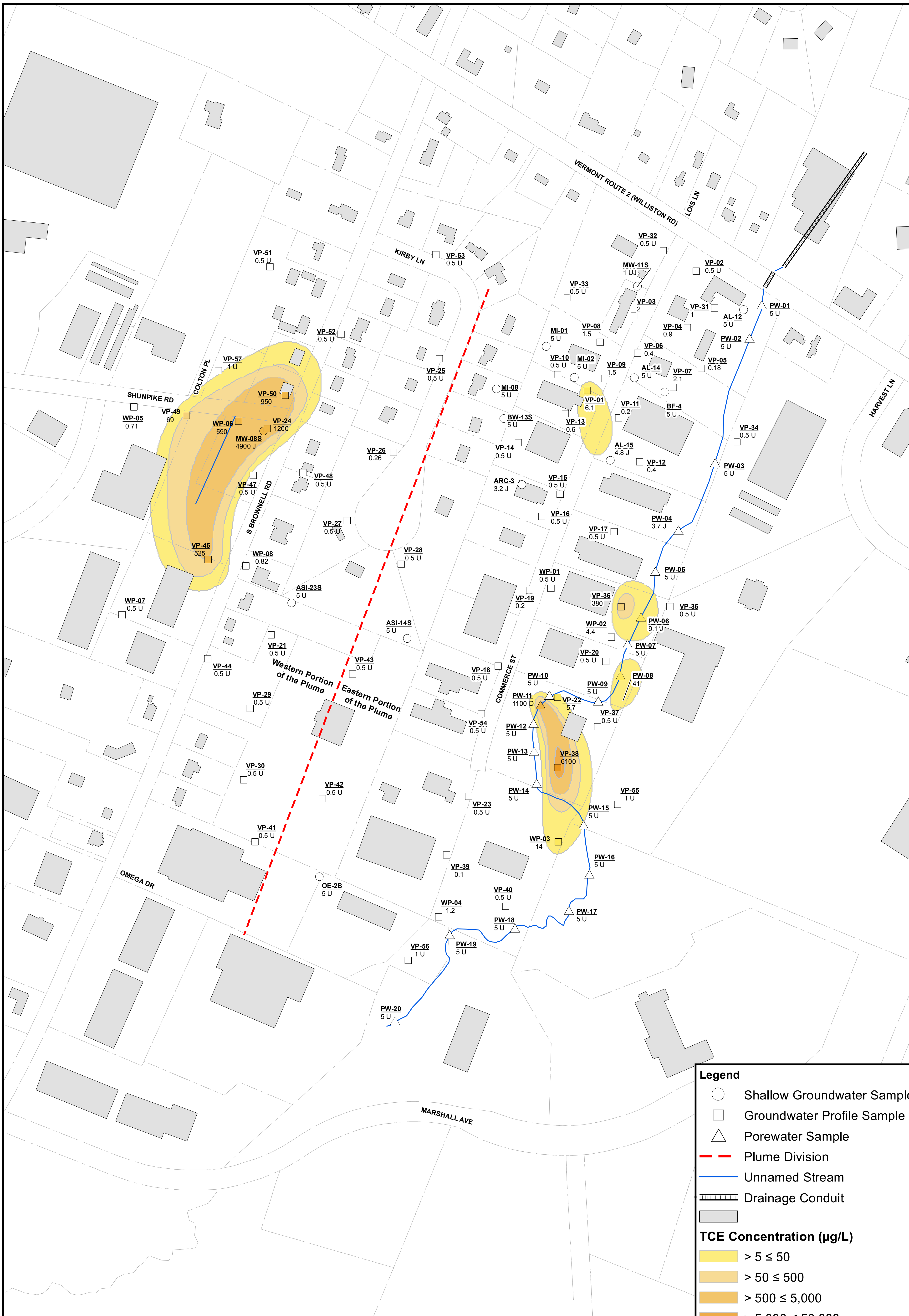
FIGURE 1-14

OCTOBER 2011 (HIGH WATER) INTERMEDIATE/ DEEP OVERBURDEN GROUNDWATER CONTOURS
COMMERCE STREET PLUME
SUPERFUND SITE
WILLISTON, VERMONT

PREPARED BY: JH	CHECKED BY: JL
PROJECT NO. 80036	DATE: JULY 2015



Notes:

1. Concentrations shown are the most recent shallow groundwater (0 to 20 feet bgs) data collected from the monitoring wells or the maximum concentration data collected during groundwater vertical profiling.

2. U = TCE not detected above sample-specific detection limit. J = Result is estimated.

0 150 300 600

Feet

1 inch = 300 feet

N

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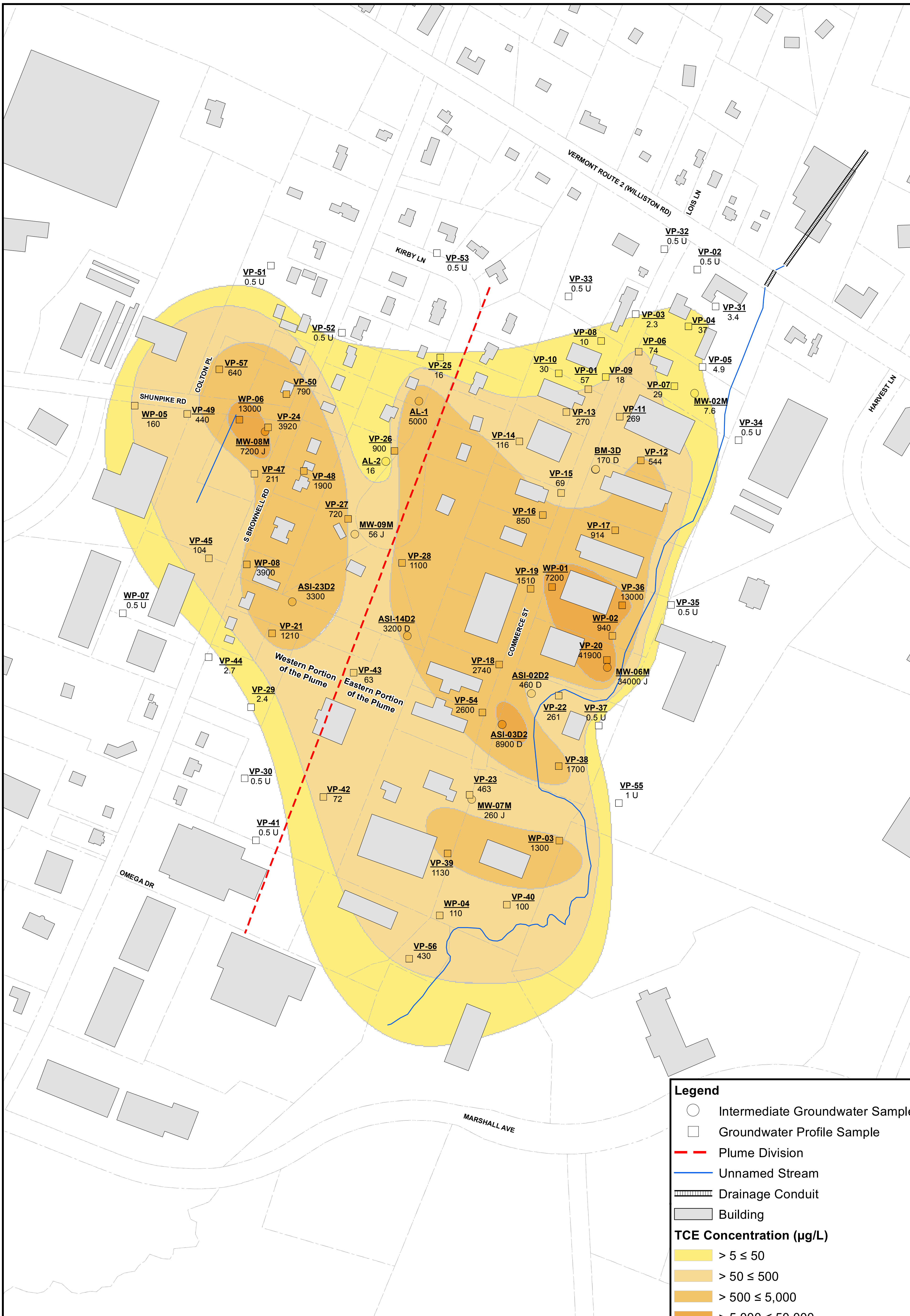
FIGURE 1-15

SHALLOW OVERBURDEN GROUNDWATER TCE CONCENTRATIONS
COMMERCE STREET PLUME
SUPERFUND SITE
WILLISTON, VERMONT

PREPARED BY: JH	CHECKED BY: JL
PROJECT NO. 80036	DATE: JULY 2015

Path: L:\80036 Commerce Street Plume\Technical Data (TD)\GIS\Maps\FS Figures\Figure 1-15 Shallow Overburden Groundwater TCE Concentrations.mxd Date Printed: 7/21/2015



Notes:

1. Concentrations shown are the most recent intermediate groundwater (20 and 30 feet bgs) data collected from the monitoring wells or the maximum concentration collected during groundwater profiling.

2. U = TCE not detected above sample-specific detection limit. J = Result is estimated. D = result is from a dilution of the sample.

0 150 300 600
Feet
1 inch = 300 feet

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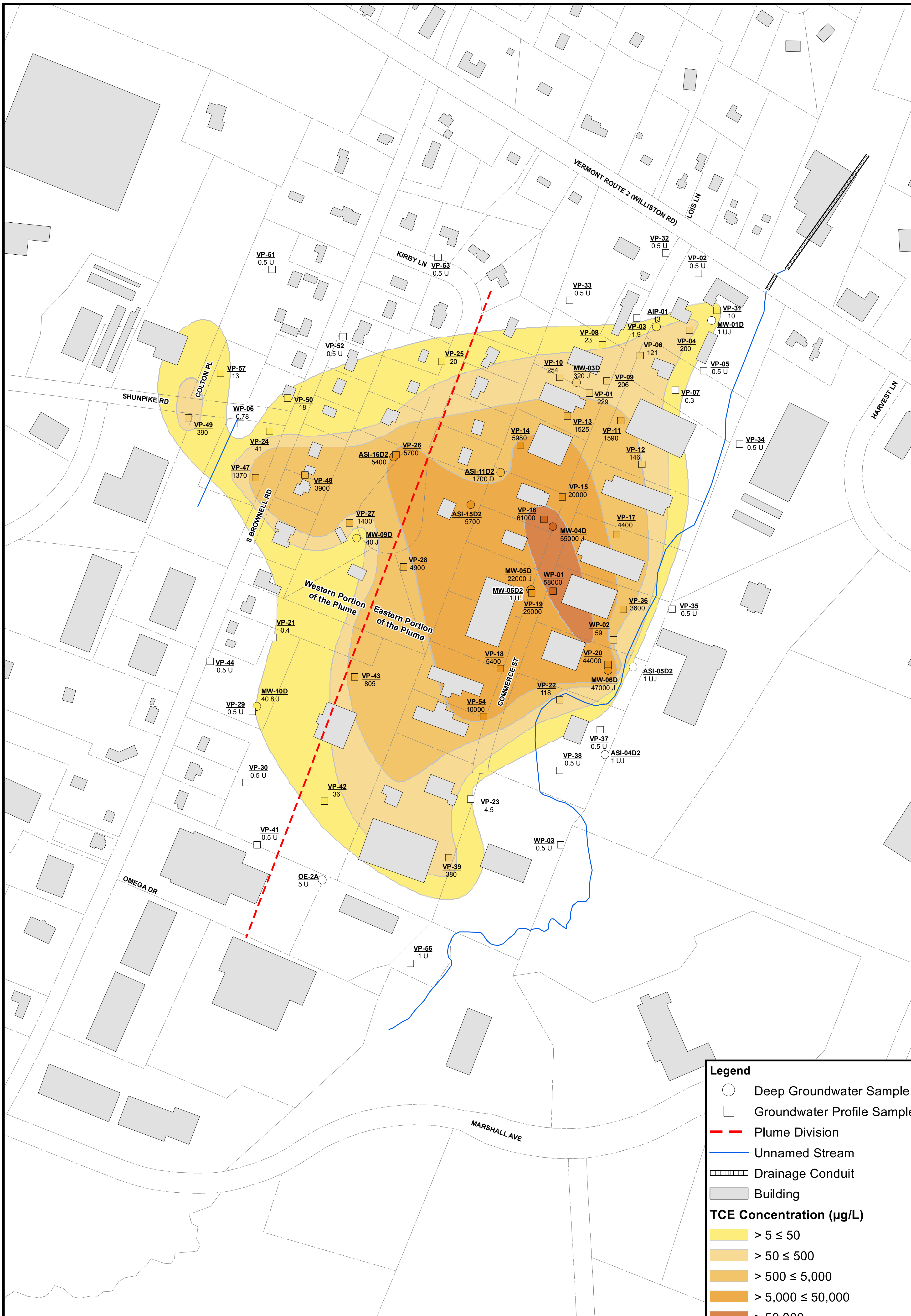
FIGURE 1-16

INTERMEDIATE OVERBURDEN GROUNDWATER TCE CONCENTRATIONS COMMERCE STREET PLUME SUPERFUND SITE WILLISTON, VERMONT

PREPARED BY: JH	CHECKED BY: JL
PROJECT NO. 80036	DATE: JULY 2015



Notes:

1. Concentrations shown are the most recent deep groundwater (>30 feet bgs) data collected from the monitoring wells or the maximum concentration data collected during groundwater profiling.

2. U = TCE not detected above sample-specific detection limit. J = Result is estimated.

0 150 300 600

Feet

1 inch = 300 feet

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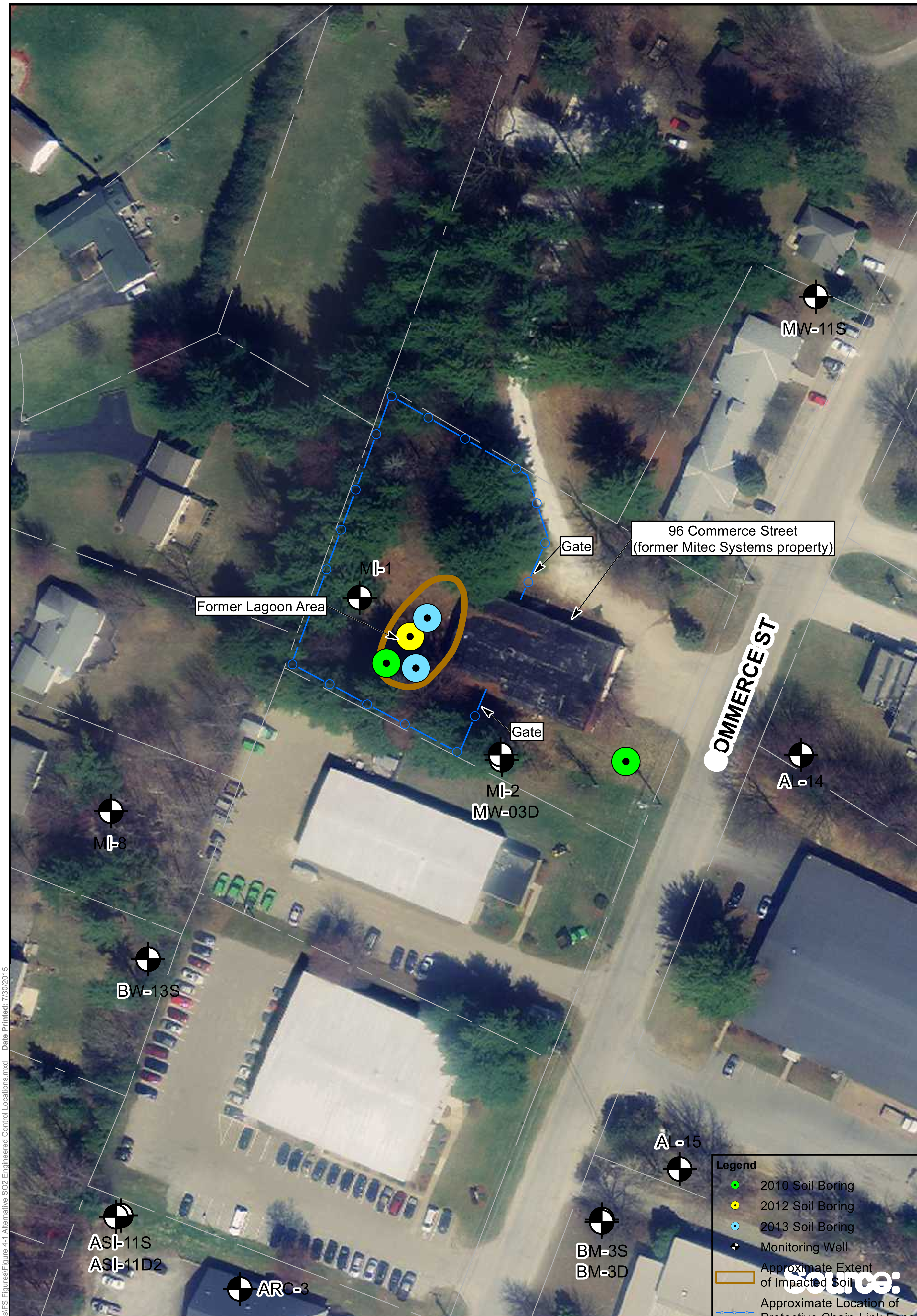
FIGURE 1-17

DEEP OVERBURDEN GROUNDWATER TCE CONCENTRATIONS
COMMERCE STREET PLUME
SUPERFUND SITE
WILLISTON, VERMONT

PREPARED BY: JH	CHECKED BY: JL
PROJECT NO. 80036	DATE: JULY 2015



Notes:

1. Locations of site features are approximate and should be used for display purposes only.

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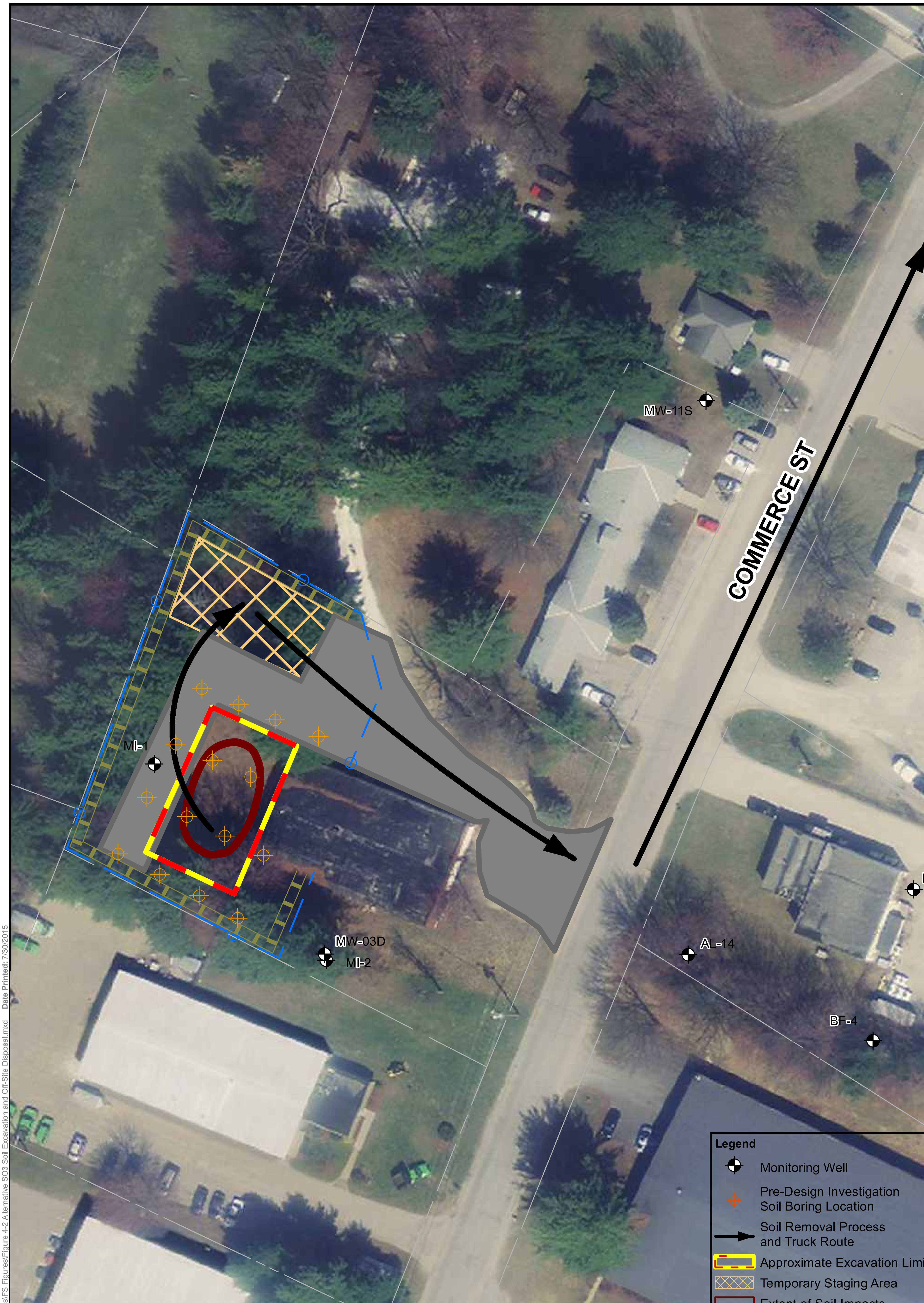
FIGURE 4-1

ALTERNATIVE SO2: ENGINEERED CONTROL LOCATIONS
COMMERCE STREET PLUME
SUPERFUND SITE
WILLISTON, VERMONT

PREPARED BY: JH	CHECKED BY: SH
PROJECT NO. 80036	DATE: JULY 2015

Path: K:\Technical Data (TD)\GIS\Maps\FS Figures\Figure 4-1 Alternative SO2 Engineered Control Locations.mxd Date Printed: 7/30/2015



Notes:

1. Locations of site features are approximate and should be used for display purposes only.

2. Excavation and temporary staging areas are approximate based on the assumed extent of hexavalent chromium impacts. Actual extents may vary based on results of the Pre-Design Investigation.

0 25 50 100

Feet

1 inch = 50 feet

N

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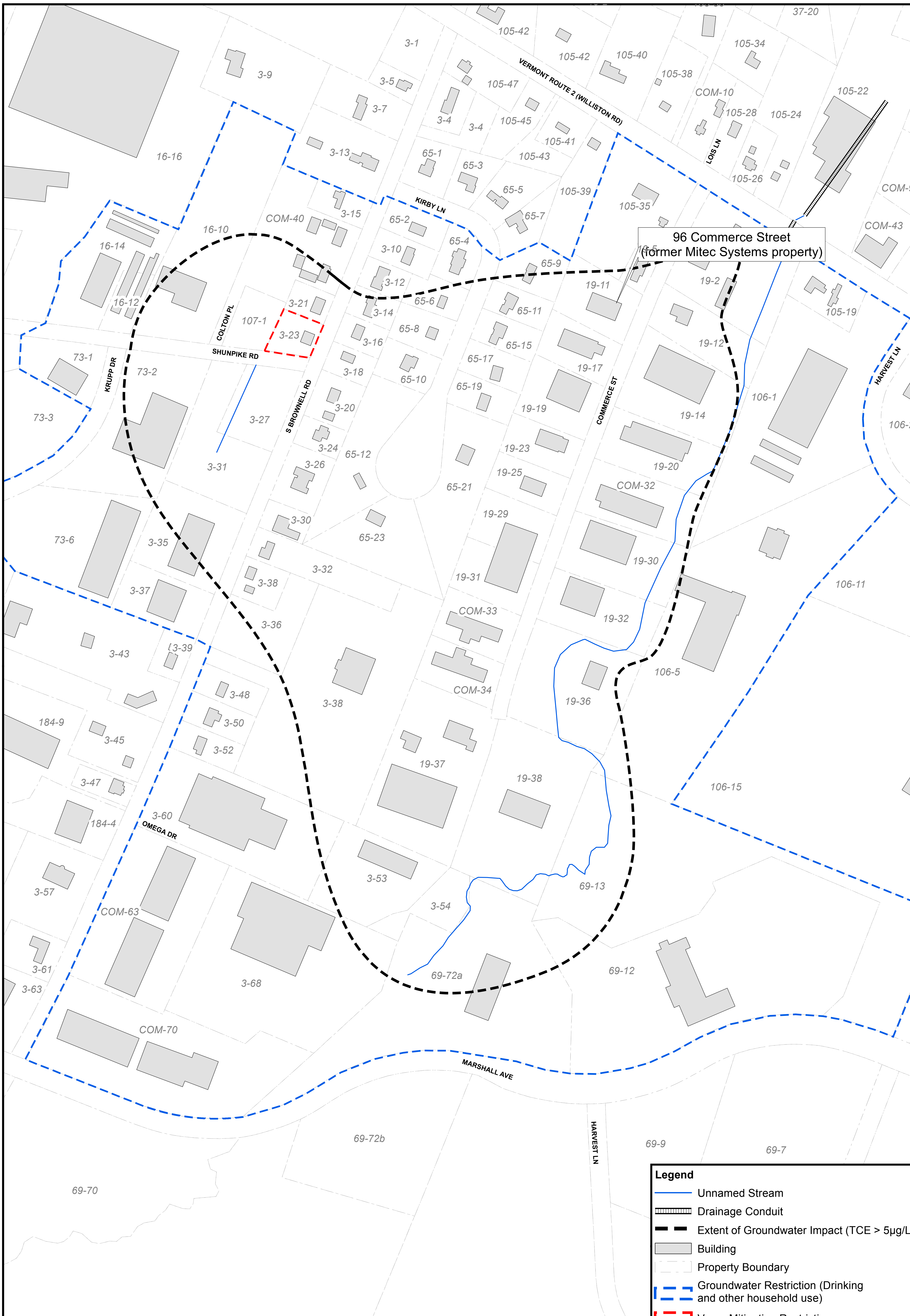
FIGURE 4-2

ALTERNATIVE SO3: SOIL EXCAVATION AND OFF-SITE DISPOSAL
COMMERCE STREET PLUME
SUPERFUND SITE
WILLISTON, VERMONT

PREPARED BY: NZ	CHECKED BY: SH
PROJECT NO. 80036	DATE: JULY 2015

Path: K:\Technical Data (TD)\GIS\Maps\FS Figures\Figure 4-2 Alternative SO3 Soil Excavation and Off-Site Disposal.mxd Date Printed: 7/30/2015



Notes:

1. Extent of groundwater impacts based on TCE concentrations observed during the October 2012 groundwater sampling round and represents the total spatial extent from the shallow, intermediate, and deep intervals. TCE was the most widespread contaminant found.

0 150 300 600
Feet
1 inch = 300 feet

N

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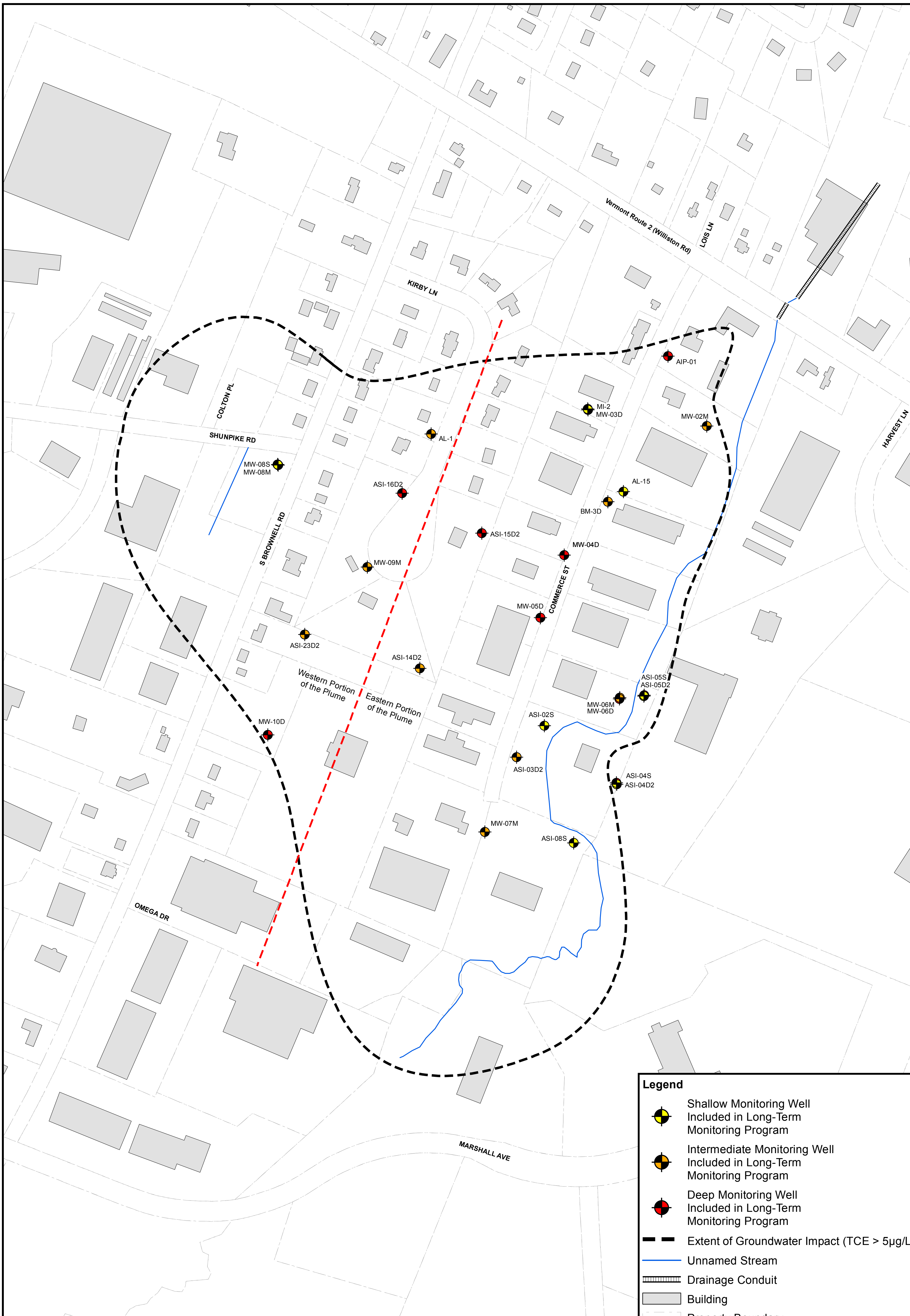
FIGURE 4-3

ALTERNATIVE GW2: LAND USE RESTRICTIONS
COMMERCE STREET PLUME
SUPERFUND SITE
WILLISTON, VERMONT

PREPARED BY: DG	CHECKED BY: SH
PROJECT NO. 80036	DATE: JULY 2015



Notes:

1. Extent of groundwater impacts based on TCE concentrations observed during the October 2012 groundwater sampling round and represents the total spatial extent from the shallow, intermediate, and deep intervals. TCE was the most widespread contaminant found.

0 150 300 600

Feet

1 inch = 300 feet

N

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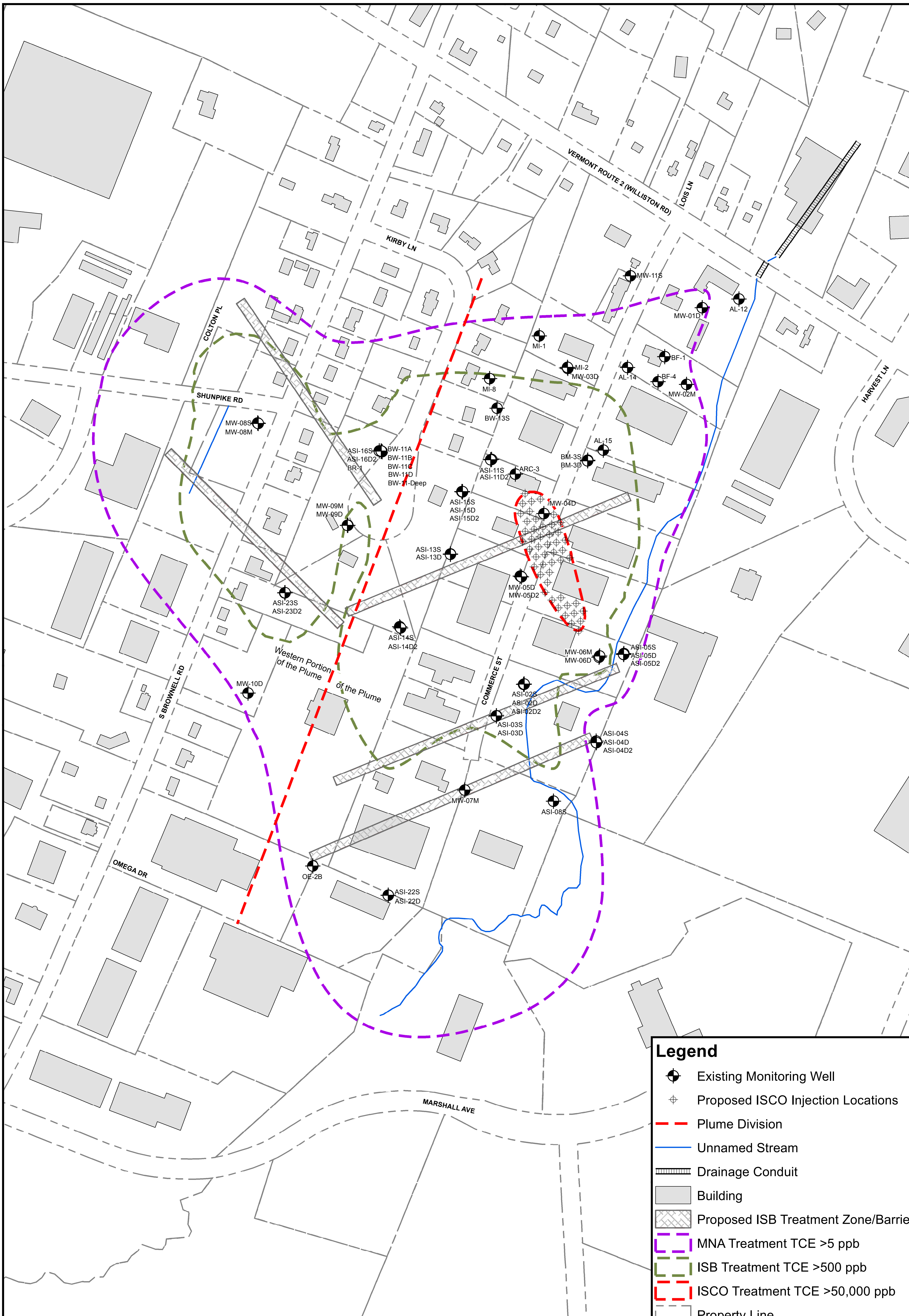
FIGURE 4-4

ALTERNATIVE GW3: MONITORED NATURAL ATTENUATION AND LONG-TERM MONITORING LOCATIONS
COMMERCE STREET PLUME
SUPERFUND SITE
WILLISTON, VERMONT

PREPARED BY: DG	CHECKED BY: SH
PROJECT NO. 80036	DATE: JULY 2015



Notes:

1. Extent of groundwater impacts based on TCE concentrations observed during the October 2012 groundwater sampling round and represents the total spatial extent from the shallow, intermediate, and deep intervals. TCE was the most widespread contaminant found.

2. A radius of influence of 20 ft. is assumed for injection wells. Wells are located based on 30 ft. spacing for sufficient coverage.

0 300 600

Feet

1 inch = 300 feet

N

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FIGURE 4-5

ALTERNATIVE GW5: IN SITU TREATMENT ZONES
COMMERCE STREET PLUME
SUPERFUND SITE
WILLISTON, VERMONT

PREPARED BY: JH	CHECKED BY: JL
PROJECT NO. 80036	DATE: JULY 2015

APPENDIX A

TABLE A-1
CANCER RISK-BASED GROUNDWATER PRELIMINARY REMEDIATION GOALS
FUTURE RESIDENTIAL EXPOSURE TO GROUNDWATER AS DRINKING WATER
COMMERCE STREET PLUME SUPERFUND SITE
WILLISTON, VERMONT

COCs	Oral Intake Rate (L-mg/kg-µg-d)	FA (unitless)	K_p (cm/hr)	τ_{event} (hr/event)	B (unitless)	t* (hr)	Dermal Intake Rate (L-mg/kg-µg-d)	Inhalation Intake Rate (L-mg/m^3-µg)	CSForal $(mg/kg\text{-}d)^{-1}$	CSFdermal $(mg/kg\text{-}d)^{-1}$	Inhalation Unit Risk $(mg/m^3)^{-1}$	PRG based on 10^{-6} cancer risk (µg/L)	PRG based on 10^{-5} cancer risk (µg/L)	PRG based on 10^{-4} cancer risk (µg/L)
1,2-Dichloroethane	1.29E-05	1.0	4.20E-03	3.80E-01	0.00E+00	9.20E-01	6.24E-07	1.78E-04	9.10E-02	9.10E-02	2.60E-02	1.71E-01	1.71E+00	1.71E+01
cis-1,2-Dichloroethylene	1.29E-05	1.0	7.67E-03	3.66E-01	2.90E-02	8.80E-01	1.12E-06	1.78E-04	NA	NA	NA	---	---	---
Arsenic	1.29E-05	NA	1.00E-03	NA	NA	NA	7.14E-08	NA	1.50E+00	1.50E+00	NA	5.15E-02	5.15E-01	5.15E+00
Cobalt	1.29E-05	NA	1.00E-03	NA	NA	NA	7.14E-08	NA	NA	NA	NA	---	---	---
Iron	1.29E-05	NA	1.00E-03	NA	NA	NA	7.14E-08	NA	NA	NA	NA	---	---	---

Exposure Assumptions	Parameter	RME	Units
Fraction Ingested	FI	1	unitless
Exposure Frequency	EF	350	days/year
Exposure Duration - child	ED_c	6	years
Exposure Duration - adult	ED_a	20	years
Ingestion Rate of Water - child	IRW_c	0.78	L/day
Ingestion Rate of Water - adult	IRW_a	2.5	L/day
Body Weight - child	BW_c	15	kg
Body Weight - adult	BW_a	80	kg
Averaging Time (Cancer)	AT-C	25,550	days
Age-adjusted skin contact factor	SFS_{adj}	7776	event-year-cm^2/kg-day
Skin Surface Area Available for Contact - child	SA_c	6,378	cm^2
Skin Surface Area Available for Contact - adult	SA_a	20,900	cm^2
Event Frequency - child	EV_c	1	event/day
Event Frequency - adult	EV_a	1	event/day
Event Duration - child	$t_{event\text{-}c}$	0.54	hr/event
Event Duration - adult	$t_{event\text{-}a}$	0.71	hr/event
Age-adjusted event duration	$t_{event\text{-}adj}$	0.67	hr/event
Fraction Absorbed Water	FA	COPC-specific	unitless
Dermal Permeability Coefficient	Kp	COPC-specific	cm/hour
Chemical Concentration in Water	CW	COPC-specific	µg/L
Conversion Factor	CF1	1.0E-03	mg/µg
Conversion Factor	CF2	1.0E-03	L/cm^3
Ratio of Permeability Coefficient	B	COPC-specific	unitless
Time to Reach Steady State	t*	COPC-specific	hour
Lag Time Per Event	τ_{event}	COPC-specific	hr/event
exposure time (inhalation)	ET	24	hr/day
conversion factor	CF3	1.00E+03	L/m^3

COC = Contaminant of Concern
CSF = Cancer Slope Factor
PRG = Preliminary Remediation Goal
RME = Reasonable Maximum Exposure

Age-Adjusted Ingestion Rate = ((Ingestion Rate $_{child}$ * Exposure Duration $_{child}$)/Body Weight $_{child}$) + ((Ingestion Rate adult * Exposure Duration adult)/Body Weight adult)
= ((0.78 L/d * 6 y)/15 kg) + ((2.5 L/d * 20 y)/80 kg) = 0.94 L-y/kg-d

Oral intake rate = Age-adjusted Ingestion Rate*Fraction ingested * Exposure Frequency*Conversion Factor1/Averaging Time
= (0.94 L-y/kg-d*1 * 350 d/y * 10^{-3} mg/ug)/(70 y * 365 d/y)

Age-Adjusted Skin Contact Rate = ((Surface Area $_{child}$ * Event Frequency $_{child}$* Exposure Duration $_{child}$)/Body Weight $_{child}$) + ((Surface Area adult * Event Frequency adult * Exposure Duration adult)/Body Weight adult)
SFSA-adj = ((6378 cm^2/ev * 1 ev/d * 6 y)/15 kg) + ((20900 cm^2/ev * 1 ev/d * 20 y)/80 kg) = 7776 ev-y-cm^2/kg-d

Age-Adjusted Event Duration = ((Exposure Duration $_{child}$*Event Duration $_{child}$)+(Exposure Duration adult*Event Duration adult))/((Exposure Duration $_{child}$) + (Exposure Duration adult))
tevent-adj = ((EDc * tevent-c) + (EDa * tevent-a))/(EDc + EDa) = 0.67 hr/event

Dermal intake rate
for inorganics:
=(Permeability Coefficient * Conversion Factor1 * Conversion Factor2 * Event Duration-adj * Skin Contact Rate-adj * Exposure Frequency)/(Averaging Time)
= (Kp cm/hr * 10^{-3} mg/µg * 10^{-3} L/cm^2 * 0.67hr/ev *7776 ev-y-cm^2/kg-d* 350 d/y)/(70 y * 365 d/y)

for organics where t*>0.67
=(2 * Fraction Absorbed * Permeability Coefficient * Conversion Factor1 * Conversion Factor2 *√ ((6*Lag Time * Event Duration $_{-adj}$)/π) * Skin Contact Rate-adj * Exposure Frequency)/(Averaging Time)
=(2*FA* Kp cm/hr * 10^{-3} mg/µg* 10^{-3} L/cm^3* √ ((6τ_{event} (hr/ev) * 0.67 hr/ev)/3.14159) *7776ev-y-cm^2/kg-d*350 d/y)/(70 y * 365 d/y)

for organics where t*<0.67
=(Fraction Absorbed * Permeability Coefficient * Conversion Factor1 * Conversion Factor2* (((Event Duration$_{adj}$)/(1+B))+(2*Lag Time((1+3B+3B^2)/(1+B)^2)) * Skin Contact Rate-adj * Exposure Frequency)/(Averaging Time)
=(FA * Kp cm/hr *10^{-3}mg/µg* 10^{-3} L/cm^3*(((0.67 hr/ev)/(1+B))+(2τevent(hr/ev)((1+3B+3B^2)/(1+B)^2))*7776ev-y-cm^2/kg-d*350d/y)/(70y*365d/y)

Inhalation intake rate
=0.0005 * Conversion Factor3 * Conversion Factor1 * Exposure Time * Exposure Frequency* Exposure Duration/Averaging Time * 24 hr/day
=(0.0005 * 1000 L/m^3 * 0.001 mg/µg * 24 hr/d * 350 d/yr * 26 y)/(70 y * 365 d/y * 24 hr/d)

cancer-based PRG = Target cancer risk /((oral intake *CSF oral)+(dermal intake *CSF dermal)+(inhalation intake *URF inhalation))

TABLE A-2
CANCER RISK-BASED GROUNDWATER PRELIMINARY REMEDIATION GOALS
FOR CHEMICALS THAT ACT VIA A MUTAGENIC MODE OF ACTION
FUTURE RESIDENTIAL EXPOSURE TO GROUNDWATER AS DRINKING WATER
COMMERCE STREET PLUME SUPERFUND SITE
WILLISTON, VERMONT

COCs	Oral Intake Rate				FA	K_p	τ_{event}	B	t*	Dermal Intake Rate				Inhalation Intake Rate				CSForal	CSFdermal	Inhalation Unit Risk	PRG based on 10^{-6} cancer risk	PRG based on 10^{-5} cancer risk	PRG based on 10^{-4} cancer risk
	Age									Age				Age									
	0-<2	2-<6	6-<16	16-<26						0-<2	2-<6	6-<16	16-<26	0-<2	2-<6	6-<16	16-<26						
	(L-mg/kg-µg-d)				(unitless)	(cm/hr)	(hr/event)	(unitless)	(hr)	(L-mg/kg-µg-d)				(L-mg/m3-µg)				$(mg/kg\text{-}d)^{-1}$	$(mg/kg\text{-}d)^{-1}$	$(mg/m^3)^{-1}$	(µg/L)	(µg/L)	(µg/L)
Methylene chloride	1.42E-06	2.85E-06	4.28E-06	4.28E-06	1.0	3.50E-03	3.20E-01	0.00E+00	7.60E-01	4.68E-08	9.37E-08	1.65E-07	1.65E-07	1.37E-05	2.74E-05	6.85E-05	6.85E-05	2.00E-03	2.00E-03	1.00E-05	1.25E+01	1.25E+02	1.25E+03
Chromium	1.42E-06	2.85E-06	4.28E-06	4.28E-06	NA	1.00E-03	NA	NA	NA	6.29E-09	1.26E-08	2.54E-08	2.54E-08	NA	NA	NA	NA	5.00E-01	2.00E+01	8.40E+01	4.17E-02	4.17E-01	4.17E+00

Exposure Assumptions	Parameter	RME				Units
		Child			Adult	
		Age				
		0-<2	2-<6	6-<16	16-<26	
Exposure Frequency	EF	350	350	350	350	days/year
Exposure Duration	ED_c	2	4	10	10	years
Ingestion Rate of Water	IRW	0.78	0.78	2.5	2.5	L/day
Fraction Ingested	FI	1	1	1	1	unitless
Body Weight	BW	15	15	80	80	kg
Averaging Time (Cancer)	AT-C	25,550	25,550	25,550	25,550	days
Skin Surface Area Available for Contact	SA	6,378	6,378	20,900	20,900	cm^2
Event Frequency	EV	1	1	1	1	event/day
Event Duration	t_{event}	0.54	0.54	0.71	0.71	hr/event
Fraction Absorbed Water	FA	COPC-specific	COPC-specific	COPC-specific	COPC-specific	unitless
Dermal Permeability Coefficient	Kp	COPC-specific	COPC-specific	COPC-specific	COPC-specific	cm/hour
Chemical Concentration in Water	CW	COPC-specific	COPC-specific	COPC-specific	COPC-specific	µg/L
Conversion Factor	CF1	1.0E-03	1.0E-03	1.0E-03	1.0E-03	mg/µg
Conversion Factor	CF2	1.0E-03	1.0E-03	1.0E-03	1.0E-03	L/cm^3
Ratio of Permeability Coefficient	B	COPC-specific	COPC-specific	COPC-specific	COPC-specific	unitless
Time to Reach Steady State	t*	COPC-specific	COPC-specific	COPC-specific	COPC-specific	hour
Lag Time Per Event	τ_{event}	COPC-specific	COPC-specific	COPC-specific	COPC-specific	hr/event
Exposure Time (inhalation)	ET	24	24	24	24	hr/day
conversion factor	CF3	1.00E+03	1.00E+03	1.00E+03	1.00E+03	L/m^3
Age-Dependent Adjustment Factor	ADAF	10	3	3	1	unitless

COC = Contaminant of Concern
CSF = Cancer Slope Factor
PRG = Preliminary Remediation Goal
RME = Reasonable Maximum Exposure

Oral intake rate = Ingestion Rate *Fraction ingested * Exposure Frequency* Exposure Duration *Conversion Factor/Body Weight *Averaging Time

Dermal intake rate
for inorganics:
=(Permeability Coefficient * Conversion Factor1 * Conversion Factor2 * Event Duration * Surface Area * Event Frequency*Exposure Frequency * Exposure Duration)/(Body Weight*Averaging Time)

for organics where t*>tevent
=(2*Fraction Absorbed * Permeability Coefficient * Conversion Factor1 * Conversion Factor2 * √ (6*Lag Time * Event Duration/π) * Surface Area * Event Frequency * Exposure Frequency * Exposure Duration)/(Body Weight * Averaging Time)

for organics where t*<tevent
=(Fraction Absorbed * Permeability Coefficient * Conversion Factor1 * Conversion Factor2 * (((Event Duration)/(1+B))+(2*Lag Time($(1+3B+3B^2)/(1+B)^2$)) * Surface Area * Event Frequency * Exposure Frequency * Exposure Duration)/(Body Weight * Averaging Time)

Inhalation intake rate =0.0005 * Conversion Factor3 * Conversion Factor1 * Exposure Time * Exposure Frequency* Exposure Duration/Averaging Time * 24 hr/day

cancer-based PRG = Target cancer risk /((((oral intake $_{0\text{-}2}$*10)+(oral intake$_{2\text{-}6}$*3)+(oral intake$_{6\text{-}16}$*3)+(oral intake$_{16\text{-}26}$*1))*CSF oral)+
(((dermal intake$_{0\text{-}2}$*10)+(dermal intake$_{2\text{-}6}$*3)+(dermal intake$_{6\text{-}16}$*3)+(dermal intake$_{16\text{-}26}$*1))*dermal CSF)+
(((inhalation intake $_{0\text{-}2}$*10)+(inhalation intake$_{2\text{-}6}$*3)+(inhalation intake$_{6\text{-}16}$*3)+(inhalation intake$_{16\text{-}26}$*1))*inhalation URF)))

TABLE A-3
CANCER RISK-BASED GROUNDWATER PRELIMINARY REMEDIATION GOALS
FOR TRICHLOROETHENE
FUTURE RESIDENTIAL EXPOSURE TO GROUNDWATER AS DRINKING WATER
COMMERCE STREET PLUME SUPERFUND SITE
WILLISTON, VERMONT

COCs	Oral Intake Rate				FA	K_p	τ_{event}	B	t*	Dermal Intake Rate				Inhalation Intake Rate				Kidney CSF (oral and dermal)	Liver & NHL CSF (oral and dermal)	Kidney Inhalation Unit Risk	Liver & NHL Inhalation Unit Risk	PRG based on 10^{-6} cancer risk	PRG based on 10^{-5} cancer risk	PRG based on 10^{-4} cancer risk
	Age									Age				Age										
	0-<2	2-<6	6-<16	16-<26						0-<2	2-<6	6-<16	16-<26	0-<2	2-<6	6-<16	16-<26							
	(L-mg/kg-µg-d)				(unitless)	(cm/hr)	(hr/event)	(unitless)	(hr)	(L-mg/kg-µg-d)				(L-mg/m3-µg)				$(mg/kg\text{-}d)^{-1}$	$(mg/kg\text{-}d)^{-1}$	$(mg/m^3)^{-1}$	$(mg/m^3)^{-1}$	(µg/L)	(µg/L)	(µg/L)
Trichloroethylene	1.42E-06	2.85E-06	4.28E-06	4.28E-06	1.0	1.20E-02	5.80E-01	1.00E-01	1.39E+00	2.16E-07	4.32E-07	7.62E-07	7.62E-07	1.37E-05	2.74E-05	6.85E-05	6.85E-05	9.30E-03	3.70E-02	1.00E-03	3.10E-03	6.03E-01	6.03E+00	6.03E+01

Exposure Assumptions	Parameter	RME				Units
		Child			Adult	
		Age				
		0-<2	2-<6	6-<16	16-<26	
Exposure Frequency	EF	350	350	350	350	days/year
Exposure Duration	ED_c	2	4	10	10	years
Ingestion Rate of Water	IRW	0.78	0.78	2.5	2.5	L/day
Fraction Ingested	FI	1	1	1	1	unitless
Body Weight	BW	15	15	80	80	kg
Averaging Time (Cancer)	AT-C	25,550	25,550	25,550	25,550	days
Skin Surface Area Available for Contact	SA	6,378	6,378	20,900	20,900	cm^2
Event Frequency	EV	1	1	1	1	event/day
Event Duration	t_{event}	0.54	0.54	0.71	0.71	hr/event
Fraction Absorbed Water	FA	COPC-specific	COPC-specific	COPC-specific	COPC-specific	unitless
Dermal Permeability Coefficient	Kp	COPC-specific	COPC-specific	COPC-specific	COPC-specific	cm/hour
Chemical Concentration in Water	CW	COPC-specific	COPC-specific	COPC-specific	COPC-specific	µg/L
Conversion Factor	CF1	1.0E-03	1.0E-03	1.0E-03	1.0E-03	mg/µg
Conversion Factor	CF2	1.0E-03	1.0E-03	1.0E-03	1.0E-03	L/cm^3
Ratio of Permeability Coefficient	B	COPC-specific	COPC-specific	COPC-specific	COPC-specific	unitless
Time to Reach Steady State	t*	COPC-specific	COPC-specific	COPC-specific	COPC-specific	hour
Lag Time Per Event	τ_{event}	COPC-specific	COPC-specific	COPC-specific	COPC-specific	hr/event
Exposure Time (inhalation)	ET	24	24	24	24	hr/day
conversion factor	CF3	1.00E+03	1.00E+03	1.00E+03	1.00E+03	L/m^3
Age-Dependent Adjustment Factor	ADAF	10	3	3	1	unitless

COC = Contaminant of Concern
CSF = Cancer Slope Factor
PRG = Preliminary Remediation Goal
NHL = Non-Hodgkin's Lymphoma
RME = Reasonable Maximum Exposure

Oral intake rate = Ingestion Rate *Fraction ingested * Exposure Frequency* Exposure Duration *Conversion Factor/Body Weight *Averaging Time

Dermal intake rate
for organics where t*>tevent
=(2*Fraction Absorbed * Permeability Coefficient* Conversion Factor1 * Conversion Factor2 * √ (6*Lag Time * Event Duration/π) * Surface Area * Event Frequency * Exposure Frequency * Exposure Duration)/(Body Weight * Averaging Time)

Inhalation intake rate =0.0005 * Conversion Factor3 * Conversion Factor1 * Exposure Time * Exposure Frequency* Exposure Duration/Averaging Time * 24 hr/day

cancer-based PRG = Target cancer risk /((((oral intake$_{0-2}$*10)+(oral intake$_{2-6}$*3)+(oral intake$_{6-16}$*3)+(oral intake$_{16-30}$*1))*Kidney CSF oral)+(((oral intake 0-2)+(oral intake2-6)+(oral intake6-16)+(oral intake16-30))*Liver & NHL CSF oral)+
(((dermal intake$_{0-2}$*10)+(dermal intake$_{2-6}$*3)+(dermal intake$_{6-16}$*3)+(dermal intake$_{16-26}$*1))*Kidney dermal CSF)+(((dermal intake 0-2)+(dermal intake2-6)+(dermal intake6-16)+(dermal intake16-26))*Liver & NHL CSF dermal)+
(((inhalation intake$_{0-2}$*10)+(inhalation intake$_{2-6}$*3)+(inhalation intake$_{6-16}$*3)+(inhalation intake$_{16-26}$*1))*Kidney inhalation URF)+(((inhalation intake0-2)+(inhalation intake2-6)+(inhalation intake6-16)+(inhalation intake16-26))*Liver & NHL inhalation URF))

TABLE A-4
CANCER RISK-BASED GROUNDWATER PRELIMINARY REMEDIATION GOALS
FOR VINYL CHLORIDE
FUTURE RESIDENTIAL EXPOSURE TO GROUNDWATER AS DRINKING WATER
COMMERCE STREET PLUME SUPERFUND SITE
WILLISTON, VERMONT

COCs	Oral Intake Rate (L-mg/kg-µg-d)	FA (unitless)	K_p (cm/hr)	τ_{event} (hr/event)	B (unitless)	t* (hr)	Dermal Intake Rate (L-mg/kg-µg-d)	Inhalation Intake Rate (L-mg/m^3-µg)	CSForal $(mg/kg\text{-}d)^{-1}$	CSFdermal $(mg/kg\text{-}d)^{-1}$	Inhalation Unit Risk $(mg/m^3)^{-1}$	PRG based on 10^{-6} cancer risk (µg/L)	PRG based on 10^{-5} cancer risk (µg/L)	PRG based on 10^{-4} cancer risk (µg/L)
Vinyl Chloride	6.49E-05	1.0	5.60E-03	2.40E-01	0.00E+00	5.70E-01	3.42E-06	6.78E-10	7.20E-01	7.20E-01	4.40E-03	2.03E-02	2.03E-01	2.03E+00

Exposure Assumptions	Parameter	RME	Units
Fraction Ingested	FI	1	unitless
Exposure Frequency	EF	350	days/year
Exposure Duration - child	ED_c	6	years
Exposure Duration - adult	ED_a	20	years
Ingestion Rate of Water - child	IRW_c	0.78	L/day
Ingestion Rate of Water - adult	IRW_a	2.5	L/day
Age-adjustedIngestion Rate of Water - adult	IRW_{aDJ}	0.94	L-y/kg-d
Body Weight - child	BW_c	15	kg
Body Weight - adult	BW_a	80	kg
Averaging Time (Cancer)	AT-C	25,550	days
Age-adjusted skin contact factor	SFS_{adj}	7776	event-year-cm^2/kg-day
Skin Surface Area Available for Contact - child	SA_c	6,378	cm^2
Skin Surface Area Available for Contact - adult	SA_a	20,900	cm^2
Event Frequency - child	EV_c	1	event/day
Event Frequency - adult	EV_a	1	event/day
Event Duration - child	$t_{event\text{-}c}$	0.54	hr/event
Event Duration - adult	$t_{event\text{-}a}$	0.71	hr/event
Age-adjusted event duration	$t_{event\text{-}adj}$	0.67	hr/event
Fraction Absorbed Water	FA	COPC-specific	unitless
Dermal Permeability Coefficient	Kp	COPC-specific	cm/hour
Chemical Concentration in Water	CW	COPC-specific	µg/L
Conversion Factor	CF1	1.0E-03	mg/µg
Conversion Factor	CF2	1.0E-03	L/cm^3
Ratio of Permeability Coefficient	B	COPC-specific	unitless
Time to Reach Steady State	t*	COPC-specific	hour
Lag Time Per Event	τ_{event}	COPC-specific	hr/event
exposure time (inhalation)	ET	24	hr/day
conversion factor	CF3	1.00E+03	L/m^3

COC = Contaminant of Concern
CSF = Cancer Slope Factor
PRG = Preliminary Remediation Goal
RME = Reasonable Maximum Exposure

Age-Adjusted Ingestion Rate = ((Ingestion Rate $_{child}$ * Exposure Duration $_{child}$)/Body Weight $_{child}$) + ((Ingestion Rate adult * Exposure Duration adult)/Body Weight adult)
= ((0.78 L/d * 6 y)/15 kg) + ((2.5 L/d * 20 y)/80 kg) = 0.94 L-y/kg-d

Oral intake rate = (Age-adjusted Ingestion Rate*Fraction ingested * Exposure Frequency*Conversion Factor1/Averaging Time) + (Ingestion Rate of Water $_{child}$*Conversion Factor1/Body Weight$_{child}$
= (0.94 L-y/kg-d*1 * 350 d/y * 10-3 mg/µg)/(70 y * 365 d/y)+((0.78 L/d*0.001 mg/µg)/15 kg)

Age-Adjusted Skin Contact Rate = ((Surface Area $_{child}$ * Event Frequency $_{child}$* Exposure Duration $_{child}$)/Body Weight $_{child}$) + ((Surface Area adult * Event Frequency adult * Exposure Duration adult)/Body Weight adult)
SFSA-adj = ((6378 cm^2/ev * 1 ev/d * 6 y)/15 kg) + ((20900 cm^2/ev * 1 ev/d * 20 y)/80 kg) = 7776 ev-y-cm^2/kg-d

Age-Adjusted Event Duration = ((Exposure Duration $_{child}$*Event Duration $_{child}$)+(Exposure Duration adult*Event Duration adult))/((Exposure Duration $_{child}$) + (Exposure Duration adult))

tevent-adj = ((EDc * tevent-c) + (EDa * tevent-a))/(EDc + EDa) = 0.67 hr/event

Dermal intake rate
for organics where t*<tevent
=(Fraction Absorbed * Permeability Coefficient * Conversion Factor1 * Conversion Factor2* (((Event Duration $_{-adj}$)/(1+B))+(2*Lag Time((1+3B+3B^2)/(1+$B)^2$)))) * (((Skin Contact Rate-adj * Exposure Frequency)/Averaging Time)
+ ((Skin Surface Area Available for Contact child*Event Frequency child)/Body Weightchild))
=(FA * Kp cm/hr *10-3mg/µg* 10-3 L/cm3*(((0.67 hr/ev)/(1+B))+(2τevent(hr/ev)((1+3B+3B^2)/(1+$B)^2$))))*(((7776ev-y-cm^2/kg-d*350d/y)/(80y*365d/y))+ ((6378cm^2*1ev/d)/15 kg))

Inhalation intake rate
=0.0005 * Conversion Factor3 * Conversion Factor1 * Exposure Time * Exposure Frequency* Exposure Duration/Averaging Time * 24 hr/day)+(0.0005 * Conversion Factor3 * Conversion Factor1)
=((0.0005 * 1000 L/m^3 * 0.001 mg/µg * 24 hr/d * 350 d/yr * 26 y)/(70 y * 365 d/y * 24 hr/d))+(0.0005 * 1000 L/m^3 * 0.001 mg/µg)

cancer-based PRG = Target cancer risk /((oral intake *CSF oral)+(dermal intake *CSF dermal)+(inhalation intake *URF inhalation))

TABLE A-5
NON-CANCER RISK-BASED GROUNDWATER PRELIMINARY REMEDIATION GOALS
FUTURE RESIDENTIAL EXPOSURE TO GROUNDWATER AS DRINKING WATER
COMMERCE STREET PLUME SUPERFUND SITE
WILLISTON, VERMONT

COCs	Oral Intake Rate (L-mg/kg-µg-d)	FA (unitless)	K_p (cm/hr)	τ_{event} (hr/event)	B (unitless)	t* (hr)	Dermal Intake Rate (L-mg/kg-µg-d)	RfDoral (mg/kg-d)	RfDdermal (mg/kg-d)	Inhalation Intake Rate (L-mg/m^3-µg)	RfC mg/m^3	PRG based on HQ=1.0 (µg/L)
1,2-Dichloroethane	4.99E-05	1.0	4.20E-03	3.80E-01	0.00E+00	9.20E-01	2.14E-06	6.00E-03	6.00E-03	4.79E-04	7.00E-03	1.30E+01
cis-1,2-Dichloroethylene	4.99E-05	1.0	7.67E-03	3.66E-01	2.90E-02	8.80E-01	3.84E-06	2.00E-03	2.00E-03	4.79E-04	NA	3.72E+01
Methylene chloride	4.99E-05	1.0	3.50E-03	3.20E-01	0.00E+00	7.60E-01	1.64E-06	6.00E-03	6.00E-03	4.79E-04	6.00E-01	1.07E+02
Trichloroethylene	4.99E-05	1.0	1.20E-02	5.80E-01	1.00E-01	1.39E+00	7.57E-06	5.00E-04	5.00E-04	4.79E-04	2.00E-03	2.82E+00
Vinyl chloride	4.99E-05	1.0	5.60E-03	2.40E-01	0.00E+00	5.70E-01	2.27E-06	3.00E-03	3.00E-03	4.79E-04	1.00E-01	4.51E+01
Arsenic	4.99E-05	NA	1.00E-03	NA	NA	NA	2.20E-07	3.0E-04	3.0E-04	NA	NA	5.99E+00
Chromium	4.99E-05	NA	1.00E-03	NA	NA	NA	2.20E-07	3.00E-03	7.50E-05	NA	NA	5.11E+01
Cobalt	4.99E-05	NA	1.00E-03	NA	NA	NA	2.20E-07	3.00E-04	3.00E-04	NA	NA	5.99E+00
Iron	4.99E-05	NA	1.00E-03	NA	NA	NA	2.20E-07	7.00E-01	7.00E-01	NA	NA	1.40E+04

Exposure Assumptions	Parameter	RME Child Age 0-<6	Units
ingestion rate water	IRW	0.78	L/day
Fraction Ingested	FI	1	unitless
exposure frequency	EF	350	days/year
exposure duration	ED	6	years
body weight	BW	15	kg
averaging time	AT_{nc}	2190	days
conversion factor	CF1	0.001	mg/µg
Permeability Coefficient	Kp	chem-specific	cm/hour
Fraction Absorbed Water	FA	chem-specific	unitless
Ratio of Permeability Coefficient	B	chem-specific	unitless
Time to Reach Steady State	t*	chem-specific	hr
Lag Time Per Event	τ_{event}	chem-specific	hr/event
Event Duration (bathing)	t_{event}	0.54	hr/event
surface area	SA	6378	cm^2/day
event frequency	EV	1	event/day
conversion factor	CF2	0.001	L/cm^3
exposure time (inhalation)	ET	24	hr/day
conversion factor	CF3	1.00E+03	L/m^3

COC = Contaminant of Concern
RfD = Reference Dose
RfC = Reference Concentration
PRG = Preliminary Remediation Goal
HQ = Hazard Quotient
RME = Reasonable Maximum Exposure

Oral intake rate

= Ingestion Rate *Fraction ingested * Exposure Frequency* Exposure Duration *Conversion Factor/Body Weight *Averaging Time
= (0.78L/d *1* 350 d/y * 6 y * 10^{-3} mg/µg)/(15 kg * 6 y * 365 d/y)

Dermal intake rate
for inorganics:
=(Permeability Coefficient x Event Duration x Surface Area * Event Frequency*Exposure Frequency * Exposure Duration x Conversion Factor1 x Conversion Factor2)/(Body Weight*Averaging Time)
= (Kp cm/hr *0.54 hr/ev*6378cm^2/d*1ev/d* 350 d/y * 6 y * 10^{-3} mg/µg)/(15 kg * 6 y * 365 d/y)

for organics where t*>0.54
=(2*Fraction Absorbed * Permeability Coefficient * √ (6*Lag Time * Event Duration/π) * Surface Area * Event Frequency * Exposure Frequency * Exposure Duration * Conversion Factor1 * Conversion Factor2)/(Body Weight * Averaging Time)
=(2*FA * Kp cm/hr * √ (6τ_{event} * 0.54/3.14159) *6378cm^2/d*1ev/d* 350 d/y * 6 y * 10^{-3} mg/µg)/(15 kg * 6 y * 365 d/y)

Inhalation intake rate
=0.0005 * Conversion Factor3 * Conversion Factor1 * Exposure Time * Exposure Frequency* Exposure Duration/Averaging Time * 24 hr/day
=(0.0005 * 1000 L/m^3 * 0.001 mg/µg * 24 hr/d * 350 d/yr * 6y)/(6 y * 365 d/y * 24 hr/d)

non-cancer-based PRG = Target HI/((ingestion intake $_{child}$/RfD_{oral})+(dermal intake $_{child}$/RfD_{dermal})+(inhalation intake $_{child}$/RfC))

TABLE A-6
CANCER RISK-BASED SHALLOW GROUNDWATER PRELIMINARY REMEDIATION GOALS
FUTURE CONSTRUCTION WORKER EXPOSURE TO GROUNDWATER
COMMERCE STREET PLUME SUPERFUND SITE
WILLISTON, VERMONT

COCs	FA (unitless)	K_p (cm/hr)	τ_{event} (hr/event)	B (unitless)	t* (hr)	Dermal Intake Rate (L-mg/kg-µg-d)	Inhalation Intake Rate (L-mg/m^3-µg)	CSF (oral and dermal) (mg/kg-d)$^{-1}$	Inhalation Unit Risk (mg/m^3)$^{-1}$	PRG based on 10^{-6} cancer risk (µg/L)	PRG based on 10^{-5} cancer risk (µg/L)	PRG based on 10^{-4} cancer risk (µg/L)
Trichloroethylene	1.0	1.20E-02	5.80E-01	1.00E-01	1.39E+00	2.33E-08	1.23E-05	1.00E+00	4.10E-03	1.35E+01	1.35E+02	1.35E+03

Exposure Assumptions	Parameter	RME	Units
exposure frequency	EF	130	days/year
exposure duration	ED	1	years
body weight	BW	80	kg
averaging time	AT_{nc}	365	days
conversion factor	CF1	0.001	mg/µg
Permeability Coefficient	Kp	0.012	cm/hour
Fraction Absorbed Water	FA	1	unitless
Ratio of Permeability Coefficient	B	0.1	unitless
Time to Reach Steady State	t*	1.39	hr
Lag Time Per Event	τ_{event}	0.58	hr/event
Event Duration	t_{event}	8	hr/event
surface area	SA	3470	cm^2/day
event frequency	EV	1	event/day
conversion factor	CF2	0.001	L/cm^3
Volatilization Factor	VF	7.25	L/m^3
exposure time (inhalation)	ET	8	hr/day
conversion factor	CF3	1.00E+03	L/m^3

COC = Contaminant of Concern
RfD = Reference Dose
RfC = Reference Concentration
PRG = Preliminary Remediation Goal
HQ = Hazard Quotient
RME = Reasonable Maximum Exposure

Dermal intake rate
for organics where t*<8
=(Fraction Absorbed*Permeability Coefficient*(((Event Duration)/(1+B))+(2*Lag Time((1+3B+3B^2)/(1+B)^2))*Surface Area*Event Frequency*Exposure Frequency*Exposure Duration*Conversion Factor1*Conversion Factor2)/(Body Weight*Averaging Time)
=(FA * Kp cm/hr *(((8 hr/ev)/(1+B))+(2τevent(hr/ev)((1+3B+3B^2)/(1+B)^2))*3470cm^2/d*1ev/d*130d/y*1 y*10^{-3}mg/µg*10^{-3}L/cm^3)/(80kg*1y*365d/y)

Inhalation intake rate
=Volatilization factor * Conversion Factor1 * Exposure Time * Exposure Frequency* Exposure Duration/Averaging Time * 24 hr/day
=(7.25 L/m^3 * 0.001 mg/µg * 8 hr/d * 130 d/yr * 1y)/(70 y * 365 d/y * 24 hr/d)

cancer-based PRG = Target cancer risk /((dermal intake *CSF dermal)+(inhalation intake *URF inhalation))

TABLE A-7
NON-CANCER RISK-BASED SHALLOW GROUNDWATER PRELIMINARY REMEDIATION GOALS
FUTURE CONSTRUCTION WORKER EXPOSURE TO GROUNDWATER
COMMERCE STREET PLUME SUPERFUND SITE
WILLISTON, VERMONT

COCs	FA (unitless)	K_p (cm/hr)	τ_{event} (hr/event)	B (unitless)	t* (hr)	Dermal Intake Rate (L-mg/kg-µg-d)	RfDdermal (mg/kg-d)	Inhalation Intake Rate (L-mg/m^3-µg)	RfC mg/m^3	PRG based on HQ=1.0 (µg/L)
Trichloroethylene	1.0	1.20E-02	5.80E-01	1.00E-01	1.39E+00	1.63E-06	5.00E-04	8.61E-04	2.00E-03	2.30E+00

Exposure Assumptions	Parameter	RME	Units
exposure frequency	EF	130	days/year
exposure duration	ED	1	years
body weight	BW	80	kg
averaging time	AT_{nc}	365	days
conversion factor	CF1	0.001	mg/µg
Permeability Coefficient	Kp	0.012	cm/hour
Fraction Absorbed Water	FA	1	unitless
Ratio of Permeability Coefficient	B	0.1	unitless
Time to Reach Steady State	t*	1.39	hr
Lag Time Per Event	τ_{event}	0.58	hr/event
Event Duration	t_{event}	8	hr/event
surface area	SA	3470	cm^2/day
event frequency	EV	1	event/day
conversion factor	CF2	0.001	L/cm^3
Volatilization Factor	VF	7.25	L/m^3
exposure time (inhalation)	ET	8	hr/day
conversion factor	CF3	1.00E+03	L/m^3

COC = Contaminant of Concern
RfD = Reference Dose
RfC = Reference Concentration
PRG = Preliminary Remediation Goal
HQ = Hazard Quotient
RME = Reasonable Maximum Exposure

Dermal intake rate
for organics where t*<8
=(Fraction Absorbed*Permeability Coefficient*(((Event Duration)/(1+B))+(2*Lag Time((1+3B+3B^2)/(1+B)^2))*Surface Area*Event Frequency*Exposure Frequency*Exposure Duration*Conversion Factor1*Conversion Factor2)/(Body Weight*Averaging Time)
=(FA * Kp cm/hr *(((8 hr/ev)/(1+B))+(2τevent(hr/ev)((1+3B+3B^2)/(1+B)^2))*3470cm^2/d*1ev/d*130d/y*1 y*10^{-3}mg/µg*10^{-3}L/cm^3)/(80kg*1y*365d/y)

Inhalation intake rate
=Volatilization factor * Conversion Factor1 * Exposure Time * Exposure Frequency* Exposure Duration/Averaging Time * 24 hr/day
=(7.25 L/m^3 * 0.001 mg/µg * 8 hr/d * 130 d/yr * 1y)/(1 y * 365 d/y * 24 hr/d)

non-cancer-based PRG = Target HI/((dermal intake /RfD_{dermal})+(inhalation intake /RfC))

APPENDIX B

TABLE B-1
RESIDENTIAL RISK-BASED SOIL PRELIMINARY REMEDIATION GOAL CALCULATIONS
FOR CHEMICALS THAT ACT VIA A MUTAGENIC MODE OF ACTION
COMMERCE STREET PLUME SUPERFUND SITE
WILLISTON, VERMONT

Cancer-based Soil PRGs- mutagenic COCs						ingestion intakes				dermal intakes				inhalation intakes				Residential		
						Age				**Age**				**Age**				PRG	PRG	PRG
lifetime resident						0-<2	2-<6	6-<16	16-<26	0-<2	2-<6	6-<16	16-<26	0-<2	2-<6	6-<16	16-<26	based on	based on	based on
COC	OABS	DABS	CSForal	CSFdermal	IURF	Intake rate	Intake rate	Intake rate	Intake rate	Intake rate	Intake rate	Intake rate	Intake rate	Intake rate	Intake rate	Intake rate	Intake rate	$1x10^{-6}$ target risk	$1x10^{-5}$ target risk	$1x10^{-4}$ target risk
	unitless	unitless	$(mg/kg/d)^{-1}$	$(mg/kg/d)^{-1}$	$(\mu g/m^3)^{-1}$													mg/kg	mg/kg	mg/kg
Benzo(a)anthracene	1	0.13	7.3E-01	7.3E-01	1.1E-04	3.65E-06	2.19E-06	5.14E-07	1.71E-07	1.28E-06	7.66E-07	2.82E-07	9.40E-08	1.96E-07	1.17E-07	2.94E-07	9.78E-08	1.53E-01	1.53E+00	1.53E+01
Benzo(a)pyrene	1	0.13	7.3E+00	7.3E+00	1.1E-03	3.65E-06	2.19E-06	5.14E-07	1.71E-07	1.28E-06	7.66E-07	2.82E-07	9.40E-08	1.96E-07	1.17E-07	2.94E-07	9.78E-08	1.53E-02	1.53E-01	1.53E+00
Benzo(b)fluoranthene	1	0.13	7.3E-01	7.3E-01	1.1E-04	3.65E-06	2.19E-06	5.14E-07	1.71E-07	1.28E-06	7.66E-07	2.82E-07	9.40E-08	1.96E-07	1.17E-07	2.94E-07	9.78E-08	1.53E-01	1.53E+00	1.53E+01
Chromium - Total[1]	1	NA	5.0E-01		8.4E-02	3.65E-06	2.19E-06	5.14E-07	1.71E-07					1.96E-07	1.17E-07	2.94E-07	9.78E-08	3.01E-01	3.01E+00	3.01E+01

	Parameter	**RME**				**Units**
		Child			**Adult**	
		Age				
		0-<2	2-<6	6-<16	16-<26	
ingestion rate	IRS	200	200	100	100	mg/day
conversion factor	CF1	0.000001	0.000001	0.000001	0.000001	kg/mg
conversion factor	CF2	1000	1000	1000	1000	µg/mg
conversion factor	CF3	24	24	24	24	hrs/day
exposure time	ET	24	24	24	24	hrs/day
event frequency	EV	1	1	1	1	event/day
exposure frequency	EF	350	350	350	350	days/year
exposure duration	ED	2	4	10	10	years
body weight	BW	15	15	80	80	kg
averaging time	ATcancer	25550	25550	25550	25550	days
surface area	SA	2690	2690	6032	6032	cm^2/day
soil to skin adherence factor	SSAF	0.2	0.2	0.07	0.07	mg/cm^2-event
particulate emission factor	PEF	1.40E+09	1.40E+09	1.40E+09	1.40E+09	m^3/kg
age-dependent adjustment factor	ADAF	10	3	3	1	unitless

ingestion intake rate = ((IRS x OABS x EF x ED x CF1)/(BW x ATc)) x ADAF

dermal intake rate = ((SA x SSAF x DABS x EV x EF x ED x CF1)/(BW x ATc)) x ADAF

inhalation intake rate = ((ET x EF x ED x CF2)/(ATc x PEF x CF3)) x ADAF

cancer-based PRG = Target cancer risk/(((CSForal x (ingestion intake $_{0\text{-}2}$ + ingestion intake $_{2\text{-}6}$ + ingestion intake $_{6\text{-}16}$ + ingestion intake $_{adult}$)) +
((CSFdermal x (dermal intake 0-2 + dermal intake 2-6 + dermal intake 6-16 + dermal intake adult)) +
((IURF x (inhalation intake 0-2 + inhalation intake 2-6 + inhalation intake 6-16 + inhalation intake adult)))

1. Total Chromium risk based PRGs are estimated based on the assumption that total chromium is comprised of 100% hexavalent chromium. This assumption is made because of the detection of hexavalent chromium in speciation data collected at the Mitec property.

TABLE B-2
RESIDENTIAL RISK-BASED SOIL PRELIMINARY REMEDIATION GOAL CALCULATIONS
FOR NON-CARCINOGENS
COMMERCE STREET PLUME SUPERFUND SITE
WILLISTON, VERMONT

Non-cancer-based Soil PRGs child COC	OABS unitless	DABS unitless	RfDoral (mg/kg/d)	RfDdermal (mg/kg/d)	RfC ($\mu g/m^3$)	ingestion Intake rate	dermal Intake rate	inhalation Intake rate	Residential PRG based on Target HQ=1 mg/kg
Chromium - Total[1]	1	NA	3.0E-03	NA	1.0E-01	1.28E-05		6.85E-07	2.34E+02

	Parameter	**RME Child Age** 0-<6	**Units**
ingestion rate	IRS	200	mg/day
conversion factor	CF1	0.000001	kg/mg
conversion factor	CF2	1000	ug/mg
conversion factor	CF3	24	hrs/day
exposure time	ET	24	hrs/day
event frequency	EV	1	event/day
exposure frequency	EF	350	days/year
exposure duration	ED	6	years
body weight	BW	15	kg
averaging time	ATnc	2190	days
surface area	SA	2690	cm^2/day
soil to skin adherence factor	SSAF	0.2	mg/cm^2-event
particulate emission factor	PEF	1.40E+09	m^3/kg

1. Total Chromium risk based PRGs are estimated based on the assumption that total chromium is comprised of 100% hexavalent chromium. This assumption is made because of the detection of hexavalent chromium in speciation data collected at the Mitec property.

child ingestion intake rate = (IRS x OABS x EF x ED x CF1)/(BW x ATnc)

child dermal intake rate = (SA x SSAF x DABS x EV x EF x ED x CF1)/(BW x ATnc)

non-cancer-based PRG = Target HQ/((ingestion intake $_{child}$/RfD_{oral})+(dermal intake $_{child}$/RfD_{dermal})+(inhalation intake $_{child}$/RfC))

APPENDIX C

TECHNICAL MEMORANDUM

To: Karen Lumino

From: Richard Sugatt

Date: July 16, 2015

Subject: Risk Evaluation and Preliminary Remedial Goals for Trichloroethylene in Sump Water at 830 South Brownell Road, Williston, VT

In April 2014 and again in July 2014, VT DEC collected samples from the sump pump at the subject property. The concentration of trichloroethylene (TCE) during the first event was measured to be 75 µg/L and 104 µg/L during the second.

The EPA Vapor Intrusion Screening Level (VISL) calculator was used to calculate the indoor air risk as though the sump water were groundwater. The calculated residential indoor air risk for a TCE concentration of 104 µg/L in groundwater was a Lifetime Elevated Cancer Risk (ELCR) cancer risk of 8.8E-05 and a Hazard Quotient (HQ) of 20. The VISL calculator uses a default attenuation factor of 0.001 for attenuation from groundwater to indoor air. Since there is no obstruction between the sump water and indoor air, it is assumed that the sump water in the basement has an attenuation factor of 1, which would increase the risks by a factor of 1000. Multiplying the VISL risks by 1000 results in an ELCR of 8.8E-02 and an HQ of 20,000, both of which are elevated above EPA's maximum acceptable risk of 1E-04 cancer risk and Hazard Quotient of 1. There is high uncertainty in these risk estimates because the TCE is diluted by indoor air exchange to an unknown extent. Although highly uncertain, Preliminary Remedial Goals were calculated as described below:

A Preliminary Remedial Goal (PRG) for an ELCR of 1E-06 can be calculated from the following equation:

(104 µg/L TCE)(ELCR =1E-06) = (ELCR =8.8E-02) (X), where X = PRG in µg/L TCE for 1E-06 cancer risk

The cancer-based PRG for 1E-06 ELCR is 1.18E-03 µg/L . For higher cancer risk levels, the PRG would be 1.18E-02 µg/L for 1E-05 ELCR, and 1.18E-01 µg/L for 1E-04 ELCR.

A PRG for HQ =1 can be calculated from the following equation:

(104 µg/L TCE)(HQ = 1) = (HQ=20000) (X), where X = PRG in µg/L for HQ =1

The non-cancer based PRG for HQ =1 is 5.2E-03 µg/L . This concentration is higher than the cancer based PRG for 1E-06 ELCR, but lower than the cancer based PRG for 1E-05 ELCR. Since the HQ must be kept at HQ =1 or less, the PRG is set at 5.2E-03 µg/L , or 0.0052 µg/L for an HQ =1. These PRGs are summarized in the table below:

Table 1. PRGs for TCE in Sump Water, Assuming Attenuation Factor of 1

PRG (µg/L TCE)				Selected
ELCR = 1E-06	ELCR = 1E-05	ELCR = 1E-04	HQ = 1E+00	PRG (µg/L)
1.18E-03	1.18E-02	1.18E-01	5.20E-03	5.2E-03

APPENDIX D

Appendix D
Present Value of Annual and Periodic Costs - Years 1 through 30
Alternative SO1: No Action
Commerce Street Plume Superfund Site
Williston, Vermont

Year (t)	GW Monitoring	Lab	Maintenance	Site Inspections	Annual Reporting	Five-Year Reviews	Contingency (@ 10%)	PM (@ 5%)	Total Non-Discounted Cost	Total Present Value
0										
1	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
2	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
3	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
4	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
5	$ -	$ -	$ -	$ -	$ -	$ 25,000	$ 2,500	$ 1,250	$ 28,750	$ 20,498
6	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
7	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
8	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
9	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
10	$ -	$ -	$ -	$ -	$ -	$ 25,000	$ 2,500	$ 1,250	$ 28,750	$ 14,615
11	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
12	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
13	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
14	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
15	$ -	$ -	$ -	$ -	$ -	$ 25,000	$ 2,500	$ 1,250	$ 28,750	$ 10,420
16	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
17	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
18	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
19	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
20	$ -	$ -	$ -	$ -	$ -	$ 25,000	$ 2,500	$ 1,250	$ 28,750	$ 7,430
21	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
22	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
23	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
24	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
25	$ -	$ -	$ -	$ -	$ -	$ 25,000	$ 2,500	$ 1,250	$ 28,750	$ 5,297
26	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
27	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
28	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
29	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
30	$ -	$ -	$ -	$ -	$ -	$ 25,000	$ 2,500	$ 1,250	$ 28,750	$ 3,777
TOTAL	$ -	$ -	$ -	$ -	$ -	$ 150,000	$ 15,000	$ 7,500	$ 172,500	$ 62,037

Assumptions:
No actions to be performed other than Five-Year Reviews
Includes 50% of the estimated Five-Year Review costs

PV Discount Rate (i)
0.070

PV = non-discounted cost X 1/((1+i)t)

Appendix D
Present Value of Annual and Periodic Costs - Years 1 through 30
Alternative SO2: Limited Action - Institutional and Engineered Controls
Commerce Street Plume Superfund Site
Williston, Vermont

Year (t)	GW Monitoring	Lab	Maintenance	Site Inspections	Annual Reporting	Five-Year Reviews	Contingency (@ 10%)	Project Management (@ 5%)	Total Non-Discounted Cost	Total Present Value
0										
1	$ -	$ -	$ -	$ 3,000	$ 1,500		$ 450	$ 225	$ 5,175	$ 4,836
2	$ -	$ -	$ -	$ 3,000	$ 1,500		$ 450	$ 225	$ 5,175	$ 4,520
3	$ -	$ -	$ -	$ 2,500	$ 1,500		$ 400	$ 200	$ 4,600	$ 3,755
4	$ -	$ -	$ -	$ 2,500	$ 1,500		$ 400	$ 200	$ 4,600	$ 3,509
5	$ -	$ -	$ 3,500	$ 2,500	$ 1,500	$ 25,000	$ 3,250	$ 1,625	$ 37,375	$ 26,648
6	$ -	$ -	$ -	$ 2,500	$ 1,500		$ 400	$ 200	$ 4,600	$ 3,065
7	$ -	$ -	$ -	$ 2,500	$ 1,500		$ 400	$ 200	$ 4,600	$ 2,865
8	$ -	$ -	$ -	$ 2,500	$ 1,500		$ 400	$ 200	$ 4,600	$ 2,677
9	$ -	$ -	$ -	$ 2,500	$ 1,500		$ 400	$ 200	$ 4,600	$ 2,502
10	$ -	$ -	$ 3,500	$ 2,500	$ 1,500	$ 25,000	$ 3,250	$ 1,625	$ 37,375	$ 19,000
11	$ -	$ -	$ -	$ 2,500	$ 1,500		$ 400	$ 200	$ 4,600	$ 2,185
12	$ -	$ -	$ -	$ 2,500	$ 1,500		$ 400	$ 200	$ 4,600	$ 2,042
13	$ -	$ -	$ -	$ 2,500	$ 1,500		$ 400	$ 200	$ 4,600	$ 1,909
14	$ -	$ -	$ -	$ 2,500	$ 1,500		$ 400	$ 200	$ 4,600	$ 1,784
15	$ -	$ -	$ 3,500	$ 2,500	$ 1,500	$ 25,000	$ 3,250	$ 1,625	$ 37,375	$ 13,546
16	$ -	$ -	$ -	$ 2,500	$ 1,500		$ 400	$ 200	$ 4,600	$ 1,558
17	$ -	$ -	$ -	$ 2,500	$ 1,500		$ 400	$ 200	$ 4,600	$ 1,456
18	$ -	$ -	$ -	$ 2,500	$ 1,500		$ 400	$ 200	$ 4,600	$ 1,361
19	$ -	$ -	$ -	$ 2,500	$ 1,500		$ 400	$ 200	$ 4,600	$ 1,272
20	$ -	$ -	$ 3,500	$ 2,500	$ 1,500	$ 25,000	$ 3,250	$ 1,625	$ 37,375	$ 9,658
21	$ -	$ -	$ -	$ 2,500	$ 1,500		$ 400	$ 200	$ 4,600	$ 1,111
22	$ -	$ -	$ -	$ 2,500	$ 1,500		$ 400	$ 200	$ 4,600	$ 1,038
23	$ -	$ -	$ -	$ 2,500	$ 1,500		$ 400	$ 200	$ 4,600	$ 970
24	$ -	$ -	$ -	$ 2,500	$ 1,500		$ 400	$ 200	$ 4,600	$ 907
25	$ -	$ -	$ 3,500	$ 2,500	$ 1,500	$ 25,000	$ 3,250	$ 1,625	$ 37,375	$ 6,886
26	$ -	$ -	$ -	$ 2,500	$ 1,500		$ 400	$ 200	$ 4,600	$ 792
27	$ -	$ -	$ -	$ 2,500	$ 1,500		$ 400	$ 200	$ 4,600	$ 740
28	$ -	$ -	$ -	$ 2,500	$ 1,500		$ 400	$ 200	$ 4,600	$ 692
29	$ -	$ -	$ -	$ 2,500	$ 1,500		$ 400	$ 200	$ 4,600	$ 647
30	$ -	$ -	$ 3,500	$ 2,500	$ 1,500	$ 25,000	$ 3,250	$ 1,625	$ 37,375	$ 4,910
TOTAL	$ -	$ -	$ 21,000	$ 76,000	$ 45,000	$ 150,000	$ 29,200	$ 14,600	$ 335,800	$ 128,844

Assumptions:
Includes 50% of the estimated Five-Year Review costs
Groundwater monitoring will not be performed
Annual site inspections of the fenced area will be performed

PV Discount Rate (i)
0.070

PV = non-discounted cost x 1/((1+i)t)

Appendix D
Present Value of Annual and Periodic Costs - Years 1 through 30
Alternative SO3: Excavation and Off-Site Disposal
Commerce Street Plume Superfund Site
Williston, Vermont

Year (t)	GW Monitoring	Lab	Maintenance	Site Inspections	Annual Reporting	Five-Year Reviews	Contingency (@ 10%)	PM (@ 5%)	Total Non-Discounted Cost	Total Present Value
0										
1	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
2	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
3	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
4	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
5	$ -	$ -	$ -	$ -	$ -	$ 25,000	$ 2,500	$ 1,250	$ 28,750	$ 20,498
6	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
7	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
8	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
9	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
10	$ -	$ -	$ -	$ -	$ -	$ 25,000	$ 2,500	$ 1,250	$ 28,750	$ 14,615
11	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
12	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
13	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
14	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
15	$ -	$ -	$ -	$ -	$ -	$ 25,000	$ 2,500	$ 1,250	$ 28,750	$ 10,420
16	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
17	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
18	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
19	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
20	$ -	$ -	$ -	$ -	$ -	$ 25,000	$ 2,500	$ 1,250	$ 28,750	$ 7,430
21	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
22	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
23	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
24	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
25	$ -	$ -	$ -	$ -	$ -	$ 25,000	$ 2,500	$ 1,250	$ 28,750	$ 5,297
26	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
27	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
28	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
29	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
30	$ -	$ -	$ -	$ -	$ -	$ 25,000	$ 2,500	$ 1,250	$ 28,750	$ 3,777
TOTAL	$ -	$ -	$ -	$ -	$ -	$ 150,000	$ 15,000	$ 7,500	$ 172,500	$ 62,037

Assumptions:
Includes 50% of the estimated Five-Year Review costs
Groundwater monitoring will not be performed

PV Discount Rate (i)
0.070

PV = non-discounted cost X 1/((1+i)t)

Appendix D
Present Value of Annual and Periodic Costs - Years 1 through 30
Alternative GW1: No Action
Commerce Street Plume Superfund Site
Williston, Vermont

Year (t)	GW Monitoring	Lab	Maintenance	Site Inspections	Annual Reporting	Five-Year Reviews	Contingency (@ 10%)	PM (@ 5%)	Total Non-Discounted Cost	Total Present Value
0										
1	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
2	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
3	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
4	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
5	$ -	$ -	$ -	$ -	$ -	$ 25,000	$ 2,500	$ 1,250	$ 28,750	$ 20,498
6	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
7	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
8	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
9	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
10	$ -	$ -	$ -	$ -	$ -	$ 25,000	$ 2,500	$ 1,250	$ 28,750	$ 14,615
11	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
12	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
13	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
14	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
15	$ -	$ -	$ -	$ -	$ -	$ 25,000	$ 2,500	$ 1,250	$ 28,750	$ 10,420
16	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
17	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
18	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
19	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
20	$ -	$ -	$ -	$ -	$ -	$ 25,000	$ 2,500	$ 1,250	$ 28,750	$ 7,430
21	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
22	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
23	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
24	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
25	$ -	$ -	$ -	$ -	$ -	$ 25,000	$ 2,500	$ 1,250	$ 28,750	$ 5,297
26	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
27	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
28	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
29	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
30	$ -	$ -	$ -	$ -	$ -	$ 25,000	$ 2,500	$ 1,250	$ 28,750	$ 3,777
TOTAL	$ -	$ -	$ -	$ -	$ -	$ 150,000	$ 15,000	$ 7,500	$ 172,500	$ 62,037

Assumptions:
Includes 50% of the estimated Five-Year Review costs
Groundwater monitoring will not be performed

PV Discount Rate (i)
0.070

PV = non-discounted cost X 1/((1+i)t)

Appendix D
Present Value of Annual and Periodic Costs - Years 1 through 30
Alternative GW2: Limited Action-Institutional Controls
Commerce Street Plume Superfund Site
Williston, Vermont

Year (t)	GW Monitoring	Lab	Maintenance	Site Inspections	Annual Reporting	Five-Year Reviews	Contingency (@ 10%)	Project Management (@ 5%)	Total Non-Discounted Cost	Total Present Value
0										
1	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
2	$ 11,000	$ 750	$ -	$ -	$ 4,500		$ 1,625	$ 813	$ 18,688	$ 16,322
3	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
4	$ 11,000	$ 750	$ -	$ -	$ 4,500		$ 1,625	$ 813	$ 18,688	$ 14,257
5	$ -	$ -	$ -	$ -	$ -	$ 25,000	$ 2,500	$ 1,250	$ 28,750	$ 20,498
6	$ 11,000	$ 750	$ 2,000	$ -	$ 4,500		$ 1,825	$ 913	$ 20,988	$ 13,985
7	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
8	$ 11,000	$ 750	$ -	$ -	$ 4,500		$ 1,625	$ 813	$ 18,688	$ 10,876
9	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
10	$ 11,000	$ 750	$ -	$ -	$ 4,500	$ 25,000	$ 4,125	$ 2,063	$ 47,438	$ 24,115
11	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
12	$ 11,000	$ 750	$ 2,000	$ -	$ 4,500		$ 1,825	$ 913	$ 20,988	$ 9,319
13	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
14	$ 11,000	$ 750	$ -	$ -	$ 4,500		$ 1,625	$ 813	$ 18,688	$ 7,247
15	$ -	$ -	$ -	$ -	$ -	$ 25,000	$ 2,500	$ 1,250	$ 28,750	$ 10,420
16	$ 11,000	$ 750	$ -	$ -	$ 4,500		$ 1,625	$ 813	$ 18,688	$ 6,330
17	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
18	$ 11,000	$ 750	$ 20,000	$ -	$ 4,500		$ 3,625	$ 1,813	$ 41,688	$ 12,334
19	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
20	$ 11,000	$ 750	$ -	$ -	$ 4,500	$ 25,000	$ 4,125	$ 2,063	$ 47,438	$ 12,259
21	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
22	$ 11,000	$ 750	$ -	$ -	$ 4,500		$ 1,625	$ 813	$ 18,688	$ 4,218
23	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
24	$ 11,000	$ 750	$ 2,000	$ -	$ 4,500		$ 1,825	$ 913	$ 20,988	$ 4,138
25	$ -	$ -	$ -	$ -	$ -	$ 25,000	$ 2,500	$ 1,250	$ 28,750	$ 5,297
26	$ 11,000	$ 750	$ -	$ -	$ 4,500		$ 1,625	$ 813	$ 18,688	$ 3,218
27	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
28	$ 11,000	$ 750	$ -	$ -	$ 4,500		$ 1,625	$ 813	$ 18,688	$ 2,811
29	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
30	$ 11,000	$ 750	$ 2,000	$ -	$ 4,500	$ 25,000	$ 4,325	$ 2,163	$ 49,738	$ 6,534
TOTAL	$ 165,000	$ 11,250	$ 28,000	$ -	$ 67,500	$ 150,000	$ 42,175	$ 21,088	$ 485,013	$ 184,178

Assumptions:
Includes 50% of the estimated Five-Year Review costs
Only limited compliance monitoirng will be performed (6 wells for VOCs every 2 years)

PV Discount Rate (i)
0.070

PV = non-discounted cost x 1/((1+i)t)

Appendix D
Present Value of Annual and Periodic Costs - Years 1 through 30
Alternative GW3: Limited Action - Monitored Natural Attenuation and Long-Term Monitoring
Commerce Street Plume Superfund Site
Williston, Vermont

Year (t)	GW Monitoring	Lab	Maintenance	Site Inspections	Annual Reporting	Five-Year Reviews	Contingency (@ 10%)	PM (@ 5%)	Total Non-Discounted Cost	Total Present Value
0										
1	$ 77,000	$ 44,010	$ -	$ -	$ 12,000		$ 13,301	$ 6,651	$ 152,962	$ 142,955
2	$ 77,000	$ 44,010	$ -	$ -	$ 12,000		$ 13,301	$ 6,651	$ 152,962	$ 133,602
3	$ 77,000	$ 44,010	$ -	$ -	$ 12,000		$ 13,301	$ 6,651	$ 152,962	$ 124,862
4	$ 77,000	$ 44,010	$ -	$ -	$ 12,000		$ 13,301	$ 6,651	$ 152,962	$ 116,694
5	$ 77,000	$ 44,010	$ 2,000	$ -	$ 12,000	$ 25,000	$ 16,001	$ 8,001	$ 184,012	$ 131,198
6	$ 38,500	$ 22,050	$ -	$ -	$ 8,000		$ 6,855	$ 3,428	$ 78,833	$ 52,529
7	$ 38,500	$ 22,050	$ -	$ -	$ 8,000		$ 6,855	$ 3,428	$ 78,833	$ 49,093
8	$ 38,500	$ 22,050	$ -	$ -	$ 8,000		$ 6,855	$ 3,428	$ 78,833	$ 45,881
9	$ 38,500	$ 22,050	$ -	$ -	$ 8,000		$ 6,855	$ 3,428	$ 78,833	$ 42,880
10	$ 38,500	$ 22,050	$ 2,000	$ -	$ 8,000	$ 25,000	$ 9,555	$ 4,778	$ 109,883	$ 55,859
11	$ 38,500	$ 22,050	$ -	$ -	$ 8,000		$ 6,855	$ 3,428	$ 78,833	$ 37,453
12	$ 38,500	$ 22,050	$ -	$ -	$ 8,000		$ 6,855	$ 3,428	$ 78,833	$ 35,003
13	$ 38,500	$ 22,050	$ -	$ -	$ 8,000		$ 6,855	$ 3,428	$ 78,833	$ 32,713
14	$ 38,500	$ 22,050	$ -	$ -	$ 8,000		$ 6,855	$ 3,428	$ 78,833	$ 30,573
15	$ 38,500	$ 22,050	$ 2,000	$ -	$ 8,000	$ 25,000	$ 9,555	$ 4,778	$ 109,883	$ 39,826
16	$ 38,500	$ 22,050	$ -	$ -	$ 8,000		$ 6,855	$ 3,428	$ 78,833	$ 26,703
17	$ 38,500	$ 22,050	$ -	$ -	$ 8,000		$ 6,855	$ 3,428	$ 78,833	$ 24,956
18	$ 38,500	$ 22,050	$ -	$ -	$ 8,000		$ 6,855	$ 3,428	$ 78,833	$ 23,324
19	$ 38,500	$ 22,050	$ -	$ -	$ 8,000		$ 6,855	$ 3,428	$ 78,833	$ 21,798
20	$ 38,500	$ 22,050	$ 2,000	$ -	$ 8,000	$ 25,000	$ 9,555	$ 4,778	$ 109,883	$ 28,396
21	$ 38,500	$ 22,050	$ -	$ -	$ 8,000		$ 6,855	$ 3,428	$ 78,833	$ 19,039
22	$ 38,500	$ 22,050	$ -	$ -	$ 8,000		$ 6,855	$ 3,428	$ 78,833	$ 17,794
23	$ 38,500	$ 22,050	$ -	$ -	$ 8,000		$ 6,855	$ 3,428	$ 78,833	$ 16,629
24	$ 38,500	$ 22,050	$ -	$ -	$ 8,000		$ 6,855	$ 3,428	$ 78,833	$ 15,542
25	$ 38,500	$ 22,050	$ 2,000	$ -	$ 8,000	$ 25,000	$ 9,555	$ 4,778	$ 109,883	$ 20,246
26	$ 38,500	$ 22,050	$ -	$ -	$ 8,000		$ 6,855	$ 3,428	$ 78,833	$ 13,575
27	$ 38,500	$ 22,050	$ -	$ -	$ 8,000		$ 6,855	$ 3,428	$ 78,833	$ 12,687
28	$ 38,500	$ 22,050	$ -	$ -	$ 8,000		$ 6,855	$ 3,428	$ 78,833	$ 11,857
29	$ 38,500	$ 22,050	$ -	$ -	$ 8,000		$ 6,855	$ 3,428	$ 78,833	$ 11,081
30	$ 38,500	$ 22,050	$ 2,000	$ -	$ 8,000	$ 25,000	$ 9,555	$ 4,778	$ 109,883	$ 14,435
TOTAL	**$ 1,347,500**	**$ 771,300**	**$ 12,000**	**$ -**	**$ 260,000**	**$ 150,000**	**$ 254,080**	**$ 127,040**	**$ 2,921,920**	**$ 1,349,179**

Assumptions

Includes 50% of the estimated Five-Year Review costs
27 wells sampled twice per for first 5 years, then annual thereafter for MNA Evaluation parameters
Assume samples will be analyzed by a commercial laboratory

PV Discount Rate (i)
0.070

PV = non-discounted cost X 1/((1+i)t)

Appendix D
Present Value of Annual and Periodic Costs - Years 1 through 30
Alternative GW5: *In Situ* Treatment and Monitored Natural Attenuation
Commerce Street Plume Superfund Site
Williston, Vermont

Year (t)	GW Monitoring	Lab	Maintenance	Site Inspections	Annual Reporting	Five-Year Reviews	Contingency (@ 10%)	PM (@ 5%)	Total Non-Discounted Cost	Total Present Value
0										
1	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
2	$ 77,000	$ 44,010	$ -	$ -	$ 12,000		$ 13,301	$ 6,651	$ 152,962	$ 133,602
3	$ 77,000	$ 44,010	$ -	$ -	$ 12,000		$ 13,301	$ 6,651	$ 152,962	$ 124,862
4	$ 77,000	$ 44,010	$ -	$ -	$ 12,000		$ 13,301	$ 6,651	$ 152,962	$ 116,694
5	$ 77,000	$ 44,010	$ 2,000	$ -	$ 12,000	$ 25,000	$ 16,001	$ 8,001	$ 184,012	$ 131,198
6	$ 77,000	$ 44,010	$ -	$ -	$ 12,000		$ 13,301	$ 6,651	$ 152,962	$ 101,925
7	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
8	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
9	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
10	$ 38,500	$ 22,050	$ 2,000	$ -	$ 8,000	$ 25,000	$ 9,555	$ 4,778	$ 109,883	$ 55,859
11	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
12	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
13	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
14	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
15	$ 38,500	$ 22,050	$ 2,000	$ -	$ 8,000	$ 25,000	$ 9,555	$ 4,778	$ 109,883	$ 39,826
16	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
17	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
18	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
19	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
20	$ 38,500	$ 22,050	$ 2,000	$ -	$ 8,000	$ 25,000	$ 9,555	$ 4,778	$ 109,883	$ 28,396
21	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
22	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
23	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
24	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
25	$ 38,500	$ 22,050	$ 2,000	$ -	$ 8,000	$ 25,000	$ 9,555	$ 4,778	$ 109,883	$ 20,246
26	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
27	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
28	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
29	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
30	$ 38,500	$ 22,050	$ 2,000	$ -	$ 8,000	$ 25,000	$ 9,555	$ 4,778	$ 109,883	$ 14,435
TOTAL	**$ 577,500**	**$ 330,300**	**$ 12,000**	**$ -**	**$ 100,000**	**$ 150,000**	**$ 116,980**	**$ 58,490**	**$ 1,345,270**	**$ 767,042**

Assumptions

Includes 50% of the estimated Five-Year Review costs
27 wells sampled twice per for first 5 years after treatments for MNA Evaluation parameters
Sampling then performed in conjunction with Five-Year Reviews
These O&M costs are applicable to any of the in-situ groundwater alternatives (ISCO, ISB and combinations)

PV Discount Rate (i)
0.070

PV = non-discounted cost X 1/((1+i)t)

Appendix D
Present Value of Annual and Periodic Costs - Years 1 through 30
Alternative VM1: No Action
Commerce Street Plume Superfund Site
Williston, Vermont

Year (t)	GW Monitoring	Lab	Maintenance	Site Inspections	Annual Reporting	Five-Year Reviews	Contingency (@ 10%)	PM (@ 5%)	Total Non-Discounted Cost	Total Present Value
0										
1	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
2	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
3	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
4	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
5	$ -	$ -	$ -	$ -	$ -	$ 25,000	$ 2,500	$ 1,250	$ 28,750	$ 20,498
6	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
7	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
8	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
9	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
10	$ -	$ -	$ -	$ -	$ -	$ 25,000	$ 2,500	$ 1,250	$ 28,750	$ 14,615
11	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
12	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
13	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
14	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
15	$ -	$ -	$ -	$ -	$ -	$ 25,000	$ 2,500	$ 1,250	$ 28,750	$ 10,420
16	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
17	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
18	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
19	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
20	$ -	$ -	$ -	$ -	$ -	$ 25,000	$ 2,500	$ 1,250	$ 28,750	$ 7,430
21	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
22	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
23	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
24	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
25	$ -	$ -	$ -	$ -	$ -	$ 25,000	$ 2,500	$ 1,250	$ 28,750	$ 5,297
26	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
27	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
28	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
29	$ -	$ -	$ -	$ -	$ -		$ -	$ -	$ -	$ -
30	$ -	$ -	$ -	$ -	$ -	$ 25,000	$ 2,500	$ 1,250	$ 28,750	$ 3,777
TOTAL	$ -	$ -	$ -	$ -	$ -	$ 150,000	$ 15,000	$ 7,500	$ 172,500	$ 62,037

Assumptions:
No actions to be performed other than Five-Year Reviews
Includes 50% of the estimated Five-Year Review costs

PV Discount Rate (i)
0.070

PV = non-discounted cost X 1/((1+i)t)

Appendix D
Present Value of Annual and Periodic Costs - Years 1 through 30
Alternative VM2: Sump Pump, Vapor Venting, Treatment and Discharge
Commerce Street Plume Superfund Site
Williston, Vermont

Year (t)	GW Monitoring	Lab	Maintenance	Site Inspections	Annual Reporting	Five-Year Reviews	Contingency (@ 10%)	PM (@ 5%)	Total Non-Discounted Cost	Total Present Value
0										
1	$ -	$ -	$ 1,500	$ 1,000	$ -		$ 250	$ 125	$ 2,875	$ 2,687
2	$ -	$ -	$ 1,500	$ 1,000	$ -		$ 250	$ 125	$ 2,875	$ 2,511
3	$ -	$ -	$ 1,500	$ 1,000	$ -		$ 250	$ 125	$ 2,875	$ 2,347
4	$ -	$ -	$ 1,500	$ 1,000	$ -		$ 250	$ 125	$ 2,875	$ 2,193
5	$ -	$ -	$ 1,500	$ 1,000	$ -	$ 25,000	$ 2,750	$ 1,375	$ 31,625	$ 22,548
6	$ -	$ -	$ 1,500	$ 1,000	$ -		$ 250	$ 125	$ 2,875	$ 1,916
7	$ -	$ -	$ 1,500	$ 1,000	$ -		$ 250	$ 125	$ 2,875	$ 1,790
8	$ -	$ -	$ 1,500	$ 1,000	$ -		$ 250	$ 125	$ 2,875	$ 1,673
9	$ -	$ -	$ 1,500	$ 1,000	$ -		$ 250	$ 125	$ 2,875	$ 1,564
10	$ -	$ -	$ 1,500	$ 1,000	$ -	$ 25,000	$ 2,750	$ 1,375	$ 31,625	$ 16,077
11	$ -	$ -	$ 1,500	$ 1,000	$ -		$ 250	$ 125	$ 2,875	$ 1,366
12	$ -	$ -	$ 1,500	$ 1,000	$ -		$ 250	$ 125	$ 2,875	$ 1,277
13	$ -	$ -	$ 1,500	$ 1,000	$ -		$ 250	$ 125	$ 2,875	$ 1,193
14	$ -	$ -	$ 1,500	$ 1,000	$ -		$ 250	$ 125	$ 2,875	$ 1,115
15	$ -	$ -	$ 1,500	$ 1,000	$ -	$ 25,000	$ 2,750	$ 1,375	$ 31,625	$ 11,462
16	$ -	$ -	$ 1,500	$ 1,000	$ -		$ 250	$ 125	$ 2,875	$ 974
17	$ -	$ -	$ 1,500	$ 1,000	$ -		$ 250	$ 125	$ 2,875	$ 910
18	$ -	$ -	$ 1,500	$ 1,000	$ -		$ 250	$ 125	$ 2,875	$ 851
19	$ -	$ -	$ 1,500	$ 1,000	$ -		$ 250	$ 125	$ 2,875	$ 795
20	$ -	$ -	$ 1,500	$ 1,000	$ -	$ 25,000	$ 2,750	$ 1,375	$ 31,625	$ 8,173
21	$ -	$ -	$ 1,500	$ 1,000	$ -		$ 250	$ 125	$ 2,875	$ 694
22	$ -	$ -	$ 1,500	$ 1,000	$ -		$ 250	$ 125	$ 2,875	$ 649
23	$ -	$ -	$ 1,500	$ 1,000	$ -		$ 250	$ 125	$ 2,875	$ 606
24	$ -	$ -	$ 1,500	$ 1,000	$ -		$ 250	$ 125	$ 2,875	$ 567
25	$ -	$ -	$ 1,500	$ 1,000	$ -	$ 25,000	$ 2,750	$ 1,375	$ 31,625	$ 5,827
26	$ -	$ -	$ 1,500	$ 1,000	$ -		$ 250	$ 125	$ 2,875	$ 495
27	$ -	$ -	$ 1,500	$ 1,000	$ -		$ 250	$ 125	$ 2,875	$ 463
28	$ -	$ -	$ 1,500	$ 1,000	$ -		$ 250	$ 125	$ 2,875	$ 432
29	$ -	$ -	$ 1,500	$ 1,000	$ -		$ 250	$ 125	$ 2,875	$ 404
30	$ -	$ -	$ 1,500	$ 1,000	$ -	$ 25,000	$ 2,750	$ 1,375	$ 31,625	$ 4,154
TOTAL	$ -	$ -	$ 45,000	$ 30,000	$ -	$ 150,000	$ 22,500	$ 11,250	$ 258,750	$ 97,713

Assumptions:
Includes 50% of the estimated Five-Year Review costs
Assumes annual inspections and maintenance of the existing vapor mitigation system

PV Discount Rate (i)
0.070

PV = non-discounted cost X 1/((1+i)t)

Appendix D
Present Value of Annual and Periodic Costs - Years 1 through 30
Alternative VM3: Enhanced Vapor Mitigation
Commerce Street Plume Superfund Site
Williston, Vermont

Year (t)	Vapor Monitoring	Lab	Maintenance	Site Inspections	Annual Reporting	Five-Year Reviews	Contingency (@ 10%)	PM (@ 5%)	Total Non-Discounted Cost	Total Present Value
0										
1	$ -	$ -	$ 1,500	$ 1,000	$ -		$ 250	$ 125	$ 2,875	$ 2,687
2	$ -	$ -	$ 1,500	$ 1,000	$ -		$ 250	$ 125	$ 2,875	$ 2,511
3	$ -	$ -	$ 1,500	$ 1,000	$ -		$ 250	$ 125	$ 2,875	$ 2,347
4	$ -	$ -	$ 1,500	$ 1,000	$ -		$ 250	$ 125	$ 2,875	$ 2,193
5	$ 5,000	$ -	$ 1,500	$ 1,000	$ -	$ 25,000	$ 3,250	$ 1,625	$ 37,375	$ 26,648
6	$ -	$ -	$ 1,500	$ 1,000	$ -		$ 250	$ 125	$ 2,875	$ 1,916
7	$ -	$ -	$ 1,500	$ 1,000	$ -		$ 250	$ 125	$ 2,875	$ 1,790
8	$ -	$ -	$ 1,500	$ 1,000	$ -		$ 250	$ 125	$ 2,875	$ 1,673
9	$ -	$ -	$ 1,500	$ 1,000	$ -		$ 250	$ 125	$ 2,875	$ 1,564
10	$ 5,000	$ -	$ 1,500	$ 1,000	$ -	$ 25,000	$ 3,250	$ 1,625	$ 37,375	$ 19,000
11	$ -	$ -	$ 1,500	$ 1,000	$ -		$ 250	$ 125	$ 2,875	$ 1,366
12	$ -	$ -	$ 1,500	$ 1,000	$ -		$ 250	$ 125	$ 2,875	$ 1,277
13	$ -	$ -	$ 1,500	$ 1,000	$ -		$ 250	$ 125	$ 2,875	$ 1,193
14	$ -	$ -	$ 1,500	$ 1,000	$ -		$ 250	$ 125	$ 2,875	$ 1,115
15	$ 5,000	$ -	$ 1,500	$ 1,000	$ -	$ 25,000	$ 3,250	$ 1,625	$ 37,375	$ 13,546
16	$ -	$ -	$ 1,500	$ 1,000	$ -		$ 250	$ 125	$ 2,875	$ 974
17	$ -	$ -	$ 1,500	$ 1,000	$ -		$ 250	$ 125	$ 2,875	$ 910
18	$ -	$ -	$ 1,500	$ 1,000	$ -		$ 250	$ 125	$ 2,875	$ 851
19	$ -	$ -	$ 1,500	$ 1,000	$ -		$ 250	$ 125	$ 2,875	$ 795
20	$ 5,000	$ -	$ 1,500	$ 1,000	$ -	$ 25,000	$ 3,250	$ 1,625	$ 37,375	$ 9,658
21	$ -	$ -	$ 1,500	$ 1,000	$ -		$ 250	$ 125	$ 2,875	$ 694
22	$ -	$ -	$ 1,500	$ 1,000	$ -		$ 250	$ 125	$ 2,875	$ 649
23	$ -	$ -	$ 1,500	$ 1,000	$ -		$ 250	$ 125	$ 2,875	$ 606
24	$ -	$ -	$ 1,500	$ 1,000	$ -		$ 250	$ 125	$ 2,875	$ 567
25	$ 5,000	$ -	$ 1,500	$ 1,000	$ -	$ 25,000	$ 3,250	$ 1,625	$ 37,375	$ 6,886
26	$ -	$ -	$ 1,500	$ 1,000	$ -		$ 250	$ 125	$ 2,875	$ 495
27	$ -	$ -	$ 1,500	$ 1,000	$ -		$ 250	$ 125	$ 2,875	$ 463
28	$ -	$ -	$ 1,500	$ 1,000	$ -		$ 250	$ 125	$ 2,875	$ 432
29	$ -	$ -	$ 1,500	$ 1,000	$ -		$ 250	$ 125	$ 2,875	$ 404
30	$ 5,000	$ -	$ 1,500	$ 1,000	$ -	$ 25,000	$ 3,250	$ 1,625	$ 37,375	$ 4,910
TOTAL	$ 30,000	$ -	$ 45,000	$ 30,000	$ -	$ 150,000	$ 25,500	$ 12,750	$ 293,250	$ 110,121

Assumptions:
Includes 50% of the estimated Five-Year Review costs
Assumes annual inspections and maintenance of the existing vapor mitigation system
Assumes vapor monitoring evey 5 years in conjuction with 5-Year Reviews

PV Discount Rate (i)
0.070

PV = non-discounted cost X 1/((1+i)t)

APPENDIX E

Engineering a Sustainable Future

MEMORANDUM

To: File 80036

From: J. Lambert

Subject: REMChlor Modeling Assumptions, Commerce Street Plume Superfund Site

Date: July 21, 2015

Remediation Evaluation Model for Chlorinated Solvents (REMChlor, 2007) was used to estimate contaminant travel times and cleanup estimates for the trichloroethylene (TCE) plume associated with the Commerce Street Plume Superfund Site (Site). Assumptions and data used to develop the model are described below. The model was run assuming TCE sorbed to the fraction of organic carbon (foc) downgradient of the former Mitec Systems property (the original source) is now acting as the "source" of the dissolved-phase plume. The model evaluates two flow lines due to the radial flow from the original source, one extending to the south/southeast (eastern flow line), and one to the west-southwest (western flow line). A site plan depicting the Study Area and the two flow lines is included as Figure E-1.

Several treatment scenarios were evaluated with the REMChlor model using the PRG for TCE (5 µg/L). Refer to Table E-1 for a summary of the time to achieve the PRG under the different scenarios.

<u>Downgradient Sorbed Concentrations</u>

The REMChlor model uses the 1999 downgradient hot spot concentrations as the source for modeling as described above. The calibration curve for the eastern flow line is provided in Attachment E-3 and the calibration curve for the western flow line is provided in Attachment E-4.

Initial Source

For the eastern flow line, the most elevated 1999 concentrations were from ASI-26 (maximum concentration of 58,000 µg/L) and ASI-12 (maximum concentration of 40,000 µg/L), which was approximately 55 meters (m) downgradient of the inferred original source (former Mitec Systems property). The initial source was assumed to be the same width as the 50,000 µg/L contour shown in Figure 4-5 of the RI (43 m). The source depth was assumed to be from 32 feet bgs (two feet above the top of the highest-concentration sample interval) to 44 feet, which is two feet into the top of clay as shown on Figure 4-6 of the RI. Therefore, the thickness of the source would be approximately 4 m. The source was assumed to start halfway between ASI-27 and ASI-26, and was assumed to end at ASI-12. The total length is 79 m. The pore volume (assuming a total porosity of 0.35) would be 13,500 m^3 and the mass in the dissolved phase would be 285 kg. The total mass (dissolved plus sorbed) was assumed to be ten times this, or 2,800 kg. The initial concentration emanating from the source was assumed to be 0.06 g/L based on the 1999

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concentration at ASI-26. The source location was assumed to be the leading edge of the plume (ASI-12).

For the western flow line, the most elevated 1999 concentrations were at ASI-16 (maximum concentration of 11,000 µg/L). The initial source width is assumed to be the same as for the eastern flow line above (43 m) and the length is assumed to be the portion of the plume greater than 5,000 µg/L across the flow line based on Figure 4-5 of the RI, which is 46 m. The source depth, based on concentrations above 5,000 µg/L in samples from ASI-16, is from 25 to 41 feet bgs, or 5 m. Assuming a porosity of 0.35 as described above, the dissolved phase mass would be 38 kg, and the total source mass would be ten times this, or 380 kg. However, a 500-kg source was a better fit for the calibrated data.

Hydrogeology

For the eastern flow line, the effective porosity was assumed to be 0.25; the groundwater velocity was set at 10 m/year; the retardation was set at 3; longitudinal dispersion was set to the travel length divided by 75; alpha y was set to 0.5; and alpha Z set to 0.05. The location of the increased biodegradation zone/2010 apparent plume end was set at the unnamed stream, 150 m from the start of the plume. The biodegradation rate at the unnamed stream was set at 0.365. This value corresponds to the 25% biodegradation value for TCE (Suarez and Rifai, 1999).

For the western flow line, a flow rate of 14 m/year was used to fit the concentrations detected with the same longitudinal, transverse, and vertical dispersivities. In order to account for the observed drop in concentration toward the western portion of Shunpike Road, the biodegradation rate was increased to 0.365 at 240 m along the flow line, similar to described above for the eastern flow line.

Time to Achieve PRGs

Table E-2 provides the maximum extent of the modeled plume exceeding the PRG at given times. This distance is measured from the start of the modeled domain; in order to account for the entire plume, the upgradient portion of the plume would need to be added. In both flow lines the concentrations remained highest closest to the source. Four options were evaluated for the eastern area: no action, source removal (ISCO), enhanced biodegradation only, and source removal (ISCO) plus biodegradation. The input parameters and resulting estimates to complete at varying distances are provided in Attachment E-5 through E-8 for the eastern portion of the plume and in Attachment E-9 and E-10 for the western portion of the plume. ISCO was only included for concentrations above 50,000 µg/L, so only bioremediation was considered for the western portion of the plume.

For the eastern portion of the plume, ISCO remediation was assumed to take 1 year (18-19 years after the start of the model, or 2017-2018) and was assumed to remove 99% of the sorbed mass. The ISCO remediation was also assumed to treat 99% of the downgradient dissolved phase concentrations including the concentrations above 50,000 µg/L, or from 0-116 m along the flow line in Figure E-1.

Plume-wide enhanced biodegradation was evaluated for both the eastern and western portions of the plume. Biodegradation rates increased from 0.02/year to 9.1/year for the plume, with biodegradation rates returning to the original value at the plume boundary (the unnamed stream for the eastern plume and the western edge of detected concentrations for the western plume). These elevated biodegradation rates were assumed to persist for 10 years, then drop to 1/10

(0.9/year) after 10 years. The biodegradation rate was selected as the 75% biodegradation rate (Suarez and Rifai, 1999). In addition, enhanced biodegradation was assumed to remove 95% of the sorbed concentrations (the modeled source) in the western portion of the plume and 80% of the sorbed concentrations in the eastern portion of the plume, due to increased TCE toxicity.

ISCO remediation plus enhanced biodegradation (as a polishing step) was also evaluated only for the eastern portion of the plume. The addition of biodegradation was assumed to increase the sorbed mass removal from 99% to 99.9%; otherwise, input parameters for both ISCO and enhanced bioremediation were used as described above.

Conclusion

Given the uncertainty of TCE initial source emplacement, uncertainty of initial source mass, radial flow from the original source area, and the fact that REMChlor does not take into account back-diffusion or release of sorbed TCE downgradient, the TCE plume appears to be best modeled as a source emanating from the 1999 elevated concentrations (over 50,000 µg/L) downgradient of the former Mitec Systems property.

The primary uncertainty is the extent of biodegradation outside of the unnamed stream, as indicated by the TCE decay rate. The TCE decay rate was conservatively estimated to be double the rate elsewhere (0.2/year). If this rate is higher, the downgradient plume concentrations would be much lower and the overall time to complete could be estimated by the results close to the unnamed stream rather than the current downgradient extent.

References

Falta, R. W., 2007. REMChor Remediation Evaluation Model for Chlorinated Solvents User's Manual, Version 1.0. September.

Suarez, M. P. and Rifai, H.S., 1999. Biodegradation rates for fuel hydrocarbons and chlorinated solvents in groundwater. Bioremediation Journal, 3:4, 337-362.

Table E-1
Time to Achieve PRGs
Commerce Street Plume Superfund Site
Williston, Vermont

Time/maximum distance to achieve PRG = 5 ppb								
	No Action or Limited Action		ISCO only TCE > 50,000 ppb		Bioremediation only TCE > 11,000 ppb		Treatment Train ISCO (eastern) + Bioremediaton (both)	
	Years from 2015	Extent of Plume (m)	Years from 2015	Extent of Plume (m)	Years from 2015	Extent of Plume (m)	Years from 2016	Extent of Plume (m)
Eastern Flow Line	251	950	122	900	215	900	54	900
Western Flow Line	114	800	114	800	74	750	74	750

Notes:

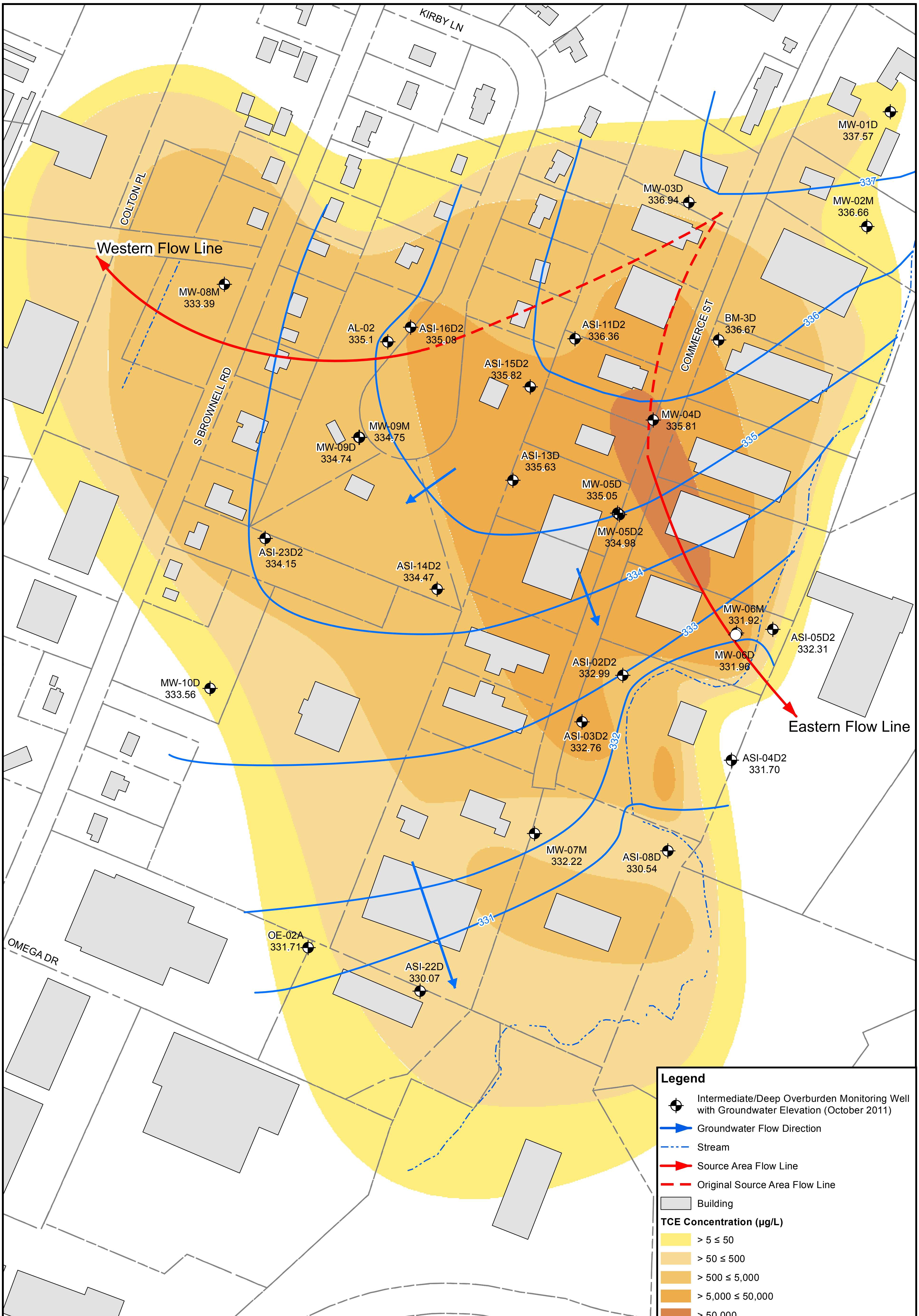
1. "ISCO only" assumes ISCO will be performed in the area of the plume with concentrations above 50,000 µg/L; technology is assumed to remove 99% of the source mass.
2. "ISB only" assumes bioremediation will be performed in the area of the plume with concentrations above 11,000 µg/L; degradation rates increase to 9.1/year from the source to unnamed stream for 10 years, and then 0.9/year thereafter. The model assumes 95% source removal for the western flow line, and 80% source removal over 10 years for the eastern flow line due to the toxicity impact of the higher concentrations.
3. "Treatment train" assumes that ISCO will result in removal of 99% of the source mass, and bioremediation will result in removal of 99.9% of the remaining source mass.
4. Basis for estimates is the RemCHLOR one-dimensional model. The model should be used for comparative purposes only; not predictive of actual remediation time.

Table E-2
Mass Calculation and Reduction Summary
Commerce Street Plume Superfund Site
Williston, Vermont

Eastern Flow Line								
2010	2045 (30 years from 2015)							
Baseline	No Action or Limited Action		ISCO only TCE > 50,000 ppb		Bioremediation only TCE > 11,000 ppb		Treatment Train ISCO (eastern) + Bioremediaton (both)	
	Remaining Mass	Percent Reduction	Remaining Mass	Percent Reduction	Remaining Mass	Percent Reduction	Remaining Mass	Percent Reduction
2,400	1,041	57%	61.7	97%	62.9	97%	0.19	99%
Western Flow Line								
2010	2045 (30 years from 2015)							
Baseline	No Action or Limited Action		ISCO only TCE > 50,000 ppb		Bioremediation only TCE > 11,000 ppb		Treatment Train ISCO (eastern) + Bioremediaton (both)	
	Remaining Mass	Percent Reduction	Remaining Mass	Percent Reduction	Remaining Mass	Percent Reduction	Remaining Mass	Percent Reduction
134	27.9	79%	27.9	79%	0.95	99%	0.95	99%

Note:

1. Mass values are reported in kilograms (Kg).
2. See Attachment E-11 for eastern flow line calculations and Attachment E-12 for western flow line calculations.
3. Baseline contaminant mass developed from groundwater data obtained during the October 2010 groundwater sampling event.



Notes:

1. Location of all features is approximate. Map is for reference purposes only. Nobis Engineering, Inc. makes no claims, warranties, representations, expressed or implied, relating to the completeness, accuracy, or reliability of the data shown.
2. Groundwater contours are based on October 2011 groundwater elevation data and were contoured with the natural neighbor interpolation method. This is one interpretation of the data; other interpretations are possible.

0 100 200 400

Feet

1 inch = 200 feet

N

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FIGURE E-1

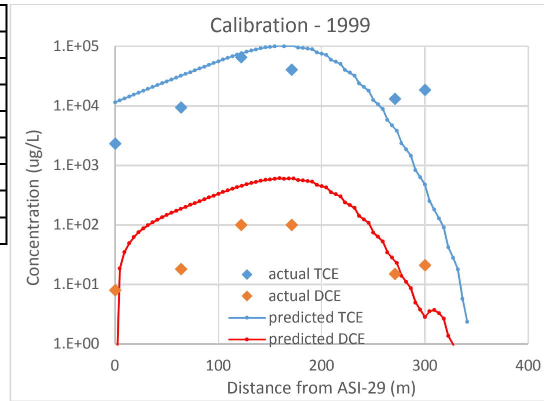
REMCHLOR FLOW LINE LOCATIONS
COMMERCE STREET PLUME
SUPERFUND SITE
WILLISTON, VERMONT

PREPARED BY: JH	CHECKED BY: JL
PROJECT NO. 80036	DATE: JULY 2015

Appendix E-1

Calibration Input Parameters - Eastern Flow Line

Well ID	Dist. from ASI-29 (m)	top/bottom depth (ft bgs)	1999 Concentration (µg/L)		
			TCE	cis 1,2-DCE	VC
ASI-29	0	31 - 36	2300	8	
ASI-27	64	31 - 36	9300	18	
ASI-26	122	35 - 40	65000	100	
ASI-12	171	35 - 40	40000	100	
ASI-06	271	31 - 36	13000	15	
ASI-01	300	31 - 36	18500	21	
ASI-04	365	30.5 - 35.5			



Input parameters:

Initial Source		Component 1: TCE		Yield	0.74
Conc. (g/L)	0.3	time (yr):	Decay Rate	Decay Rate	Decay Rate
Mass (Kg)	5000	50	0.02	0.02	0.2
Gamma	1	time (yr):	0.02	0.02	0.2
Source Dimensions		20	0.02	0.02	0.2
Width (m)	30.5	Component 2: 1,2-DCE		Yield	0.161
Depth (m)	12		Decay Rate	Decay Rate	Decay Rate
Darcy Velocity (m/yr)	10		2.5	2.5	3
Porosity	0.25		2.5	2.5	3
Source Remediation			2.5	2.5	3
Fraction Removed	0	Component 3: VC		Yield	0
Remed. Start (yr)	0		Decay Rate	Decay Rate	Decay Rate
Remed. End (yr)	0		4.5	4.5	5
Source Decay (1/yr)	0		4.5	4.5	5
Transport Parameters			4.5	4.5	5
Retardation Factor	3	Dist. from Source			
SigmaV	0.18	X1 (m)	50	X2 (m)	300
vMin	0	Simulation Parameters			
vMax	1.72		Intervals	Min Value	Max Value
#Stream Tubes	100	x-direction (m)	100	0.01	400
alpha y (m)	0.4	y-direction (m)	1	0	0
alpha z (m)	0.04	z-direction	1	0	0
		Time (yr)	40	0	40

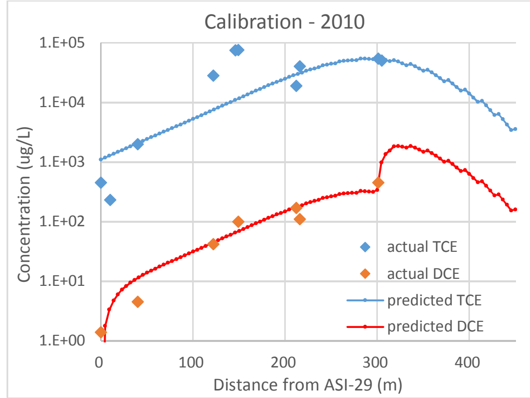
Output results (15 years from start)

Distance	TCE	1,2-DCE	VC	total VOC
0.01	11365.4	0.043564	2.37E-06	11365.5
4.555	12234	18.4785	0.397954	12252.9
9.101	13172.8	34.658	1.3094	13208.8
13.646	14187.8	49.1772	2.46457	14239.5
18.191	15284.8	62.5096	3.71988	15351.1
22.737	16468.1	75.027	5.00233	16548.1
27.282	17740.4	87.0189	6.27798	17833.7
31.827	19104.6	98.7144	7.53441	19210.9
36.373	20564.2	110.301	8.77115	20683.3
40.918	22125.1	121.946	9.99487	22257
45.464	23793.9	133.794	11.2155	23938.9
50.009	25577.2	145.968	12.444	25735.6
54.554	27486.9	158.608	13.6941	27659.2
59.1	29532.5	171.824	14.9778	29719.3
63.645	31717.6	185.682	16.3035	31919.6
68.19	34065.9	200.361	17.6892	34284
72.736	36584.7	215.933	19.1437	36819.8
77.281	39286.7	232.498	20.6776	39539.9
81.826	42142.4	249.897	22.2785	42414.6
86.372	45232	268.626	23.9921	45524.6
90.917	48536.6	288.585	25.8106	48851
95.462	51930.7	309.033	27.6687	52267.5
100.008	55644.8	331.356	29.6913	56005.9
104.553	59582.9	354.986	31.8284	59969.7
109.098	63371.3	377.7	33.8806	63782.9
113.644	67638.7	403.253	36.1858	68078.1
118.189	72086.9	429.869	38.5849	72555.4
122.735	75806.5	452.125	40.5908	76299.2
127.28	80326.8	479.148	43.0239	80848.9
131.825	84904.6	506.506	45.4861	85456.6
136.371	87659.1	522.976	46.9694	88229
140.916	91838.7	547.945	49.2156	92435.9
145.461	95870.4	572.027	51.3816	96493.8
150.007	96411.5	575.274	51.6753	97038.4
154.552	99439.6	593.36	53.3018	100086
159.097	102082	609.139	54.7209	102745
163.643	99210.4	592.014	53.1835	99855.6
168.188	100329	598.7	53.7851	100982
172.733	100888	602.043	54.0861	101544
177.279	94086.3	561.456	50.4403	94698.2
181.824	92963.7	554.761	49.8394	93568.3
186.369	91264.3	544.623	48.9289	91857.8
190.915	89004.8	531.142	47.7181	89583.6
195.46	78144.7	466.335	41.8959	78652.9
200.006	74694.6	445.748	40.0466	75180.4
204.551	70884.7	423.013	38.0042	71345.8
209.096	59006.6	352.13	31.6359	59390.4
213.642	54799.4	327.024	29.3804	55155.8
218.187	50504.7	301.395	27.078	50833.2
222.732	39714.5	237.002	21.2928	39972.8
227.278	35776.9	213.505	19.1818	36009.6

231.823	31973.6	190.808	17.1427	32181.6
236.368	23682.4	141.329	12.6973	23836.4
240.914	20668.8	123.345	11.0816	20803.2
245.459	17890.8	106.767	9.5922	18007.1
250.004	12453.5	74.3183	6.67696	12534.5
254.55	10519.5	62.7773	5.64009	10588
259.095	8811.32	52.5832	4.72423	8868.62
263.641	5753.44	34.3347	3.08473	5790.86
268.186	4700.13	28.0489	2.52	4730.7
272.731	3806.75	22.7175	2.04101	3831.5
277.277	2327.83	13.8918	1.24808	2342.97
281.822	1837.72	10.9669	0.985301	1849.67
286.367	1438.05	8.58187	0.771021	1447.41
290.913	821.845	4.90452	0.440637	827.19
295.458	626.235	3.73718	0.33576	630.308
300.003	472.737	2.82443	0.253481	475.815
304.549	248.021	3.52415	0.183487	251.729
309.094	179.416	3.69349	0.201865	183.312
313.639	128.326	3.27876	0.202917	131.807
318.185	90.6184	2.66729	0.185422	93.4711
322.73	41.9285	1.35702	0.103472	43.389
327.275	27.9241	0.971459	0.080099	28.9756
331.821	17.9344	0.658536	0.057841	18.6508
336.366	5.74595	0.219403	0.020231	5.98558
340.912	2.35861	0.093019	0.008947	2.46058
345.457	0	0	0	0
350.002	0	0	0	0
354.548	0	0	0	0
359.093	0	0	0	0
363.638	0	0	0	0
368.184	0	0	0	0
372.729	0	0	0	0
377.274	0	0	0	0
381.82	0	0	0	0
386.365	0	0	0	0
390.91	0	0	0	0
395.456	0	0	0	0
400.001	0	0	0	0
404.546	0	0	0	0
409.092	0	0	0	0
413.637	0	0	0	0
418.183	0	0	0	0
422.728	0	0	0	0
427.273	0	0	0	0
431.819	0	0	0	0
436.364	0	0	0	0
440.909	0	0	0	0
445.455	0	0	0	0
450	0	0	0	0

Appendix E-1
Calibration Input Parameters - Eastern Flow Line

Well ID	Dist. from ASI-29 (m)	top/bottom depth (ft bgs)	2010 Concentration (µg/L)		
			TCE	cis 1,2-DCE	VC
MW-03D	0	35.2 - 40.2	450	1.4	
VP-1	10	38 - 40	230		
VP-13	40	38 - 40	2000	4.5	
VP-15	122	38 - 40	28000	42	
VP-16	146	38 - 40	75000		
MW-04D	149	34.5 - 39.5	76000	100	
MW-05D	212	28.5 - 33.5	19000	170	
VP-19	216	33 - 35	40000	110	
VP-20	301	33 - 35	54000	450	
MW-06D	305	32.9 - 37.9	50000		
VP-37	330	38 - 40	0		
ASI-04D2	365	30.5 - 35.5	0		



Input parameters:

Initial Source		Component 1: TCE		Yield	0.74
Conc. (g/L)	0.3	time (yr):	Decay Rate	Decay Rate	Decay Rate
Mass (Kg)	5000	50	0.02	0.02	0.2
Gamma	1	time (yr):	0.02	0.02	0.2
Source Dimensions		20	0.02	0.02	0.2
Width (m)	30.5	Component 2: 1,2-DCE		Yield	0.161
Depth (m)	12		Decay Rate	Decay Rate	Decay Rate
Darcy Velocity (m/yr)	10		2.5	2.5	3
Porosity	0.25		2.5	2.5	3
Source Remediation			2.5	2.5	3
Fraction Removed	0	Component 3: VC		Yield	0
Remed. Start (yr)	0		Decay Rate	Decay Rate	Decay Rate
Remed. End (yr)	0		4.5	4.5	5
Source Decay (1/yr)	0		4.5	4.5	5
Transport Parameters			4.5	4.5	5
Retardation Factor	3	Dist. from Source			
SigmaV	0.18	X1 (m)	50	X2 (m)	300
vMin	0	Simulation Parameters			
vMax	1.72		Intervals	Min Value	Max Value
#Stream Tubes	100	x-direction (m)	100	0.01	400
alpha y (m)	0.4	y-direction (m)	1	0	0
alpha z (m)	0.04	z-direction	1	0	0
		Time (yr)	40	0	40

Output results (26 years from start)

Distance	TCE	1,2-DCE	VC	total VOC
0.01	1100.54	0.004218	2.29E-07	1100.55
4.555	1182.59	1.7861	0.038463	1184.42
9.101	1271.11	3.34398	0.126322	1274.58
13.646	1366.64	4.73638	0.237335	1371.61
18.191	1469.69	6.00966	0.357571	1476.06
22.737	1580.63	7.20013	0.47998	1588.31
27.282	1699.67	8.33589	0.601293	1708.61
31.827	1827.07	9.43926	0.720341	1837.23
36.373	1963.09	10.5282	0.837081	1974.46
40.918	2108.23	11.6186	0.952145	2120.8
45.464	2263.09	12.7242	1.0665	2276.88
50.009	2428.53	13.8584	1.18132	2443.57
54.554	2605.22	15.0318	1.29772	2621.55
59.1	2794.22	16.2561	1.41694	2811.89
63.645	2996.61	17.5421	1.54017	3015.69
68.19	3214	18.9028	1.6688	3234.58
72.736	3446.96	20.3445	1.8036	3469.11
77.281	3697.19	21.8796	1.94586	3721.02
81.826	3966.2	23.5188	2.09671	3991.81
86.372	4257.07	25.2823	2.25807	4284.61
90.917	4569.02	27.1664	2.42975	4598.62
95.462	4905.01	29.1897	2.61351	4936.82
100.008	5266.96	31.3647	2.81053	5301.14
104.553	5656.9	33.7038	3.02201	5693.62
109.098	6083.15	36.2575	3.25253	6122.66
113.644	6537.38	38.9763	3.49769	6579.85
118.189	7026.57	41.9023	3.7613	7072.24
122.735	7553	45.0493	4.04463	7602.09
127.28	8136.45	48.5356	4.35834	8189.34
131.825	8749.2	52.196	4.6876	8806.08
136.371	9406.9	56.124	5.04084	9468.07
140.916	10111.6	60.3316	5.41914	10177.3
145.461	10910.1	65.0992	5.8477	10981
150.007	11725.7	69.9681	6.28533	11802
154.552	12594.9	75.1567	6.75164	12676.8
159.097	13518.3	80.6683	7.24695	13606.2
163.643	14602.8	87.1415	7.82863	14697.8
168.188	15659.6	93.4489	8.39539	15761.5
172.733	16772.7	100.092	8.9923	16881.8
177.279	17939.4	107.055	9.61795	18056.1
181.824	19389	115.707	10.3953	19515.1
186.369	20700.7	123.535	11.0986	20835.4
190.915	22058.4	131.638	11.8267	22201.9
195.46	23454.2	139.967	12.575	23606.7
200.006	24878	148.465	13.3385	25039.8
204.551	26874.6	160.38	14.409	27049.4
209.096	28418.9	169.596	15.237	28603.7
213.642	29963.1	178.811	16.065	30158
218.187	31490.2	187.925	16.8838	31695
222.732	33982.9	202.801	18.2204	34204
227.278	35571.7	212.282	19.0722	35803

Appendix E-1
Calibration Input Parameters - Eastern Flow Line

231.823	37096.4	221.381	19.8897	37337.7
236.368	38533.8	229.96	20.6604	38784.4
240.914	41519.7	247.778	22.2613	41789.7
245.459	42918.4	256.126	23.0113	43197.5
250.004	44168.3	263.585	23.6815	44455.6
254.55	45244.4	270.007	24.2584	45538.7
259.095	48655.2	290.362	26.0872	48971.7
263.641	49560.8	295.766	26.5727	49883.1
268.186	50228.7	299.752	26.9308	50555.4
272.731	50639.8	302.205	27.1512	50969.1
277.277	50778.3	303.032	27.2255	51108.6
281.822	54439.5	324.881	29.1885	54793.5
286.367	54238.2	323.679	29.0806	54590.9
290.913	53727.4	320.631	28.8067	54076.8
295.458	52907.7	315.739	28.3672	53251.8
300.003	56585.9	338.3	30.3431	56954.6
304.549	54222	980.167	51.5398	55253.7
309.094	51662	1354.29	85.715	53102
313.639	48936.9	1553.61	116.486	50607
318.185	51183	1828.04	155.736	53166.8
322.73	48165.6	1846.25	171.4	50183.2
327.275	45051.1	1809.04	178.557	47038.7
331.821	41877.1	1735.35	179.025	43791.5
336.366	43724.6	1855.42	198.287	45778.3
340.912	40363.8	1738.53	190.157	42292.5
345.457	37022.4	1611.59	179.319	38813.3
350.002	33736.1	1479.76	166.763	35382.7
354.548	35166.1	1552.25	176.857	36895.2
359.093	31814.2	1409.78	161.741	33385.7
363.638	28588.5	1270.48	146.524	30005.5
368.184	25515	1136.31	131.571	26782.8
372.729	22614.7	1008.76	117.155	23740.6
377.274	23522.8	1050.8	122.382	24696
381.82	20692.2	925.16	107.931	21725.3
386.365	18073.8	808.622	94.4592	18976.8
390.91	15673.9	701.61	82.0416	16457.6
395.456	16278.8	729.051	85.3365	17093.2
400.001	14008.3	627.546	73.498	14709.4
404.546	11966.8	536.209	62.8292	12565.8
409.092	10147.7	454.777	53.3068	10655.8
413.637	10524.3	471.74	55.3164	11051.3
418.183	8853.99	396.912	46.5519	9297.45
422.728	7393.17	331.452	38.881	7763.5
427.273	6126.89	274.7	32.2281	6433.82
431.819	6345.66	284.529	33.3864	6663.57
436.364	5216.51	233.909	27.4489	5477.87
440.909	4255.54	190.825	22.3946	4468.76
445.455	3444.9	154.478	18.13	3617.5
450	3563.33	159.794	18.7552	3741.88

Appendix E-1

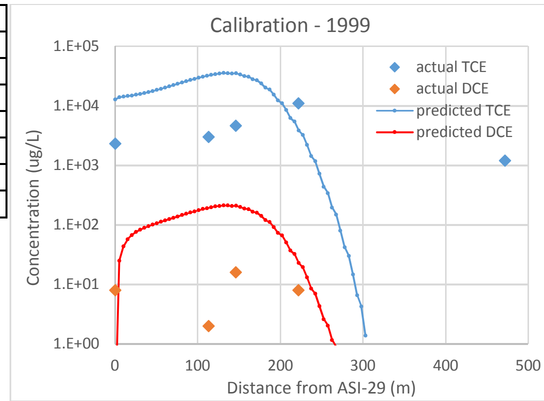
Calibration Input Parameters - Eastern Flow Line

2010 Flow Line						
Sample Location	top depth (ft bgs)	bottom depth (ft bgs)	distance from source (m)	TCE	1,2-DCE	VC
MW-03D	35.2	40.2	0	450	1.4	
VP-01	38	40	10	230		
VP-13	38	40	40	2000	4.5	
VP-15	38	40	122	28000	42	
VP-16	38	40	146	75000		
MW-04D	34.5	39.5	149	76000	100	
MW-05D	28.5	33.5	212	19000	170	
VP-19	33	35	216	40000	110	
VP-20	33	35	301	54000	450	
MW-06D	32.9	37.9	305	50000		
ASI-04D2	30.5	35.5	365			
1999 Flow Line						
Sample Location	top depth (ft bgs)	bottom depth (ft bgs)	distance from source (m)	TCE	1,2-DCE	VC
ASI-29	31	36	0	2300	8	
ASI-27	31	36	64	9300	18	
ASI-26	35	40	122	65000	100	
ASI-12	35	40	171	40000	100	
ASI-06	31	36	271	13000	15	
ASI-01	31	36	300	18500	21	
ASI-04			365			

Appendix E-2

Calibration Input Parameters - Eastern Flow Line

Well ID	Dist. from ASI-29 (m)	top/bottom depth (ft bgs)	1999 Concentration (µg/L)		
			TCE	cis 1,2-DCE	VC
ASI-29	0	31 - 36	2300	8	
ASI-24	113	36.5 - 41.5	3000	2	
ASI-11	146	35 - 40	4595	16	
ASI-16	222	30 - 35	11000	8	
ASI-20	472	25 - 30	1200		
ASI-31	563	25 - 30	3		



Input parameters:

Initial Source		Component 1: TCE		Yield	0.74
Conc. (g/L)	0.3	time (yr):	Decay Rate	Decay Rate	Decay Rate
Mass (Kg)	5000	50	0.02	0.02	0.02
Gamma	1	time (yr):	0.02	0.02	0.02
Source Dimensions		20	0.02	0.02	0.02
Width (m)	30.5	Component 2: 1,2-DCE		Yield	0.161
Depth (m)	12		Decay Rate	Decay Rate	Decay Rate
Darcy Velocity (m/yr)	16		2.5	2.5	2.5
Porosity	0.25		2.5	2.5	2.5
Source Remediation			2.5	2.5	2.5
Fraction Removed	0	Component 3: VC		Yield	0
Remed. Start (yr)	0		Decay Rate	Decay Rate	Decay Rate
Remed. End (yr)	0		4.5	4.5	4.5
Source Decay (1/yr)	0		4.5	4.5	4.5
Transport Parameters			4.5	4.5	4.5
Retardation Factor	3	Dist. from Source			
SigmaV	0.18	X1 (m)	50	X2 (m)	300
vMin	0		Simulation Parameters		
vMax	1.72		Intervals	Min Value	Max Value
#Stream Tubes	100	x-direction (m)	100	0.01	400
alpha y (m)	4	y-direction (m)	1	0	0
alpha z (m)	0.4	z-direction	1	0	0
		Time (yr)	40	0	40

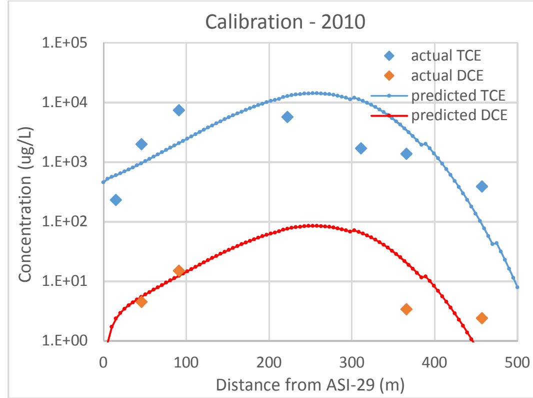
Output results (15 years from start)

Distance	TCE	1,2-DCE	VC	total VOC
0.01	12670.4	0.05396	3.25E-06	12670.5
5.06	13866.7	25.0282	0.645226	13892.4
10.111	14265.8	43.593	1.91934	14311.3
15.161	14511.8	56.9828	3.25024	14572
20.212	14830	67.2432	4.46099	14901.7
25.262	15238.8	75.5705	5.51682	15319.9
30.312	15729.5	82.6845	6.43084	15818.6
35.363	16294.8	89.0599	7.23136	16391.1
40.413	16930.3	95.0202	7.94824	17033.3
45.464	17634.3	100.796	8.60839	17743.7
50.514	18407.9	106.562	9.23489	18523.7
55.564	19248.3	112.421	9.84385	19370.6
60.615	20155.9	118.458	10.4488	20284.8
65.665	21138.5	124.781	11.0642	21274.3
70.716	22179.8	131.337	11.6889	22322.9
75.766	23303.4	138.296	12.341	23454
80.816	24466.6	145.427	13.002	24625
85.867	25669.3	152.747	13.6749	25835.7
90.917	26976.8	160.656	14.3971	27151.8
95.968	28230.7	168.22	15.0855	28414
101.018	29447.5	175.542	15.7499	29638.8
106.068	30832.7	183.854	16.5018	31033
111.119	31920.6	190.381	17.0921	32128.1
116.169	32815.8	195.75	17.5773	33029.1
121.22	34045.6	203.109	18.2408	34267
126.27	34506.8	205.877	18.4911	34731.2
131.321	35492.5	211.771	19.022	35723.3
136.371	35306.6	210.671	18.9241	35536.2
141.421	34609.8	206.519	18.5519	34834.9
146.472	34908.1	208.305	18.7129	35135.2
151.522	33339	198.945	17.8724	33555.8
156.573	31231.9	186.373	16.7433	31435
161.623	30704.6	183.229	16.4611	30904.3
166.673	27843	166.154	14.9272	28024.1
171.724	26886.5	160.447	14.4146	27061.4
176.774	23522.8	140.375	12.6114	23675.8
181.825	20069.7	119.768	10.7601	20200.2
186.875	18751.4	111.901	10.0534	18873.3
191.925	15367.3	91.7067	8.2391	15467.3
196.976	12250.1	73.1043	6.56783	12329.8
202.026	11039	65.8771	5.91855	11110.8
207.077	8424.49	50.2746	4.51678	8479.28
212.127	6241.6	37.2478	3.34643	6282.2
217.177	5412.26	32.2987	2.90179	5447.46
222.228	3829.42	22.8528	2.05315	3854.33
227.278	3241.8	19.346	1.7381	3262.88
232.329	2187.94	13.057	1.17307	2202.17
237.379	1430.5	8.53678	0.766968	1439.8
242.429	1162.36	6.93659	0.623203	1169.92
247.48	723.691	4.31877	0.388011	728.398
252.53	435.982	2.60181	0.233754	438.818

257.581	339.571	2.02646	0.182063	341.78
262.631	194.409	1.16018	0.104234	195.674
267.681	147.455	0.879967	0.079059	148.414
272.732	80.0123	0.47749	0.042899	80.5327
277.782	41.7561	0.249188	0.022388	42.0277
282.833	30.111	0.179694	0.016144	30.3069
287.883	14.5967	0.087109	0.007826	14.6917
292.933	6.5469	0.03907	0.00351	6.58948
297.984	4.23399	0.025267	0.00227	4.26153
303.034	1.37047	0.008179	0.000735	1.37938
308.085	0	0	0	0
313.135	0	0	0	0
318.185	0	0	0	0
323.236	0	0	0	0
328.286	0	0	0	0
333.337	0	0	0	0
338.387	0	0	0	0
343.437	0	0	0	0
348.488	0	0	0	0
353.538	0	0	0	0
358.589	0	0	0	0
363.639	0	0	0	0
368.689	0	0	0	0
373.74	0	0	0	0
378.79	0	0	0	0
383.841	0	0	0	0
388.891	0	0	0	0
393.942	0	0	0	0
398.992	0	0	0	0
404.042	0	0	0	0
409.093	0	0	0	0
414.143	0	0	0	0
419.194	0	0	0	0
424.244	0	0	0	0
429.294	0	0	0	0
434.345	0	0	0	0
439.395	0	0	0	0
444.446	0	0	0	0
449.496	0	0	0	0
454.546	0	0	0	0
459.597	0	0	0	0
464.647	0	0	0	0
469.698	0	0	0	0
474.748	0	0	0	0
479.798	0	0	0	0
484.849	0	0	0	0
489.899	0	0	0	0
494.95	0	0	0	0
500	0	0	0	0

Appendix E-2
Calibration Input Parameters - Eastern Flow Line

Well ID	Dist. from ASI-29 (m)	top/bottom depth (ft bgs)	2010 Concentration (µg/L)		
			TCE	cis 1,2-DCE	VC
VP-01	15	38 - 40	230		
VP-13	46	38 - 40	2000	4.5	
VP-14	91	38 - 40	7400	15	
VP-26	222	33 - 35	5700		
VP-48	311	28 - 30	1700		
VP-47	366	33 - 35	1370	3.4	
VP-49	457	33 - 35	390	2.4	



Input parameters:

Initial Source		Component 1: TCE		Yield	0.74
Conc. (g/L)	0.3	time (yr):	Decay Rate	Decay Rate	Decay Rate
Mass (Kg)	5000	50	0.02	0.02	0.02
Gamma	0.9	time (yr):	0.02	0.02	0.02
Source Dimensions		20	0.02	0.02	0.02
Width (m)	30.5	Component 2: 1,2-DCE		Yield	0.161
Depth (m)	12		Decay Rate	Decay Rate	Decay Rate
Darcy Velocity (m/yr)	9		2.5	2.5	2.5
Porosity	0.25		2.5	2.5	2.5
Source Remediation			2.5	2.5	2.5
Fraction Removed	0	Component 3: VC		Yield	0
Remed. Start (yr)	0		Decay Rate	Decay Rate	Decay Rate
Remed. End (yr)	0		4.5	4.5	4.5
Source Decay (1/yr)	0		4.5	4.5	4.5
Transport Parameters			4.5	4.5	4.5
Retardation Factor	3	Dist. from Source			
SigmaV	0.18	X1 (m)	50	X2 (m)	300
vMin	0	Simulation Parameters			
vMax	1.72		Intervals	Min Value	Max Value
#Stream Tubes	100	x-direction (m)	100	0.01	500
alpha y (m)	4	y-direction (m)	1	0	0
alpha z (m)	0.4	z-direction	1	0	0
		Time (yr)	30	0	30

Output results (26 years from start)

Distance	TCE	1,2-DCE	VC	total VOC
0.01	455.037	0.001938	1.17E-07	455.039
5.06	522.913	0.945349	0.024418	523.883
10.111	564.326	1.72886	0.076345	566.132
15.161	601.623	2.36943	0.135614	604.128
20.212	643.743	2.92793	0.194929	646.866
25.262	691.989	3.44182	0.252116	695.683
30.312	746.553	3.93508	0.307012	750.795
35.363	807.646	4.42488	0.360288	812.431
40.413	875.613	4.92455	0.412929	880.951
45.464	950.988	5.44535	0.466018	956.899
50.514	1034.21	5.99578	0.520507	1040.73
55.564	1125.96	6.58417	0.577352	1133.12
60.615	1226.92	7.21779	0.637407	1234.77
65.665	1337.82	7.90343	0.701453	1346.42
70.716	1459.46	8.64758	0.770217	1468.87
75.766	1592.67	9.45657	0.844385	1602.97
80.816	1738.34	10.3367	0.924611	1749.6
85.867	1897.38	11.2941	1.01153	1909.69
90.917	2070.74	12.3351	1.10576	2084.19
95.968	2259.4	13.466	1.2079	2274.07
101.018	2464.31	14.6927	1.31853	2480.32
106.068	2686.45	16.0214	1.43823	2703.91
111.119	2926.74	17.4577	1.56754	2945.77
116.169	3186.07	19.0071	1.70694	3206.78
121.22	3465.21	20.6744	1.85689	3487.74
126.27	3764.84	22.4636	2.01776	3789.32
131.321	4100.48	24.4675	2.1979	4127.15
136.371	4446.89	26.5354	2.38376	4475.81
141.421	4815.77	28.7373	2.58165	4847.09
146.472	5207.09	31.073	2.79154	5240.95
151.522	5620.44	33.5401	3.01323	5656.99
156.573	6055.04	36.1339	3.2463	6094.42
161.623	6509.62	38.847	3.49008	6551.96
166.673	6982.42	41.6687	3.74361	7027.83
171.724	7471.08	44.585	4.00563	7519.67
176.774	7972.61	47.5781	4.27456	8024.47
181.825	8483.41	50.6265	4.54844	8538.58
186.875	8999.15	53.7044	4.82498	9057.68
191.925	9514.89	56.7822	5.10151	9576.77
196.976	10025	59.8266	5.37503	10090.2
202.026	10523.3	62.8005	5.64221	10591.8
207.077	11003.2	65.664	5.89949	11074.7
212.127	11457.4	68.3748	6.14304	11531.9
217.177	12300.4	73.4057	6.59504	12380.4
222.228	12740.2	76.0301	6.83082	12823
227.278	13135.9	78.3914	7.04297	13221.3
232.329	13479.8	80.4439	7.22738	13567.5
237.379	13764.7	82.1441	7.38013	13854.2
242.429	13983.9	83.452	7.49764	14074.8
247.48	14131.4	84.3326	7.57675	14223.3
252.53	14202.5	84.7571	7.61489	14294.9

257.581	14193.7	84.7042	7.61014	14286
262.631	14102.7	84.1611	7.56135	14194.4
267.681	13928.9	83.1243	7.4682	14019.5
272.732	13673.5	81.6	7.33125	13762.4
277.782	13339	79.604	7.15192	13425.8
282.833	12929.8	77.162	6.93252	13013.9
287.883	12451.7	74.3087	6.67617	12532.7
292.933	11911.9	71.0869	6.38671	11989.3
297.984	11318.6	67.5465	6.06863	11392.2
303.034	11969.4	71.4302	6.41756	12047.2
308.085	11286.4	67.3541	6.05135	11359.8
313.135	10568.5	63.07	5.66644	10637.2
318.185	9826.59	58.6425	5.26867	9890.5
323.236	9071.6	54.137	4.86387	9130.6
328.286	8314.13	49.6166	4.45774	8368.21
333.337	7564.23	45.1414	4.05567	7613.43
338.387	6831.13	40.7664	3.66261	6875.56
343.437	6123.04	36.5407	3.28295	6162.86
348.488	5446.99	32.5062	2.92048	5482.42
353.538	4808.74	28.6973	2.57828	4840.02
358.589	4212.73	25.1405	2.25872	4240.13
363.639	3662.07	21.8543	1.96347	3685.89
368.689	3158.61	18.8497	1.69353	3179.15
373.74	2702.99	16.1308	1.44925	2720.57
378.79	2294.84	13.695	1.23041	2309.77
383.841	1932.85	11.5347	1.03632	1945.42
388.891	2021.35	12.0629	1.08377	2034.49
393.942	1687.95	10.0732	0.905018	1698.93
398.992	1398.23	8.34429	0.749682	1407.33
404.042	1148.9	6.85631	0.615997	1156.37
409.093	936.364	5.58798	0.502045	942.454
414.143	756.926	4.51714	0.405836	761.848
419.194	606.858	3.62157	0.325376	610.805
424.244	482.535	2.87964	0.258718	485.673
429.294	380.502	2.27074	0.204012	382.977
434.345	297.545	1.77567	0.159533	299.48
439.395	230.722	1.37689	0.123705	232.223
444.446	177.395	1.05865	0.095113	178.549
449.496	135.23	0.807018	0.072506	136.109
454.546	102.198	0.609889	0.054795	102.862
459.597	76.5569	0.456872	0.041047	77.0548
464.647	56.8359	0.339182	0.030473	57.2056
469.698	41.806	0.249487	0.022415	42.0779
474.748	43.3824	0.258895	0.02326	43.6645
479.798	31.5913	0.188529	0.016938	31.7968
484.849	22.7707	0.13589	0.012209	22.9188
489.899	16.2313	0.096864	0.008703	16.3368
494.95	11.4259	0.068187	0.006126	11.5002
500	7.92547	0.047297	0.004249	7.97702

Appendix E-2

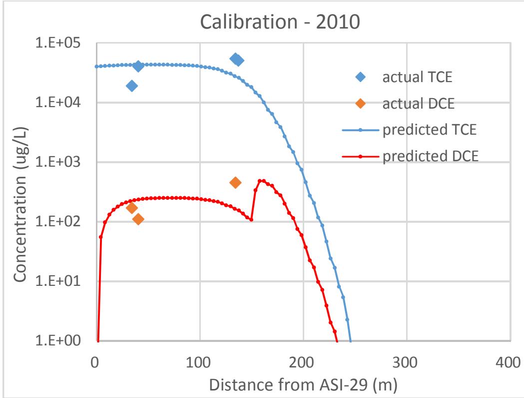
Calibration Input Parameters - Western Flow Line

2010 Flow Line						
Sample Location	top depth (ft bgs)	bottom depth (ft bgs)	distance from source (m)	TCE	1,2-DCE	VC
VP-01	38	40	15	230		
VP-13	38	40	46	2000	4.5	
VP-14	38	40	91	7400	15	
VP-26	33	35	222	5700		
VP-48	28	30	311	1700		
VP-47	33	35	366	1370	3.4	
VP-49	33	35	457	390	2.4	
1999 Flow Line						
Sample Location	top depth (ft bgs)	bottom depth (ft bgs)	distance from source (m)	TCE	1,2-DCE	VC
ASI-29	31	36	0	2300	8	
ASI-24	36.5	41.5	113	3000	2	
ASI-11	35	40	146	4595	16	
ASI-16	30	35	222	11000	8	
ASI-20	25	30	472	1200		
ASI-31	25	30	563	3		

Appendix E-3

Calibration Input Parameters - Eastern Flow Line

Well ID	Dist. from ASI-12 (m)	top/bottom depth (ft bgs)	2010 Concentration (µg/L) TCE	cis 1,2-DCE	VC
MW-05D	34	28.5 - 33.5	19000	170	
VP-19	40	33 - 35	40000	110	
VP-20	134	33 - 35	54000	450	
MW-06D	137	32.9 - 37.9	50000		
VP-37	183	38 - 40	0		
ASI-04D2	213	30.5 - 35.5	0		



Input parameters:

Initial Source		Component 1: TCE		Yield	0.74
Conc. (g/L)	0.06	time (yr):	Decay Rate	Decay Rate	Decay Rate
Mass (Kg)	2800	50	0.02	0.02	0.365
Gamma	1	time (yr):	0.02	0.02	0.365
Source Dimensions		20	0.02	0.02	0.365
Width (m)	43	Component 2: 1,2-DCE		Yield	0.161
Depth (m)	4		Decay Rate	Decay Rate	Decay Rate
Darcy Velocity (m/yr)	10		2.5	2.5	3
Porosity	0.25		2.5	2.5	3
Source Remediation			2.5	2.5	3
Fraction Removed	0	Component 3: VC		Yield	0
Remed. Start (yr)	0		Decay Rate	Decay Rate	Decay Rate
Remed. End (yr)	0		4.5	4.5	5
Source Decay (1/yr)	0		4.5	4.5	5
Transport Parameters			4.5	4.5	5
Retardation Factor	3	Dist. from Source			
SigmaV	0.18	X1 (m)	50	X2 (m)	150
vMin	0		Simulation Parameters		
vMax	1.72		Intervals	Min Value	Max Value
#Stream Tubes	100	x-direction (m)	100	0.01	400
alpha y (m)	0.4	y-direction (m)	1	0	0
alpha z (m)	0.04	z-direction	1	0	0
		Time (yr)	20	0	20

Output results (11 years from start)

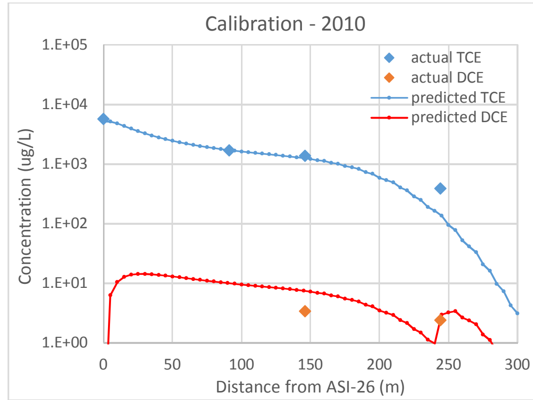
Distance	TCE	1,2-DCE	VC	total VOC
0.01	39871.8	0.152827	8.3E-06	39872
4.05	40254.5	54.8075	1.06274	40310.4
8.091	40641	97.6032	3.35876	40742
12.131	41029.5	131.32	6.05946	41166.9
16.171	41407.9	158.017	8.74411	41574.6
20.212	41755.1	179.186	11.2103	41945.5
24.252	42054.4	195.939	13.3736	42263.7
28.292	42298.8	209.144	15.214	42523.1
32.332	42488.5	219.503	16.746	42724.8
36.373	42628.6	227.587	18.0008	42874.2
40.413	42724.6	233.854	19.0154	42977.5
44.453	42782.6	238.674	19.8266	43041.1
48.494	42809.7	242.353	20.4696	43072.6
52.534	42807	245.102	20.9722	43073.1
56.574	42783.6	247.139	21.3627	43052.1
60.615	42732.2	248.545	21.6567	43002.4
64.655	42653.8	249.427	21.8709	42925.1
68.695	42569.1	249.986	22.0294	42841.2
72.735	42433	250.014	22.1185	42705.1
76.776	42304.7	249.912	22.1786	42576.8
80.816	42083.1	249.114	22.1623	42354.3
84.856	41778.8	247.714	22.0806	42048.6
88.897	41535.1	246.589	22.0147	41803.7
92.937	41042.4	243.909	21.8021	41308.1
96.977	40679	241.947	21.6482	40942.6
101.018	39902.6	237.479	21.2647	40161.4
105.058	38878	231.495	20.7414	39130.2
109.098	38202.4	227.568	20.3999	38450.4
113.138	36721.9	218.816	19.6228	36960.4
117.179	35799.8	213.379	19.1415	36032.3
121.219	33801.3	201.506	18.0807	34020.9
125.259	31456.4	187.555	16.832	31660.7
129.3	30113.2	179.573	16.1186	30308.9
133.34	27318.9	162.925	14.626	27496.5
137.38	25791.6	153.832	13.8114	25959.2
141.421	22713	135.478	12.1644	22860.6
145.461	19567.9	116.723	10.481	19695.1
149.501	17972.4	107.213	9.62777	18089.2
153.542	14552.9	333.752	13.5229	14900.2
157.582	12739.8	479.873	23.6773	13243.4
161.622	9908.39	479.856	29.021	10417.3
165.662	7508.46	423.969	29.837	7962.26
169.703	6368.34	400.23	31.6747	6800.24
173.743	4633.73	312.581	26.8825	4973.19
177.783	3850.73	274.467	25.2734	4150.47
181.824	2685	198.705	19.2092	2902.91
185.864	1817.69	138.399	13.9001	1969.99
189.904	1456.98	113.684	11.8132	1582.48
193.945	942.652	74.7993	7.96179	1025.41
197.985	738.683	59.5158	6.47885	804.677
202.025	456.099	37.1319	4.10593	497.337

206.065	272.713	22.3891	2.50785	297.61
210.106	205.433	17.0041	1.92928	224.366
214.146	116.897	9.72892	1.11354	127.739
218.186	85.8766	7.18719	0.830118	93.8939
222.227	46.3503	3.8935	0.452447	50.6962
226.267	24.0512	2.02666	0.236743	26.3146
230.307	16.8169	1.42183	0.167037	18.4058
234.348	8.09515	0.685954	0.080895	8.862
238.388	5.39698	0.45844	0.054294	5.90971
242.428	2.25131	0.191553	0.022753	2.46561
246.468	0.717626	0.061152	0.007283	0.786061
250.509	0.285829	0.024396	0.002914	0.313139
254.549	0	0	0	0
258.589	0	0	0	0
262.63	0	0	0	0
266.67	0	0	0	0
270.71	0	0	0	0
274.751	0	0	0	0
278.791	0	0	0	0
282.831	0	0	0	0
286.872	0	0	0	0
290.912	0	0	0	0
294.952	0	0	0	0
298.992	0	0	0	0
303.033	0	0	0	0
307.073	0	0	0	0
311.113	0	0	0	0
315.154	0	0	0	0
319.194	0	0	0	0
323.234	0	0	0	0
327.275	0	0	0	0
331.315	0	0	0	0
335.355	0	0	0	0
339.395	0	0	0	0
343.436	0	0	0	0
347.476	0	0	0	0
351.516	0	0	0	0
355.557	0	0	0	0
359.597	0	0	0	0
363.637	0	0	0	0
367.678	0	0	0	0
371.718	0	0	0	0
375.758	0	0	0	0
379.798	0	0	0	0
383.839	0	0	0	0
387.879	0	0	0	0
391.919	0	0	0	0
395.96	0	0	0	0
400	0	0	0	0

Appendix E-4

Calibration Input Parameters - Western Flow Line

Well ID	Dist. from ASI-29 (m)	top/bottom depth (ft bgs)	2010 Concentration (µg/L) TCE	cis 1,2-DCE	VC
VP-26	0	33 - 35	5700		
VP-48	91	28 - 30	1700		
VP-47	146	33 - 35	1370	3.4	
VP-49	244	33 - 35	390	2.4	



Input parameters:

Initial Source		Component 1: TCE		Yield	0.74
Conc. (g/L)	0.01	time (yr):	Decay Rate	Decay Rate	Decay Rate
Mass (Kg)	500	50	0.02	0.02	0.365
Gamma	0.9	time (yr):	0.02	0.02	0.365
Source Dimensions		20	0.02	0.02	0.365
Width (m)	43	Component 2: 1,2-DCE		Yield	0.161
Depth (m)	5		Decay Rate	Decay Rate	Decay Rate
Darcy Velocity (m/yr)	14		2.5	2.5	2.5
Porosity	0.25		2.5	2.5	2.5
Source Remediation			2.5	2.5	2.5
Fraction Removed	0	Component 3: VC		Yield	0
Remed. Start (yr)	0		Decay Rate	Decay Rate	Decay Rate
Remed. End (yr)	0		4.5	4.5	4.5
Source Decay (1/yr)	0		4.5	4.5	4.5
Transport Parameters			4.5	4.5	4.5
Retardation Factor	3	Dist. from Source			
SigmaV	0.18	X1 (m)	50	X2 (m)	240
vMin	0	Simulation Parameters			
vMax	1.72		Intervals	Min Value	Max Value
#Stream Tubes	100	x-direction (m)	61	0.01	500
alpha y (m)	4	y-direction (m)	1	0	0
alpha z (m)	0.4	z-direction	1	0	0
		Time (yr)	20	0	20

Output results (26 years from start)

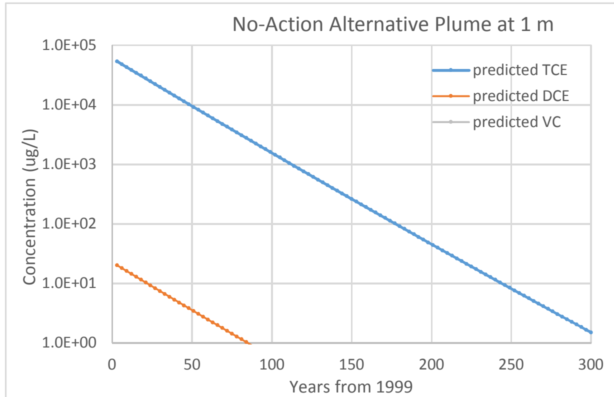
Distance	TCE	1,2-DCE	VC	total VOC
0.01	5.13E+03	1.41E-02	5.45E-07	5.13E+03
5.01	5.14E+03	6.28E+00	1.09E-01	5.15E+03
10.01	4.80E+03	1.05E+01	3.28E-01	4.81E+03
15.009	4.34E+03	1.28E+01	5.42E-01	4.36E+03
20.009	3.91E+03	1.39E+01	7.14E-01	3.93E+03
25.009	3.55E+03	1.43E+01	8.39E-01	3.57E+03
30.009	3.25E+03	1.43E+01	9.24E-01	3.26E+03
35.009	2.99E+03	1.41E+01	9.78E-01	3.01E+03
40.009	2.78E+03	1.38E+01	1.01E+00	2.79E+03
45.008	2.60E+03	1.34E+01	1.02E+00	2.61E+03
50.008	2.44E+03	1.30E+01	1.02E+00	2.46E+03
55.008	2.31E+03	1.26E+01	1.02E+00	2.32E+03
60.008	2.19E+03	1.21E+01	1.00E+00	2.20E+03
65.008	2.09E+03	1.18E+01	9.85E-01	2.10E+03
70.008	2.00E+03	1.14E+01	9.66E-01	2.01E+03
75.008	1.92E+03	1.10E+01	9.46E-01	1.93E+03
80.007	1.85E+03	1.07E+01	9.25E-01	1.86E+03
85.007	1.78E+03	1.04E+01	9.04E-01	1.79E+03
90.007	1.72E+03	1.01E+01	8.83E-01	1.73E+03
95.007	1.67E+03	9.80E+00	8.63E-01	1.68E+03
100.007	1.62E+03	9.54E+00	8.43E-01	1.63E+03
105.007	1.57E+03	9.29E+00	8.23E-01	1.58E+03
110.006	1.53E+03	9.06E+00	8.05E-01	1.54E+03
115.006	1.49E+03	8.82E+00	7.86E-01	1.50E+03
120.006	1.45E+03	8.61E+00	7.68E-01	1.46E+03
125.006	1.42E+03	8.41E+00	7.51E-01	1.43E+03
130.006	1.37E+03	8.17E+00	7.30E-01	1.38E+03
135.005	1.34E+03	7.96E+00	7.13E-01	1.35E+03
140.005	1.29E+03	7.69E+00	6.88E-01	1.30E+03
145.005	1.26E+03	7.48E+00	6.70E-01	1.26E+03
150.005	1.22E+03	7.26E+00	6.51E-01	1.23E+03
155.005	1.16E+03	6.92E+00	6.20E-01	1.17E+03
160.005	1.12E+03	6.68E+00	5.99E-01	1.13E+03
165.004	1.05E+03	6.26E+00	5.62E-01	1.06E+03
170.004	1.01E+03	6.00E+00	5.38E-01	1.01E+03
175.004	9.24E+02	5.51E+00	4.95E-01	9.30E+02
180.004	8.76E+02	5.22E+00	4.69E-01	8.81E+02
185.004	8.26E+02	4.93E+00	4.42E-01	8.31E+02
190.004	7.33E+02	4.37E+00	3.93E-01	7.38E+02
195.003	6.82E+02	4.07E+00	3.65E-01	6.87E+02
200.003	5.88E+02	3.51E+00	3.15E-01	5.92E+02
205.003	5.38E+02	3.21E+00	2.88E-01	5.42E+02
210.003	4.90E+02	2.92E+00	2.63E-01	4.93E+02
215.003	4.03E+02	2.41E+00	2.16E-01	4.06E+02
220.003	3.61E+02	2.15E+00	1.93E-01	3.63E+02
225.002	2.85E+02	1.70E+00	1.53E-01	2.87E+02
230.002	2.50E+02	1.49E+00	1.34E-01	2.52E+02
235.002	1.90E+02	1.13E+00	1.02E-01	1.91E+02
240.002	1.63E+02	9.75E-01	8.75E-02	1.64E+02
245.002	1.36E+02	2.96E+00	1.20E-01	1.39E+02
250.002	9.53E+01	3.24E+00	1.49E-01	9.87E+01

255.001	7.77E+01	3.40E+00	1.88E-01	8.13E+01
260.001	5.21E+01	2.67E+00	1.70E-01	5.50E+01
265.001	4.16E+01	2.39E+00	1.71E-01	4.42E+01
270.001	3.30E+01	2.06E+00	1.62E-01	3.52E+01
275.001	2.08E+01	1.38E+00	1.16E-01	2.23E+01
280.001	1.61E+01	1.12E+00	1.00E-01	1.74E+01
285	9.73E+00	7.00E-01	6.52E-02	1.05E+01
290	7.36E+00	5.46E-01	5.30E-02	7.96E+00
295	4.23E+00	3.21E-01	3.20E-02	4.58E+00
300	3.12E+00	2.42E-01	2.48E-02	3.39E+00

Appendix E-5
No-Action Alternative - Eastern Flow Line

Eastern Plume
No-Action Alternative

Residential PRG:		
	PRG	PRG
TCE	2.8	5
Time Achieved (yrs)	282	267
Date Achieved	2281	2266
Time from 2015 (yrs)	266	251



Input parameters:

Initial Source		Component 1: TCE		Yield	0.74
Conc. (g/L)	0.06	time (yr):	Decay Rate	Decay Rate	Decay Rate
Mass (Kg)	2800	50	0.02	0.02	0.365
Gamma	1	time (yr):	0.02	0.02	0.365
Source Dimensions		20	0.02	0.02	0.365
Width (m)	43	Component 2: 1,2-DCE		Yield	0.161
Depth (m)	4		Decay Rate	Decay Rate	Decay Rate
Darcy Velocity (m/yr)	10		2.5	2.5	3
Porosity	0.25		2.5	2.5	3
Source Remediation			2.5	2.5	3
Fraction Removed	0	Component 3: VC		Yield	0
Remed. Start (yr)	0		Decay Rate	Decay Rate	Decay Rate
Remed. End (yr)	0		4.5	4.5	5
Source Decay (1/yr)	0		4.5	4.5	5
Transport Parameters			4.5	4.5	5
Retardation Factor	3	Dist. from Source			
SigmaV	0.18	X1 (m)	50	X2 (m)	150
vMin	0		Simulation Parameters		
vMax	1.72		Intervals	Min Value	Max Value
#Stream Tubes	100	x-direction (m)	11	0.01	10
alpha y (m)	0.4	y-direction (m)	1	0	0
alpha z (m)	0.04	z-direction	1	0	0
		Time (yr)	100	0	300

Output results (1 meter from start)

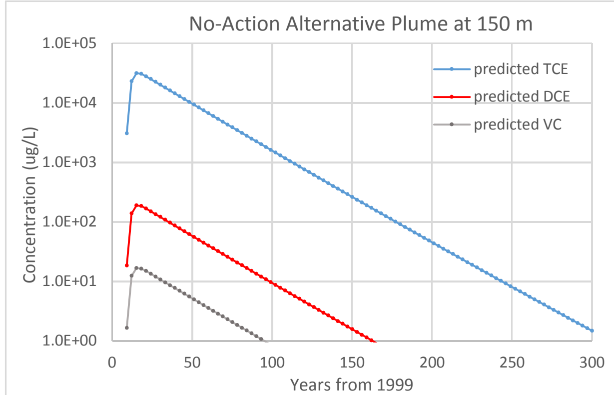
Years	TCE	1,2-DCE	VC	total VOC
3	53790	20.1256	0.10678	53810.2
6	48114.8	18.0022	0.095514	48132.9
9	43043.6	16.1048	0.085447	43059.8
12	38511.7	14.4092	0.076451	38526.1
15	34461.1	12.8937	0.06841	34474
18	30840.3	11.5389	0.061222	30851.9
21	27603.3	10.3278	0.054796	27613.7
24	24709.1	9.24494	0.049051	24718.4
27	22121	8.2766	0.043913	22129.3
30	19806.4	7.41059	0.039318	19813.8
33	17736.1	6.63599	0.035209	17742.8
36	15884.2	5.94308	0.031532	15890.1
39	14227.3	5.32316	0.028243	14232.6
42	12744.8	4.76847	0.0253	12749.6
45	11418.1	4.27209	0.022666	11422.4
48	10230.8	3.82785	0.020309	10234.6
51	9167.97	3.43021	0.0182	9171.42
54	8216.57	3.07424	0.016311	8219.66
57	7364.77	2.75554	0.01462	7367.54
60	6602.06	2.47017	0.013106	6604.55
63	5919.04	2.21461	0.01175	5921.27
66	5307.3	1.98573	0.010536	5309.3
69	4759.35	1.78072	0.009448	4761.14
72	4268.48	1.59705	0.008473	4270.08
75	3828.68	1.4325	0.0076	3830.12
78	3434.59	1.28506	0.006818	3435.89
81	3081.43	1.15292	0.006117	3082.59
84	2764.91	1.03449	0.005489	2765.95
87	2481.18	0.928336	0.004925	2482.12
90	2226.83	0.833171	0.004421	2227.67
93	1998.79	0.747847	0.003968	1999.54
96	1794.3	0.671339	0.003562	1794.98
99	1610.92	0.602727	0.003198	1611.53
102	1446.45	0.54119	0.002871	1447
105	1298.92	0.485991	0.002579	1299.41
108	1166.57	0.436473	0.002316	1167.01
111	1047.83	0.392044	0.00208	1048.22
114	941.276	0.352178	0.001869	941.63
117	845.657	0.316402	0.001679	845.975
120	759.837	0.284293	0.001508	760.123
123	682.804	0.255471	0.001355	683.061
126	613.65	0.229597	0.001218	613.88
129	551.562	0.206367	0.001095	551.769
132	495.811	0.185508	0.000984	495.998
135	445.746	0.166776	0.000885	445.914
138	400.782	0.149952	0.000796	400.932
141	360.393	0.134841	0.000715	360.528
144	324.11	0.121266	0.000643	324.232
147	291.513	0.10907	0.000579	291.623
150	262.224	0.098111	0.000521	262.322
153	235.903	0.088263	0.000468	235.992

156	212.248	0.079412	0.000421	212.328
159	190.986	0.071457	0.000379	191.058
162	171.873	0.064306	0.000341	171.937
165	154.689	0.057877	0.000307	154.747
168	139.239	0.052096	0.000276	139.291
171	125.346	0.046898	0.000249	125.393
174	112.851	0.042223	0.000224	112.894
177	101.613	0.038018	0.000202	101.651
180	91.5039	0.034236	0.000182	91.5383
183	82.4095	0.030834	0.000164	82.4405
186	74.2271	0.027772	0.000147	74.255
189	66.8643	0.025017	0.000133	66.8894
192	60.2383	0.022538	0.00012	60.261
195	54.2748	0.020307	0.000108	54.2952
198	48.907	0.018299	9.71E-05	48.9254
201	44.0747	0.016491	8.75E-05	44.0913
204	39.7242	0.014863	7.89E-05	39.7391
207	35.8069	0.013397	7.11E-05	35.8203
210	32.2793	0.012077	6.41E-05	32.2915
213	29.1024	0.010889	5.78E-05	29.1133
216	26.2409	0.009818	5.21E-05	26.2508
219	23.6633	0.008854	4.7E-05	23.6722
222	21.3411	0.007985	4.24E-05	21.3492
225	19.2489	0.007202	3.82E-05	19.2561
228	17.3636	0.006497	3.45E-05	17.3701
231	15.6646	0.005861	3.11E-05	15.6705
234	14.1333	0.005288	2.81E-05	14.1386
237	12.753	0.004772	2.53E-05	12.7578
240	11.5088	0.004306	2.28E-05	11.5131
243	10.387	0.003886	2.06E-05	10.3909
246	9.37555	0.003508	1.86E-05	9.37908
249	8.46346	0.003167	1.68E-05	8.46665
252	7.6409	0.002859	1.52E-05	7.64377
255	6.89899	0.002581	1.37E-05	6.90159
258	6.22976	0.002331	1.24E-05	6.23211
261	5.62603	0.002105	1.12E-05	5.62815
264	5.08133	0.001901	1.01E-05	5.08325
267	4.58984	0.001717	9.11E-06	4.59157
270	4.14631	0.001551	8.23E-06	4.14787
273	3.74603	0.001402	7.44E-06	3.74743
276	3.38473	0.001266	6.72E-06	3.386
279	3.05859	0.001144	6.07E-06	3.05974
282	2.76415	0.001034	5.49E-06	2.76519
285	2.49832	0.000935	4.96E-06	2.49926
288	2.25827	0.000845	4.48E-06	2.25912
291	2.0415	0.000764	4.05E-06	2.04227
294	1.84572	0.000691	3.66E-06	1.84642
297	1.66889	0.000624	3.31E-06	1.66951
300	1.50914	0.000565	3E-06	1.50971

Appendix E-5
No-Action Alternative - Eastern Flow Line

Eastern Plume
No-Action Alternative

Residential PRG:		
	PRG	PRG
TCE	2.8	5
Time Achieved (yrs)	282	267
Date Achieved	2281	2266
Time from 2015 (yrs)	266	251



Input parameters:

Initial Source		Component 1: TCE		Yield	0.74
Conc. (g/L)	0.06	time (yr):	Decay Rate	Decay Rate	Decay Rate
Mass (Kg)	2800	50	0.02	0.02	0.365
Gamma	1	time (yr):	0.02	0.02	0.365
Source Dimensions		20	0.02	0.02	0.365
Width (m)	43	Component 2: 1,2-DCE		Yield	0.161
Depth (m)	4		Decay Rate	Decay Rate	Decay Rate
Darcy Velocity (m/yr)	10		2.5	2.5	3
Porosity	0.25		2.5	2.5	3
Source Remediation			2.5	2.5	3
Fraction Removed	0	Component 3: VC		Yield	0
Remed. Start (yr)	0		Decay Rate	Decay Rate	Decay Rate
Remed. End (yr)	0		4.5	4.5	5
Source Decay (1/yr)	0		4.5	4.5	5
Transport Parameters			4.5	4.5	5
Retardation Factor	3	Dist. from Source			
SigmaV	0.18	X1 (m)	50	X2 (m)	150
vMin	0		Simulation Parameters		
vMax	1.72		Intervals	Min Value	Max Value
#Stream Tubes	100	x-direction (m)	31	0.01	300
alpha y (m)	0.4	y-direction (m)	1	0	0
alpha z (m)	0.04	z-direction	1	0	0
		Time (yr)	100	0	300

Output results (150 m from start)

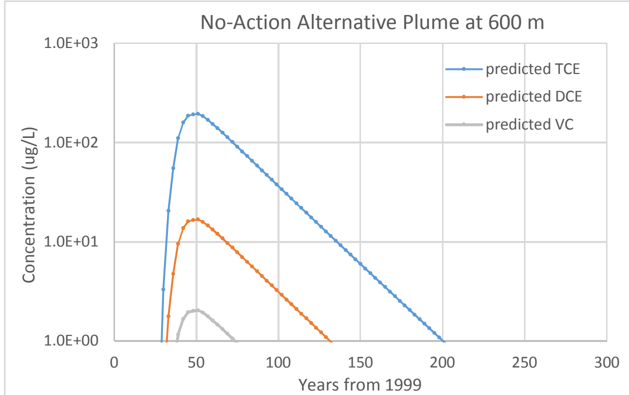
Years	TCE	1,2-DCE	VC	total VOC
3	0	0	0	0
6	0	0	0	0
9	3086.26	18.4725	1.65132	3106.39
12	23175.2	138.926	12.4196	23326.5
15	31471.9	188.764	16.8697	31677.5
18	30702.6	184.188	16.4582	30903.3
21	27907.4	167.429	14.9599	28089.8
24	25083.7	150.492	13.4463	25247.6
27	22476.8	134.853	12.0488	22623.7
30	20124.6	120.741	10.7879	20256.1
33	18017.1	108.097	9.65822	18134.9
36	16130.5	96.7777	8.64686	16235.9
39	14441.7	86.6457	7.74159	14536.1
42	12931.2	77.5829	6.93185	13015.7
45	11579.9	69.4759	6.2075	11655.6
48	10371.1	62.2231	5.55948	10438.8
51	9289.46	55.7339	4.97969	9350.18
54	8321.64	49.9272	4.46088	8376.03
57	7455.52	44.7308	3.99659	7504.25
60	6680.3	40.0797	3.58103	6723.96
63	5986.43	35.9167	3.20907	6025.56
66	5365.25	32.1898	2.87608	5400.31
69	4809.11	28.8531	2.57796	4840.54
72	4311.11	25.8653	2.311	4339.28
75	3865.13	23.1896	2.07193	3890.39
78	3465.72	20.7932	1.85782	3488.37
81	3107.93	18.6466	1.66603	3128.24
84	2787.4	16.7235	1.49421	2805.62
87	2500.23	15.0006	1.34027	2516.57
90	2242.91	13.4567	1.20233	2257.57
93	2012.3	12.0732	1.07871	2025.45
96	1805.62	10.8331	0.967913	1817.42
99	1620.35	9.72155	0.868598	1630.94
102	1454.26	8.72508	0.779566	1463.76
105	1305.34	7.83164	0.699738	1313.87
108	1171.81	7.03049	0.628158	1179.47
111	1052.06	6.31202	0.563965	1058.94
114	944.657	5.66763	0.50639	950.831
117	848.314	5.08961	0.454745	853.859
120	761.887	4.57107	0.408415	766.867
123	684.341	4.10582	0.366846	688.814
126	614.758	3.68835	0.329546	618.776
129	552.313	3.3137	0.296071	555.923
132	496.268	2.97744	0.266028	499.511
135	445.959	2.67561	0.23906	448.874
138	400.797	2.40465	0.21485	403.416
141	360.248	2.16137	0.193113	362.602
144	323.838	1.94292	0.173596	325.955
147	291.142	1.74676	0.156069	293.045
150	261.775	1.57057	0.140326	263.486
153	235.397	1.4123	0.126186	236.936

156	211.701	1.27013	0.113484	213.084
159	190.411	1.1424	0.102071	191.655
162	171.281	1.02763	0.091816	172.4
165	154.09	0.924488	0.082601	155.097
168	138.64	0.831792	0.074319	139.546
171	124.753	0.748474	0.066875	125.568
174	112.269	0.673575	0.060183	113.003
177	101.045	0.606238	0.054166	101.706
180	90.9539	0.545693	0.048757	91.5484
183	81.8793	0.491248	0.043892	82.4144
186	73.7181	0.442283	0.039517	74.1999
189	66.3781	0.398246	0.035582	66.8119
192	59.7749	0.358629	0.032043	60.1656
195	53.8345	0.322989	0.028858	54.1864
198	48.4897	0.290922	0.025993	48.8066
201	43.6803	0.262067	0.023415	43.9658
204	39.3521	0.236099	0.021095	39.6093
207	35.4566	0.212728	0.019007	35.6884
210	31.9502	0.19169	0.017127	32.159
213	28.7936	0.172752	0.015435	28.9818
216	25.9517	0.155701	0.013912	26.1213
219	23.3927	0.140348	0.01254	23.5456
222	21.0883	0.126523	0.011305	21.2262
225	19.013	0.114071	0.010192	19.1373
228	17.1437	0.102856	0.00919	17.2557
231	15.4598	0.092754	0.008287	15.5609
234	13.9428	0.083652	0.007474	14.0339
237	12.576	0.075452	0.006741	12.6582
240	11.3444	0.068062	0.006081	11.4185
243	10.2344	0.061403	0.005486	10.3013
246	9.23404	0.055401	0.00495	9.2944
249	8.33232	0.049991	0.004467	8.38678
252	7.51944	0.045114	0.004031	7.56859
255	6.78657	0.040717	0.003638	6.83093
258	6.12577	0.036752	0.003284	6.1658
261	5.52988	0.033177	0.002964	5.56602
264	4.99266	0.029954	0.002676	5.0253
267	4.50793	0.027046	0.002417	4.53739
270	4.07068	0.024423	0.002182	4.09728
273	3.67622	0.022056	0.001971	3.70024
276	3.32032	0.019921	0.00178	3.34202
279	2.99919	0.017994	0.001608	3.01879
282	2.70939	0.016255	0.001452	2.7271
285	2.44785	0.014686	0.001312	2.46384
288	2.21177	0.01327	0.001186	2.22623
291	1.99867	0.011991	0.001071	2.01173
294	1.80628	0.010837	0.000968	1.81809
297	1.63258	0.009795	0.000875	1.64325
300	1.47573	0.008854	0.000791	1.48538

Appendix E-5
No-Action Alternative - Eastern Flow Line

Eastern Plume
No-Action Alternative

Residential PRG:		
	PRG	PRG
TCE	2.8	5
Time Achieved (yrs)	156	174
Date Achieved	2155	2173
Time from 2015 (yrs)	140	158



Input parameters:

Initial Source		Component 1: TCE		Yield	0.74
Conc. (g/L)	0.06	time (yr):	Decay Rate	Decay Rate	Decay Rate
Mass (Kg)	2800	50	0.02	0.02	0.365
Gamma	1	time (yr):	0.02	0.02	0.365
Source Dimensions		20	0.02	0.02	0.365
Width (m)	43	Component 2: 1,2-DCE		Yield	0.161
Depth (m)	4		Decay Rate	Decay Rate	Decay Rate
Darcy Velocity (m/yr)	10		2.5	2.5	3
Porosity	0.25		2.5	2.5	3
Source Remediation			2.5	2.5	3
Fraction Removed	0	Component 3: VC		Yield	0
Remed. Start (yr)	0		Decay Rate	Decay Rate	Decay Rate
Remed. End (yr)	0		4.5	4.5	5
Source Decay (1/yr)	0		4.5	4.5	5
Transport Parameters			4.5	4.5	5
Retardation Factor	3	Dist. from Source			
SigmaV	0.18	X1 (m)	50	X2 (m)	150
vMin	0		Simulation Parameters		
vMax	1.72		Intervals	Min Value	Max Value
#Stream Tubes	100	x-direction (m)	51	0.01	2000
alpha y (m)	0.4	y-direction (m)	1	0	0
alpha z (m)	0.04	z-direction	1	0	0
		Time (yr)	100	0	300

Output results (600 m from start)

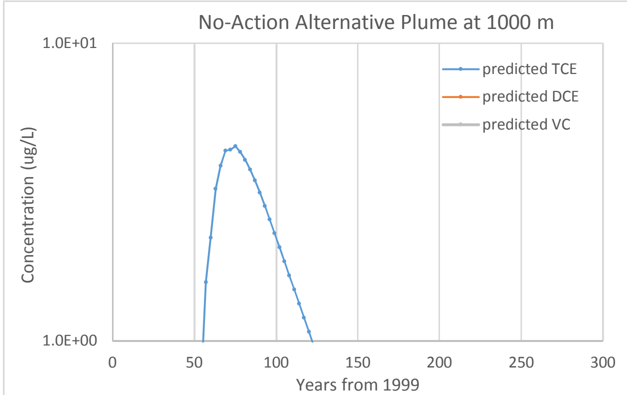
Years	TCE	1,2-DCE	VC	total VOC
3	0	0	0	0
6	0	0	0	0
9	0	0	0	0
12	0	0	0	0
15	0	0	0	0
18	0	0	0	0
21	0	0	0	0
24	0	0	0	0
27	0.103424	0.008911	0.001083	0.113418
30	3.29248	0.283668	0.034487	3.61064
33	20.5412	1.76975	0.215158	22.5261
36	55.0578	4.74358	0.5767	60.3781
39	110.885	9.55341	1.16146	121.6
42	159.702	13.7594	1.67279	175.134
45	186.279	16.0491	1.95117	204.28
48	191.887	16.5323	2.00991	210.429
51	194.493	16.7568	2.03721	213.287
54	184.168	15.8672	1.92906	201.964
57	168.926	14.554	1.7694	185.249
60	153.756	13.247	1.61051	168.613
63	139.151	11.9887	1.45753	152.597
66	125.426	10.8063	1.31377	137.546
69	112.752	9.71426	1.18101	123.647
72	101.187	8.71791	1.05988	110.965
75	90.6733	7.81208	0.949753	99.4352
78	81.2451	6.99978	0.850998	89.0959
81	72.8134	6.27333	0.76268	79.8494
84	65.2353	5.62043	0.683304	71.539
87	58.4495	5.03579	0.612226	64.0975
90	52.3738	4.51233	0.548586	57.4347
93	46.9339	4.04365	0.491607	51.4692
96	42.0633	3.62402	0.44059	46.1279
99	37.7022	3.24828	0.394909	41.3454
102	33.7966	2.91179	0.354	37.0624
105	30.2995	2.61049	0.31737	33.2273
108	27.1673	2.34064	0.284563	29.7925
111	24.3617	2.09891	0.255175	26.7158
114	21.8484	1.88238	0.22885	23.9597
117	19.5967	1.68838	0.205265	21.4904
120	17.5791	1.51455	0.184131	19.2778
123	15.771	1.35877	0.165193	17.295
126	14.1506	1.21916	0.14822	15.518
129	12.6981	1.09402	0.133006	13.9252
132	11.3961	0.981844	0.119368	12.4973
135	10.2287	0.881268	0.10714	11.2171
138	9.18199	0.791087	0.096176	10.0693
141	8.24333	0.710215	0.086344	9.03989
144	7.40149	0.637685	0.077527	8.1167
147	6.64637	0.572627	0.069617	7.28862
150	5.96898	0.514265	0.062522	6.54577
153	5.36124	0.461905	0.056156	5.8793

156	4.81593	0.414923	0.050444	5.2813
159	4.32658	0.372762	0.045319	4.74466
162	3.88739	0.334923	0.040718	4.26303
165	3.49318	0.300959	0.036589	3.83073
168	3.1393	0.270471	0.032882	3.44265
171	2.82159	0.243098	0.029555	3.09424
174	2.53632	0.21852	0.026567	2.78141
177	2.28015	0.196449	0.023883	2.50048
180	2.05008	0.176627	0.021473	2.24818
183	1.84343	0.158823	0.019309	2.02156
186	1.6578	0.14283	0.017365	1.81799
189	1.49102	0.128461	0.015618	1.6351
192	1.34117	0.115551	0.014048	1.47077
195	1.20652	0.103949	0.012638	1.32311
198	1.08551	0.093523	0.01137	1.1904
201	0.976739	0.084152	0.010231	1.07112
204	0.878966	0.075728	0.009207	0.963901
207	0.791067	0.068155	0.008286	0.867509
210	0.712037	0.061347	0.007458	0.780842
213	0.640973	0.055224	0.006714	0.70291
216	0.577064	0.049718	0.006044	0.632826
219	0.519584	0.044765	0.005442	0.569791
222	0.46788	0.040311	0.004901	0.513092
225	0.421367	0.036303	0.004414	0.462084
228	0.379519	0.032698	0.003975	0.416193
231	0.341865	0.029454	0.003581	0.3749
234	0.307979	0.026534	0.003226	0.33774
237	0.277483	0.023907	0.002906	0.304296
240	0.250033	0.021542	0.002619	0.274194
243	0.225322	0.019413	0.00236	0.247095
246	0.203076	0.017496	0.002127	0.222699
249	0.183045	0.015771	0.001917	0.200733
252	0.165008	0.014217	0.001728	0.180953
255	0.148764	0.012817	0.001558	0.16314
258	0.134134	0.011557	0.001405	0.147095
261	0.120955	0.010421	0.001267	0.132643
264	0.109082	0.009398	0.001143	0.119623
267	0.098386	0.008477	0.001031	0.107893
270	0.088747	0.007646	0.00093	0.097323
273	0.080062	0.006898	0.000839	0.0877979
276	0.072233	0.006223	0.000757	0.0792133
279	0.065178	0.005615	0.000683	0.0714756
282	0.058817	0.005067	0.000616	0.0645005
285	0.053083	0.004573	0.000556	0.0582122
288	0.047913	0.004128	0.000502	0.0525423
291	0.04325	0.003726	0.000453	0.0474297
294	0.039046	0.003364	0.000409	0.042819
297	0.035254	0.003037	0.000369	0.0386605
300	0.031833	0.002743	0.000333	0.0349094

Appendix E-5
No-Action Alternative - Eastern Flow Line

Eastern Plume
No-Action Alternative

Residential PRG:		
	PRG	PRG
TCE	2.8	5
Time Achieved (yrs)	96	75
Date Achieved	2095	2074
Time from 2015 (yrs)	80	59



Input parameters:

Initial Source		Component 1: TCE		Yield	0.37
Conc. (g/L)	0.06	time (yr):	Decay Rate	Decay Rate	Decay Rate
Mass (Kg)	2800	50	0.02	0.02	0.365
Gamma	1	time (yr):	0.02	0.02	0.365
Source Dimensions		20	0.02	0.02	0.365
Width (m)	43	Component 2: 1,2-DCE		Yield	0.161
Depth (m)	4		Decay Rate	Decay Rate	Decay Rate
Darcy Velocity (m/yr)	10		2.5	2.5	3
Porosity	0.25		2.5	2.5	3
Source Remediation			2.5	2.5	3
Fraction Removed	0	Component 3: VC		Yield	0
Remed. Start (yr)	0		Decay Rate	Decay Rate	Decay Rate
Remed. End (yr)	0		4.5	4.5	5
Source Decay (1/yr)	0		4.5	4.5	5
Transport Parameters			4.5	4.5	5
Retardation Factor	3	Dist. from Source			
SigmaV	0.18	X1 (m)	50	X2 (m)	150
vMin	0	Simulation Parameters			
vMax	1.72		Intervals	Min Value	Max Value
#Stream Tubes	100	x-direction (m)	51	0.01	2000
alpha y (m)	0.5	y-direction (m)	1	0	0
alpha z (m)	0.05	z-direction	1	0	0
		Time (yr)	100	0	300

Output results (1000 m from start)

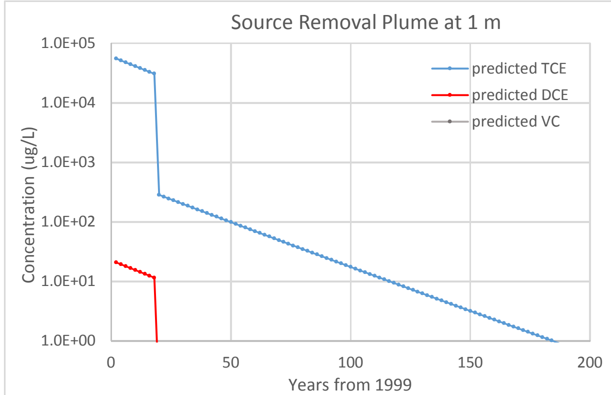
Years	TCE	1,2-DCE	VC	total VOC
3	0	0	0	0
6	0	0	0	0
9	0	0	0	0
12	0	0	0	0
15	0	0	0	0
18	0	0	0	0
21	0	0	0	0
24	0	0	0	0
27	0	0	0	0
30	0	0	0	0
33	0	0	0	0
36	0	0	0	0
39	0	0	0	0
42	0	0	0	0
45	0.007679	0.000662	8.04E-05	0.0084212
48	0.068136	0.00587	0.000714	0.0747204
51	0.317213	0.02733	0.003323	0.347866
54	0.69852	0.060182	0.007317	0.766018
57	1.57732	0.135896	0.016522	1.72974
60	2.2211	0.191362	0.023265	2.43573
63	3.25066	0.280065	0.034049	3.56477
66	3.88481	0.334701	0.040691	4.2602
69	4.36056	0.37569	0.045675	4.78193
72	4.39623	0.378763	0.046048	4.82104
75	4.5107	0.388625	0.047247	4.94657
78	4.31473	0.371742	0.045195	4.73167
81	4.06004	0.349798	0.042527	4.45237
84	3.76858	0.324687	0.039474	4.13274
87	3.46006	0.298106	0.036242	3.79441
90	3.15035	0.271422	0.032998	3.45477
93	2.83741	0.244461	0.02972	3.11159
96	2.56199	0.220732	0.026835	2.80956
99	2.30058	0.198209	0.024097	2.52289
102	2.06465	0.177882	0.021626	2.26415
105	1.85211	0.159571	0.0194	2.03108
108	1.6623	0.143218	0.017412	1.82293
111	1.49005	0.128377	0.015607	1.63403
114	1.33556	0.115067	0.013989	1.46462
117	1.19709	0.103137	0.012539	1.31276
120	1.073	0.092445	0.011239	1.17668
123	0.961821	0.082867	0.010075	1.05476
126	0.862167	0.074281	0.009031	0.945479
129	0.772987	0.066598	0.008097	0.847682
132	0.693094	0.059714	0.00726	0.760069
135	0.621521	0.053548	0.00651	0.681579
138	0.557388	0.048023	0.005838	0.611249
141	0.49994	0.043073	0.005237	0.54825
144	0.448463	0.038638	0.004697	0.491798
147	0.402329	0.034663	0.004214	0.441206
150	0.360985	0.031101	0.003781	0.395867
153	0.323926	0.027908	0.003393	0.355227

156	0.290705	0.025046	0.003045	0.318796
159	0.260922	0.02248	0.002733	0.286135
162	0.234216	0.020179	0.002453	0.256849
165	0.210269	0.018116	0.002202	0.230587
168	0.188791	0.016266	0.001977	0.207035
171	0.169527	0.014606	0.001776	0.185909
174	0.152246	0.013117	0.001595	0.166958
177	0.136743	0.011781	0.001432	0.149956
180	0.122832	0.010583	0.001287	0.134701
183	0.110348	0.009507	0.001156	0.121011
186	0.099145	0.008542	0.001038	0.108726
189	0.089089	0.007676	0.000933	0.0976981
192	0.080063	0.006898	0.000839	0.0877991
195	0.071959	0.0062	0.000754	0.078912
198	0.064682	0.005573	0.000678	0.0709324
201	0.058148	0.00501	0.000609	0.0637669
204	0.05228	0.004504	0.000548	0.0573317
207	0.047009	0.00405	0.000492	0.0515517
210	0.042275	0.003642	0.000443	0.0463596
213	0.038021	0.003276	0.000398	0.0416951
216	0.034199	0.002946	0.000358	0.0375041
219	0.030765	0.002651	0.000322	0.0337381
222	0.027679	0.002385	0.00029	0.0303536
225	0.024905	0.002146	0.000261	0.0273117
228	0.022412	0.001931	0.000235	0.0245773
231	0.02017	0.001738	0.000211	0.0221191
234	0.018155	0.001564	0.00019	0.019909
237	0.016343	0.001408	0.000171	0.0179217
240	0.014713	0.001268	0.000154	0.0161345
243	0.013247	0.001141	0.000139	0.0145272
246	0.011929	0.001028	0.000125	0.0130813
249	0.010743	0.000926	0.000113	0.0117807
252	0.009676	0.000834	0.000101	0.0106105
255	0.008715	0.000751	9.13E-05	0.0095576
258	0.007851	0.000676	8.22E-05	0.0086101
261	0.007074	0.000609	7.41E-05	0.0077574
264	0.006374	0.000549	6.68E-05	0.0069899
267	0.005744	0.000495	6.02E-05	0.006299
270	0.005177	0.000446	5.42E-05	0.005677
273	0.004666	0.000402	4.89E-05	0.005117
276	0.004206	0.000362	4.41E-05	0.0046127
279	0.003792	0.000327	3.97E-05	0.0041585
282	0.003419	0.000295	3.58E-05	0.0037495
285	0.003083	0.000266	3.23E-05	0.003381
288	0.00278	0.00024	2.91E-05	0.0030491
291	0.002508	0.000216	2.63E-05	0.0027501
294	0.002262	0.000195	2.37E-05	0.0024806
297	0.002041	0.000176	2.14E-05	0.0022378
300	0.001841	0.000159	1.93E-05	0.002019

Appendix E-6
Source Removal - Eastern Flow Line

Eastern Plume
Source Removal

Residential PRG:		
	PRG	PRG
TCE	2.8	5
Time Achieved (yrs)	154	138
Date Achieved	2153	2137
Time from 2015 (yrs)	138	122



Input parameters:

Initial Source		Component 1: TCE		Yield	0.74
Conc. (g/L)	0.06	time (yr):	Decay Rate	Decay Rate	Decay Rate
Mass (Kg)	2800	19	0.02	0.02	0.365
Gamma	1	time (yr):	1.13	0.02	0.365
Source Dimensions		18	0.02	0.02	0.365
Width (m)	43	Component 2: 1,2-DCE		Yield	0.161
Depth (m)	4		Decay Rate	Decay Rate	Decay Rate
Darcy Velocity (m/yr)	10		2.5	2.5	3
Porosity	0.25		2.5	2.5	3
Source Remediation			2.5	2.5	3
Fraction Removed	0.99	Component 3: VC		Yield	0
Remed. Start (yr)	18		Decay Rate	Decay Rate	Decay Rate
Remed. End (yr)	19		4.5	4.5	5
Source Decay (1/yr)	0		4.5	4.5	5
Transport Parameters			4.5	4.5	5
Retardation Factor	3	Dist. from Source			
SigmaV	0.18	X1 (m)	116	X2 (m)	240
vMin	0		Simulation Parameters		
vMax	1.72		Intervals	Min Value	Max Value
#Stream Tubes	100	x-direction (m)	11	0.01	10
alpha y (m)	0.4	y-direction (m)	1	0	0
alpha z (m)	0.04	z-direction	1	0	0
		Time (yr)	100	0	200

% Removal	99%	
Darcy Velocity	10	m/yr
Treatment Zone Width	116	m
Porosity	0.35	
Calculated λ*	1.1343	1/year

*Calculated λ from: Clu In Training- Practical Models to Support Decision Making Strategy Session #5, slide 29 $\lambda = (-V/w\theta)*\ln(C_{out}-C_{in})$

Output results (1 meter from start)

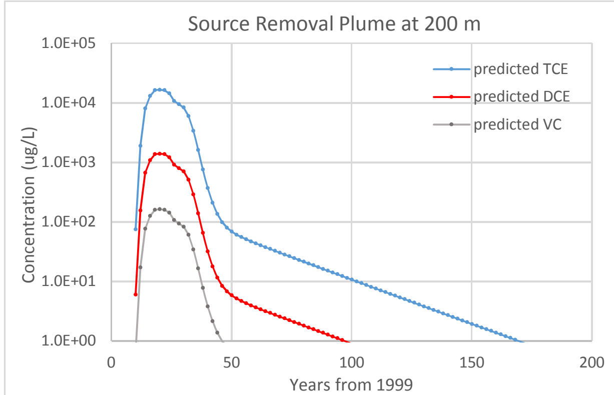
Years	TCE	1,2-DCE	VC	total VOC
2	55828.3	20.8883	0.110826	55849.3
4	51826.8	19.3911	0.102883	51846.3
6	48114.8	18.0022	0.095514	48132.9
8	44671	16.7137	0.088678	44687.8
10	41476	15.5183	0.082336	41491.6
12	38511.7	14.4092	0.076451	38526.1
14	35761.1	13.3801	0.070991	35774.5
16	33208.8	12.4251	0.065924	33221.3
18	30840.3	11.5389	0.061222	30851.9
20	284.268	0.106473	0.000578	284.375
22	264.893	0.099116	0.000527	264.993
24	246.852	0.092362	0.00049	246.945
26	230.051	0.086075	0.000457	230.138
28	214.404	0.080219	0.000426	214.485
30	199.831	0.074767	0.000397	199.906
32	186.258	0.069688	0.00037	186.328
34	173.615	0.064958	0.000345	173.68
36	161.838	0.060552	0.000321	161.899
38	150.868	0.056447	0.000299	150.924
40	140.648	0.052623	0.000279	140.701
42	131.126	0.049061	0.00026	131.176
44	122.256	0.045742	0.000243	122.301
46	113.99	0.042649	0.000226	114.033
48	106.289	0.039768	0.000211	106.329
50	99.1129	0.037083	0.000197	99.1502
52	92.4258	0.034581	0.000183	92.4605
54	86.1939	0.032249	0.000171	86.2263
56	80.3861	0.030076	0.00016	80.4164
58	74.9733	0.028051	0.000149	75.0015
60	69.9283	0.026164	0.000139	69.9546
62	65.2259	0.024404	0.000129	65.2505
64	60.8427	0.022764	0.000121	60.8656
66	56.7567	0.021236	0.000113	56.7781
68	52.9477	0.01981	0.000105	52.9676
70	49.3966	0.018482	9.81E-05	49.4152
72	46.0859	0.017243	9.15E-05	46.1032
74	42.9992	0.016088	8.54E-05	43.0153
76	40.121	0.015011	7.96E-05	40.1361
78	37.4374	0.014007	7.43E-05	37.4514
80	34.9348	0.013071	6.93E-05	34.948
82	32.6012	0.012198	6.47E-05	32.6134
84	30.4248	0.011383	6.04E-05	30.4362
86	28.3951	0.010624	5.64E-05	28.4057
88	26.502	0.009916	5.26E-05	26.512
90	24.7363	0.009255	4.91E-05	24.7456
92	23.0893	0.008639	4.58E-05	23.098
94	21.553	0.008064	4.28E-05	21.5611
96	20.1199	0.007528	3.99E-05	20.1275
98	18.7829	0.007028	3.73E-05	18.79
100	17.5356	0.006561	3.48E-05	17.5422
102	16.3719	0.006126	3.25E-05	16.3781

104	15.2862	0.005719	3.03E-05	15.2919
106	14.2731	0.00534	2.83E-05	14.2784
108	13.3277	0.004987	2.65E-05	13.3327
110	12.4456	0.004656	2.47E-05	12.4503
112	11.6224	0.004348	2.31E-05	11.6267
114	10.8541	0.004061	2.15E-05	10.8582
116	10.1371	0.003793	2.01E-05	10.1409
118	9.46789	0.003542	1.88E-05	9.47145
120	8.84327	0.003309	1.76E-05	8.84659
122	8.26023	0.003091	1.64E-05	8.26334
124	7.716	0.002887	1.53E-05	7.7189
126	7.20795	0.002697	1.43E-05	7.21066
128	6.73366	0.002519	1.34E-05	6.73619
130	6.29087	0.002354	1.25E-05	6.29324
132	5.87746	0.002199	1.17E-05	5.87968
134	5.49148	0.002055	1.09E-05	5.49354
136	5.13107	0.00192	1.02E-05	5.133
138	4.79454	0.001794	9.52E-06	4.79634
140	4.48028	0.001676	8.89E-06	4.48197
142	4.18682	0.001566	8.31E-06	4.18839
144	3.91275	0.001464	7.77E-06	3.91422
146	3.65679	0.001368	7.26E-06	3.65816
148	3.41773	0.001279	6.78E-06	3.41901
150	3.19444	0.001195	6.34E-06	3.19564
152	2.98587	0.001117	5.93E-06	2.98699
154	2.79105	0.001044	5.54E-06	2.7921
156	2.60905	0.000976	5.18E-06	2.61004
158	2.43904	0.000913	4.84E-06	2.43995
160	2.2802	0.000853	4.53E-06	2.28106
162	2.13181	0.000798	4.23E-06	2.13261
164	1.99316	0.000746	3.96E-06	1.99391
166	1.86361	0.000697	3.7E-06	1.86431
168	1.74256	0.000652	3.46E-06	1.74321
170	1.62944	0.00061	3.23E-06	1.63006
172	1.52374	0.00057	3.02E-06	1.52431
174	1.42496	0.000533	2.83E-06	1.42549
176	1.33264	0.000499	2.65E-06	1.33314
178	1.24635	0.000466	2.47E-06	1.24682
180	1.16571	0.000436	2.31E-06	1.16615
182	1.09033	0.000408	2.16E-06	1.09074
184	1.01987	0.000382	2.02E-06	1.02025
186	0.954005	0.000357	1.89E-06	0.954364
188	0.892433	0.000334	1.77E-06	0.892769
190	0.834873	0.000312	1.66E-06	0.835187
192	0.781059	0.000292	1.55E-06	0.781353
194	0.730746	0.000273	1.45E-06	0.731021
196	0.683704	0.000256	1.36E-06	0.683961
198	0.639718	0.000239	1.27E-06	0.639959
200	0.598589	0.000224	1.19E-06	0.598814

Appendix E-6
Source Removal - Eastern Flow Line

Eastern Plume
Source Removal

Residential PRG:		
	PRG	PRG
TCE	2.8	5
Time Achieved (yrs)	140	124
Date Achieved	2139	2123
Time from 2015 (yrs)	124	108



Input parameters:

Initial Source		Component 1: TCE		Yield	0.74
Conc. (g/L)	0.06	time (yr):	Decay Rate	Decay Rate	Decay Rate
Mass (Kg)	2800	19	0.02	0.02	0.365
Gamma	1	time (yr):	1.13	0.02	0.365
Source Dimensions		18	0.02	0.02	0.365
Width (m)	43	Component 2: 1,2-DCE		Yield	0.161
Depth (m)	4		Decay Rate	Decay Rate	Decay Rate
Darcy Velocity (m/yr)	10		2.5	2.5	3
Porosity	0.25		2.5	2.5	3
Source Remediation			2.5	2.5	3
Fraction Removed	0.99	Component 3: VC		Yield	0
Remed. Start (yr)	18		Decay Rate	Decay Rate	Decay Rate
Remed. End (yr)	19		4.5	4.5	5
Source Decay (1/yr)	0		4.5	4.5	5
Transport Parameters			4.5	4.5	5
Retardation Factor	3	Dist. from Source			
SigmaV	0.18	X1 (m)	116	X2 (m)	150
vMin	0		Simulation Parameters		
vMax	1.72		Intervals	Min Value	Max Value
#Stream Tubes	100	x-direction (m)	31	0.01	300
alpha y (m)	0.4	y-direction (m)	1	0	0
alpha z (m)	0.04	z-direction	1	0	0
		Time (yr)	100	0	200

% Removal	99%	
Darcy Velocity	10	m/yr
Treatment Zone Width	116	m
Porosity	0.35	
Calculated λ*	1.1343	1/year

*Calculated λ from: Clu In Training- Practical Models to Support Decision Making
Strategy Session #5, slide 29 $\lambda = (-V/w\theta)*\ln(C_{out}-C_{in})$

Output results (200 m from start)

Years	TCE	1,2-DCE	VC	total VOC
2	0	0	0	0
4	0	0	0	0
6	0	0	0	0
8	0	0	0	0
10	75.3097	6.00725	0.644241	81.9612
12	1894.34	155.082	17.2974	2066.72
14	8072.02	671.214	76.7438	8819.98
16	13024.7	1090.6	126.135	14241.5
18	16338.3	1374.16	160.134	17872.6
20	16597.6	1398.07	163.348	18159
22	16208.3	1366.53	159.921	17734.7
24	14337.1	1215.07	143.493	15695.7
26	10772.6	912.364	107.669	11792.6
28	9415.91	795.176	93.3415	10304.4
30	8309.94	702.331	82.5237	9094.79
32	6013.79	510.534	60.4264	6584.75
34	3369.15	287.394	34.2989	3690.84
36	1622.44	138.837	16.6654	1777.94
38	760.103	65.121	7.83535	833.06
40	371.053	31.7645	3.81781	406.635
42	209.857	17.9231	2.14582	229.926
44	135.376	11.5256	1.37241	148.274
46	98.6145	8.37002	0.991314	107.976
48	80.1534	6.78864	0.800986	87.743
50	68.8844	5.82587	0.685633	75.3959
52	61.0044	5.15439	0.605548	66.7643
54	55.598	4.69549	0.551189	60.8447
56	50.8509	4.2929	0.503577	55.6473
58	46.9911	3.96633	0.465115	51.4226
60	43.5647	3.67668	0.431056	47.6724
62	40.4737	3.41556	0.400387	44.2897
64	37.6315	3.17551	0.372206	41.1792
66	35.0451	2.95717	0.346596	38.3488
68	32.6628	2.75611	0.323024	35.7419
70	30.4292	2.56758	0.300915	33.2977
72	28.352	2.39227	0.280358	31.0246
74	26.4431	2.23119	0.261481	28.9358
76	24.6513	2.07998	0.243754	26.975
78	22.9937	1.94012	0.227364	25.1612
80	21.4394	1.80896	0.211989	23.4604
82	19.9998	1.68749	0.197754	21.8851
84	18.654	1.57393	0.184444	20.4124
86	17.4031	1.46838	0.172075	19.0436
88	16.2364	1.36994	0.160538	17.7669
90	15.1467	1.27799	0.149762	16.5744
92	14.1338	1.19252	0.139747	15.466
94	13.1883	1.11275	0.130399	14.4315
96	12.3055	1.03826	0.121669	13.4655
98	11.4836	0.968918	0.113542	12.5661
100	10.7172	0.904246	0.105964	11.7274
102	10.0016	0.843867	0.098888	10.9443

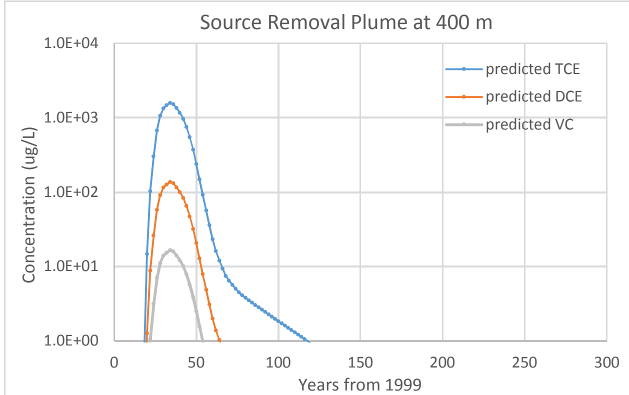
104	9.33515	0.787638	0.092299	10.2151
106	8.7133	0.73517	0.08615	9.53462
108	8.13326	0.68623	0.080415	8.89991
110	7.59214	0.640573	0.075065	8.30777
112	7.08708	0.597958	0.070071	7.75511
114	6.61623	0.558231	0.065415	7.23987
116	6.17695	0.521167	0.061072	6.75919
118	5.76723	0.486597	0.057021	6.31084
120	5.38482	0.454332	0.05324	5.89239
122	5.02783	0.424212	0.04971	5.50176
124	4.69489	0.39612	0.046418	5.13743
126	4.3842	0.369905	0.043346	4.79745
128	4.09425	0.345442	0.04048	4.48017
130	3.82366	0.322611	0.037804	4.18408
132	3.57112	0.301304	0.035307	3.90773
134	3.33541	0.281416	0.032977	3.6498
136	3.11538	0.262851	0.030801	3.40904
138	2.91002	0.245525	0.028771	3.18432
140	2.71833	0.229351	0.026876	2.97455
142	2.53937	0.214252	0.025106	2.77873
144	2.37231	0.200156	0.023454	2.59592
146	2.21634	0.186997	0.021912	2.42525
148	2.07072	0.17471	0.020473	2.2659
150	1.93475	0.163238	0.019128	2.11712
152	1.8078	0.152527	0.017873	1.9782
154	1.68923	0.142523	0.016701	1.84845
156	1.57853	0.133183	0.015606	1.72732
158	1.47515	0.12446	0.014584	1.6142
160	1.37862	0.116316	0.01363	1.50856
162	1.28845	0.108708	0.012738	1.40989
164	1.20423	0.101602	0.011906	1.31774
166	1.12557	0.094965	0.011128	1.23166
168	1.05209	0.088766	0.010402	1.15126
170	0.983457	0.082975	0.009723	1.07615
172	0.919341	0.077566	0.009089	1.006
174	0.859443	0.072512	0.008497	0.940452
176	0.803484	0.067791	0.007944	0.879218
178	0.751197	0.063379	0.007427	0.822003
180	0.702349	0.059258	0.006944	0.76855
182	0.656707	0.055407	0.006492	0.718606
184	0.614058	0.051808	0.006071	0.671937
186	0.574205	0.048446	0.005677	0.628328
188	0.536962	0.045304	0.005309	0.587574
190	0.502157	0.042367	0.004964	0.549489
192	0.469629	0.039623	0.004643	0.513895
194	0.43923	0.037058	0.004342	0.48063
196	0.410814	0.03466	0.004061	0.449536
198	0.384254	0.03242	0.003799	0.420472
200	0.359427	0.030325	0.003553	0.393305

Appendix E-6
Source Removal - Eastern Flow Line

Eastern Plume
Source Removal

Residential PRG:		
	PRG	PRG
TCE	2.8	5
Time Achieved (yrs)	90	76
Date Achieved	2089	2075
Time from 2015 (yrs)	74	60

note: Commercial/Industrial PRG applicable starting at 400 m from TCE source along flow line



Input parameters:

Initial Source		Component 1: TCE		Yield	0.74
Conc. (g/L)	0.06	time (yr):	Decay Rate	Decay Rate	Decay Rate
Mass (Kg)	2800	19	0.02	0.02	0.365
Gamma	1	time (yr):	1.13	0.02	0.365
Source Dimensions		18	0.02	0.02	0.365
Width (m)	43	Component 2: 1,2-DCE		Yield	0.161
Depth (m)	4		Decay Rate	Decay Rate	Decay Rate
Darcy Velocity (m/yr)	10		2.5	2.5	3
Porosity	0.25		2.5	2.5	3
Source Remediation			2.5	2.5	3
Fraction Removed	0.99	Component 3: VC		Yield	0
Remed. Start (yr)	18		Decay Rate	Decay Rate	Decay Rate
Remed. End (yr)	19		4.5	4.5	5
Source Decay (1/yr)	0		4.5	4.5	5
Transport Parameters			4.5	4.5	5
Retardation Factor	3	Dist. from Source			
SigmaV	0.18	X1 (m)	116	X2 (m)	150
vMin	0	Simulation Parameters			
vMax	1.72		Intervals	Min Value	Max Value
#Stream Tubes	100	x-direction (m)	51	0.01	2000
alpha y (m)	0.4	y-direction (m)	1	0	0
alpha z (m)	0.04	z-direction	1	0	0
		Time (yr)	100	0	200

% Removal	99%	
Darcy Velocity	10	m/yr
Treatment Zone Width	116	m
Porosity	0.35	
Calculated λ*	1.1343	1/year

*Calculated λ from: Clu In Training- Practical Models to Support Decision Making Strategy Session #5, slide 29 $\lambda = (-V/w\theta)*\ln(C_{out}-C_{in})$

Output results (400 m from start)

Years	TCE	1,2-DCE	VC	total VOC
2	0	0	0	0
4	0	0	0	0
6	0	0	0	0
8	0	0	0	0
10	0	0	0	0
12	0	0	0	0
14	0	0	0	0
16	0	0	0	0
18	0.417516	0.035971	0.004373	0.457861
20	14.7705	1.27257	0.154711	16.1978
22	102.589	8.8387	1.07456	112.503
24	302.66	26.076	3.17019	331.906
26	673.469	58.0236	7.05421	738.547
28	1061.55	91.4592	11.1192	1164.13
30	1338.92	115.357	14.0245	1468.3
32	1472.15	126.835	15.42	1614.41
34	1584.35	136.501	16.5952	1737.44
36	1519.09	130.879	15.9116	1665.88
38	1345.75	115.945	14.096	1475.79
40	1159.05	99.8596	12.1404	1271.05
42	964.21	83.0728	10.0996	1057.38
44	753.578	64.9255	7.89331	826.397
46	546.707	47.1023	5.72646	599.536
48	371.719	32.026	3.89356	407.639
50	238.828	20.5765	2.50159	261.906
52	148.571	12.8003	1.5562	162.927
54	92.2258	7.94583	0.966014	101.138
56	56.5995	4.87641	0.592849	62.0688
58	35.8675	3.09021	0.375692	39.3334
60	23.2803	2.00574	0.243848	25.5299
62	16.0795	1.38535	0.168423	17.6332
64	11.9445	1.0291	0.125112	13.0987
66	9.33253	0.804057	0.097753	10.2343
68	7.4751	0.644027	0.078298	8.19743
70	6.42734	0.553756	0.067323	7.04842
72	5.63278	0.4853	0.059	6.17708
74	5.00115	0.43088	0.052384	5.48441
76	4.51935	0.389371	0.047338	4.95606
78	4.13368	0.356143	0.043298	4.53312
80	3.80889	0.328159	0.039896	4.17694
82	3.52825	0.303981	0.036957	3.86919
84	3.27313	0.282001	0.034284	3.58941
86	3.03825	0.261764	0.031824	3.33184
88	2.82271	0.243194	0.029566	3.09547
90	2.62845	0.226457	0.027532	2.88244
92	2.45004	0.211087	0.025663	2.68679
94	2.28169	0.196582	0.023899	2.50217
96	2.12793	0.183335	0.022289	2.33355
98	1.98385	0.170921	0.02078	2.17556
100	1.84999	0.159388	0.019378	2.02876
102	1.72582	0.14869	0.018077	1.89258

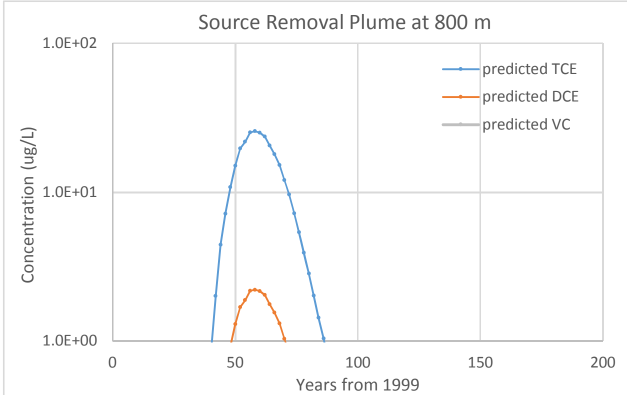
104	1.6097	0.138686	0.016861	1.76525
106	1.50196	0.129404	0.015732	1.6471
108	1.40137	0.120737	0.014679	1.53679
110	1.30755	0.112654	0.013696	1.4339
112	1.22022	0.105129	0.012781	1.33813
114	1.13865	0.098102	0.011927	1.24868
116	1.0627	0.091558	0.011131	1.16539
118	0.991842	0.085454	0.010389	1.08768
120	0.925723	0.079757	0.009696	1.01518
122	0.864104	0.074448	0.009051	0.947603
124	0.806611	0.069495	0.008449	0.884555
126	0.752963	0.064873	0.007887	0.825723
128	0.702936	0.060562	0.007363	0.770862
130	0.656267	0.056542	0.006874	0.719682
132	0.612711	0.052789	0.006418	0.671917
134	0.572082	0.049289	0.005992	0.627363
136	0.534173	0.046022	0.005595	0.585791
138	0.498799	0.042975	0.005225	0.546998
140	0.465786	0.04013	0.004879	0.510795
142	0.434981	0.037476	0.004556	0.477014
144	0.406232	0.035	0.004255	0.445487
146	0.379401	0.032688	0.003974	0.416063
148	0.354358	0.03053	0.003712	0.388599
150	0.330983	0.028516	0.003467	0.362966
152	0.309165	0.026637	0.003238	0.33904
154	0.288798	0.024882	0.003025	0.316705
156	0.269786	0.023244	0.002826	0.295855
158	0.252036	0.021715	0.00264	0.27639
160	0.235465	0.020287	0.002466	0.258218
162	0.219994	0.018954	0.002304	0.241252
164	0.205548	0.017709	0.002153	0.225411
166	0.19206	0.016547	0.002012	0.210619
168	0.179466	0.015462	0.00188	0.196808
170	0.167704	0.014449	0.001757	0.18391
172	0.156721	0.013503	0.001642	0.171865
174	0.146464	0.012619	0.001534	0.160617
176	0.136884	0.011793	0.001434	0.150111
178	0.127936	0.011023	0.00134	0.140299
180	0.119579	0.010303	0.001253	0.131134
182	0.111773	0.00963	0.001171	0.122574
184	0.104481	0.009002	0.001094	0.114577
186	0.09767	0.008415	0.001023	0.107107
188	0.091306	0.007867	0.000956	0.100129
190	0.085361	0.007354	0.000894	0.0936092
192	0.079806	0.006876	0.000836	0.0875181
194	0.074617	0.006429	0.000782	0.0818269
196	0.069768	0.006011	0.000731	0.0765093
198	0.065237	0.005621	0.000683	0.0715404
200	0.061003	0.005256	0.000639	0.0668972

Appendix E-6
Source Removal - Eastern Flow Line

Eastern Plume
Source Removal

Residential PRG:		
	PRG	PRG
TCE	2.8	5
Time Achieved (yrs)	82	78
Date Achieved	2081	2077
Time from 2015 (yrs)	66	62

note: Commercial/Industrial PRG applicable starting at 400 m from TCE source along flow line



Input parameters:

Initial Source		Component 1: TCE		Yield	0.37
Conc. (g/L)	0.06	time (yr):	Decay Rate	Decay Rate	Decay Rate
Mass (Kg)	2800	19	0.02	0.02	0.365
Gamma	1	time (yr):	1.13	0.02	0.365
Source Dimensions		18	0.02	0.02	0.365
Width (m)	43	Component 2: 1,2-DCE		Yield	0.161
Depth (m)	4		Decay Rate	Decay Rate	Decay Rate
Darcy Velocity (m/yr)	10		2.5	2.5	3
Porosity	0.25		2.5	2.5	3
Source Remediation			2.5	2.5	3
Fraction Removed	0.99	Component 3: VC		Yield	0
Remed. Start (yr)	18		Decay Rate	Decay Rate	Decay Rate
Remed. End (yr)	19		4.5	4.5	5
Source Decay (1/yr)	0		4.5	4.5	5
Transport Parameters			4.5	4.5	5
Retardation Factor	3	Dist. from Source			
SigmaV	0.18	X1 (m)	116	X2 (m)	150
vMin	0		Simulation Parameters		
vMax	1.72		Intervals	Min Value	Max Value
#Stream Tubes	100	x-direction (m)	51	0.01	2000
alpha y (m)	0.4	y-direction (m)	1	0	0
alpha z (m)	0.04	z-direction	1	0	0
		Time (yr)	100	0	200

% Removal	99%	
Darcy Velocity	10	m/yr
Treatment Zone Width	116	m
Porosity	0.35	
Calculated λ*	1.1343	1/year

*Calculated λ from: Clu In Training- Practical Models to Support Decision Making Strategy Session #5, slide 29 $\lambda = (-V/w\theta) * \ln(C_{out}-C_{in})$

Output results (800 m from start)

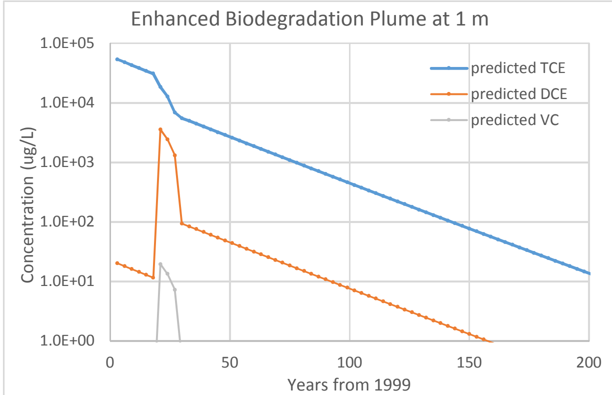
Years	TCE	1,2-DCE	VC	total VOC
2	0	0	0	0
4	0	0	0	0
6	0	0	0	0
8	0	0	0	0
10	0	0	0	0
12	0	0	0	0
14	0	0	0	0
16	0	0	0	0
18	0	0	0	0
20	0	0	0	0
22	0	0	0	0
24	0	0	0	0
26	0	0	0	0
28	0	0	0	0
30	0	0	0	0
32	0	0	0	0
34	0	0	0	0
36	0.027547	0.002373	0.000289	0.0302089
38	0.19027	0.016393	0.001993	0.208656
40	0.789568	0.068026	0.00827	0.865864
42	2.01045	0.173213	0.021058	2.20472
44	4.42822	0.381519	0.046383	4.85612
46	7.17818	0.618445	0.075188	7.87181
48	10.7956	0.930105	0.113078	11.8387
50	15.0875	1.29989	0.158034	16.5455
52	19.6261	1.69091	0.205573	21.5226
54	21.8293	1.88073	0.22865	23.9387
56	25.1839	2.16975	0.263787	27.6174
58	25.6381	2.20888	0.268545	28.1155
60	25.0931	2.16193	0.262837	27.5179
62	23.6251	2.03545	0.24746	25.908
64	20.5278	1.7686	0.215017	22.5114
66	18.0058	1.55131	0.188601	19.7457
68	15.2393	1.31296	0.159623	16.7119
70	12.0289	1.03636	0.125996	13.1913
72	9.62695	0.829423	0.100837	10.5572
74	7.21112	0.621283	0.075533	7.90793
76	5.38219	0.463709	0.056376	5.90227
78	3.92673	0.338312	0.04113	4.30617
80	2.83577	0.24432	0.029703	3.1098
82	2.021	0.174122	0.021169	2.21629
84	1.43396	0.123545	0.01502	1.57252
86	1.04213	0.089786	0.010916	1.14283
88	0.724356	0.062408	0.007587	0.794351
90	0.550444	0.047424	0.005766	0.603634
92	0.40176	0.034614	0.004208	0.440582
94	0.288337	0.024842	0.00302	0.3162
96	0.228455	0.019683	0.002393	0.250531
98	0.181453	0.015633	0.001901	0.198987
100	0.149025	0.01284	0.001561	0.163426
102	0.124376	0.010716	0.001303	0.136394

104	0.104354	0.008991	0.001093	0.114438
106	0.090187	0.00777	0.000945	0.0989016
108	0.07918	0.006822	0.000829	0.0868314
110	0.070272	0.006054	0.000736	0.0770626
112	0.063478	0.005469	0.000665	0.0696115
114	0.058539	0.005044	0.000613	0.0641961
116	0.05379	0.004634	0.000563	0.0589874
118	0.049233	0.004242	0.000516	0.0539903
120	0.045508	0.003921	0.000477	0.049905
122	0.042363	0.00365	0.000444	0.0464562
124	0.039225	0.00338	0.000411	0.0430157
126	0.036484	0.003143	0.000382	0.0400091
128	0.033974	0.002927	0.000356	0.0372569
130	0.031592	0.002722	0.000331	0.0346444
132	0.029484	0.00254	0.000309	0.0323332
134	0.027455	0.002365	0.000288	0.0301079
136	0.02562	0.002207	0.000268	0.0280955
138	0.023882	0.002058	0.00025	0.0261896
140	0.022288	0.00192	0.000233	0.0244416
142	0.020786	0.001791	0.000218	0.0227947
144	0.019402	0.001672	0.000203	0.0212767
146	0.018102	0.00156	0.00019	0.0198512
148	0.016897	0.001456	0.000177	0.0185298
150	0.015773	0.001359	0.000165	0.0172967
152	0.014722	0.001268	0.000154	0.0161442
154	0.013744	0.001184	0.000144	0.0150716
156	0.01283	0.001105	0.000134	0.0140696
158	0.011979	0.001032	0.000125	0.0131361
160	0.011184	0.000964	0.000117	0.0122652
162	0.010443	0.0009	0.000109	0.0114518
164	0.009751	0.00084	0.000102	0.0106936
166	0.009106	0.000785	9.54E-05	0.009986
168	0.008504	0.000733	8.91E-05	0.0093253
170	0.007942	0.000684	8.32E-05	0.0087091
172	0.007417	0.000639	7.77E-05	0.008134
174	0.006928	0.000597	7.26E-05	0.007597
176	0.006471	0.000557	6.78E-05	0.007096
178	0.006044	0.000521	6.33E-05	0.0066283
180	0.005646	0.000486	5.91E-05	0.0061917
182	0.005274	0.000454	5.52E-05	0.0057841
184	0.004927	0.000425	5.16E-05	0.0054036
186	0.004603	0.000397	4.82E-05	0.0050483
188	0.004301	0.000371	4.51E-05	0.0047167
190	0.004019	0.000346	4.21E-05	0.004407
192	0.003755	0.000324	3.93E-05	0.0041178
194	0.003509	0.000302	3.68E-05	0.0038478
196	0.003279	0.000282	3.43E-05	0.0035957
198	0.003064	0.000264	3.21E-05	0.0033602
200	0.002864	0.000247	3E-05	0.0031403

Appendix E-7
No-Action Alternative - Eastern Flow Line

Eastern Plume
Enhanced Biodegradation

Residential PRG:		
	PRG	PRG
TCE	2.8	5
Time Achieved (yrs)	249	231
Date Achieved	2248	2230
Time from 2015 (yrs)	233	215



Input parameters:

Initial Source		Component 1: TCE		Yield	0.74
Conc. (g/L)	0.06	time (yr):	Decay Rate	Decay Rate	Decay Rate
Mass (Kg)	2800	28	0.9	0.9	0.365
Gamma	1	time (yr):	9.1	9.1	0.365
Source Dimensions		18	0.02	0.02	0.365
Width (m)	43	Component 2: 1,2-DCE		Yield	0.161
Depth (m)	4		Decay Rate	Decay Rate	Decay Rate
Darcy Velocity (m/yr)	10		2.5	2.5	3
Porosity	0.25		2.5	2.5	3
Source Remediation			2.5	2.5	3
Fraction Removed	0.8	Component 3: VC		Yield	0
Remed. Start (yr)	18		Decay Rate	Decay Rate	Decay Rate
Remed. End (yr)	28		4.5	4.5	5
Source Decay (1/yr)	0		4.5	4.5	5
Transport Parameters			4.5	4.5	5
Retardation Factor	3	Dist. from Source			
SigmaV	0.18	X1 (m)	50	X2 (m)	150
vMin	0	Simulation Parameters			
vMax	1.72		Intervals	Min Value	Max Value
#Stream Tubes	100	x-direction (m)	11	0.01	10
alpha y (m)	0.4	y-direction (m)	1	0	0
alpha z (m)	0.04	z-direction	1	0	0
		Time (yr)	100	0	300

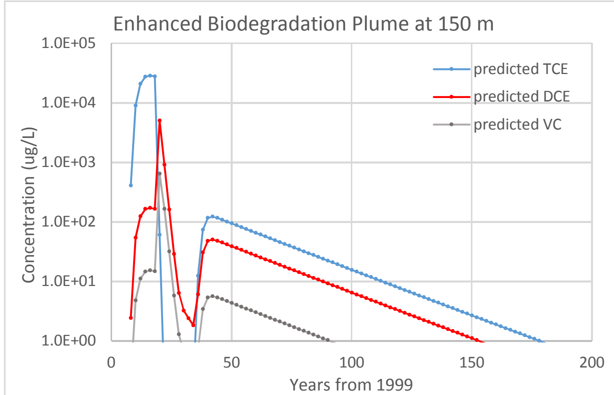
Output results (1 meter from start)

Years	TCE	1,2-DCE	VC	total VOC
3	53790	20.1256	0.10678	53810.2
6	48114.8	18.0022	0.095514	48132.9
9	43043.6	16.1048	0.085447	43059.8
12	38511.7	14.4092	0.076451	38526.1
15	34461.1	12.8937	0.06841	34474
18	30840.3	11.5389	0.061222	30851.9
21	18555.3	3542.45	19.4967	22117.3
24	12695.5	2424.12	13.3442	15133
27	6863.3	1311.08	7.22075	8181.6
30	5515.11	93.8764	0.499872	5609.48
33	4945.38	84.1786	0.448232	5030
36	4435.02	75.4914	0.401975	4510.91
39	3977.8	67.7088	0.360534	4045.87
42	3568.13	60.7355	0.323403	3629.19
45	3201.03	54.4868	0.29013	3255.81
48	2872.03	48.8867	0.260311	2921.18
51	2577.15	43.8673	0.233584	2621.25
54	2312.81	39.3678	0.209625	2352.38
57	2075.82	35.3339	0.188145	2111.34
60	1863.33	31.717	0.168886	1895.22
63	1672.79	28.4737	0.151616	1701.42
66	1501.91	25.5649	0.136127	1527.61
69	1348.63	22.9559	0.122235	1371.71
72	1211.14	20.6156	0.109773	1231.86
75	1087.79	18.5159	0.098593	1106.4
78	977.111	16.632	0.088562	993.832
81	877.796	14.9415	0.07956	892.817
84	788.664	13.4244	0.071482	802.16
87	708.663	12.0626	0.064231	720.79
90	636.85	10.8402	0.057722	647.747
93	572.378	9.74281	0.051878	582.173
96	514.491	8.75748	0.046632	523.295
99	462.51	7.87268	0.04192	470.425
102	415.828	7.07807	0.037689	422.944
105	373.9	6.36438	0.033889	380.298
108	336.237	5.72329	0.030475	341.99
111	302.401	5.14735	0.027408	307.576
114	272	4.62988	0.024653	276.655
117	244.683	4.1649	0.022177	248.87
120	220.134	3.74703	0.019952	223.901
123	198.069	3.37146	0.017952	201.459
126	178.236	3.03387	0.016155	181.286
129	160.407	2.73038	0.014539	163.152
132	144.377	2.45752	0.013086	146.847
135	129.963	2.21217	0.011779	132.187
138	117.001	1.99154	0.010604	119.003
141	105.343	1.7931	0.009548	107.145
144	94.8568	1.61462	0.008597	96.4801
147	85.424	1.45405	0.007742	86.8858
150	76.9376	1.3096	0.006973	78.2541
153	69.3017	1.17962	0.006281	70.4876

156	62.4304	1.06266	0.005658	63.4987
159	56.2465	0.957404	0.005098	57.209
162	50.6805	0.862663	0.004593	51.5478
165	45.6703	0.777381	0.004139	46.4518
168	41.1598	0.700604	0.003731	41.8641
171	37.0987	0.631478	0.003362	37.7335
174	33.4419	0.569233	0.003031	34.0141
177	30.1487	0.513178	0.002733	30.6646
180	27.1827	0.462693	0.002464	27.6479
183	24.5111	0.417218	0.002222	24.9306
186	22.1044	0.376252	0.002003	22.4827
189	19.9362	0.339345	0.001807	20.2773
192	17.9825	0.30609	0.00163	18.2902
195	16.222	0.276123	0.00147	16.4996
198	14.6353	0.249116	0.001326	14.8858
201	13.2053	0.224775	0.001197	13.4313
204	11.9162	0.202832	0.00108	12.1201
207	10.7541	0.183051	0.000975	10.9381
210	9.70631	0.165217	0.00088	9.87241
213	8.76154	0.149135	0.000794	8.91147
216	7.90954	0.134633	0.000717	8.04489
219	7.14113	0.121553	0.000647	7.26333
222	6.44804	0.109756	0.000584	6.55838
225	5.82282	0.099113	0.000528	5.92246
228	5.25877	0.089512	0.000477	5.34875
231	4.74984	0.08085	0.000431	4.83112
234	4.2906	0.073033	0.000389	4.36402
237	3.87616	0.065978	0.000351	3.94249
240	3.50211	0.059611	0.000317	3.56204
243	3.16448	0.053864	0.000287	3.21863
246	2.85969	0.048676	0.000259	2.90862
249	2.58452	0.043992	0.000234	2.62874
252	2.33606	0.039763	0.000212	2.37603
255	2.1117	0.035944	0.000191	2.14783
258	1.90908	0.032496	0.000173	1.94175
261	1.72608	0.029381	0.000156	1.75561
264	1.56077	0.026567	0.000141	1.58748
267	1.41144	0.024025	0.000128	1.43559
270	1.27652	0.021728	0.000116	1.29837
273	1.15462	0.019653	0.000105	1.17438
276	1.04446	0.017778	9.47E-05	1.06233
279	0.944905	0.016084	8.56E-05	0.961075
282	0.854924	0.014552	7.75E-05	0.869554
285	0.773589	0.013168	7.01E-05	0.786826
288	0.70006	0.011916	6.34E-05	0.71204
291	0.633583	0.010785	5.74E-05	0.644425
294	0.573475	0.009761	5.2E-05	0.583289
297	0.519121	0.008836	4.71E-05	0.528004
300	0.469964	0.007999	4.26E-05	0.478006

Eastern Plume
Enhanced Biodegradation

Residential PRG:		
	PRG	PRG
TCE	2.8	5
Time Achieved (yrs)	150	134
Date Achieved	2149	2133
Time from 2015 (yrs)	134	118



Input parameters:

Initial Source		Component 1: TCE		Yield	0.74
Conc. (g/L)	0.06	time (yr):	Decay Rate	Decay Rate	Decay Rate
Mass (Kg)	2800	28	0.9	0.9	0.365
Gamma	1	time (yr):	9.1	9.1	0.365
Source Dimensions		18	0.02	0.02	0.365
Width (m)	43	Component 2: 1,2-DCE		Yield	0.161
Depth (m)	4		Decay Rate	Decay Rate	Decay Rate
Darcy Velocity (m/yr)	10		2.5	2.5	3
Porosity	0.25		2.5	2.5	3
Source Remediation			2.5	2.5	3
Fraction Removed	0.8	Component 3: VC		Yield	0
Remed. Start (yr)	18		Decay Rate	Decay Rate	Decay Rate
Remed. End (yr)	28		4.5	4.5	5
Source Decay (1/yr)	0		4.5	4.5	5
Transport Parameters			4.5	4.5	5
Retardation Factor	3	Dist. from Source			
SigmaV	0.18	X1 (m)	50	X2 (m)	150
vMin	0		Simulation Parameters		
vMax	1.72		Intervals	Min Value	Max Value
#Stream Tubes	100	x-direction (m)	31	0.01	300
alpha y (m)	0.4	y-direction (m)	1	0	0
alpha z (m)	0.04	z-direction	1	0	0
		Time (yr)	100	0	200

Output results (150 m from start)

Years	TCE	1,2-DCE	VC	total VOC
2	0	0	0	0
4	0	0	0	0
6	0	0	0	0
8	407.961	2.43887	0.21787	410.618
10	9023.72	54.0535	4.83292	9082.61
12	20858.2	125.037	11.178	20994.4
14	27436.2	164.539	14.706	27615.5
16	28570.4	171.378	15.3149	28757.1
18	27633.1	165.773	14.8127	27813.7
20	61.0568	5035.02	644.831	5740.91
22	0.134031	911.232	165.235	1076.6
24	0.000293	162.443	31.8411	194.284
26	6.62E-07	28.9819	5.79314	34.7751
28	3.34E-08	6.42909	1.29041	7.7195
30	6.14E-06	3.22108	0.646312	3.8674
32	0.001093	2.40015	0.481505	2.88275
34	0.173583	1.8392	0.362657	2.37544
36	12.4518	6.09293	0.762535	19.3073
38	74.2559	30.8805	3.45183	108.588
40	116.534	48.2443	5.37349	170.152
42	122.236	50.6108	5.63768	178.485
44	116.599	48.281	5.37857	170.259
46	109.011	45.1399	5.02875	159.18
48	101.49	42.0259	4.68185	148.198
50	94.4155	39.0963	4.35549	137.867
52	87.8219	36.366	4.05132	128.239
54	81.6891	33.8265	3.76841	119.284
56	75.9876	31.4656	3.50539	110.959
58	70.6875	29.2709	3.26089	103.219
60	65.7604	27.2306	3.0336	96.0247
62	61.1799	25.3339	2.8223	89.3361
64	56.9214	23.5705	2.62585	83.1177
66	52.962	21.9309	2.4432	77.3362
68	49.2806	20.4065	2.27337	71.9605
70	45.8574	18.989	2.11545	66.9619
72	42.6742	17.6709	1.96861	62.3137
74	39.714	16.4451	1.83205	57.9911
76	36.961	15.3051	1.70505	53.9712
78	34.4007	14.2449	1.58694	50.2325
80	32.0193	13.2588	1.47708	46.7551
82	29.8042	12.3416	1.3749	43.5207
84	27.7439	11.4884	1.27985	40.5121
86	25.8272	10.6947	1.19144	37.7134
88	24.0442	9.95641	1.10918	35.1098
90	22.3855	9.26953	1.03266	32.6876
92	20.8422	8.63047	0.961468	30.4341
94	19.4062	8.03588	0.895228	28.3374
96	18.0702	7.48262	0.833593	26.3864
98	16.8269	6.96781	0.776241	24.571
100	15.67	6.48875	0.722871	22.8816
102	14.5934	6.04292	0.673205	21.3095

104	13.5914	5.62801	0.626982	19.8464
106	12.6588	5.24185	0.583962	18.4846
108	11.7908	4.88243	0.543921	17.2172
110	10.9829	4.54788	0.506651	16.0375
112	10.2309	4.23647	0.471958	14.9393
114	9.53079	3.94657	0.439663	13.917
116	8.87906	3.6767	0.409598	12.9654
118	8.2723	3.42545	0.381608	12.0794
120	7.70739	3.19153	0.355548	11.2545
122	7.18142	2.97373	0.331284	10.4864
124	6.69166	2.77093	0.308691	9.77128
126	6.23562	2.58208	0.287654	9.10536
128	5.81094	2.40623	0.268063	8.48523
130	5.41545	2.24246	0.249819	7.90774
132	5.04713	2.08995	0.232828	7.3699
134	4.70409	1.9479	0.217003	6.86899
136	4.38458	1.81559	0.202263	6.40243
138	4.08697	1.69235	0.188534	5.96785
140	3.80974	1.57756	0.175746	5.56305
142	3.5515	1.47062	0.163833	5.18596
144	3.31092	1.371	0.152735	4.83466
146	3.08679	1.27819	0.142395	4.50738
148	2.87797	1.19173	0.132762	4.20246
150	2.68341	1.11116	0.123787	3.91836
152	2.50212	1.03609	0.115424	3.65364
154	2.33319	0.966141	0.107631	3.40697
156	2.17578	0.900957	0.10037	3.1771
158	2.02908	0.840211	0.093602	2.96289
160	1.89236	0.783599	0.087296	2.76326
162	1.76494	0.730836	0.081418	2.5772
164	1.64618	0.681659	0.075939	2.40378
166	1.53548	0.635821	0.070833	2.24214
168	1.4323	0.593094	0.066073	2.09147
170	1.33612	0.553265	0.061636	1.95102
172	1.24645	0.516136	0.057499	1.82008
174	1.16286	0.481521	0.053643	1.69802
176	1.08492	0.449249	0.050048	1.58422
178	1.01226	0.419159	0.046696	1.47811
180	0.944503	0.391104	0.04357	1.37918
182	0.881327	0.364944	0.040656	1.28693
184	0.822416	0.34055	0.037938	1.2009
186	0.767479	0.317801	0.035404	1.12068
188	0.716245	0.296586	0.033041	1.04587
190	0.668464	0.2768	0.030837	0.976101
192	0.623899	0.258347	0.028781	0.911027
194	0.582333	0.241135	0.026863	0.850331
196	0.543562	0.22508	0.025075	0.793717
198	0.507395	0.210104	0.023406	0.740906
200	0.473658	0.196134	0.02185	0.691642

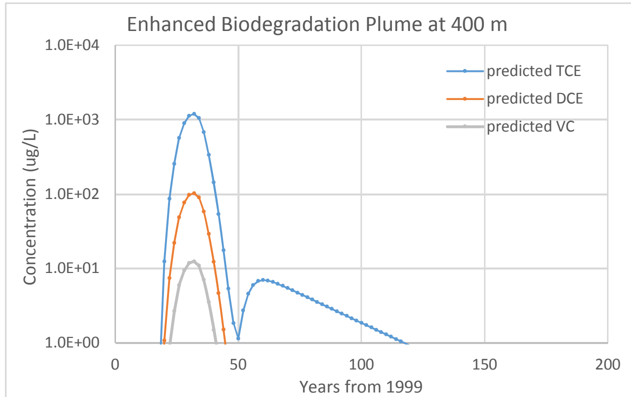
Appendix E-7

No-Action Alternative - Eastern Flow Line

Eastern Plume

Enhanced Biodegradation

Residential PRG:		
	PRG	PRG
TCE	2.8	5
Time Achieved (yrs)	114	98
Date Achieved	2113	2097
Time from 2015 (yrs)	98	82



Input parameters:

Initial Source		Component 1: TCE		Yield	0.74
Conc. (g/L)	0.06	time (yr):	Decay Rate	Decay Rate	Decay Rate
Mass (Kg)	2800	28	0.9	0.9	0.365
Gamma	1	time (yr):	9.1	9.1	0.365
Source Dimensions		18	0.02	0.02	0.365
Width (m)	43	Component 2: 1,2-DCE		Yield	0.161
Depth (m)	4		Decay Rate	Decay Rate	Decay Rate
Darcy Velocity (m/yr)	10		2.5	2.5	3
Porosity	0.25		2.5	2.5	3
Source Remediation			2.5	2.5	3
Fraction Removed	0.8	Component 3: VC		Yield	0
Remed. Start (yr)	18		Decay Rate	Decay Rate	Decay Rate
Remed. End (yr)	28		4.5	4.5	5
Source Decay (1/yr)	0		4.5	4.5	5
Transport Parameters			4.5	4.5	5
Retardation Factor	3	Dist. from Source			
SigmaV	0.18	X1 (m)	50	X2 (m)	150
vMin	0		Simulation Parameters		
vMax	1.72		Intervals	Min Value	Max Value
#Stream Tubes	100	x-direction (m)	51	0.01	2000
alpha y (m)	0.4	y-direction (m)	1	0	0
alpha z (m)	0.04	z-direction	1	0	0
		Time (yr)	100	0	200

Output results (400 m from start)

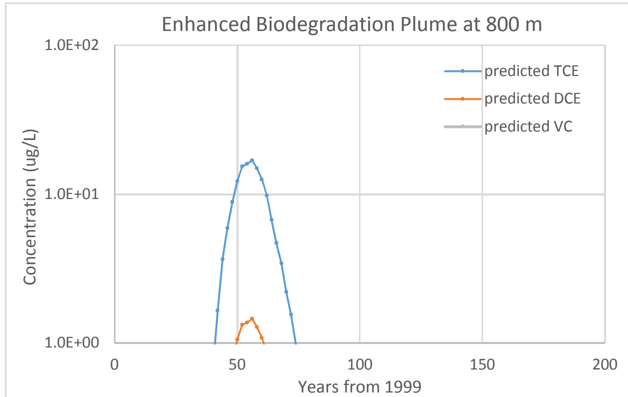
Years	TCE	1,2-DCE	VC	total VOC
2	0	0	0	0
4	0	0	0	0
6	0	0	0	0
8	0	0	0	0
10	0	0	0	0
12	0	0	0	0
14	0	0	0	0
16	0	0	0	0
18	0.353272	0.030436	0.0037	0.387409
20	12.4977	1.07676	0.130906	13.7054
22	86.8038	7.47868	0.909218	95.1917
24	256.09	22.0637	2.68239	280.836
26	569.842	49.0955	5.96878	624.907
28	898.21	77.3865	9.40825	985.005
30	1131.51	97.4863	11.8519	1240.84
32	1192.24	102.719	12.4881	1307.45
34	1050.31	90.4906	11.0014	1151.8
36	677.85	58.401	7.10011	743.351
38	338.15	29.1337	3.54193	370.825
40	143.526	12.3656	1.50335	157.395
42	54.0957	4.66068	0.566622	59.323
44	17.6227	1.51831	0.184588	19.3256
46	5.36042	0.461834	0.056148	5.8784
48	1.85432	0.159761	0.019423	2.0335
50	1.14257	0.09844	0.011968	1.25298
52	2.74323	0.236347	0.028734	3.00831
54	4.57405	0.394084	0.047911	5.01605
56	6.01625	0.518338	0.063017	6.5976
58	6.78363	0.584453	0.071055	7.43914
60	7.04521	0.60699	0.073795	7.726
62	6.9182	0.596047	0.072464	7.58671
64	6.62941	0.571166	0.06944	7.27002
66	6.24985	0.538465	0.065464	6.85378
68	5.8593	0.504816	0.061373	6.42549
70	5.47074	0.471339	0.057303	5.99939
72	5.09714	0.439151	0.05339	5.58968
74	4.74566	0.408869	0.049708	5.20424
76	4.41713	0.380564	0.046267	4.84396
78	4.11016	0.354116	0.043052	4.50733
80	3.82454	0.329509	0.04006	4.19411
82	3.55864	0.3066	0.037275	3.90252
84	3.31131	0.285291	0.034684	3.63129
86	3.08129	0.265473	0.032275	3.37904
88	2.86738	0.247043	0.030034	3.14446
90	2.66845	0.229904	0.027951	2.9263
92	2.48344	0.213964	0.026013	2.72341
94	2.31137	0.199139	0.02421	2.53472
96	2.15133	0.185351	0.022534	2.35921
98	2.00247	0.172526	0.020975	2.19597
100	1.86401	0.160596	0.019525	2.04413
102	1.73521	0.149499	0.018175	1.90288

104	1.61539	0.139176	0.01692	1.77149
106	1.50392	0.129573	0.015753	1.64925
108	1.40022	0.120638	0.014667	1.53552
110	1.30373	0.112325	0.013656	1.42971
112	1.21395	0.10459	0.012716	1.33126
114	1.13041	0.097392	0.011841	1.23964
116	1.05267	0.090695	0.011026	1.15439
118	0.980331	0.084462	0.010269	1.07506
120	0.913007	0.078661	0.009563	1.00123
122	0.850348	0.073263	0.008907	0.932518
124	0.792029	0.068238	0.008296	0.868563
126	0.737747	0.063562	0.007728	0.809036
128	0.687219	0.059208	0.007198	0.753625
130	0.640183	0.055156	0.006706	0.702045
132	0.596397	0.051383	0.006247	0.654027
134	0.555633	0.047871	0.00582	0.609324
136	0.517681	0.044602	0.005422	0.567705
138	0.482345	0.041557	0.005052	0.528955
140	0.449443	0.038722	0.004708	0.492873
142	0.418807	0.036083	0.004387	0.459276
144	0.390278	0.033625	0.004088	0.42799
146	0.36371	0.031336	0.00381	0.398855
148	0.338967	0.029204	0.003551	0.371722
150	0.315923	0.027219	0.003309	0.346451
152	0.294461	0.02537	0.003084	0.322915
154	0.274469	0.023647	0.002875	0.300992
156	0.255848	0.022043	0.00268	0.280571
158	0.238501	0.020548	0.002498	0.261548
160	0.222342	0.019156	0.002329	0.243827
162	0.207287	0.017859	0.002171	0.227318
164	0.193262	0.016651	0.002024	0.211937
166	0.180194	0.015525	0.001887	0.197606
168	0.168017	0.014476	0.00176	0.184253
170	0.156671	0.013498	0.001641	0.171811
172	0.146099	0.012587	0.00153	0.160216
174	0.136246	0.011739	0.001427	0.149412
176	0.127064	0.010947	0.001331	0.139342
178	0.118507	0.01021	0.001241	0.129958
180	0.110531	0.009523	0.001158	0.121211
182	0.103097	0.008882	0.00108	0.113059
184	0.096167	0.008285	0.001007	0.10546
186	0.089708	0.007729	0.00094	0.0983763
188	0.083686	0.00721	0.000877	0.0917729
190	0.078073	0.006726	0.000818	0.0856168
192	0.072839	0.006276	0.000763	0.0798774
194	0.067959	0.005855	0.000712	0.0745264
196	0.06341	0.005463	0.000664	0.0695371
198	0.059168	0.005098	0.00062	0.064885
200	0.055212	0.004757	0.000578	0.0605469

Appendix E-7
No-Action Alternative - Eastern Flow Line

Eastern Plume
Enhanced Biodegradation

Residential PRG:		
	PRG	PRG
TCE	2.8	5
Time Achieved (yrs)	70	66
Date Achieved	2069	2065
Time from 2015 (yrs)	54	50



Input parameters:

Initial Source		Component 1: TCE		Yield	0.37
Conc. (g/L)	0.06	time (yr):	Decay Rate	Decay Rate	Decay Rate
Mass (Kg)	2800	28	0.9	0.9	0.365
Gamma	1	time (yr):	9.1	9.1	0.365
Source Dimensions		18	0.02	0.02	0.365
Width (m)	43	Component 2: 1,2-DCE		Yield	0.161
Depth (m)	4		Decay Rate	Decay Rate	Decay Rate
Darcy Velocity (m/yr)	10		2.5	2.5	3
Porosity	0.25		2.5	2.5	3
Source Remediation			2.5	2.5	3
Fraction Removed	0.8	Component 3: VC		Yield	0
Remed. Start (yr)	18		Decay Rate	Decay Rate	Decay Rate
Remed. End (yr)	28		4.5	4.5	5
Source Decay (1/yr)	0		4.5	4.5	5
Transport Parameters			4.5	4.5	5
Retardation Factor	3	Dist. from Source			
SigmaV	0.18	X1 (m)	50	X2 (m)	150
vMin	0		Simulation Parameters		
vMax	1.72		Intervals	Min Value	Max Value
#Stream Tubes	100	x-direction (m)	51	1	2000
alpha y (m)	0.5	y-direction (m)	1	0	0
alpha z (m)	0.05	z-direction	1	0	0
		Time (yr)	100	0	200

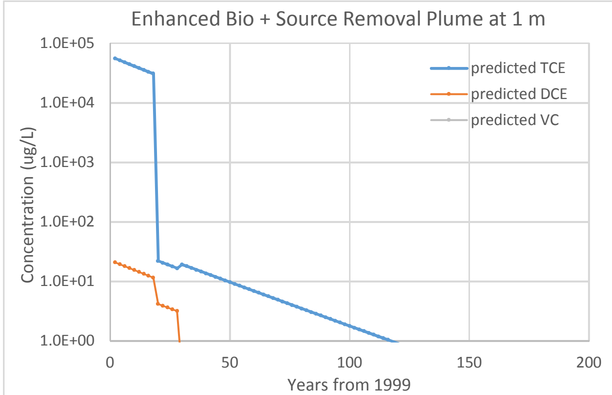
Output results (800 m from start)

Years	TCE	1,2-DCE	VC	total VOC
2	0	0	0	0
4	0	0	0	0
6	0	0	0	0
8	0	0	0	0
10	0	0	0	0
12	0	0	0	0
14	0	0	0	0
16	0	0	0	0
18	0	0	0	0
20	0	0	0	0
22	0	0	0	0
24	0	0	0	0
26	0	0	0	0
28	0	0	0	0
30	0	0	0	0
32	0	0	0	0
34	0	0	0	0
36	0.022712	0.001957	0.000238	0.0249071
38	0.156877	0.013516	0.001643	0.172036
40	0.650997	0.056088	0.006819	0.713903
42	1.65761	0.142814	0.017363	1.81779
44	3.65106	0.314562	0.038243	4.00386
46	5.9184	0.509908	0.061992	6.4903
48	8.87094	0.764287	0.092918	9.72815
50	12.23	1.05369	0.128102	13.4118
52	15.3847	1.32549	0.161146	16.8713
54	15.9568	1.37478	0.167139	17.4987
56	16.858	1.45243	0.176579	18.487
58	14.8732	1.28142	0.155788	16.3104
60	12.537	1.08014	0.131318	13.7484
62	9.79065	0.843526	0.102552	10.7367
64	6.70927	0.578046	0.070276	7.35759
66	4.69638	0.404622	0.049192	5.15019
68	3.428	0.295344	0.035907	3.75925
70	2.2073	0.190173	0.02312	2.4206
72	1.55272	0.133777	0.016264	1.70276
74	0.953497	0.08215	0.009987	1.04563
76	0.570821	0.04918	0.005979	0.62598
78	0.370962	0.031961	0.003886	0.406809
80	0.286498	0.024684	0.003001	0.314183
82	0.215447	0.018562	0.002257	0.236266
84	0.185762	0.016005	0.001946	0.203712
86	0.173584	0.014955	0.001818	0.190358
88	0.162679	0.014016	0.001704	0.178399
90	0.14737	0.012697	0.001544	0.161611
92	0.138406	0.011925	0.00145	0.151781
94	0.129838	0.011186	0.00136	0.142384
96	0.122394	0.010545	0.001282	0.134221
98	0.11356	0.009784	0.001189	0.124534
100	0.106419	0.009169	0.001115	0.116702
102	0.099307	0.008556	0.00104	0.108903

104	0.092602	0.007978	0.00097	0.101551
106	0.086309	0.007436	0.000904	0.0946488
108	0.080405	0.006927	0.000842	0.0881748
110	0.074876	0.006451	0.000784	0.0821107
112	0.069706	0.006006	0.00073	0.0764419
114	0.064884	0.00559	0.00068	0.0711538
116	0.060393	0.005203	0.000633	0.0662292
118	0.056214	0.004843	0.000589	0.0616463
120	0.052326	0.004508	0.000548	0.0573819
122	0.048707	0.004196	0.00051	0.0534139
124	0.04534	0.003906	0.000475	0.0497217
126	0.042207	0.003636	0.000442	0.0462858
128	0.039293	0.003385	0.000412	0.0430895
130	0.036581	0.003152	0.000383	0.040116
132	0.034058	0.002934	0.000357	0.0373493
134	0.031711	0.002732	0.000332	0.034775
136	0.029527	0.002544	0.000309	0.0323799
138	0.027494	0.002369	0.000288	0.0301511
140	0.025603	0.002206	0.000268	0.0280772
142	0.023843	0.002054	0.00025	0.0261472
144	0.022205	0.001913	0.000233	0.0243511
146	0.020681	0.001782	0.000217	0.0226796
148	0.019262	0.00166	0.000202	0.0211238
150	0.017942	0.001546	0.000188	0.0196757
152	0.016713	0.00144	0.000175	0.0183278
154	0.015569	0.001341	0.000163	0.0170731
156	0.014504	0.00125	0.000152	0.0159051
158	0.013512	0.001164	0.000142	0.0148177
160	0.012589	0.001085	0.000132	0.0138054
162	0.011729	0.001011	0.000123	0.0128629
164	0.010929	0.000942	0.000114	0.0119853
166	0.010184	0.000877	0.000107	0.0111681
168	0.00949	0.000818	9.94E-05	0.0104071
170	0.008844	0.000762	9.26E-05	0.0096985
172	0.008242	0.00071	8.63E-05	0.0090386
174	0.007682	0.000662	8.05E-05	0.008424
176	0.00716	0.000617	7.5E-05	0.0078516
178	0.006674	0.000575	6.99E-05	0.0073184
180	0.006221	0.000536	6.52E-05	0.0068218
182	0.005799	0.0005	6.07E-05	0.0063591
184	0.005406	0.000466	5.66E-05	0.0059282
186	0.00504	0.000434	5.28E-05	0.0055267
188	0.004699	0.000405	4.92E-05	0.0051527
190	0.004381	0.000377	4.59E-05	0.0048042
192	0.004085	0.000352	4.28E-05	0.0044795
194	0.003809	0.000328	3.99E-05	0.0041769
196	0.003552	0.000306	3.72E-05	0.003895
198	0.003312	0.000285	3.47E-05	0.0036323
200	0.003089	0.000266	3.24E-05	0.0033874

Eastern Plume
Enhanced Bio + Source Removal

Residential PRG:		
	PRG	PRG
TCE	2.8	5
Time Achieved (yrs)	70	88
Date Achieved	2069	2087
Time from 2015 (yrs)	54	72



Input parameters:

Initial Source		Component 1: TCE		Yield	0.74
Conc. (g/L)	0.06	time (yr):	Decay Rate	Decay Rate	Decay Rate
Mass (Kg)	2800	28	0.9	0.9	0.365
Gamma	1	time (yr):	9.1	9.1	0.365
Source Dimensions		18	0.02	0.02	0.365
Width (m)	43	Component 2: 1,2-DCE		Yield	0.161
Depth (m)	4		Decay Rate	Decay Rate	Decay Rate
Darcy Velocity (m/yr)	10		2.5	2.5	3
Porosity	0.25		2.5	2.5	3
Source Remediation			2.5	2.5	3
Fraction Removed	0.999	Component 3: VC		Yield	0
Remed. Start (yr)	18		Decay Rate	Decay Rate	Decay Rate
Remed. End (yr)	19		4.5	4.5	5
Source Decay (1/yr)	0		4.5	4.5	5
Transport Parameters			4.5	4.5	5
Retardation Factor	3	Dist. from Source			
SigmaV	0.18	X1 (m)	50	X2 (m)	150
vMin	0	Simulation Parameters			
vMax	1.72		Intervals	Min Value	Max Value
#Stream Tubes	100	x-direction (m)	11	0.01	10
alpha y (m)	0.4	y-direction (m)	1	0	0
alpha z (m)	0.04	z-direction	1	0	0
		Time (yr)	100	0	200

Output results (1 meter from start)

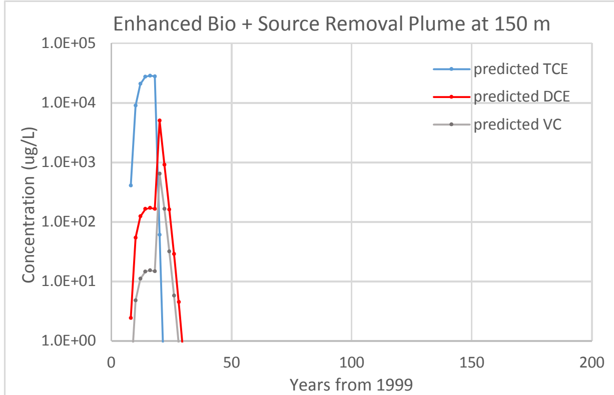
Years	TCE	1,2-DCE	VC	total VOC
2	55828.3	20.8883	0.110826	55849.3
4	51826.8	19.3911	0.102883	51846.3
6	48114.8	18.0022	0.095514	48132.9
8	44671	16.7137	0.088678	44687.8
10	41476	15.5183	0.082336	41491.6
12	38511.7	14.4092	0.076451	38526.1
14	35761.1	13.3801	0.070991	35774.5
16	33208.8	12.4251	0.065924	33221.3
18	30840.3	11.5389	0.061222	30851.9
20	21.9509	4.19014	0.023103	26.1642
22	20.4878	3.91044	0.021519	24.4197
24	19.1231	3.64995	0.020083	22.7931
26	17.8501	3.40698	0.018746	21.2758
28	16.6626	3.18034	0.017499	19.8605
30	19.252	0.327699	0.001745	19.5814
32	17.973	0.305928	0.001629	18.2805
34	16.7797	0.285616	0.001521	17.0668
36	15.6664	0.266666	0.00142	15.9344
38	14.6276	0.248985	0.001326	14.8779
40	13.6583	0.232486	0.001238	13.8921
42	12.7539	0.217091	0.001156	12.9722
44	11.9099	0.202725	0.001079	12.1137
46	11.1223	0.189319	0.001008	11.3126
48	10.3872	0.176807	0.000941	10.565
50	9.7012	0.165129	0.000879	9.86721
52	9.06089	0.154231	0.000821	9.21595
54	8.46324	0.144058	0.000767	8.60807
56	7.90538	0.134562	0.000717	8.04066
58	7.38463	0.125698	0.000669	7.51099
60	6.89849	0.117423	0.000625	7.01654
62	6.44466	0.109698	0.000584	6.55494
64	6.02096	0.102486	0.000546	6.12399
66	5.62537	0.095752	0.00051	5.72163
68	5.25601	0.089465	0.000476	5.34595
70	4.91113	0.083595	0.000445	4.99517
72	4.58909	0.078113	0.000416	4.66761
74	4.28836	0.072994	0.000389	4.36174
76	4.00752	0.068214	0.000363	4.07609
78	3.74524	0.06375	0.000339	3.80933
80	3.50028	0.05958	0.000317	3.56018
82	3.2715	0.055686	0.000297	3.32748
84	3.0578	0.052049	0.000277	3.11013
86	2.8582	0.048651	0.000259	2.90711
88	2.67174	0.045477	0.000242	2.71746
90	2.49756	0.042512	0.000226	2.5403
92	2.33484	0.039743	0.000212	2.3748
94	2.18282	0.037155	0.000198	2.22018
96	2.04079	0.034737	0.000185	2.07572
98	1.90809	0.032479	0.000173	1.94074
100	1.78409	0.030368	0.000162	1.81462
102	1.66823	0.028396	0.000151	1.69678

104	1.55996	0.026553	0.000141	1.58666
106	1.45879	0.024831	0.000132	1.48375
108	1.36423	0.023221	0.000124	1.38758
110	1.27586	0.021717	0.000116	1.2977
112	1.19327	0.020311	0.000108	1.21369
114	1.11608	0.018997	0.000101	1.13518
116	1.04392	0.017769	9.46E-05	1.06179
118	0.976474	0.016621	8.85E-05	0.993184
120	0.913425	0.015548	8.28E-05	0.929056
122	0.854484	0.014545	7.74E-05	0.869106
124	0.799382	0.013607	7.25E-05	0.813061
126	0.747866	0.01273	6.78E-05	0.760664
128	0.699701	0.01191	6.34E-05	0.711674
130	0.654666	0.011143	5.93E-05	0.665869
132	0.612557	0.010427	5.55E-05	0.623039
134	0.573181	0.009756	5.2E-05	0.582989
136	0.53636	0.00913	4.86E-05	0.545538
138	0.501926	0.008544	4.55E-05	0.510515
140	0.469723	0.007995	4.26E-05	0.477761
142	0.439606	0.007483	3.98E-05	0.447128
144	0.411437	0.007003	3.73E-05	0.418478
146	0.38509	0.006555	3.49E-05	0.39168
148	0.360446	0.006135	3.27E-05	0.366614
150	0.337394	0.005743	3.06E-05	0.343167
152	0.315829	0.005376	2.86E-05	0.321234
154	0.295656	0.005033	2.68E-05	0.300715
156	0.276783	0.004711	2.51E-05	0.281519
158	0.259126	0.004411	2.35E-05	0.26356
160	0.242606	0.00413	2.2E-05	0.246757
162	0.227148	0.003866	2.06E-05	0.231035
164	0.212685	0.00362	1.93E-05	0.216325
166	0.199151	0.00339	1.81E-05	0.202559
168	0.186487	0.003174	1.69E-05	0.189678
170	0.174635	0.002973	1.58E-05	0.177623
172	0.163543	0.002784	1.48E-05	0.166342
174	0.153163	0.002607	1.39E-05	0.155784
176	0.143447	0.002442	1.3E-05	0.145902
178	0.134353	0.002287	1.22E-05	0.136653
180	0.125842	0.002142	1.14E-05	0.127995
182	0.117874	0.002006	1.07E-05	0.119891
184	0.110416	0.001879	1E-05	0.112305
186	0.103434	0.001761	9.37E-06	0.105204
188	0.096897	0.001649	8.78E-06	0.0985551
190	0.090777	0.001545	8.23E-06	0.0923308
192	0.085048	0.001448	7.71E-06	0.0865032
194	0.079683	0.001356	7.22E-06	0.0810469
196	0.07466	0.001271	6.77E-06	0.0759379
198	0.069957	0.001191	6.34E-06	0.0711539
200	0.065552	0.001116	5.94E-06	0.0666741

Appendix E-8
Biodegradation + ISCO - Eastern Flow Line

Eastern Plume
Enhanced Bio + Source Removal

Residential PRG:		
	PRG	PRG
TCE	5	5
Time Achieved (yrs)	22	22
Date Achieved	2021	2021
Time from 2015 (yrs)	6	6



Input parameters:

Initial Source		Component 1: TCE		Yield	0.74
Conc. (g/L)	0.06	time (yr):	Decay Rate	Decay Rate	Decay Rate
Mass (Kg)	2800	28	0.9	0.9	0.2
Gamma	1	time (yr):	9.1	9.1	0.2
Source Dimensions		18	0.02	0.02	0.2
Width (m)	43	Component 2: 1,2-DCE		Yield	0.161
Depth (m)	4		Decay Rate	Decay Rate	Decay Rate
Darcy Velocity (m/yr)	10		2.5	2.5	3
Porosity	0.25		2.5	2.5	3
Source Remediation			2.5	2.5	3
Fraction Removed	0.999	Component 3: VC		Yield	0
Remed. Start (yr)	18		Decay Rate	Decay Rate	Decay Rate
Remed. End (yr)	19		4.5	4.5	5
Source Decay (1/yr)	0		4.5	4.5	5
Transport Parameters			4.5	4.5	5
Retardation Factor	3	Dist. from Source			
SigmaV	0.18	X1 (m)	50	X2 (m)	150
vMin	0		Simulation Parameters		
vMax	1.72		Intervals	Min Value	Max Value
#Stream Tubes	100	x-direction (m)	31	0.01	300
alpha y (m)	0.4	y-direction (m)	1	0	0
alpha z (m)	0.04	z-direction	1	0	0
		Time (yr)	100	0	200

Output results (150 m from start)

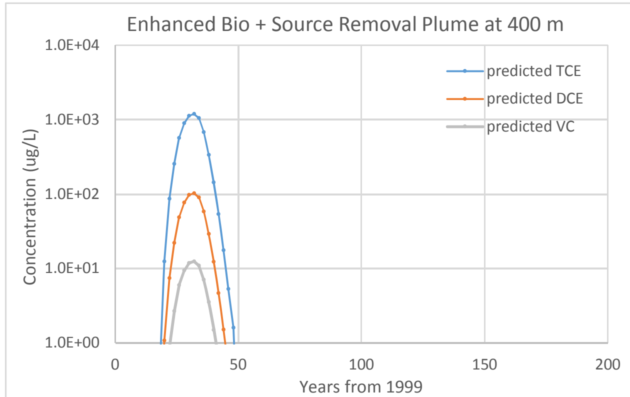
Years	TCE	1,2-DCE	VC	total VOC
2	0	0	0	0
4	0	0	0	0
6	0	0	0	0
8	407.961	2.43887	0.21787	410.618
10	9023.72	54.0535	4.83292	9082.61
12	20858.2	125.037	11.178	20994.4
14	27436.2	164.539	14.706	27615.5
16	28570.4	171.378	15.3149	28757.1
18	27633.1	165.773	14.8127	27813.7
20	61.0568	5035.02	644.831	5740.91
22	0.134031	911.232	165.235	1076.6
24	0.000293	162.443	31.8411	194.284
26	6.45E-07	28.8334	5.76356	34.5969
28	1.5E-09	4.53203	0.910512	5.44255
30	8.4E-09	0.470307	0.094617	0.564924
32	1.74E-06	0.038339	0.007714	0.0460554
34	0.000384	0.005452	0.001081	0.0069177
36	0.039152	0.018321	0.00223	0.0597024
38	0.253155	0.105069	0.011726	0.369951
40	0.40495	0.167623	0.018668	0.591241
42	0.427662	0.177065	0.019723	0.62445
44	0.409784	0.16968	0.018902	0.598366
46	0.384673	0.159286	0.017745	0.561704
48	0.359552	0.148885	0.016586	0.525023
50	0.335809	0.139053	0.015491	0.490353
52	0.313589	0.129852	0.014466	0.457907
54	0.292838	0.121259	0.013509	0.427606
56	0.27347	0.113239	0.012615	0.399325
58	0.255394	0.105754	0.011781	0.37293
60	0.238524	0.098769	0.011003	0.348295
62	0.222778	0.092249	0.010277	0.325303
64	0.208081	0.086163	0.009599	0.303843
66	0.194363	0.080482	0.008966	0.283811
68	0.181557	0.07518	0.008375	0.265113
70	0.169603	0.07023	0.007824	0.247657
72	0.158444	0.065609	0.007309	0.231362
74	0.148025	0.061295	0.006828	0.216148
76	0.138298	0.057267	0.00638	0.201944
78	0.129216	0.053506	0.005961	0.188683
80	0.120736	0.049995	0.00557	0.1763
82	0.112817	0.046716	0.005204	0.164737
84	0.105423	0.043654	0.004863	0.15394
86	0.098518	0.040795	0.004545	0.143857
88	0.092069	0.038124	0.004247	0.13444
90	0.086046	0.03563	0.003969	0.125646
92	0.080421	0.033301	0.00371	0.117432
94	0.075167	0.031125	0.003467	0.10976
96	0.07026	0.029093	0.003241	0.102594
98	0.065676	0.027195	0.00303	0.0959002
100	0.061393	0.025422	0.002832	0.0896471
102	0.057393	0.023765	0.002648	0.0838055

104	0.053655	0.022218	0.002475	0.0783481
106	0.050164	0.020772	0.002314	0.0732493
108	0.046901	0.019421	0.002164	0.0684855
110	0.043853	0.018159	0.002023	0.0640343
112	0.041004	0.016979	0.001892	0.0598751
114	0.038343	0.015877	0.001769	0.0559885
116	0.035856	0.014847	0.001654	0.0523566
118	0.033531	0.013885	0.001547	0.0489624
120	0.031359	0.012985	0.001447	0.0457904
122	0.029328	0.012144	0.001353	0.0428257
124	0.027431	0.011359	0.001265	0.0400547
126	0.025657	0.010624	0.001184	0.0374647
128	0.023999	0.009938	0.001107	0.0350437
130	0.022449	0.009296	0.001036	0.0327807
132	0.021	0.008696	0.000969	0.0306651
134	0.019646	0.008135	0.000906	0.0286873
136	0.01838	0.007611	0.000848	0.0268382
138	0.017196	0.00712	0.000793	0.0251095
140	0.016089	0.006662	0.000742	0.0234931
142	0.015054	0.006233	0.000694	0.0219817
144	0.014086	0.005833	0.00065	0.0205685
146	0.013181	0.005458	0.000608	0.0192469
148	0.012335	0.005108	0.000569	0.0180111
150	0.011543	0.00478	0.000532	0.0168553
152	0.010803	0.004473	0.000498	0.0157744
154	0.010111	0.004187	0.000466	0.0147635
156	0.009463	0.003918	0.000437	0.0138179
158	0.008857	0.003668	0.000409	0.0129335
160	0.008291	0.003433	0.000382	0.0121062
162	0.007761	0.003214	0.000358	0.0113323
164	0.007265	0.003008	0.000335	0.0106084
166	0.006801	0.002816	0.000314	0.0099311
168	0.006367	0.002637	0.000294	0.0092974
170	0.005961	0.002468	0.000275	0.0087046
172	0.005581	0.002311	0.000257	0.0081499
174	0.005226	0.002164	0.000241	0.0076309
176	0.004893	0.002026	0.000226	0.0071452
178	0.004582	0.001897	0.000211	0.0066908
180	0.004291	0.001777	0.000198	0.0062655
182	0.004018	0.001664	0.000185	0.0058675
184	0.003763	0.001558	0.000174	0.005495
186	0.003524	0.001459	0.000163	0.0051464
188	0.003301	0.001367	0.000152	0.0048201
190	0.003092	0.00128	0.000143	0.0045147
192	0.002896	0.001199	0.000134	0.0042288
194	0.002713	0.001123	0.000125	0.0039611
196	0.002541	0.001052	0.000117	0.0037106
198	0.002381	0.000986	0.00011	0.0034761
200	0.00223	0.000923	0.000103	0.0032565

Appendix E-8
Biodegradation + ISCO - Eastern Flow Line

Eastern Plume
Enhanced Bio + Source Removal

Residential PRG:		
	PRG	PRG
TCE	2.8	5
Time Achieved (yrs)	48	48
Date Achieved	2047	2047
Time from 2015 (yrs)	32	32



Input parameters:

Initial Source		Component 1: TCE		Yield	0.74
Conc. (g/L)	0.06	time (yr):	Decay Rate	Decay Rate	Decay Rate
Mass (Kg)	2800	28	0.75	0.9	0.2
Gamma	1	time (yr):	9.1	9.1	0.2
Source Dimensions		18	0.02	0.02	0.2
Width (m)	43	Component 2: 1,2-DCE		Yield	0.161
Depth (m)	4		Decay Rate	Decay Rate	Decay Rate
Darcy Velocity (m/yr)	10		2.5	2.5	3
Porosity	0.25		2.5	2.5	3
Source Remediation			2.5	2.5	3
Fraction Removed	0.999	Component 3: VC		Yield	0
Remed. Start (yr)	18		Decay Rate	Decay Rate	Decay Rate
Remed. End (yr)	19		4.5	4.5	5
Source Decay (1/yr)	0		4.5	4.5	5
Transport Parameters			4.5	4.5	5
Retardation Factor	3	Dist. from Source			
SigmaV	0.18	X1 (m)	50	X2 (m)	150
vMin	0		Simulation Parameters		
vMax	1.72		Intervals	Min Value	Max Value
#Stream Tubes	100	x-direction (m)	51	0.01	2000
alpha y (m)	0.4	y-direction (m)	1	0	0
alpha z (m)	0.04	z-direction	1	0	0
		Time (yr)	100	0	200

Output results (400 m from start)

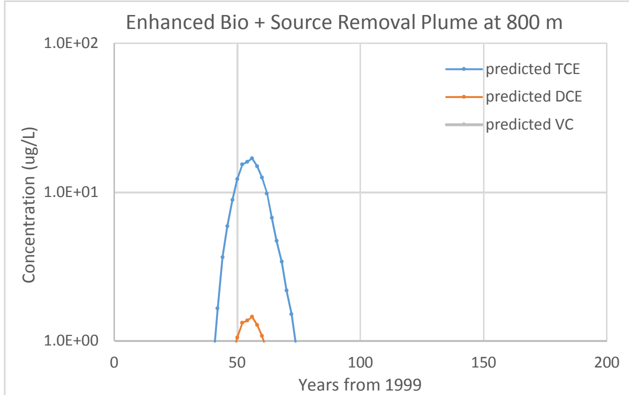
Years	TCE	1,2-DCE	VC	total VOC
2	0	0	0	0
4	0	0	0	0
6	0	0	0	0
8	0	0	0	0
10	0	0	0	0
12	0	0	0	0
14	0	0	0	0
16	0	0	0	0
18	0.353268	0.030436	0.0037	0.387404
20	12.4976	1.07674	0.130904	13.7052
22	86.8026	7.47859	0.909207	95.1904
24	256.086	22.0634	2.68236	280.832
26	569.834	49.0948	5.9687	624.898
28	898.197	77.3853	9.40812	984.991
30	1131.49	97.4849	11.8517	1240.83
32	1192.23	102.718	12.488	1307.43
34	1050.32	90.4914	11.0015	1151.81
36	677.857	58.4017	7.10018	743.359
38	338.156	29.1343	3.542	370.832
40	143.53	12.366	1.5034	157.399
42	54.1055	4.66153	0.566725	59.3337
44	17.6246	1.51847	0.184608	19.3277
46	5.3426	0.460298	0.055961	5.85886
48	1.61444	0.139094	0.01691	1.77045
50	0.037924	0.003267	0.000397	0.0415881
52	0.010214	0.00088	0.000107	0.0112008
54	0.016154	0.001392	0.000169	0.0177153
56	0.020946	0.001805	0.000219	0.0229698
58	0.023716	0.002043	0.000248	0.0260073
60	0.024747	0.002132	0.000259	0.0271378
62	0.024392	0.002102	0.000255	0.026749
64	0.023465	0.002022	0.000246	0.0257327
66	0.022204	0.001913	0.000233	0.0243493
68	0.020898	0.0018	0.000219	0.022917
70	0.019588	0.001688	0.000205	0.021481
72	0.018321	0.001579	0.000192	0.0200918
74	0.017125	0.001475	0.000179	0.0187795
76	0.016002	0.001379	0.000168	0.0175479
78	0.014948	0.001288	0.000157	0.0163922
80	0.013963	0.001203	0.000146	0.0153127
82	0.013043	0.001124	0.000137	0.0143037
84	0.012184	0.00105	0.000128	0.0133614
86	0.011382	0.000981	0.000119	0.0124817
88	0.010633	0.000916	0.000111	0.0116604
90	0.009934	0.000856	0.000104	0.0108935
92	0.009281	0.0008	9.72E-05	0.0101776
94	0.008671	0.000747	9.08E-05	0.0095091
96	0.008102	0.000698	8.49E-05	0.0088849
98	0.007571	0.000652	7.93E-05	0.0083021
100	0.007074	0.000609	7.41E-05	0.0077578
102	0.006611	0.00057	6.92E-05	0.0072496

104	0.006178	0.000532	6.47E-05	0.0067749
106	0.005774	0.000497	6.05E-05	0.0063317
108	0.005396	0.000465	5.65E-05	0.0059177
110	0.005044	0.000435	5.28E-05	0.005531
112	0.004714	0.000406	4.94E-05	0.0051698
114	0.004407	0.00038	4.62E-05	0.0048324
116	0.004119	0.000355	4.31E-05	0.0045173
118	0.003851	0.000332	4.03E-05	0.0042229
120	0.0036	0.00031	3.77E-05	0.0039478
122	0.003366	0.00029	3.53E-05	0.0036908
124	0.003147	0.000271	3.3E-05	0.0034508
126	0.002942	0.000253	3.08E-05	0.0032264
128	0.002751	0.000237	2.88E-05	0.0030168
130	0.002572	0.000222	2.69E-05	0.002821
132	0.002405	0.000207	2.52E-05	0.0026379
134	0.00225	0.000194	2.36E-05	0.0024669
136	0.002104	0.000181	2.2E-05	0.002307
138	0.001968	0.00017	2.06E-05	0.0021576
140	0.00184	0.000159	1.93E-05	0.002018
142	0.001721	0.000148	1.8E-05	0.0018875
144	0.00161	0.000139	1.69E-05	0.0017655
146	0.001506	0.00013	1.58E-05	0.0016515
148	0.001409	0.000121	1.48E-05	0.0015449
150	0.001318	0.000114	1.38E-05	0.0014452
152	0.001233	0.000106	1.29E-05	0.001352
154	0.001153	9.94E-05	1.21E-05	0.0012649
156	0.001079	9.3E-05	1.13E-05	0.0011835
158	0.00101	8.7E-05	1.06E-05	0.0011073
160	0.000945	8.14E-05	9.9E-06	0.0010361
162	0.000884	7.62E-05	9.26E-06	0.0009695
164	0.000827	7.13E-05	8.67E-06	0.0009073
166	0.000774	6.67E-05	8.11E-06	0.000849
168	0.000725	6.24E-05	7.59E-06	0.0007946
170	0.000678	5.84E-05	7.1E-06	0.0007437
172	0.000635	5.47E-05	6.65E-06	0.000696
174	0.000594	5.12E-05	6.22E-06	0.0006515
176	0.000556	4.79E-05	5.82E-06	0.0006098
178	0.00052	4.48E-05	5.45E-06	0.0005708
180	0.000487	4.2E-05	5.1E-06	0.0005343
182	0.000456	3.93E-05	4.78E-06	0.0005002
184	0.000427	3.68E-05	4.47E-06	0.0004683
186	0.0004	3.44E-05	4.19E-06	0.0004384
188	0.000374	3.22E-05	3.92E-06	0.0004105
190	0.00035	3.02E-05	3.67E-06	0.0003843
192	0.000328	2.83E-05	3.44E-06	0.0003599
194	0.000307	2.65E-05	3.22E-06	0.000337
196	0.000288	2.48E-05	3.01E-06	0.0003155
198	0.000269	2.32E-05	2.82E-06	0.0002955
200	0.000252	2.17E-05	2.64E-06	0.0002767

Appendix E-8
Biodegradation + ISCO - Eastern Flow Line

Eastern Plume
Enhanced Bio + Source Removal

Residential PRG:		
	PRG	PRG
TCE	2.8	5
Time Achieved (yrs)	66	70
Date Achieved	2065	2069
Time from 2015 (yrs)	50	54



Input parameters:

Initial Source		Component 1: TCE		Yield	0.74
Conc. (g/L)	0.06	time (yr):	Decay Rate	Decay Rate	Decay Rate
Mass (Kg)	2800	28	0.75	0.9	0.2
Gamma	1	time (yr):	9.1	9.1	0.2
Source Dimensions		18	0.02	0.02	0.2
Width (m)	43	Component 2: 1,2-DCE		Yield	0.161
Depth (m)	4		Decay Rate	Decay Rate	Decay Rate
Darcy Velocity (m/yr)	10		2.5	2.5	3
Porosity	0.25		2.5	2.5	3
Source Remediation			2.5	2.5	3
Fraction Removed	0.999	Component 3: VC		Yield	0
Remed. Start (yr)	18		Decay Rate	Decay Rate	Decay Rate
Remed. End (yr)	19		4.5	4.5	5
Source Decay (1/yr)	0		4.5	4.5	5
Transport Parameters			4.5	4.5	5
Retardation Factor	3	Dist. from Source			
SigmaV	0.18	X1 (m)	50	X2 (m)	150
vMin	0	Simulation Parameters			
vMax	1.72		Intervals	Min Value	Max Value
#Stream Tubes	100	x-direction (m)	51	0.01	2000
alpha y (m)	0.4	y-direction (m)	1	0	0
alpha z (m)	0.04	z-direction	1	0	0
		Time (yr)	100	0	200

Output results (800 m from start)

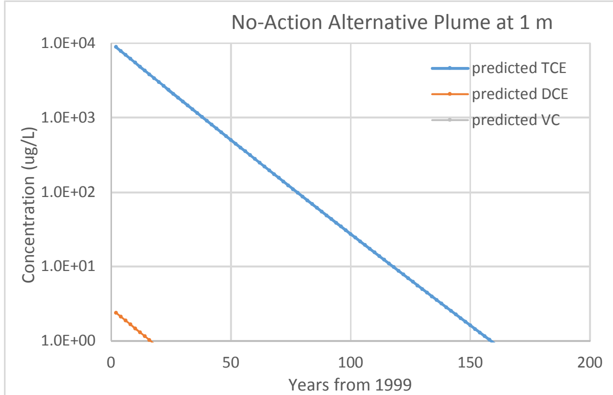
Years	TCE	1,2-DCE	VC	total VOC
2	0	0	0	0
4	0	0	0	0
6	0	0	0	0
8	0	0	0	0
10	0	0	0	0
12	0	0	0	0
14	0	0	0	0
16	0	0	0	0
18	0	0	0	0
20	0	0	0	0
22	0	0	0	0
24	0	0	0	0
26	0	0	0	0
28	0	0	0	0
30	0	0	0	0
32	0	0	0	0
34	0	0	0	0
36	0.022712	0.001957	0.000238	0.0249067
38	0.156874	0.013516	0.001643	0.172033
40	0.650983	0.056086	0.006819	0.713888
42	1.65758	0.142811	0.017362	1.81775
44	3.65098	0.314555	0.038242	4.00378
46	5.91827	0.509896	0.061991	6.49016
48	8.87075	0.764271	0.092916	9.72793
50	12.2297	1.05367	0.128099	13.4115
52	15.3845	1.32547	0.161144	16.8711
54	15.9565	1.37476	0.167136	17.4984
56	16.8578	1.4524	0.176576	18.4867
58	14.8731	1.28141	0.155787	16.3103
60	12.5377	1.0802	0.131326	13.7492
62	9.79131	0.843583	0.102559	10.7375
64	6.70861	0.577989	0.070269	7.35687
66	4.69346	0.404371	0.049161	5.14699
68	3.41858	0.294532	0.035808	3.74892
70	2.18584	0.188324	0.022896	2.39706
72	1.51304	0.130358	0.015848	1.65924
74	0.891	0.076765	0.009333	0.977098
76	0.483749	0.041678	0.005067	0.530494
78	0.262256	0.022595	0.002747	0.287598
80	0.160202	0.013802	0.001678	0.175682
82	0.07623	0.006568	0.000798	0.0835961
84	0.04016	0.00346	0.000421	0.0440404
86	0.026606	0.002292	0.000279	0.0291768
88	0.017514	0.001509	0.000183	0.0192063
90	0.006335	0.000546	6.64E-05	0.0069474
92	0.003086	0.000266	3.23E-05	0.0033846
94	0.002002	0.000172	2.1E-05	0.0021951
96	0.00168	0.000145	1.76E-05	0.0018424
98	0.000412	3.55E-05	4.32E-06	0.000452
100	0.000388	3.34E-05	4.07E-06	0.0004258
102	0.000366	3.15E-05	3.83E-06	0.0004011

104	0.000338	2.91E-05	3.54E-06	0.0003704
106	0.000316	2.72E-05	3.31E-06	0.0003465
108	0.000296	2.55E-05	3.1E-06	0.0003242
110	0.000276	2.38E-05	2.89E-06	0.0003029
112	0.000258	2.22E-05	2.7E-06	0.0002831
114	0.000241	2.08E-05	2.53E-06	0.0002645
116	0.000225	1.94E-05	2.36E-06	0.0002472
118	0.000211	1.81E-05	2.21E-06	0.000231
120	0.000197	1.7E-05	2.06E-06	0.0002158
122	0.000184	1.58E-05	1.93E-06	0.0002017
124	0.000172	1.48E-05	1.8E-06	0.0001885
126	0.000161	1.38E-05	1.68E-06	0.0001761
128	0.00015	1.29E-05	1.57E-06	0.0001646
130	0.00014	1.21E-05	1.47E-06	0.0001538
132	0.000131	1.13E-05	1.37E-06	0.0001438
134	0.000123	1.06E-05	1.28E-06	0.0001344
136	0.000115	9.87E-06	1.2E-06	0.0001256
138	0.000107	9.22E-06	1.12E-06	0.0001174
140	0.0001	8.62E-06	1.05E-06	0.0001097
142	9.35E-05	8.06E-06	9.8E-07	0.0001026
144	8.74E-05	7.53E-06	9.16E-07	9.59E-05
146	8.18E-05	7.04E-06	8.56E-07	8.965E-05
148	7.64E-05	6.59E-06	8.01E-07	8.382E-05
150	7.15E-05	6.16E-06	7.49E-07	7.837E-05
152	6.68E-05	5.76E-06	7E-07	7.328E-05
154	6.25E-05	5.38E-06	6.54E-07	6.852E-05
156	5.84E-05	5.03E-06	6.12E-07	6.407E-05
158	5.46E-05	4.71E-06	5.72E-07	5.992E-05
160	5.11E-05	4.4E-06	5.35E-07	5.603E-05
162	4.78E-05	4.12E-06	5.01E-07	5.24E-05
164	4.47E-05	3.85E-06	4.68E-07	4.901E-05
166	4.18E-05	3.6E-06	4.38E-07	4.584E-05
168	3.91E-05	3.37E-06	4.1E-07	4.288E-05
170	3.66E-05	3.15E-06	3.83E-07	4.011E-05
172	3.42E-05	2.95E-06	3.58E-07	3.752E-05
174	3.2E-05	2.76E-06	3.35E-07	3.51E-05
176	2.99E-05	2.58E-06	3.14E-07	3.283E-05
178	2.8E-05	2.41E-06	2.93E-07	3.072E-05
180	2.62E-05	2.26E-06	2.75E-07	2.874E-05
182	2.45E-05	2.11E-06	2.57E-07	2.689E-05
184	2.29E-05	1.98E-06	2.4E-07	2.516E-05
186	2.15E-05	1.85E-06	2.25E-07	2.354E-05
188	2.01E-05	1.73E-06	2.1E-07	2.203E-05
190	1.88E-05	1.62E-06	1.97E-07	2.062E-05
192	1.76E-05	1.52E-06	1.84E-07	1.929E-05
194	1.65E-05	1.42E-06	1.72E-07	1.806E-05
196	1.54E-05	1.33E-06	1.61E-07	1.69E-05
198	1.44E-05	1.24E-06	1.51E-07	1.582E-05
200	1.35E-05	1.16E-06	1.41E-07	1.481E-05

Appendix E-9
No-Action Alternative - Western Flow Line

Western Plume
No-Action Alternative

Residential PRG:		
	PRG	PRG
TCE	2.8	5
Time Achieved (yrs)	142	130
Date Achieved	2141	2129
Time from 2015 (yrs)	126	114



Input parameters:

Initial Source		Component 1: TCE		Yield	0.74
Conc. (g/L)	0.01	time (yr):	Decay Rate	Decay Rate	Decay Rate
Mass (Kg)	500	50	0.02	0.02	0.365
Gamma	0.9	time (yr):	0.02	0.02	0.365
Source Dimensions		20	0.02	0.02	0.365
Width (m)	43	Component 2: 1,2-DCE		Yield	0.161
Depth (m)	5		Decay Rate	Decay Rate	Decay Rate
Darcy Velocity (m/yr)	14		2.5	2.5	2.5
Porosity	0.25		2.5	2.5	2.5
Source Remediation			2.5	2.5	2.5
Fraction Removed	0	Component 3: VC		Yield	0
Remed. Start (yr)	0		Decay Rate	Decay Rate	Decay Rate
Remed. End (yr)	0		4.5	4.5	4.5
Source Decay (1/yr)	0		4.5	4.5	4.5
Transport Parameters			4.5	4.5	4.5
Retardation Factor	3	Dist. from Source			
SigmaV	0.18	X1 (m)	50	X2 (m)	240
vMin	0		Simulation Parameters		
vMax	1.72		Intervals	Min Value	Max Value
#Stream Tubes	100	x-direction (m)	11	0.01	10
alpha y (m)	4	y-direction (m)	1	0	0
alpha z (m)	0.4	z-direction	1	0	0
		Time (yr)	100	0	300

Output results (1 meter from start)

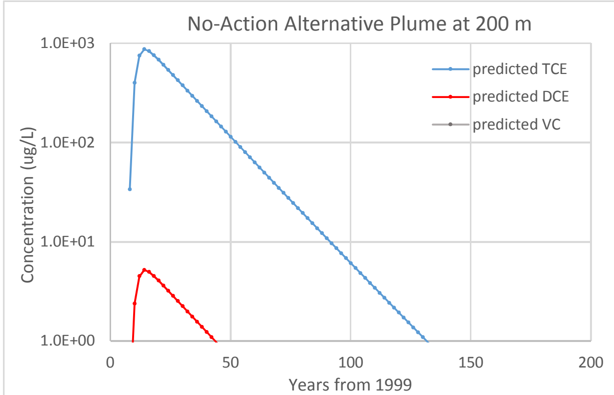
Years	TCE	1,2-DCE	VC	total VOC
2	8882.2	2.39658	0.009166	8884.6
4	7866.85	2.12262	0.008119	7868.98
6	6968.59	1.88026	0.007192	6970.48
8	6173.79	1.6658	0.006371	6175.46
10	5470.44	1.47603	0.005646	5471.92
12	4847.91	1.30806	0.005003	4849.23
14	4296.85	1.15937	0.004434	4298.02
16	3808.98	1.02773	0.003931	3810.01
18	3376.98	0.911172	0.003485	3377.9
20	2994.41	0.807947	0.00309	2995.22
22	2655.56	0.716519	0.002741	2656.28
24	2355.39	0.635528	0.002431	2356.03
26	2089.45	0.563771	0.002156	2090.01
28	1853.79	0.500188	0.001913	1854.3
30	1644.95	0.443838	0.001698	1645.4
32	1459.84	0.393892	0.001507	1460.24
34	1295.75	0.349616	0.001337	1296.1
36	1150.26	0.310361	0.001187	1150.57
38	1021.25	0.275552	0.001054	1021.53
40	906.836	0.244681	0.000936	907.082
42	805.353	0.217299	0.000831	805.571
44	715.327	0.193008	0.000738	715.521
46	635.452	0.171456	0.000656	635.624
48	564.575	0.152332	0.000583	564.728
50	501.673	0.13536	0.000518	501.808
52	445.84	0.120296	0.00046	445.961
54	396.276	0.106922	0.000409	396.383
56	352.27	0.095049	0.000364	352.365
58	313.194	0.084505	0.000323	313.279
60	278.49	0.075142	0.000287	278.566
62	247.666	0.066825	0.000256	247.733
64	220.283	0.059436	0.000227	220.343
66	195.955	0.052872	0.000202	196.008
68	174.337	0.047039	0.00018	174.384
70	155.125	0.041855	0.00016	155.167
72	138.048	0.037248	0.000142	138.086
74	122.868	0.033152	0.000127	122.902
76	109.372	0.029511	0.000113	109.402
78	97.3715	0.026273	0.0001	97.3979
80	86.6992	0.023393	8.95E-05	86.7227
82	77.2069	0.020832	7.97E-05	77.2278
84	68.7631	0.018553	7.1E-05	68.7817
86	61.2508	0.016527	6.32E-05	61.2674
88	54.5664	0.014723	5.63E-05	54.5812
90	48.618	0.013118	5.02E-05	48.6311
92	43.3237	0.01169	4.47E-05	43.3354
94	38.611	0.010418	3.98E-05	38.6214
96	34.4154	0.009286	3.55E-05	34.4248
98	30.6798	0.008278	3.17E-05	30.6881
100	27.3532	0.00738	2.82E-05	27.3607
102	24.3905	0.006581	2.52E-05	24.3972

104	21.7516	0.005869	2.24E-05	21.7575
106	19.4006	0.005235	2E-05	19.4059
108	17.306	0.004669	1.79E-05	17.3107
110	15.4396	0.004166	1.59E-05	15.4438
112	13.7762	0.003717	1.42E-05	13.7799
114	12.2936	0.003317	1.27E-05	12.2969
116	10.9719	0.00296	1.13E-05	10.9749
118	9.79364	0.002642	1.01E-05	9.79629
120	8.743	0.002359	9.02E-06	8.74536
122	7.80606	0.002106	8.06E-06	7.80817
124	6.97041	0.001881	7.19E-06	6.9723
126	6.22501	0.00168	6.42E-06	6.2267
128	5.56002	0.0015	5.74E-06	5.56153
130	4.9667	0.00134	5.13E-06	4.96805
132	4.43725	0.001197	4.58E-06	4.43845
134	3.96474	0.00107	4.09E-06	3.96581
136	3.54299	0.000956	3.66E-06	3.54395
138	3.1665	0.000854	3.27E-06	3.16736
140	2.83037	0.000764	2.92E-06	2.83114
142	2.53024	0.000683	2.61E-06	2.53092
144	2.26221	0.00061	2.33E-06	2.26282
146	2.02282	0.000546	2.09E-06	2.02337
148	1.809	0.000488	1.87E-06	1.80949
150	1.61797	0.000437	1.67E-06	1.61841
152	1.44729	0.000391	1.49E-06	1.44769
154	1.29478	0.000349	1.34E-06	1.29513
156	1.15848	0.000313	1.2E-06	1.1588
158	1.03666	0.00028	1.07E-06	1.03694
160	0.927759	0.00025	9.57E-07	0.92801
162	0.8304	0.000224	8.57E-07	0.830625
164	0.743348	0.000201	7.67E-07	0.743549
166	0.665503	0.00018	6.87E-07	0.665683
168	0.595882	0.000161	6.15E-07	0.596043
170	0.533608	0.000144	5.51E-07	0.533753
172	0.477901	0.000129	4.93E-07	0.47803
174	0.42806	0.000115	4.42E-07	0.428176
176	0.383463	0.000103	3.96E-07	0.383567
178	0.343554	9.27E-05	3.55E-07	0.343647
180	0.307835	8.31E-05	3.18E-07	0.307919
182	0.275863	7.44E-05	2.85E-07	0.275938
184	0.247241	6.67E-05	2.55E-07	0.247308
186	0.221614	5.98E-05	2.29E-07	0.221674
188	0.198668	5.36E-05	2.05E-07	0.198722
190	0.178118	4.81E-05	1.84E-07	0.178166
192	0.159713	4.31E-05	1.65E-07	0.159756
194	0.143226	3.86E-05	1.48E-07	0.143265
196	0.128457	3.47E-05	1.33E-07	0.128492
198	0.115224	3.11E-05	1.19E-07	0.115255
200	0.103366	2.79E-05	1.07E-07	0.103394

Appendix E-9
No-Action Alternative - Western Flow Line

Western Plume
No-Action Alternative

Residential PRG:		
	PRG	PRG
TCE	2.8	5
Time Achieved (yrs)	114	104
Date Achieved	2113	2103
Time from 2015 (yrs)	98	88



Input parameters:

Initial Source		Component 1: TCE		Yield	0.74
Conc. (g/L)	0.01	time (yr):	Decay Rate	Decay Rate	Decay Rate
Mass (Kg)	500	50	0.02	0.02	0.365
Gamma	0.9	time (yr):	0.02	0.02	0.365
Source Dimensions		20	0.02	0.02	0.365
Width (m)	43	Component 2: 1,2-DCE		Yield	0.161
Depth (m)	5		Decay Rate	Decay Rate	Decay Rate
Darcy Velocity (m/yr)	14		2.5	2.5	2.5
Porosity	0.25		2.5	2.5	2.5
Source Remediation			2.5	2.5	2.5
Fraction Removed	0	Component 3: VC		Yield	0
Remed. Start (yr)	0		Decay Rate	Decay Rate	Decay Rate
Remed. End (yr)	0		4.5	4.5	4.5
Source Decay (1/yr)	0		4.5	4.5	4.5
Transport Parameters			4.5	4.5	4.5
Retardation Factor	3	Dist. from Source			
SigmaV	0.18	X1 (m)	50	X2 (m)	240
vMin	0		Simulation Parameters		
vMax	1.72		Intervals	Min Value	Max Value
#Stream Tubes	100	x-direction (m)	31	0.01	300
alpha y (m)	4	y-direction (m)	1	0	0
alpha z (m)	0.4	z-direction	1	0	0
		Time (yr)	100	0	200

Output results (200 m from start)

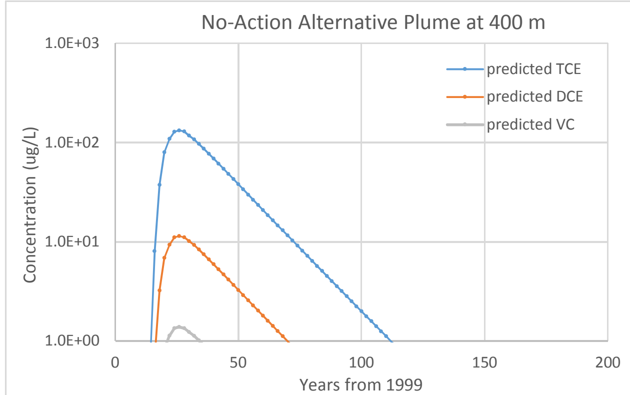
Years	TCE	1,2-DCE	VC	total VOC
2	0	0	0	0
4	0	0	0	0
6	0	0	0	0
8	33.6505	0.200433	0.017965	33.8689
10	398.572	2.37703	0.21339	401.163
12	753.379	4.4943	0.403599	758.277
14	872.583	5.20584	0.467544	878.256
16	831.156	4.95878	0.445367	836.561
18	757.354	4.5185	0.405827	762.278
20	680.025	4.05716	0.364393	684.447
22	605.432	3.61213	0.324423	609.368
24	537.5	3.20683	0.288022	540.995
26	476.936	2.8455	0.255569	480.037
28	423.077	2.52416	0.226708	425.828
30	375.193	2.23848	0.201049	377.633
32	332.802	1.98556	0.178334	334.966
34	295.184	1.76113	0.158176	297.104
36	261.85	1.56225	0.140314	263.553
38	232.309	1.38601	0.124484	233.82
40	206.119	1.22974	0.11045	207.459
42	182.915	1.09131	0.098016	184.104
44	162.344	0.968577	0.086993	163.4
46	144.102	0.859743	0.077218	145.039
48	127.932	0.763265	0.068553	128.763
50	113.591	0.677706	0.060868	114.329
52	100.87	0.601808	0.054051	101.525
54	89.5854	0.534485	0.048005	90.1679
56	79.5762	0.474767	0.042641	80.0936
58	70.6938	0.421773	0.037882	71.1534
60	62.8125	0.374752	0.033658	63.2209
62	55.8167	0.333014	0.02991	56.1797
64	49.607	0.295965	0.026582	49.9295
66	44.0947	0.263078	0.023628	44.3814
68	39.1998	0.233874	0.021005	39.4547
70	34.8531	0.20794	0.018676	35.0797
72	30.9926	0.184908	0.016608	31.1941
74	27.5638	0.164451	0.01477	27.743
76	24.5173	0.146275	0.013138	24.6767
78	21.8106	0.130126	0.011687	21.9524
80	19.4052	0.115775	0.010398	19.5314
82	17.2675	0.103021	0.009253	17.3798
84	15.3676	0.091686	0.008235	15.4675
86	13.6783	0.081608	0.00733	13.7673
88	12.1764	0.072647	0.006525	12.2556
90	10.8409	0.064679	0.005809	10.9113
92	9.65307	0.057592	0.005173	9.71584
94	8.59658	0.051289	0.004607	8.65247
96	7.65686	0.045682	0.004103	7.70665
98	6.82065	0.040693	0.003655	6.865
100	6.07657	0.036254	0.003256	6.11608
102	5.41438	0.032303	0.002901	5.44959

104	4.82499	0.028787	0.002585	4.85636
106	4.30032	0.025657	0.002304	4.32828
108	3.8332	0.02287	0.002054	3.85812
110	3.41727	0.020388	0.001831	3.43949
112	3.04687	0.018178	0.001633	3.06668
114	2.71704	0.01621	0.001456	2.73471
116	2.42317	0.014457	0.001298	2.43893
118	2.16137	0.012895	0.001158	2.17542
120	1.92809	0.011503	0.001033	1.94063
122	1.72022	0.010263	0.000922	1.73141
124	1.53496	0.009158	0.000823	1.54494
126	1.36982	0.008173	0.000734	1.37873
128	1.22261	0.007294	0.000655	1.23056
130	1.09136	0.006511	0.000585	1.09845
132	0.974318	0.005813	0.000522	0.980653
134	0.869942	0.00519	0.000466	0.875599
136	0.776846	0.004635	0.000416	0.781898
138	0.693801	0.004139	0.000372	0.698312
140	0.619746	0.003698	0.000332	0.623776
142	0.553635	0.003303	0.000297	0.557234
144	0.494638	0.002951	0.000265	0.497854
146	0.441983	0.002637	0.000237	0.444857
148	0.394983	0.002357	0.000212	0.397552
150	0.353025	0.002106	0.000189	0.355321
152	0.315564	0.001883	0.000169	0.317616
154	0.282113	0.001683	0.000151	0.283947
156	0.252239	0.001505	0.000135	0.253879
158	0.225557	0.001346	0.000121	0.227023
160	0.201722	0.001204	0.000108	0.203033
162	0.180428	0.001076	9.67E-05	0.181601
164	0.161401	0.000963	8.65E-05	0.162451
166	0.144399	0.000862	7.74E-05	0.145338
168	0.129204	0.000771	6.92E-05	0.130044
170	0.115622	0.00069	6.2E-05	0.116373
172	0.10348	0.000617	5.54E-05	0.104153
174	0.092624	0.000553	4.96E-05	0.0932267
176	0.082918	0.000495	4.44E-05	0.0834569
178	0.074255	0.000443	3.98E-05	0.074738
180	0.06649	0.000397	3.56E-05	0.0669218
182	0.059543	0.000355	3.19E-05	0.0599303
184	0.053329	0.000318	2.86E-05	0.0536757
186	0.047769	0.000285	2.56E-05	0.0480797
188	0.042794	0.000255	2.29E-05	0.0430722
190	0.038342	0.000229	2.05E-05	0.0385908
192	0.034357	0.000205	1.84E-05	0.0345799
194	0.030789	0.000184	1.65E-05	0.0309895
196	0.027596	0.000165	1.48E-05	0.0277752
198	0.024736	0.000148	1.33E-05	0.0248973
200	0.022176	0.000132	1.19E-05	0.0223202

Appendix E-9
No-Action Alternative - Western Flow Line

Western Plume
No-Action Alternative

Residential PRG:		
	PRG	PRG
TCE	2.8	5
Time Achieved (yrs)	96	86
Date Achieved	2095	2085
Time from 2015 (yrs)	80	70



Input parameters:

Initial Source		Component 1: TCE		Yield	0.74
Conc. (g/L)	0.01	time (yr):	Decay Rate	Decay Rate	Decay Rate
Mass (Kg)	500	50	0.02	0.02	0.365
Gamma	0.9	time (yr):	0.02	0.02	0.365
Source Dimensions		20	0.02	0.02	0.365
Width (m)	43	Component 2: 1,2-DCE		Yield	0.161
Depth (m)	5		Decay Rate	Decay Rate	Decay Rate
Darcy Velocity (m/yr)	14		2.5	2.5	2.5
Porosity	0.25		2.5	2.5	2.5
Source Remediation			2.5	2.5	2.5
Fraction Removed	0	Component 3: VC		Yield	0
Remed. Start (yr)	0		Decay Rate	Decay Rate	Decay Rate
Remed. End (yr)	0		4.5	4.5	4.5
Source Decay (1/yr)	0		4.5	4.5	4.5
Transport Parameters			4.5	4.5	4.5
Retardation Factor	3	Dist. from Source			
SigmaV	0.18	X1 (m)	50	X2 (m)	240
vMin	0		Simulation Parameters		
vMax	1.72		Intervals	Min Value	Max Value
#Stream Tubes	100	x-direction (m)	31	0.01	300
alpha y (m)	4	y-direction (m)	1	0	0
alpha z (m)	0.4	z-direction	1	0	0
		Time (yr)	100	0	200

Output results (400 m from start)

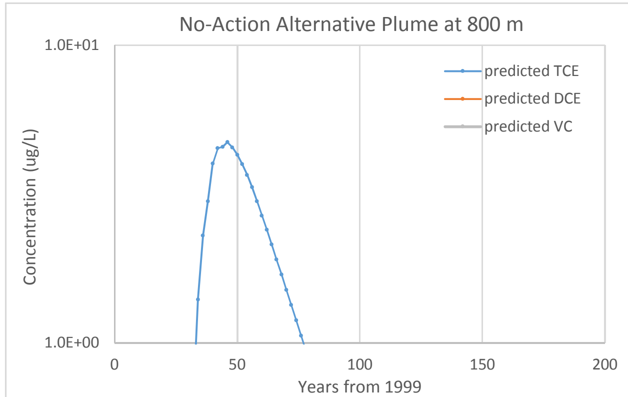
Years	TCE	1,2-DCE	VC	total VOC
2	0	0	0	0
4	0	0	0	0
6	0	0	0	0
8	0	0	0	0
10	0	0	0	0
12	0	0	0	0
14	0.485708	0.041712	0.005039	0.532459
16	8.04045	0.69158	0.0838	8.81583
18	37.4382	3.22261	0.391073	41.0519
20	79.7498	6.86706	0.833906	87.4508
22	108.625	9.35482	1.13634	119.116
24	128.678	11.0827	1.34648	141.107
26	132.449	11.408	1.38612	145.243
28	128.876	11.1006	1.34882	141.326
30	117.754	10.1426	1.23245	129.129
32	107.667	9.27386	1.1269	118.068
34	96.7098	8.33011	1.01223	106.052
36	86.5086	7.45144	0.905461	94.8655
38	77.1534	6.64564	0.807546	84.6066
40	68.6692	5.91486	0.718746	75.3028
42	60.9716	5.25182	0.638178	66.8616
44	54.1728	4.6662	0.567016	59.406
46	48.0788	4.14129	0.503232	52.7233
48	42.6699	3.6754	0.446618	46.792
50	37.8705	3.262	0.396384	41.5289
52	33.6126	2.89524	0.351817	36.8596
54	29.8355	2.5699	0.312283	32.7177
56	26.4852	2.28132	0.277216	29.0438
58	23.5135	2.02535	0.246111	25.785
60	20.8759	1.79815	0.218504	22.8925
62	18.5382	1.5968	0.194036	20.329
64	16.4642	1.41815	0.172328	18.0547
66	14.6234	1.2596	0.153061	16.0361
68	12.9908	1.11897	0.135972	14.2458
70	11.5416	0.994143	0.120804	12.6566
72	10.2558	0.883388	0.107345	11.2465
74	9.11421	0.785057	0.095397	9.99466
76	8.10098	0.697782	0.084791	8.88356
78	7.20124	0.620282	0.075374	7.89689
80	6.4023	0.551465	0.067012	7.02078
82	5.69286	0.490357	0.059586	6.24281
84	5.06266	0.436074	0.05299	5.55172
86	4.50287	0.387857	0.047131	4.93786
88	4.00549	0.345015	0.041925	4.39243
90	3.56353	0.306946	0.037299	3.90777
92	3.17076	0.273115	0.033188	3.47706
94	2.82169	0.243047	0.029534	3.09427
96	2.51136	0.216317	0.026286	2.75397
98	2.23547	0.192553	0.023398	2.45142
100	1.99016	0.171423	0.020831	2.18241
102	1.772	0.152632	0.018547	1.94317

104	1.57796	0.135918	0.016516	1.73039
106	1.40536	0.121051	0.01471	1.54112
108	1.2518	0.107824	0.013102	1.37273
110	1.11517	0.096056	0.011672	1.2229
112	0.993588	0.085583	0.0104	1.08957
114	0.885375	0.076262	0.009267	0.970904
116	0.789051	0.067965	0.008259	0.865275
118	0.703299	0.060579	0.007361	0.771239
120	0.62695	0.054003	0.006562	0.687515
122	0.558961	0.048146	0.005851	0.612958
124	0.49841	0.042931	0.005217	0.546558
126	0.444476	0.038285	0.004652	0.487414
128	0.39643	0.034147	0.004149	0.434726
130	0.353624	0.03046	0.003701	0.387784
132	0.31548	0.027174	0.003302	0.345957
134	0.281487	0.024246	0.002946	0.30868
136	0.251189	0.021636	0.002629	0.275455
138	0.224181	0.01931	0.002346	0.245838
140	0.200103	0.017236	0.002094	0.219433
142	0.178633	0.015387	0.00187	0.19589
144	0.159488	0.013738	0.001669	0.174894
146	0.142412	0.012267	0.001491	0.156169
148	0.127181	0.010955	0.001331	0.139467
150	0.113593	0.009784	0.001189	0.124566
152	0.10147	0.00874	0.001062	0.111272
154	0.090652	0.007808	0.000949	0.0994089
156	0.080997	0.006977	0.000848	0.0888218
158	0.07238	0.006234	0.000758	0.0793722
160	0.064688	0.005572	0.000677	0.0709367
162	0.05782	0.00498	0.000605	0.0634057
164	0.051688	0.004452	0.000541	0.0566813
166	0.046212	0.003981	0.000484	0.0506764
168	0.041322	0.003559	0.000433	0.0453132
170	0.036953	0.003183	0.000387	0.0405227
172	0.03305	0.002847	0.000346	0.0362431
174	0.029564	0.002546	0.000309	0.0324194
176	0.026448	0.002278	0.000277	0.0290027
178	0.023663	0.002038	0.000248	0.0259493
180	0.021175	0.001824	0.000222	0.0232202
182	0.01895	0.001632	0.000198	0.0207807
184	0.016961	0.001461	0.000178	0.0185997
186	0.015183	0.001308	0.000159	0.0166497
188	0.013593	0.001171	0.000142	0.0149059
190	0.012171	0.001048	0.000127	0.0133463
192	0.010899	0.000939	0.000114	0.0119514
194	0.009761	0.000841	0.000102	0.0107036
196	0.008743	0.000753	9.15E-05	0.0095872
198	0.007832	0.000675	8.2E-05	0.0085882
200	0.007016	0.000604	7.34E-05	0.0076943

Appendix E-9
No-Action Alternative - Western Flow Line

Western Plume
No-Action Alternative

Residential PRG:		
	PRG	PRG
TCE	2.8	5
Time Achieved (yrs)	60	48
Date Achieved	2059	2047
Time from 2015 (yrs)	44	32



Input parameters:

Initial Source		Component 1: TCE		Yield	0.37
Conc. (g/L)	0.01	time (yr):	Decay Rate	Decay Rate	Decay Rate
Mass (Kg)	500	50	0.02	0.02	0.365
Gamma	0.9	time (yr):	0.02	0.02	0.365
Source Dimensions		20	0.02	0.02	0.365
Width (m)	43	Component 2: 1,2-DCE		Yield	0.161
Depth (m)	5		Decay Rate	Decay Rate	Decay Rate
Darcy Velocity (m/yr)	14		2.5	2.5	2.5
Porosity	0.25		2.5	2.5	2.5
Source Remediation			2.5	2.5	2.5
Fraction Removed	0	Component 3: VC		Yield	0
Remed. Start (yr)	0		Decay Rate	Decay Rate	Decay Rate
Remed. End (yr)	0		4.5	4.5	4.5
Source Decay (1/yr)	0		4.5	4.5	4.5
Transport Parameters			4.5	4.5	4.5
Retardation Factor	3	Dist. from Source			
SigmaV	0.18	X1 (m)	50	X2 (m)	240
vMin	0		Simulation Parameters		
vMax	1.72		Intervals	Min Value	Max Value
#Stream Tubes	100	x-direction (m)	51	0.01	2000
alpha y (m)	4	y-direction (m)	1	0	0
alpha z (m)	0.4	z-direction	1	0	0
		Time (yr)	100	0	200

Output results (800 m from start)

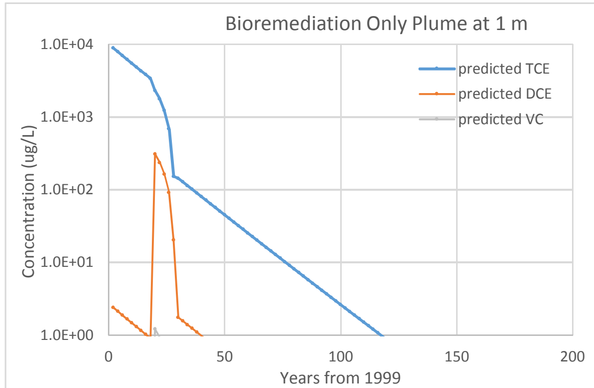
Years	TCE	1,2-DCE	VC	total VOC
2	0	0	0	0
4	0	0	0	0
6	0	0	0	0
8	0	0	0	0
10	0	0	0	0
12	0	0	0	0
14	0	0	0	0
16	0	0	0	0
18	0	0	0	0
20	0	0	0	0
22	0	0	0	0
24	0	0	0	0
26	0.004073	0.000351	4.27E-05	0.0044664
28	0.046217	0.003982	0.000484	0.050683
30	0.21862	0.018836	0.00229	0.239746
32	0.613467	0.052854	0.006426	0.672746
34	1.40124	0.120726	0.014677	1.53664
36	2.29883	0.198059	0.024079	2.52097
38	2.98865	0.257491	0.031305	3.27745
40	4.00205	0.344801	0.041919	4.38877
42	4.51368	0.388882	0.047278	4.94984
44	4.55936	0.392817	0.047757	4.99993
46	4.72417	0.407017	0.049483	5.18067
48	4.53624	0.390825	0.047515	4.97458
50	4.28403	0.369096	0.044873	4.698
52	3.9881	0.3436	0.041773	4.37347
54	3.66788	0.316011	0.038419	4.02231
56	3.34011	0.287771	0.034986	3.66287
58	2.9919	0.257771	0.031339	3.28101
60	2.67566	0.230525	0.028026	2.93421
62	2.40346	0.207074	0.025175	2.63571
64	2.14153	0.184506	0.022431	2.34846
66	1.9066	0.164266	0.019971	2.09084
68	1.69635	0.146151	0.017768	1.86026
70	1.50851	0.129967	0.015801	1.65428
72	1.34095	0.115531	0.014046	1.47053
74	1.19166	0.102669	0.012482	1.30681
76	1.05878	0.091221	0.01109	1.16109
78	0.940605	0.081039	0.009852	1.0315
80	0.835563	0.071989	0.008752	0.916304
82	0.742238	0.063949	0.007775	0.813962
84	0.659156	0.05679	0.006904	0.722851
86	0.585628	0.050456	0.006134	0.642218
88	0.52033	0.04483	0.00545	0.570609
90	0.462279	0.039828	0.004842	0.506949
92	0.410821	0.035395	0.004303	0.450519
94	0.365089	0.031455	0.003824	0.400368
96	0.324524	0.02796	0.003399	0.355883
98	0.288497	0.024856	0.003022	0.316375
100	0.256487	0.022098	0.002687	0.281272
102	0.228071	0.01965	0.002389	0.250109

104	0.202821	0.017474	0.002124	0.22242
106	0.180392	0.015542	0.00189	0.197823
108	0.160469	0.013825	0.001681	0.175975
110	0.142762	0.0123	0.001495	0.156557
112	0.127028	0.010944	0.001331	0.139303
114	0.113041	0.009739	0.001184	0.123965
116	0.10061	0.008668	0.001054	0.110332
118	0.089556	0.007716	0.000938	0.0982098
120	0.079728	0.006869	0.000835	0.0874316
122	0.070988	0.006116	0.000744	0.0778473
124	0.063214	0.005446	0.000662	0.0693223
126	0.056299	0.004851	0.00059	0.0617392
128	0.050147	0.004321	0.000525	0.0549931
130	0.044674	0.003849	0.000468	0.0489904
132	0.039803	0.003429	0.000417	0.0436487
134	0.035467	0.003056	0.000372	0.0388946
136	0.031609	0.002723	0.000331	0.034663
138	0.028173	0.002427	0.000295	0.0308957
140	0.025115	0.002164	0.000263	0.0275415
142	0.022391	0.001929	0.000235	0.0245546
144	0.019965	0.00172	0.000209	0.0218946
146	0.017805	0.001534	0.000186	0.0195252
148	0.01588	0.001368	0.000166	0.0174145
150	0.014165	0.00122	0.000148	0.015534
152	0.012637	0.001089	0.000132	0.0138584
154	0.011276	0.000971	0.000118	0.0123651
156	0.010062	0.000867	0.000105	0.0110341
158	0.00898	0.000774	9.41E-05	0.0098477
160	0.008015	0.000691	8.4E-05	0.0087899
162	0.007155	0.000616	7.49E-05	0.0078468
164	0.006388	0.00055	6.69E-05	0.0070058
166	0.005704	0.000491	5.98E-05	0.0062557
168	0.005094	0.000439	5.34E-05	0.0055866
170	0.00455	0.000392	4.77E-05	0.0049897
172	0.004064	0.00035	4.26E-05	0.0044572
174	0.003631	0.000313	3.8E-05	0.003982
176	0.003244	0.00028	3.4E-05	0.0035579
178	0.002899	0.00025	3.04E-05	0.0031793
180	0.002591	0.000223	2.71E-05	0.0028414
182	0.002316	0.0002	2.43E-05	0.0025398
184	0.00207	0.000178	2.17E-05	0.0022704
186	0.001851	0.000159	1.94E-05	0.0020299
188	0.001655	0.000143	1.73E-05	0.0018151
190	0.00148	0.000128	1.55E-05	0.0016232
192	0.001324	0.000114	1.39E-05	0.0014517
194	0.001184	0.000102	1.24E-05	0.0012986
196	0.001059	9.13E-05	1.11E-05	0.0011617
198	0.000948	8.17E-05	9.93E-06	0.0010394
200	0.000848	7.31E-05	8.88E-06	0.0009301

Appendix E-10
Enhanced Biodegradation - Western Flow Line

Western Plume
Enhanced Bioremediation Only

Residential PRG:		
	PRG	PRG
TCE	2.8	5
Time Achieved (yrs)	100	90
Date Achieved	2099	2089
Time from 2015 (yrs)	84	74



Input parameters:

Initial Source		Component 1: TCE		Yield	0.74
Conc. (g/L)	0.01	time (yr):	Decay Rate	Decay Rate	Decay Rate
Mass (Kg)	500	28	0.9	0.9	0.365
Gamma	0.9	time (yr):	9.1	9.1	0.365
Source Dimensions		18	0.02	0.02	0.365
Width (m)	43	Component 2: 1,2-DCE		Yield	0.161
Depth (m)	5		Decay Rate	Decay Rate	Decay Rate
Darcy Velocity (m/yr)	14		2.5	2.5	2.5
Porosity	0.25		2.5	2.5	2.5
Source Remediation			2.5	2.5	2.5
Fraction Removed	0.95	Component 3: VC		Yield	0
Remed. Start (yr)	18		Decay Rate	Decay Rate	Decay Rate
Remed. End (yr)	28		4.5	4.5	4.5
Source Decay (1/yr)	0		4.5	4.5	4.5
Transport Parameters			4.5	4.5	4.5
Retardation Factor	3	Dist. from Source			
SigmaV	0.18	X1 (m)	46	X2 (m)	240
vMin	0	Simulation Parameters			
vMax	1.72		Intervals	Min Value	Max Value
#Stream Tubes	100	x-direction (m)	11	0.01	10
alpha y (m)	4	y-direction (m)	1	0	0
alpha z (m)	0.4	z-direction	1	0	0
		Time (yr)	100	0	200

Output results (1 meter from start)

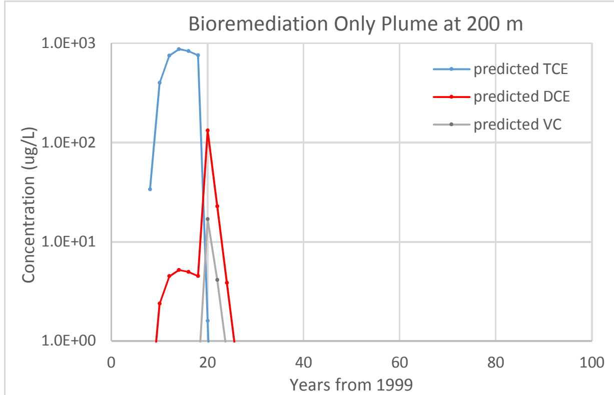
Years	TCE	1,2-DCE	VC	total VOC	
2	1.009	8882.2	2.39658	0.0091664	8884.6
4	1.009	7866.85	2.12262	0.0081186	7868.98
6	1.009	6968.59	1.88026	0.0071916	6970.48
8	1.009	6173.79	1.6658	0.0063714	6175.46
10	1.009	5470.44	1.47603	0.0056455	5471.92
12	1.009	4847.91	1.30806	0.0050031	4849.23
14	1.009	4296.85	1.15937	0.0044344	4298.02
16	1.009	3808.98	1.02773	0.0039309	3810.01
18	1.009	3376.98	0.911172	0.0034851	3377.9
20	1.009	2312.67	308.095	1.2098	2621.98
22	1.009	1769.01	235.689	0.925571	2005.62
24	1.009	1227.02	163.505	0.642219	1391.17
26	1.009	687.479	91.6462	0.360141	779.485
28	1.009	152.66	20.4162	0.0805287	173.157
30	1.009	143.428	1.75515	0.0067303	145.19
32	1.009	127.648	1.56205	0.0059898	129.216
34	1.009	113.62	1.39038	0.0053316	115.016
36	1.009	101.147	1.23775	0.0047463	102.389
38	1.009	90.0552	1.10202	0.0042258	91.1615
40	1.009	80.1905	0.981301	0.0037629	81.1756
42	1.009	71.4159	0.873924	0.0033512	72.2931
44	1.009	63.6098	0.778401	0.0029849	64.3912
46	1.009	56.6645	0.69341	0.002659	57.3606
48	1.009	50.4842	0.617781	0.0023689	51.1044
50	1.009	44.9839	0.550473	0.0021108	45.5365
52	1.009	40.0882	0.490563	0.0018811	40.5806
54	1.009	35.7299	0.437231	0.0016766	36.1688
56	1.009	31.8497	0.389747	0.0014945	32.2409
58	1.009	28.3945	0.347466	0.0013324	28.7433
60	1.009	25.3175	0.309812	0.001188	25.6285
62	1.009	22.5768	0.276275	0.0010594	22.8542
64	1.009	20.1355	0.2464	0.0009448	20.3828
66	1.009	17.9605	0.219784	0.0008428	18.1811
68	1.009	16.0224	0.196068	0.0007518	16.2193
70	1.009	14.2954	0.174934	0.0006708	14.471
72	1.009	12.7561	0.156098	0.0005986	12.9128
74	1.009	11.3841	0.139308	0.0005342	11.5239
76	1.009	10.1609	0.12434	0.0004768	10.2857
78	1.009	9.07033	0.110994	0.0004256	9.18175
80	1.009	8.09783	0.099094	0.00038	8.19731
82	1.009	7.23052	0.08848	0.0003393	7.31934
84	1.009	6.45692	0.079014	0.000303	6.53624
86	1.009	5.76682	0.070569	0.0002706	5.83766
88	1.009	5.15112	0.063035	0.0002417	5.2144
90	1.009	4.60174	0.056312	0.0002159	4.65827
92	1.009	4.11147	0.050312	0.0001929	4.16198
94	1.009	3.6739	0.044958	0.0001724	3.71903
96	1.009	3.28331	0.040178	0.0001541	3.32364
98	1.009	2.9346	0.035911	0.0001377	2.97065
100	1.009	2.62326	0.032101	0.0001231	2.65549
102	1.009	2.34525	0.028699	0.00011	2.37406
104	1.009	2.09695	0.025661	9.84E-05	2.12271
106	1.009	1.87518	0.022947	8.799E-05	1.89821

108	1.009	1.67707	0.020522	7.869E-05	1.69767
110	1.009	1.50007	0.018357	7.039E-05	1.5185
112	1.009	1.34192	0.016421	6.297E-05	1.35841
114	1.009	1.20059	0.014692	5.634E-05	1.21534
116	1.009	1.07428	0.013146	5.041E-05	1.08747
118	1.009	0.96137	0.011764	4.511E-05	0.97318
120	1.009	0.860435	0.010529	4.037E-05	0.871005
122	1.009	0.770191	0.009425	3.614E-05	0.779652
124	1.009	0.689495	0.008437	3.235E-05	0.697965
126	1.009	0.617329	0.007554	2.897E-05	0.624912
128	1.009	0.552783	0.006764	2.594E-05	0.559573
130	1.009	0.495046	0.006058	2.323E-05	0.501127
132	1.009	0.443392	0.005426	2.081E-05	0.448839
134	1.009	0.397176	0.00486	1.864E-05	0.402055
136	1.009	0.355819	0.004354	1.67E-05	0.36019
138	1.009	0.318807	0.003901	1.496E-05	0.322724
140	1.009	0.285679	0.003496	1.341E-05	0.289189
142	1.009	0.256024	0.003133	1.201E-05	0.259169
144	1.009	0.229475	0.002808	1.077E-05	0.232294
146	1.009	0.205703	0.002517	9.652E-06	0.20823
148	1.009	0.184416	0.002257	8.653E-06	0.186681
150	1.009	0.165351	0.002023	7.759E-06	0.167382
152	1.009	0.148274	0.001814	6.958E-06	0.150095
154	1.009	0.132977	0.001627	6.24E-06	0.13461
156	1.009	0.119271	0.00146	5.597E-06	0.120736
158	1.009	0.106991	0.001309	5.02E-06	0.108305
160	1.009	0.095987	0.001175	4.504E-06	0.097166
162	1.009	0.086124	0.001054	4.041E-06	0.087182
164	1.009	0.077284	0.000946	3.626E-06	0.078233
166	1.009	0.069359	0.000849	3.255E-06	0.070211
168	1.009	0.062254	0.000762	2.921E-06	0.063019
170	1.009	0.055883	0.000684	2.622E-06	0.05657
172	1.009	0.05017	0.000614	2.354E-06	0.050787
174	1.009	0.045046	0.000551	2.114E-06	0.0456
176	1.009	0.040451	0.000495	1.898E-06	0.040948
178	1.009	0.036328	0.000445	1.705E-06	0.036774
180	1.009	0.032629	0.000399	1.531E-06	0.03303
182	1.009	0.02931	0.000359	1.375E-06	0.02967
184	1.009	0.026332	0.000322	1.236E-06	0.026655
186	1.009	0.023659	0.00029	1.11E-06	0.023949
188	1.009	0.02126	0.00026	9.976E-07	0.021521
190	1.009	0.019106	0.000234	8.965E-07	0.01934
192	1.009	0.017172	0.00021	8.058E-07	0.017383
194	1.009	0.015436	0.000189	7.243E-07	0.015626
196	1.009	0.013877	0.00017	6.511E-07	0.014047
198	1.009	0.012477	0.000153	5.854E-07	0.01263
200	1.009	0.011219	0.000137	5.264E-07	0.011357

Appendix E-10
Enhanced Biodegradation - Western Flow Line

Western Plume
Enhanced Bioremediation Only

Residential PRG:		
	PRG	PRG
TCE	2.8	5
Time Achieved (yrs)	20	20
Date Achieved	2019	2019
Time from 2015 (yrs)	4	4



Input parameters:

Initial Source		Component 1: TCE		Yield	0.74
Conc. (g/L)	0.01	time (yr):	Decay Rate	Decay Rate	Decay Rate
Mass (Kg)	500	28	0.9	0.9	0.365
Gamma	0.9	time (yr):	9.1	9.1	0.365
Source Dimensions		18	0.02	0.02	0.365
Width (m)	43	Component 2: 1,2-DCE		Yield	0.161
Depth (m)	5		Decay Rate	Decay Rate	Decay Rate
Darcy Velocity (m/yr)	14		2.5	2.5	2.5
Porosity	0.25		2.5	2.5	2.5
Source Remediation			2.5	2.5	2.5
Fraction Removed	0.95	Component 3: VC		Yield	0
Remed. Start (yr)	18		Decay Rate	Decay Rate	Decay Rate
Remed. End (yr)	28		4.5	4.5	4.5
Source Decay (1/yr)	0		4.5	4.5	4.5
Transport Parameters			4.5	4.5	4.5
Retardation Factor	3	Dist. from Source			
SigmaV	0.18	X1 (m)	46	X2 (m)	240
vMin	0	Simulation Parameters			
vMax	1.72		Intervals	Min Value	Max Value
#Stream Tubes	100	x-direction (m)	31	0.01	300
alpha y (m)	4	y-direction (m)	1	0	0
alpha z (m)	0.4	z-direction	1	0	0
		Time (yr)	100	0	200

Output results (200 m from start)

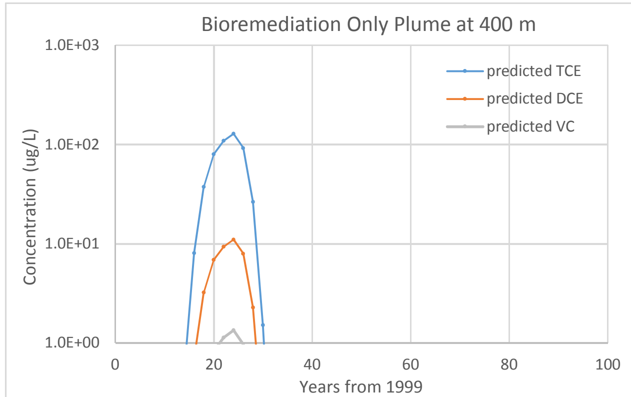
Years	TCE	1,2-DCE	VC	total VOC
2	0	0	0	0
4	0	0	0	0
6	0	0	0	0
8	33.6505	0.200433	0.017965	33.8689
10	398.572	2.37703	0.21339	401.163
12	753.379	4.4943	0.403599	758.277
14	872.583	5.20584	0.467544	878.256
16	831.156	4.95878	0.445367	836.561
18	757.354	4.5185	0.405827	762.278
20	1.59807	131.952	16.8949	150.445
22	0.003344	22.7603	4.12639	26.89
24	6.98E-06	3.86764	0.757978	4.62562
26	1.62E-08	0.662566	0.132408	0.794974
28	1.95E-09	0.159634	0.032013	0.191646
30	3.39E-07	0.087993	0.017638	0.105631
32	5.27E-05	0.061931	0.012413	0.0743967
34	0.00596	0.041409	0.008085	0.0554533
36	0.170216	0.085109	0.010785	0.266111
38	0.568038	0.2368	0.026508	0.831346
40	0.714575	0.295685	0.032903	1.04316
42	0.686222	0.283904	0.031587	1.00171
44	0.620113	0.256566	0.028547	0.905226
46	0.553791	0.22913	0.025494	0.808415
48	0.493389	0.204139	0.022714	0.720242
50	0.439411	0.181806	0.020229	0.641446
52	0.391342	0.161917	0.018016	0.571275
54	0.348568	0.144219	0.016047	0.508834
56	0.310507	0.128472	0.014295	0.453274
58	0.276638	0.114459	0.012735	0.403833
60	0.246496	0.101987	0.011348	0.359832
62	0.219667	0.090887	0.010113	0.320667
64	0.195784	0.081005	0.009013	0.285802
66	0.17452	0.072207	0.008034	0.254762
68	0.155586	0.064374	0.007163	0.227123
70	0.138725	0.057397	0.006386	0.202508
72	0.123707	0.051183	0.005695	0.180585
74	0.110329	0.045648	0.005079	0.161056
76	0.09841	0.040717	0.00453	0.143657
78	0.08779	0.036323	0.004042	0.128155
80	0.078327	0.032408	0.003606	0.11434
82	0.069892	0.028918	0.003218	0.102028
84	0.062374	0.025807	0.002871	0.0910528
86	0.055672	0.023034	0.002563	0.0812688
88	0.049696	0.020562	0.002288	0.0725454
90	0.044367	0.018357	0.002042	0.0647667
92	0.039615	0.016391	0.001824	0.0578294
94	0.035376	0.014637	0.001629	0.0516417
96	0.031595	0.013072	0.001455	0.046122
98	0.028222	0.011677	0.001299	0.0411974
100	0.025212	0.010431	0.001161	0.0368033
102	0.022525	0.00932	0.001037	0.032882

104	0.020128	0.008328	0.000927	0.0293822
106	0.017988	0.007442	0.000828	0.0262582
108	0.016077	0.006652	0.00074	0.0234692
110	0.014371	0.005946	0.000662	0.0209791
112	0.012848	0.005316	0.000591	0.0187556
114	0.011488	0.004753	0.000529	0.0167698
116	0.010273	0.00425	0.000473	0.0149961
118	0.009187	0.003801	0.000423	0.0134116
120	0.008218	0.0034	0.000378	0.0119961
122	0.007351	0.003042	0.000338	0.0107313
124	0.006577	0.002721	0.000303	0.009601
126	0.005885	0.002435	0.000271	0.0085908
128	0.005266	0.002179	0.000242	0.0076878
130	0.004713	0.00195	0.000217	0.0068806
132	0.004219	0.001746	0.000194	0.0061589
134	0.003777	0.001563	0.000174	0.0055136
136	0.003382	0.001399	0.000156	0.0049365
138	0.003028	0.001253	0.000139	0.0044203
140	0.002712	0.001122	0.000125	0.0039586
142	0.002429	0.001005	0.000112	0.0035455
144	0.002176	0.0009	0.0001	0.0031759
146	0.001949	0.000806	8.97E-05	0.0028452
148	0.001746	0.000723	8.04E-05	0.0025492
150	0.001565	0.000647	7.2E-05	0.0022843
152	0.001402	0.00058	6.46E-05	0.0020472
154	0.001257	0.00052	5.79E-05	0.0018349
156	0.001127	0.000466	5.19E-05	0.0016448
158	0.00101	0.000418	4.65E-05	0.0014745
160	0.000906	0.000375	4.17E-05	0.0013221
162	0.000812	0.000336	3.74E-05	0.0011856
164	0.000728	0.000301	3.35E-05	0.0010632
166	0.000653	0.00027	3.01E-05	0.0009536
168	0.000586	0.000242	2.7E-05	0.0008554
170	0.000526	0.000218	2.42E-05	0.0007675
172	0.000472	0.000195	2.17E-05	0.0006886
174	0.000423	0.000175	1.95E-05	0.0006179
176	0.00038	0.000157	1.75E-05	0.0005545
178	0.000341	0.000141	1.57E-05	0.0004977
180	0.000306	0.000127	1.41E-05	0.0004468
182	0.000275	0.000114	1.26E-05	0.0004011
184	0.000247	0.000102	1.14E-05	0.0003601
186	0.000222	9.17E-05	1.02E-05	0.0003234
188	0.000199	8.23E-05	9.16E-06	0.0002904
190	0.000179	7.39E-05	8.23E-06	0.0002609
192	0.000161	6.64E-05	7.39E-06	0.0002343
194	0.000144	5.97E-05	6.64E-06	0.0002105
196	0.00013	5.36E-05	5.96E-06	0.0001891
198	0.000116	4.82E-05	5.36E-06	0.00017
200	0.000105	4.33E-05	4.82E-06	0.0001527

Appendix E-10
Enhanced Biodegradation - Western Flow Line

Western Plume
Enhanced Bioremediation Only

Residential PRG:		
	PRG	PRG
TCE	2.8	5
Time Achieved (yrs)	30	30
Date Achieved	2029	2029
Time from 2015 (yrs)	14	14



Input parameters:

Initial Source		Component 1: TCE		Yield	0.74
Conc. (g/L)	0.01	time (yr):	Decay Rate	Decay Rate	Decay Rate
Mass (Kg)	500	28	0.9	0.9	0.365
Gamma	0.9	time (yr):	9.1	9.1	0.365
Source Dimensions		18	0.02	0.02	0.365
Width (m)	43	Component 2: 1,2-DCE		Yield	0.161
Depth (m)	5		Decay Rate	Decay Rate	Decay Rate
Darcy Velocity (m/yr)	14		2.5	2.5	2.5
Porosity	0.25		2.5	2.5	2.5
Source Remediation			2.5	2.5	2.5
Fraction Removed	0.95	Component 3: VC		Yield	0
Remed. Start (yr)	18		Decay Rate	Decay Rate	Decay Rate
Remed. End (yr)	28		4.5	4.5	4.5
Source Decay (1/yr)	0		4.5	4.5	4.5
Transport Parameters			4.5	4.5	4.5
Retardation Factor	3	Dist. from Source			
SigmaV	0.18	X1 (m)	46	X2 (m)	240
vMin	0		Simulation Parameters		
vMax	1.72		Intervals	Min Value	Max Value
#Stream Tubes	100	x-direction (m)	31	0.01	300
alpha y (m)	4	y-direction (m)	1	0	0
alpha z (m)	0.4	z-direction	1	0	0
		Time (yr)	100	0	200

Output results (400 m from start)

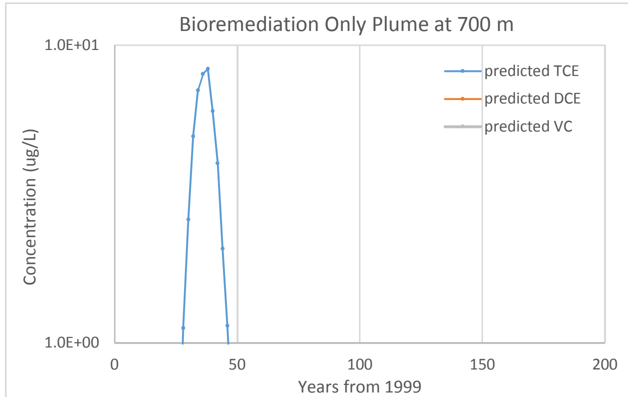
Years	TCE	1,2-DCE	VC	total VOC
2	0	0	0	0
4	0	0	0	0
6	0	0	0	0
8	0	0	0	0
10	0	0	0	0
12	0	0	0	0
14	0.485708	0.041712	0.005039	0.532459
16	8.04045	0.69158	0.0838	8.81583
18	37.4382	3.22261	0.391073	41.0519
20	79.7498	6.86706	0.833906	87.4508
22	108.625	9.35482	1.13634	119.116
24	128.046	11.0295	1.34029	140.416
26	91.7758	7.91701	0.96494	100.658
28	26.3764	2.27705	0.277966	28.9314
30	1.51614	0.131557	0.016227	1.66393
32	0.027055	0.002493	0.000344	0.0298927
34	0.000285	5.38E-05	1.39E-05	0.0003532
36	3.65E-06	8E-06	2.88E-06	1.453E-05
38	7.89E-07	3.94E-06	1.44E-06	6.168E-06
40	8.24E-05	9.64E-06	1.8E-06	9.382E-05
42	0.002491	0.000218	2.73E-05	0.0027357
44	0.015983	0.001385	0.00017	0.0175389
46	0.040499	0.003502	0.000429	0.0444299
48	0.06083	0.005254	0.000642	0.0667268
50	0.069369	0.005989	0.000731	0.0760895
52	0.068929	0.00595	0.000726	0.0756054
54	0.064353	0.005555	0.000678	0.0705853
56	0.05846	0.005046	0.000616	0.0641214
58	0.052465	0.004528	0.000553	0.0575462
60	0.046865	0.004045	0.000494	0.0514033
62	0.041796	0.003607	0.00044	0.0458434
64	0.037249	0.003215	0.000392	0.0408557
66	0.033189	0.002865	0.00035	0.0364034
68	0.029573	0.002552	0.000311	0.0324367
70	0.026352	0.002274	0.000278	0.0289044
72	0.023485	0.002027	0.000247	0.0257595
74	0.020932	0.001807	0.00022	0.0229595
76	0.018659	0.001611	0.000196	0.0204664
78	0.016636	0.001436	0.000175	0.0182464
80	0.014833	0.00128	0.000156	0.0162694
82	0.013227	0.001142	0.000139	0.0145084
84	0.011797	0.001018	0.000124	0.0129397
86	0.010523	0.000908	0.000111	0.0115421
88	0.009388	0.00081	9.89E-05	0.0102968
90	0.008376	0.000723	8.82E-05	0.009187
92	0.007474	0.000645	7.87E-05	0.0081979
94	0.00667	0.000576	7.02E-05	0.0073163
96	0.005954	0.000514	6.27E-05	0.0065302
98	0.005315	0.000459	5.6E-05	0.0058294
100	0.004745	0.00041	5E-05	0.0052045
102	0.004237	0.000366	4.46E-05	0.0046471

104	0.003784	0.000327	3.98E-05	0.00415
106	0.003379	0.000292	3.56E-05	0.0037065
108	0.003018	0.000261	3.18E-05	0.0033108
110	0.002697	0.000233	2.84E-05	0.0029577
112	0.002409	0.000208	2.54E-05	0.0026426
114	0.002153	0.000186	2.27E-05	0.0023614
116	0.001924	0.000166	2.03E-05	0.0021104
118	0.00172	0.000148	1.81E-05	0.0018863
120	0.001537	0.000133	1.62E-05	0.0016862
122	0.001374	0.000119	1.45E-05	0.0015075
124	0.001229	0.000106	1.29E-05	0.0013479
126	0.001099	9.49E-05	1.16E-05	0.0012054
128	0.000983	8.48E-05	1.04E-05	0.001078
130	0.000879	7.59E-05	9.26E-06	0.0009643
132	0.000786	6.79E-05	8.28E-06	0.0008626
134	0.000704	6.07E-05	7.41E-06	0.0007718
136	0.00063	5.43E-05	6.63E-06	0.0006906
138	0.000563	4.86E-05	5.93E-06	0.000618
140	0.000504	4.35E-05	5.31E-06	0.0005531
142	0.000451	3.9E-05	4.75E-06	0.0004951
144	0.000404	3.49E-05	4.26E-06	0.0004433
146	0.000362	3.12E-05	3.81E-06	0.0003969
148	0.000324	2.8E-05	3.41E-06	0.0003554
150	0.00029	2.5E-05	3.06E-06	0.0003183
152	0.00026	2.24E-05	2.74E-06	0.0002851
154	0.000233	2.01E-05	2.45E-06	0.0002554
156	0.000209	1.8E-05	2.2E-06	0.0002288
158	0.000187	1.61E-05	1.97E-06	0.000205
160	0.000167	1.45E-05	1.76E-06	0.0001837
162	0.00015	1.3E-05	1.58E-06	0.0001646
164	0.000135	1.16E-05	1.42E-06	0.0001475
166	0.000121	1.04E-05	1.27E-06	0.0001323
168	0.000108	9.33E-06	1.14E-06	0.0001186
170	9.69E-05	8.37E-06	1.02E-06	0.0001063
172	8.69E-05	7.5E-06	9.15E-07	9.534E-05
174	7.8E-05	6.73E-06	8.21E-07	8.551E-05
176	6.99E-05	6.04E-06	7.36E-07	7.669E-05
178	6.27E-05	5.41E-06	6.61E-07	6.88E-05
180	5.63E-05	4.86E-06	5.93E-07	6.172E-05
182	5.05E-05	4.36E-06	5.32E-07	5.538E-05
184	4.53E-05	3.91E-06	4.77E-07	4.97E-05
186	4.07E-05	3.51E-06	4.28E-07	4.46E-05
188	3.65E-05	3.15E-06	3.84E-07	4.003E-05
190	3.28E-05	2.83E-06	3.45E-07	3.594E-05
192	2.94E-05	2.54E-06	3.1E-07	3.226E-05
194	2.64E-05	2.28E-06	2.78E-07	2.897E-05
196	2.37E-05	2.05E-06	2.5E-07	2.601E-05
198	2.13E-05	1.84E-06	2.24E-07	2.336E-05
200	1.91E-05	1.65E-06	2.01E-07	2.098E-05

Appendix E-10
Enhanced Biodegradation - Western Flow Line

Western Plume
Enhanced Bioremediation Only

Residential PRG:		
	PRG	PRG
TCE	2.8	5
Time Achieved (yrs)	42	40
Date Achieved	2041	2039
Time from 2015 (yrs)	26	24



Input parameters:

Initial Source		Component 1: TCE		Yield	0.37
Conc. (g/L)	0.01	time (yr):	Decay Rate	Decay Rate	Decay Rate
Mass (Kg)	500	28	0.9	0.9	0.365
Gamma	0.9	time (yr):	9.1	9.1	0.365
Source Dimensions		18	0.02	0.02	0.365
Width (m)	43	Component 2: 1,2-DCE		Yield	0.161
Depth (m)	5		Decay Rate	Decay Rate	Decay Rate
Darcy Velocity (m/yr)	14		2.5	2.5	2.5
Porosity	0.25		2.5	2.5	2.5
Source Remediation			2.5	2.5	2.5
Fraction Removed	0.95	Component 3: VC		Yield	0
Remed. Start (yr)	18		Decay Rate	Decay Rate	Decay Rate
Remed. End (yr)	28		4.5	4.5	4.5
Source Decay (1/yr)	0		4.5	4.5	4.5
Transport Parameters			4.5	4.5	4.5
Retardation Factor	3	Dist. from Source			
SigmaV	0.18	X1 (m)	46	X2 (m)	240
vMin	0		Simulation Parameters		
vMax	1.72		Intervals	Min Value	Max Value
#Stream Tubes	100	x-direction (m)	51	0.01	2000
alpha y (m)	4	y-direction (m)	1	0	0
alpha z (m)	0.4	z-direction	1	0	0
		Time (yr)	100	0	200

Output results (700 m from start)

Years	TCE	1,2-DCE	VC	total VOC
2	0	0	0	0
4	0	0	0	0
6	0	0	0	0
8	0	0	0	0
10	0	0	0	0
12	0	0	0	0
14	0	0	0	0
16	0	0	0	0
18	0	0	0	0
20	0	0	0	0
22	0.000965	8.32E-05	1.01E-05	0.0010588
24	0.043381	0.003738	0.000454	0.0475726
26	0.305579	0.026328	0.003201	0.335107
28	1.12379	0.096822	0.011771	1.23238
30	2.6001	0.224015	0.027235	2.85135
32	4.95051	0.426518	0.051854	5.42889
34	7.06384	0.608594	0.07399	7.74642
36	8.01681	0.690699	0.083972	8.79148
38	8.32677	0.717404	0.087218	9.13139
40	6.01654	0.518363	0.06302	6.59792
42	4.01228	0.345683	0.042026	4.39999
44	2.07655	0.178908	0.021751	2.27721
46	1.14221	0.098408	0.011964	1.25258
48	0.521379	0.04492	0.005461	0.57176
50	0.133067	0.011465	0.001394	0.145926
52	0.031558	0.002719	0.000331	0.0346069
54	0.007553	0.000651	7.91E-05	0.0082825
56	0.001945	0.000168	2.04E-05	0.0021332
58	0.003267	0.000281	3.42E-05	0.0035823
60	0.004687	0.000404	4.91E-05	0.0051398
62	0.005704	0.000491	5.97E-05	0.0062551
64	0.006222	0.000536	6.52E-05	0.0068234
66	0.006268	0.00054	6.57E-05	0.0068738
68	0.006029	0.000519	6.32E-05	0.0066119
70	0.005608	0.000483	5.87E-05	0.00615
72	0.005137	0.000443	5.38E-05	0.0056329
74	0.004645	0.0004	4.86E-05	0.0050934
76	0.004174	0.00036	4.37E-05	0.0045772
78	0.003737	0.000322	3.91E-05	0.0040976
80	0.003337	0.000288	3.5E-05	0.00366
82	0.002979	0.000257	3.12E-05	0.0032668
84	0.002657	0.000229	2.78E-05	0.0029133
86	0.002369	0.000204	2.48E-05	0.0025978
88	0.002112	0.000182	2.21E-05	0.0023161
90	0.001883	0.000162	1.97E-05	0.0020649
92	0.001679	0.000145	1.76E-05	0.0018411
94	0.001497	0.000129	1.57E-05	0.0016417
96	0.001335	0.000115	1.4E-05	0.001464
98	0.001191	0.000103	1.25E-05	0.0013058
100	0.001062	9.15E-05	1.11E-05	0.0011647
102	0.000947	8.16E-05	9.92E-06	0.0010391

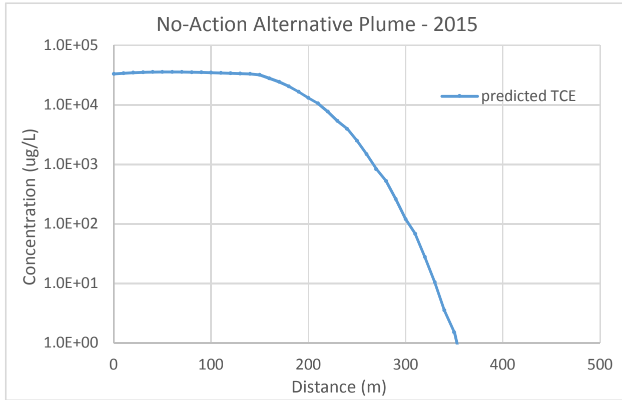
104	0.000845	7.28E-05	8.85E-06	0.0009271
106	0.000754	6.5E-05	7.9E-06	0.0008272
108	0.000673	5.8E-05	7.05E-06	0.0007383
110	0.000601	5.18E-05	6.29E-06	0.000659
112	0.000536	4.62E-05	5.62E-06	0.0005882
114	0.000479	4.13E-05	5.02E-06	0.0005252
116	0.000428	3.68E-05	4.48E-06	0.0004689
118	0.000382	3.29E-05	4E-06	0.0004188
120	0.000341	2.94E-05	3.57E-06	0.000374
122	0.000305	2.62E-05	3.19E-06	0.0003341
124	0.000272	2.34E-05	2.85E-06	0.0002984
126	0.000243	2.09E-05	2.55E-06	0.0002667
128	0.000217	1.87E-05	2.28E-06	0.0002383
130	0.000194	1.67E-05	2.03E-06	0.0002129
132	0.000174	1.5E-05	1.82E-06	0.0001903
134	0.000155	1.34E-05	1.63E-06	0.0001701
136	0.000139	1.2E-05	1.45E-06	0.0001521
138	0.000124	1.07E-05	1.3E-06	0.000136
140	0.000111	9.56E-06	1.16E-06	0.0001216
142	9.92E-05	8.55E-06	1.04E-06	0.0001088
144	8.87E-05	7.64E-06	9.29E-07	9.729E-05
146	7.94E-05	6.84E-06	8.31E-07	8.704E-05
148	7.1E-05	6.12E-06	7.44E-07	7.787E-05
150	6.35E-05	5.47E-06	6.66E-07	6.968E-05
152	5.69E-05	4.9E-06	5.96E-07	6.236E-05
154	5.09E-05	4.38E-06	5.33E-07	5.581E-05
156	4.56E-05	3.92E-06	4.77E-07	4.996E-05
158	4.08E-05	3.51E-06	4.27E-07	4.472E-05
160	3.65E-05	3.15E-06	3.82E-07	4.004E-05
162	3.27E-05	2.82E-06	3.42E-07	3.586E-05
164	2.93E-05	2.52E-06	3.07E-07	3.211E-05
166	2.62E-05	2.26E-06	2.75E-07	2.876E-05
168	2.35E-05	2.02E-06	2.46E-07	2.576E-05
170	2.1E-05	1.81E-06	2.2E-07	2.308E-05
172	1.89E-05	1.62E-06	1.98E-07	2.068E-05
174	1.69E-05	1.46E-06	1.77E-07	1.853E-05
176	1.51E-05	1.3E-06	1.59E-07	1.661E-05
178	1.36E-05	1.17E-06	1.42E-07	1.489E-05
180	1.22E-05	1.05E-06	1.27E-07	1.334E-05
182	1.09E-05	9.4E-07	1.14E-07	1.196E-05
184	9.78E-06	8.43E-07	1.02E-07	1.073E-05
186	8.77E-06	7.56E-07	9.19E-08	9.618E-06
188	7.87E-06	6.78E-07	8.24E-08	8.626E-06
190	7.06E-06	6.08E-07	7.39E-08	7.737E-06
192	6.33E-06	5.45E-07	6.63E-08	6.941E-06
194	5.68E-06	4.89E-07	5.95E-08	6.227E-06
196	5.09E-06	4.39E-07	5.34E-08	5.587E-06
198	4.57E-06	3.94E-07	4.79E-08	5.014E-06
200	4.1E-06	3.54E-07	4.3E-08	4.5E-06

Mass Estimate, Eastern Flow Line

Eastern Plume

2010 Comparison

Mass Estimate (kg):	2400



Input parameters:

Initial Source		Component 1: TCE		Yield	0.74
Conc. (g/L)	0.06	time (yr):	Decay Rate	Decay Rate	Decay Rate
Mass (Kg)	2800	50	0.02	0.02	0.365
Gamma	1	time (yr):	0.02	0.02	0.365
Source Dimensions		20	0.02	0.02	0.365
Width (m)	43	Component 2: 1,2-DCE		Yield	0.161
Depth (m)	4		Decay Rate	Decay Rate	Decay Rate
Darcy Velocity (m/yr)	10		2.5	2.5	3
Porosity	0.25		2.5	2.5	3
Source Remediation			2.5	2.5	3
Fraction Removed	0	Component 3: VC		Yield	0
Remed. Start (yr)	0		Decay Rate	Decay Rate	Decay Rate
Remed. End (yr)	0		4.5	4.5	5
Source Decay (1/yr)	0		4.5	4.5	5
Transport Parameters			4.5	4.5	5
Retardation Factor	3	Dist. from Source			
SigmaV	0.18	X1 (m)	50	X2 (m)	150
vMin	0		Simulation Parameters		
vMax	1.72		Intervals	Min Value	Max Value
#Stream Tubes	100	x-direction (m)	101	0.01	1000
alpha y (m)	0.4	y-direction (m)	1	0	0
alpha z (m)	0.04	z-direction	1	0	0
		Time (yr)	23	0	46

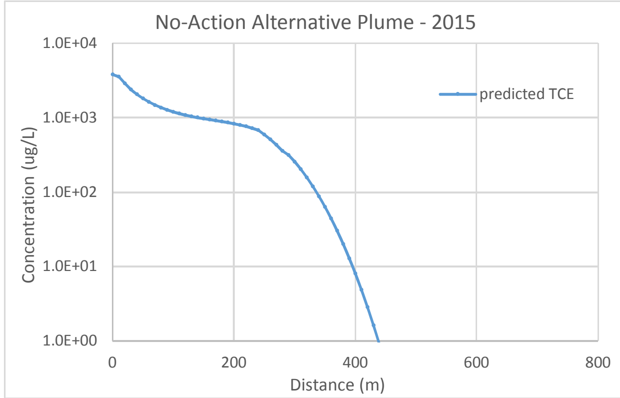
Output results (16 years from start)

Distance (m	TCE Conc. (	mass (kg)
0.01	33130.6	115.9571
10.01	33921.5	118.7253
20.01	34678.3	121.3741
30.01	35214.2	123.2497
40.01	35488.1	124.1959
50.009	35569.2	124.4922
60.009	35525	124.3375
70.009	35399.7	123.899
80.009	35220.3	123.2711
90.009	34998.9	122.4962
100.009	34755.1	121.6429
110.009	34444.9	120.5572
120.009	34035.8	119.1253
130.009	33604.8	117.6168
140.009	32855.3	114.9821
150.008	31743.1	111.1009
160.008	27658.7	96.80545
170.008	24218.1	84.76335
180.008	20346.3	71.21205
190.008	16580.3	58.03105
200.008	13024.2	45.5847
210.008	10538.2	36.8837
220.008	7692.36	26.92326
230.008	5334.2	18.6697
240.008	3950.79	13.82638
250.007	2493.32	8.72662
260.007	1479.43	5.178005
270.007	822.96	2.88036
280.007	524.233	1.834816
290.007	260.623	0.912181
300.007	120.708	0.422478
310.007	67.9255	0.237739
320.007	27.7813	0.097235
330.007	10.4444	0.036555
340.007	3.52773	0.012347
350.007	1.52719	0.005345
360.006	0.305307	0.001069
370.006	0	0
380.006	0	0
390.006	0	0
400.006	0	0
410.006	0	0
420.006	0	0
430.006	0	0
440.006	0	0
450.005	0	0
460.005	0	0
470.005	0	0
480.005	0	0
490.005	0	0
500.005	0	0

510.005	0	0
520.005	0	0
530.005	0	0
540.005	0	0
550.005	0	0
560.004	0	0
570.004	0	0
580.004	0	0
590.004	0	0
600.004	0	0
610.004	0	0
620.004	0	0
630.004	0	0
640.004	0	0
650.004	0	0
660.003	0	0
670.003	0	0
680.003	0	0
690.003	0	0
700.003	0	0
710.003	0	0
720.003	0	0
730.003	0	0
740.003	0	0
750.003	0	0
760.002	0	0
770.002	0	0
780.002	0	0
790.002	0	0
800.002	0	0
810.002	0	0
820.002	0	0
830.002	0	0
840.002	0	0
850.001	0	0
860.001	0	0
870.001	0	0
880.001	0	0
890.001	0	0
900.001	0	0
910.001	0	0
920.001	0	0
930.001	0	0
940.001	0	0
950	0	0
960	0	0
970	0	0
980	0	0
990	0	0
1000	0	

Western Plume
2010 Comparison

Mass Estimate (kg):	134



Input parameters:

Initial Source		Component 1: TCE		Yield	0.74
Conc. (g/L)	0.01	time (yr):	Decay Rate	Decay Rate	Decay Rate
Mass (Kg)	500	50	0.02	0.02	0.365
Gamma	0.9	time (yr):	0.02	0.02	0.365
Source Dimensions		20	0.02	0.02	0.365
Width (m)	43	Component 2: 1,2-DCE		Yield	0.161
Depth (m)	5		Decay Rate	Decay Rate	Decay Rate
Darcy Velocity (m/yr)	14		2.5	2.5	2.5
Porosity	0.25		2.5	2.5	2.5
Source Remediation			2.5	2.5	2.5
Fraction Removed	0	Component 3: VC		Yield	0
Remed. Start (yr)	0		Decay Rate	Decay Rate	Decay Rate
Remed. End (yr)	0		4.5	4.5	4.5
Source Decay (1/yr)	0		4.5	4.5	4.5
Transport Parameters			4.5	4.5	4.5
Retardation Factor	3	Dist. from Source			
SigmaV	0.18	X1 (m)	50	X2 (m)	240
vMin	0		Simulation Parameters		
vMax	1.72		Intervals	Min Value	Max Value
#Stream Tubes	100	x-direction (m)	101	0.01	1000
alpha y (m)	4	y-direction (m)	1	0	0
alpha z (m)	0.4	z-direction	1	0	0
		Time (yr)	23	0	46

Output results (16 years from start)

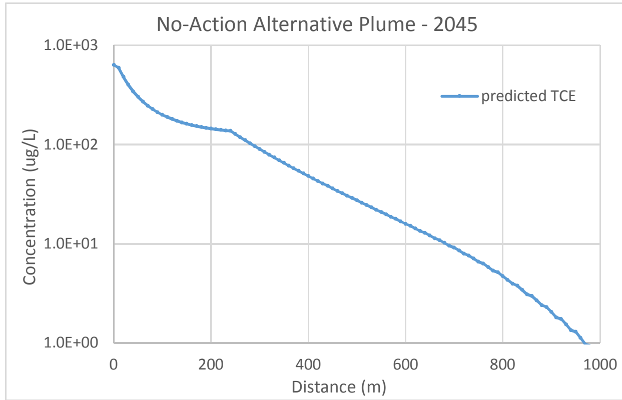
Distance (m	TCE Conc. (	mass (kg)
0.01	3.80E+03	9.4942
10.01	3.55E+03	12.42987
20.01	2.89E+03	10.13205
30.01	2.40E+03	8.40196
40.01	2.05E+03	7.190661
50.009	1.81E+03	6.320265
60.009	1.62E+03	5.67084
70.009	1.48E+03	5.171565
80.009	1.37E+03	4.777955
90.009	1.27E+03	4.46117
100.009	1.20E+03	4.20217
110.009	1.14E+03	3.98699
120.009	1.09E+03	3.806075
130.009	1.04E+03	3.65204
140.009	1.01E+03	3.518688
150.008	9.72E+02	3.402175
160.008	9.42E+02	3.297039
170.008	9.14E+02	3.199427
180.008	8.87E+02	3.10512
190.008	8.60E+02	3.00979
200.008	8.31E+02	2.909046
210.008	8.00E+02	2.79859
220.008	7.64E+02	2.674511
230.008	7.24E+02	2.533706
240.008	6.78E+02	2.373935
250.007	5.91E+02	2.068738
260.007	5.08E+02	1.779082
270.007	4.31E+02	1.507153
280.007	3.59E+02	1.25544
290.007	3.15E+02	1.102927
300.007	2.55E+02	0.893652
310.007	2.03E+02	0.709027
320.007	1.57E+02	0.550057
330.007	1.19E+02	0.416714
340.007	8.80E+01	0.307915
350.007	6.33E+01	0.221657
360.006	4.44E+01	0.155346
370.006	3.02E+01	0.105872
380.006	2.00E+01	0.070117
390.006	1.29E+01	0.045093
400.006	8.04E+00	0.028142
410.006	4.87E+00	0.017032
420.006	2.85E+00	0.009989
430.006	1.62E+00	0.005673
440.006	8.90E-01	0.003116
450.005	4.72E-01	0.001653
460.005	2.41E-01	0.000843
470.005	1.66E-01	0.00058
480.005	7.85E-02	0.000275
490.005	3.44E-02	0.00012
500.005	1.28E-02	4.49E-05

510.005	2.72E-03	9.52E-06
520.005	0.00E+00	0
530.005	0.00E+00	0
540.005	0.00E+00	0
550.005	0.00E+00	0
560.004	0.00E+00	0
570.004	0.00E+00	0
580.004	0.00E+00	0
590.004	0.00E+00	0
600.004	0.00E+00	0
610.004	0.00E+00	0
620.004	0.00E+00	0
630.004	0.00E+00	0
640.004	0.00E+00	0
650.004	0.00E+00	0
660.003	0.00E+00	0
670.003	0.00E+00	0
680.003	0.00E+00	0
690.003	0.00E+00	0
700.003	0.00E+00	0
710.003	0.00E+00	0
720.003	0.00E+00	0
730.003	0.00E+00	0
740.003	0.00E+00	0
750.003	0.00E+00	0
760.002	0.00E+00	0
770.002	0.00E+00	0
780.002	0.00E+00	0
790.002	0.00E+00	0
800.002	0.00E+00	0
810.002	0.00E+00	0
820.002	0.00E+00	0
830.002	0.00E+00	0
840.002	0.00E+00	0
850.001	0.00E+00	0
860.001	0.00E+00	0
870.001	0.00E+00	0
880.001	0.00E+00	0
890.001	0.00E+00	0
900.001	0.00E+00	0
910.001	0.00E+00	0
920.001	0.00E+00	0
930.001	0.00E+00	0
940.001	0.00E+00	0
950	0.00E+00	0
960	0.00E+00	0
970	0.00E+00	0
980	0.00E+00	0
990	0.00E+00	0
1000	0.00E+00	

Appendix E-12
Mass Estimate, Eastern Flow Line

Western Plume
2045 Comparison

Mass Estimate (kg):	27.9



Input parameters:

Initial Source		Component 1: TCE		Yield	0.74
Conc. (g/L)	0.01	time (yr):	Decay Rate	Decay Rate	Decay Rate
Mass (Kg)	500	50	0.02	0.02	0.365
Gamma	0.9	time (yr):	0.02	0.02	0.365
Source Dimensions		20	0.02	0.02	0.365
Width (m)	43	Component 2: 1,2-DCE		Yield	0.161
Depth (m)	5		Decay Rate	Decay Rate	Decay Rate
Darcy Velocity (m/yr)	14		2.5	2.5	2.5
Porosity	0.25		2.5	2.5	2.5
Source Remediation			2.5	2.5	2.5
Fraction Removed	0	Component 3: VC		Yield	0
Remed. Start (yr)	0		Decay Rate	Decay Rate	Decay Rate
Remed. End (yr)	0		4.5	4.5	4.5
Source Decay (1/yr)	0		4.5	4.5	4.5
Transport Parameters			4.5	4.5	4.5
Retardation Factor	3	Dist. from Source			
SigmaV	0.18	X1 (m)	50	X2 (m)	240
vMin	0	Simulation Parameters			
vMax	1.72		Intervals	Min Value	Max Value
#Stream Tubes	100	x-direction (m)	101	0.01	1000
alpha y (m)	4	y-direction (m)	1	0	0
alpha z (m)	0.4	z-direction	1	0	0
		Time (yr)	23	0	46

Output results (46 years from start)

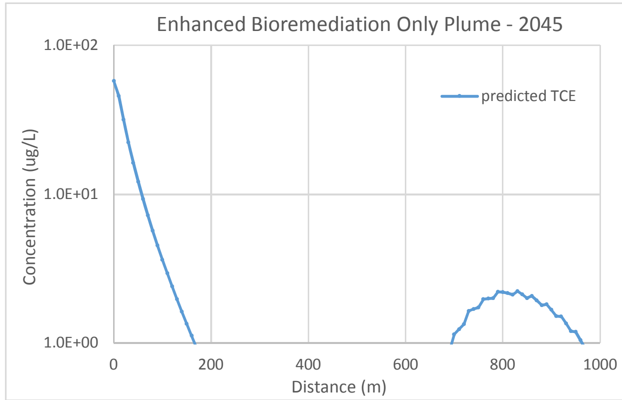
Distance (m	TCE Conc. (	mass (kg)
0.01	633.605	1.584013
10.01	592.165	2.072578
20.01	482.411	1.688439
30.01	399.801	1.399304
40.01	341.994	1.196859
50.009	300.389	1.051362
60.009	269.364	0.942774
70.009	245.505	0.859268
80.009	226.691	0.793419
90.009	211.548	0.740418
100.009	199.158	0.697053
110.009	188.883	0.661091
120.009	180.269	0.630941
130.009	172.984	0.605444
140.009	166.78	0.583672
150.008	161.468	0.565138
160.008	156.9	0.54915
170.008	152.963	0.535371
180.008	149.566	0.523481
190.008	146.632	0.513212
200.008	144.102	0.504357
210.008	141.932	0.496762
220.008	140.072	0.490252
230.008	138.491	0.484719
240.008	137.163	0.480022
250.007	127.381	0.445834
260.007	118.471	0.414649
270.007	110.348	0.386218
280.007	102.906	0.360171
290.007	96.0806	0.336282
300.007	89.8213	0.314375
310.007	84.0484	0.294169
320.007	78.724	0.275534
330.007	73.8204	0.258371
340.007	69.2707	0.242447
350.007	65.0542	0.227667
360.006	61.1602	0.214061
370.006	57.5259	0.201341
380.006	54.1434	0.189502
390.006	51.0163	0.178557
400.006	48.0788	0.168276
410.006	45.3343	0.15867
420.006	42.7995	0.149798
430.006	40.3999	0.1414
440.006	38.1498	0.133511
450.005	36.079	0.126277
460.005	34.0993	0.119348
470.005	32.2359	0.112826
480.005	30.4794	0.106678
490.005	28.8843	0.101095
500.005	27.3259	0.095641

510.005	25.8509	0.090478
520.005	24.5319	0.085862
530.005	23.2154	0.081254
540.005	21.9639	0.076874
550.005	20.8699	0.073037
560.004	19.746	0.069111
570.004	18.6729	0.065355
580.004	17.7642	0.062175
590.004	16.7944	0.05878
600.004	15.8643	0.055525
610.004	15.1095	0.052883
620.004	14.264	0.049924
630.004	13.4494	0.047073
640.004	12.8237	0.044883
650.004	12.0792	0.042273
660.003	11.3595	0.039758
670.003	10.8425	0.037949
680.003	10.1818	0.035636
690.003	9.54137	0.033395
700.003	9.11672	0.031909
710.003	8.527	0.029845
720.003	7.95501	0.027843
730.003	7.6088	0.026631
740.003	7.08136	0.024785
750.003	6.57036	0.022994
760.002	6.2908	0.022018
770.002	5.81993	0.02037
780.002	5.36517	0.018778
790.002	5.14204	0.017997
800.002	4.72417	0.016535
810.002	4.32271	0.015129
820.002	3.93841	0.013784
830.002	3.77991	0.01323
840.002	3.42972	0.012003
850.001	3.09722	0.01084
860.001	2.97546	0.010414
870.001	2.67476	0.009362
880.001	2.392	0.008372
890.001	2.30016	0.008051
900.001	2.04677	0.007164
910.001	1.81115	0.006339
920.001	1.74323	0.006101
930.001	1.53428	0.00537
940.001	1.34235	0.004698
950	1.29319	0.004526
960	1.12496	0.003937
970	0.972478	0.003404
980	0.937693	0.003282
990	0.805699	0.00282
1000	0.687741	

Appendix E-12
Mass Estimate, Eastern Flow Line

Western Plume
2045 Comparison

Mass Estimate (kg):	0.95



Input parameters:

Initial Source		Component 1: TCE		Yield	0.74
Conc. (g/L)	0.01	time (yr):	Decay Rate	Decay Rate	Decay Rate
Mass (Kg)	500	28	0.9	0.9	0.365
Gamma	0.9	time (yr):	9.1	9.1	0.365
Source Dimensions		18	0.02	0.02	0.365
Width (m)	43	Component 2: 1,2-DCE		Yield	0.161
Depth (m)	5		Decay Rate	Decay Rate	Decay Rate
Darcy Velocity (m/yr)	14		2.5	2.5	2.5
Porosity	0.25		2.5	2.5	2.5
Source Remediation			2.5	2.5	2.5
Fraction Removed	0.95	Component 3: VC		Yield	0
Remed. Start (yr)	18		Decay Rate	Decay Rate	Decay Rate
Remed. End (yr)	28		4.5	4.5	4.5
Source Decay (1/yr)	0		4.5	4.5	4.5
Transport Parameters			4.5	4.5	4.5
Retardation Factor	3	Dist. from Source			
SigmaV	0.18	X1 (m)	46	X2 (m)	240
vMin	0	Simulation Parameters			
vMax	1.72		Intervals	Min Value	Max Value
#Stream Tubes	100	x-direction (m)	101	0.01	1000
alpha y (m)	4	y-direction (m)	1	0	0
alpha z (m)	0.4	z-direction	1	0	0
		Time (yr)	23	0	46

Output results 46 years from start)

Distance (m	TCE Conc. (	mass (kg)
0.01	57.4306	0.143577
10.01	45.5895	0.159563
20.01	31.5669	0.110484
30.01	22.2503	0.077876
40.01	16.1979	0.056687
50.009	12.1153	0.042404
60.009	9.25666	0.032398
70.009	7.19257	0.025174
80.009	5.66499	0.019827
90.009	4.51175	0.015791
100.009	3.62681	0.012694
110.009	2.93849	0.010285
120.009	2.39698	0.008389
130.009	1.96681	0.006884
140.009	1.6222	0.005677
150.008	1.34411	0.004704
160.008	1.11826	0.003914
170.008	0.933778	0.003268
180.008	0.782293	0.002738
190.008	0.657326	0.002301
200.008	0.553791	0.001938
210.008	0.467637	0.001637
220.008	0.395659	0.001385
230.008	0.335313	0.001174
240.008	0.284551	0.000996
250.007	0.26404	0.000924
260.007	0.244827	0.000857
270.007	0.22668	0.000793
280.007	0.209337	0.000733
290.007	0.192441	0.000674
300.007	0.176054	0.000616
310.007	0.160106	0.00056
320.007	0.144374	0.000505
330.007	0.128885	0.000451
340.007	0.113928	0.000399
350.007	0.0996	0.000349
360.006	0.08574	0.0003
370.006	0.07277	0.000255
380.006	0.060899	0.000213
390.006	0.050184	0.000176
400.006	0.040499	0.000142
410.006	0.032162	0.000113
420.006	0.025116	8.79E-05
430.006	0.019228	6.73E-05
440.006	0.014407	5.04E-05
450.005	0.010607	3.71E-05
460.005	0.007666	2.68E-05
470.005	0.005416	1.9E-05
480.005	0.003749	1.31E-05
490.005	0.002548	8.92E-06
500.005	0.001698	5.94E-06

Appendix E-12
Mass Estimate, Eastern Flow Line

510.005	0.001104	3.86E-06
520.005	0.000707	2.47E-06
530.005	0.000446	1.56E-06
540.005	0.00028	9.79E-07
550.005	0.000287	1.01E-06
560.004	0.000316	1.11E-06
570.004	0.000433	1.51E-06
580.004	0.003875	1.36E-05
590.004	0.006034	2.11E-05
600.004	0.009211	3.22E-05
610.004	0.082977	0.00029
620.004	0.117786	0.000412
630.004	0.164094	0.000574
640.004	0.384707	0.001346
650.004	0.432521	0.001514
660.003	0.482539	0.001689
670.003	0.716474	0.002508
680.003	0.789103	0.002762
690.003	0.865701	0.00303
700.003	1.14221	0.003998
710.003	1.23794	0.004333
720.003	1.33535	0.004674
730.003	1.63875	0.005736
740.003	1.68838	0.005909
750.003	1.7276	0.006046
760.002	1.97033	0.006896
770.002	1.99278	0.006975
780.002	2.00136	0.007005
790.002	2.21071	0.007737
800.002	2.19375	0.007678
810.002	2.16115	0.007564
820.002	2.10854	0.00738
830.002	2.2236	0.007783
840.002	2.11751	0.007411
850.001	2.00098	0.007003
860.001	2.06865	0.00724
870.001	1.93256	0.006764
880.001	1.79147	0.00627
890.001	1.82028	0.006371
900.001	1.66855	0.00584
910.001	1.51551	0.005304
920.001	1.51025	0.005286
930.001	1.3526	0.004734
940.001	1.20227	0.004208
950	1.18645	0.004153
960	1.04467	0.003656
970	0.912912	0.003195
980	0.894172	0.00313
990	0.774436	0.002711
1000	0.665404	