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Final
Feasibility Study
Riverfront Superfund Site
New Haven, Missouri

Operable Unit 4
The Orchard Street/Maiden Lane Site

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Abbreviations and Acronyms

AES	Architect Engineering Services
ARAR	applicable or relevant and appropriate requirements
bgs	below ground surface
BVSPC	Black & Veatch Special Projects Corp.
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
cis-DCE	cis-1,2-dichloroethene
COC	contaminant of concern
CSR	Code of State Regulations
DOT	Department of Transportation
DNAPL	Dense Non-Aqueous Phase Liquid
DO	Dissolved Oxygen
EPC	exposure point concentration
ESI	Expanded Site Investigation
FS	feasibility study
GAC	granular activated carbon
GC	gas chromatograph
gpm	gallons per minute
GRA	general response action
HAP	hazardous air pollution
HHRA	human health risk assessment
IWA	In-Well Aeration
LTRA	long term remedial action
MCL	maximum contaminant level
MCLG	maximum contaminant level goal
MDNR	Missouri Department of Natural Resources
Mg/kg	milligram per kilogram
Ml/min	milliliters per minute
NA	Natural Attenuation
$NaMnO_4$	Sodium Permanganate
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NHPA	National Historic Preservation Act
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List

O&M	operation and maintenance
ORP	oxidation-reduction potential
OSHA	Occupational Safety and Health Act
OSWER	Office of Solid Waste and Emergency Response
OU	Operable Unit
PCB	Polychlorinated Biphenyls
PCE	tetrachloroethene
POTW	publicly owned treatment works
PSOD	Potential Soil Oxidant Demand
PRG	Preliminary Remediation Goal
RA	remedial action
RAO	remedial action objective
RBC	rotating biological contactor
RBCA	Risk Based Correction Action
RD	Remedial Design
RCRA	Resource Conservation and Recovery Act
RI	remedial investigation
ROD	Record of Decision
SARA	Superfund Amendments and Reauthorization Act
SDWA	Safe Drinking Water Act
SMCL	secondary maximum contaminant level
SWDA	Solid Waste Disposal Act
SVE	soil vapor extraction
TBC	to-be-considered
TCE	trichloroethene
TCLP	Toxic Characteristic Leaching Procedure
TE-SVE	thermally enhanced soil vapor extraction
trans-DCE	trans-1,2-dichloroethene
ug/m^3	micrograms per cubic meter
ug/kg	micrograms per kilogram
ug/L	micrograms per liter
UIC	Underground Injection Control
USC	United States Code
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency

USGS	U.S. Geological Survey
UV	ultra violet
VOA	volatile organic analysis
VOC	volatile organic compound
VC	Vinyl Chloride

Executive Summary

The United States Environmental Protection Agency (USEPA) has initiated a remedial investigation and feasibility study (RI/FS) for the Orchard Street/Maiden Lane Operable Unit (OU) 4 of the Riverfront Site in New Haven, Missouri. The RI/FS process is the methodology authorized by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980 as amended by the Superfund Amendments and Reauthorization Act (SARA) of 1986 (i.e., the Superfund program) for characterizing the nature and extent of risks posed by uncontrolled hazardous waste sites and for evaluating potential remedial options.

Site History, Contamination, and Risk

New Haven (population estimated at 2,000 in 2007) is located along the southern bank of the Missouri River in Franklin County, Missouri, about 50 miles west of St. Louis, Missouri. In 1986, the volatile organic compound (VOC) tetrachloroethene (PCE) was detected in two public supply groundwater wells (Wells W1 and W2) in the northern part of New Haven. Following the discovery of contamination, several investigations were conducted by the Missouri Department of Natural Resources (MDNR) and USEPA. The site became known as the Riverfront Site and, in December 2000, the PCE contamination prompted the listing of the Riverfront Site on the National Priorities List (NPL) for environmental clean-up under Superfund.

The Riverfront Site consists of six OUs within and near the City of New Haven, Missouri. OU4, known as the Orchard Street/Maiden Lane Subsite, includes contaminated soils, groundwater, and the City of New Haven sanitary sewer system within the OU4 area. It may also include contaminated shallow bedrock. OU4 is located in east-central New Haven, north of State Highway 100.

The scope of this FS addresses only OU4, the Orchard Street/Maiden Lane Subsite, and as such, the other OUs will not be discussed any further in this document except as they relate to OU4. Discussion of the remedial alternatives for OU1 can be found in Volume 1 of the OU1/OU3 FS Report (BVSPC, 2003), while the remedial alternatives for OU3 are discussed in the second volume of the 2003 FS Report. The Final FS for OU5 was provided to USEPA under separate cover by BVSPC (BVSPC, 2006). The investigations of OU2 and OU6 are ongoing.

Currently (2008), the OU4 boundaries cover a 192-acre area. The boundaries of the OU are approximately Maupin Avenue to the west, Circle Drive to the south, and the Missouri River to the north. The eastern boundary runs through undeveloped land east of Miller Street. OU4 is mostly residential and the topography is steep.

At OU4, the surficial soils are loess (wind deposited) and thin. Throughout most of the subsite, a layer of residuum underlies the soils. Below the residual layer are the bedrock layers of the Ozark aquifer. The top two bedrock layers of the Ozark aquifer below OU4 are the Cotter and Jefferson City Dolomite units. The Cotter contains two sandstone beds, the "upper sandstone" and the Swan Creek sandstone. Where the upper sandstone is exposed along creek beds in OU4, there are often small seeps or springs. Below the Jefferson City Dolomite is the Roubidoux Formation. The Roubidoux is a reliable water producing formation, producing sufficient water for domestic supply and even some industrial use. Monitoring well results have detected PCE contamination in all three of these units. Below the Roubidoux is the Gasconade Dolomite unit. As of 2007, samples from the Gasconade unit were not contaminated by PCE or other OU4 contaminants.

At New Haven, there are two groundwater flow systems. In the soils and shallow bedrock units, groundwater flows with the topography. Therefore, in the southern portions of OU4, the shallow groundwater flows to the south. In the north, shallow groundwater flows north to the Missouri River. The deep groundwater is controlled by the northward regional flow down from the uplands of the Ozarks, which are south of New Haven.

During the 1980s and 1990s, after two public supply wells for the City of New Haven were found to be contaminated with the VOC PCE, the MDNR and the USEPA investigated to determine the source of the contamination. By 1994 the investigations had determined that PCE had been released at OU4, but it was unclear if this release was the source of the contamination that closed wells W1 and W2. In 1998, the USEPA requested that the USGS provide assistance in determining the groundwater flow directions at New Haven. As the RI progressed, it became clear that while OU4 was contaminated with PCE, it was down- and side-gradient to the two contaminated City wells and was not the source of the contamination that closed them.

From 2000 to 2002, the investigation was systematically installing bedrock monitoring wells in a "walk upgradient" of the two contaminated City wells. The monitoring well investigation led to a focus on an area around Maiden Lane. At that time, USEPA was concerned that PCE disposed of into the City sewer system at OU2 may have leaked from the sewer lines around Maiden Lane and created the PCE plume. However, by sampling various media (soils, tree cores, in-door vapor from homes, sewer water, surface water, and groundwater) and from discussions with residents, the investigation found that most likely a private citizen had disposed of significant amounts of PCE into his home's grey water (sewer) line, which discharged into a low area behind

(south of) Maiden Lane. Here the PCE migrated through the soils into the bedrock and then into the bedrock aquifer.

At this time (2008), the PCE soil contamination is nearly all confined to this small (less than 0.2 acre) area south of Maiden Lane. The groundwater plume extends from the shallow groundwater at the soil-rock interface below the source area soils through the bed-rock to the north, possibly as far as the Missouri River. Groundwater contamination also extends slightly south of the soil source area, due to local topography. Overall, the PCE plume extends from the source area to wells W1 (approximately 3,800 ft downgradient) and W2 (approximately 3,000 ft downgradient) and probably to the Missouri River (approximately 4,000 ft downgradient).

Risk assessments were performed to determine the effects of the contamination at OU4 on human health and the environment. Exposure to contaminated groundwater at OU4 was found to pose unacceptable excess risks to future and current residents, current and future industrial workers, and current and future construction workers. The risk assessment also found that the contaminated soils at OU4 posed significant risks to future residents. The ecological risk assessment for the Riverfront Site found that OU4 poses minimal risk to ecological receptors.

Remedial Action Objectives

To satisfy CERCLA requirements, remedial action objectives were developed for OU4 at the Riverfront Site. Remedial action objectives were used to develop general response actions for the Site. The remedial action objectives developed for the contaminated groundwater and contaminated soil at OU4 are presented in Table ES-1.

Remedial actions must comply with applicable or relevant and appropriate requirements (ARARs) of federal laws and more stringent, promulgated state laws. Chemical-specific, action-specific, and location-specific ARARs for OU4 have been preliminarily identified.

Information concerning the nature and extent of contamination in the soil and groundwater was used to estimate the volume of contamination that would need to be remediated. The RI estimated the volume of contaminated soil using a preliminary remediation goal (PRG) of 483 ug/kg PCE. This FS used the slightly higher soil PRG of 550 ug/kg PCE used in the OU4 Risk Assessment. The USEPA has already conducted two rounds of in-situ soil treatment (see Section 1.4.7), which should have remediated the contaminated soils. However, confirmation soil sampling has not yet been conducted. For the soil containment and treatment alternatives, it has been conservatively assumed that the soil volume that will require treatment is the same as the RI soil volume.

The RI estimated that the volume of soil contaminated above the RI's PRG was approximately 2,300 yd^3. The RI calculated the contaminated soil volume by dividing the soil into five layers and estimating the volume of soil contaminated above the PRG in each layer. However, the actual volume that must be contained is larger, approximately 3,700 yd^3 because the area of the largest layer must be continued. The surface area to be contained is approximately 600 yd^2. The groundwater volume above the PCE federal maximum contaminant level (MCL) of 5 ug/L is approximately 120 million gallons (16,000,000 cubic feet). This volume of contaminated groundwater is contained within approximately 160 million cubic feet of bedrock.

General response actions were identified for both soil and groundwater contamination. Remedial technologies and process options were identified for each general response action. Remedial technologies refer to general categories of technology types, and process options refer to specific processes within each technology type. The remedial technologies and process options identified were screened on the basis of technical implementability, effectiveness, implementability specifically at OU4, and cost.

Remedial Alternatives

Combining individual process options develops possible solutions for the contamination problem, which are referred to as remedial alternatives. The remedial alternatives combine technologies to address both groundwater and soil contamination at OU4.

The goals in developing the preliminary remedial alternatives are to provide both a range of cleanup options and sufficient detail to adequately compare alternatives. Alternatives are listed with the primary process option chosen for soil, followed by a slash, and then followed by the primary process option chosen for groundwater, (i.e., in-situ chemical oxidation/monitoring means that the soils will be treated using in-situ chemical oxidation and monitoring will be used for groundwater).

The guidance document suggests three general types of response actions: a no action response, plume containment, and active remediation. The groundwater portions of the remedial alternatives include the first two general types of response actions so as to provide ranges in the time and costs required for practicable remediation activities. No active remediation alternatives have been prepared because active remediation of the plume would be impracticable. See Appendix B, which contains the Groundwater Technical Impracticability Evaluation Report.

Alternative 1—No Action/ No Action. Alternative 1 would not involve any remedial actions other than closure of the existing monitoring wells, and the subsite

would remain in its present condition. This alternative, required by the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) and CERCLA, is a baseline alternative against which the effectiveness of the other alternatives can be compared. Under the no action alternative, the subsite is left "as is" and no funds would be expended for monitoring, control, or cleanup of the contaminated groundwater and soils. Five-year reviews of the subsite would be required under CERCLA, so funds would have to be expended to conduct the OU4 portion of the 5-year review.

Alternative 2— Capping, Sheet Piling, and Rock Grouting, Hydraulic Containment and Above-Ground Treatment. Alternative 2 would use hydraulic containment, above-ground groundwater treatment, monitored natural attenuation, and institutional controls to address the potential health risks associated with contaminated groundwater. This alternative would minimize the migration of the heavily contaminated portions of the plume farther downgradient. The existing garage would be removed and then sheet piling, rock grouting, and a cap would be used to create an enclosure around the contaminated soils to prevent groundwater flow from contacting the contaminated soils. Water from within the enclosure would be pumped out, creating an inward hydraulic gradient. Hydraulic containment wells would also be placed within the edge of the heavily contaminated portion of the plume to prevent further plume migration. Extracted groundwater would be treated with granular activated carbon (GAC) to remove VOCs. With the source area soils contained, natural attenuation processes should begin to reduce the contaminant levels in the plume. The contaminated groundwater would be monitored, as described in Alternative 3. Monitoring the plume would allow EPA to track the migration of the plume. Institutional controls would consist of well certification and public education to prevent human contact with the contaminated groundwater. Institutional controls for the soils would consist of proprietary controls in the form of environmental covenants on the properties where the containment was built. These controls would restrict activities that could damage the containment structure and would allow EPA, MDNR, or their contractor access.

Alternative 3—In-Situ Chemical Oxidation Treatment/Monitoring. Alternative 3 would use in-situ chemical oxidation to address the potential health risks associated with contaminated soil. An oxidizing chemical would be injected into the soil using direct push technology. As the chemical is released into the soil, it would mix with the contaminated soil and oxidize the contaminants. Alternative 3 would use groundwater monitoring and institutional controls to address the potential health risks associated with the contaminated groundwater. Monitoring of the groundwater would

involve the installation of monitoring wells and periodically sampling those wells. Sampling would allow the migration of the plume to be monitored. Institutional controls, as described in Alternative 2, would be implemented to prevent contact with contaminated groundwater while the remediation efforts were being conducted.

Comparison of Alternatives

A detailed comparative analysis of the three alternatives against seven of the nine criteria required by the NCP was performed. These criteria include: protection of human health and the environment; compliance with ARARs; long-term effectiveness and permanence; reduction of toxicity, mobility, or volume through treatment; short-term effectiveness; implementability, and costs. The two remaining criteria, state acceptance and community acceptance, will be addressed in the Record of Decision after the public comment period. Table ES-2 provides a summary of the detailed comparative analysis.

Table ES-1
Remedial Action Objectives and General Response Actions
Operable Unit 4, Riverfront Superfund Site
New Haven, Missouri

Groundwater		
Remedial Action Objectives	General Response Actions	
For protection of human health: Prevent exposure to groundwater with contaminant levels greater than MCLs and MCLGs. For protection of the environment: Minimize further migration of the groundwater contaminant plume.	No Action Institutional Controls Other Controls Natural Attenuation Containment Removal Treatment Disposal	No Action Activity and Use Limitations Alternative Drinking Water Source Monitoring Relocation Focused Monitoring Hydraulic Control Technically Impracticable Technically Impracticable On-site Treated Effluent Discharge Off-site Treated Effluent Discharge
Soils		
Remedial Action Objectives	General Response Actions	
For protection of human health: Prevent exposure to soil containing contaminants at concentrations which result in an excess cancer risk greater than 1 x 10^{-6} or a Hazard Quotient greater than 1.0, whichever is less. For protection of the environment: Reduce the soil contaminant levels, or prevent migration of soil contaminants, to provide protection of groundwater.	No Action Institutional Controls Other Controls Containment Removal Disposal Treatment	No Action Activity and Use Limitations Monitoring Capping Surface Controls Vertical Barriers Horizontal Barriers Excavation Building Demolition Off-site Disposal On-site Disposal Physical Ex-Situ Treatment Physical/Chemical Ex-Situ Treatment Physical/Thermal Ex-Situ Treatment Biological Ex-Situ Treatment In-Situ Treatment

Table ES-2
Comparative Analysis of Alternatives
Operable Unit 4, Riverfront Superfund Site
New Haven, Missouri

Evaluation Criteria	Alternative 1 No Action/ No Action	Alternative 2 Capping, Sheet Piling, and Rock Grouting / Hydraulic Containment, Above Ground Treatment, and Monitoring	Alternative 3 In Situ Chemical Oxidation / Monitoring	Alternative Rankings
Overall Protection of Human Health and the Environment	Human health protection RAOs currently met by four site-specific factors. Would not prevent future direct contact with contaminated groundwater. Environmental protection RAOs would not be met because contamination above cleanup levels would remain in the groundwater and the soil.	Protective by containing heavily contaminated groundwater and soil/shallow bedrock (if soil/bedrock is still contaminated after earlier treatment). Amount of contamination migrating from soils and shallow bedrock to groundwater would be minimized, which should allow natural processes to reduce the downgradient plume. Human health RAOs currently met by four site-specific factors. Would prevent future direct contact with contaminated groundwater. Groundwater environmental protection RAO would not be met because contamination above cleanup levels would remain in the groundwater. Monitoring would allow determination of whether soil environmental protection RAO had been met and if groundwater plume was threatening new receptors.	Protective by actively remediating the source area soils. Human health RAOs currently met by four site-specific factors. Would prevent future direct contact with contaminated groundwater. Groundwater environmental protection RAO would not be met because contamination above cleanup levels would remain in the groundwater. Monitoring would allow determination of whether soil environmental protection RAO had been met and if groundwater plume was threatening new receptors.	Ranked from alternative that would provide the most overall protection of human health to least overall protection: 3, 2, 1 Ranked from alternative that would provide the most overall protection to the environment to least overall protection: 3, 2, 1
Compliance with Applicable or Relevant and Appropriate Requirements (ARARs)	Present and future groundwater concentrations would not meet chemical-specific ARARs. Location-specific ARARs are not applicable. Would comply with action-specific ARARs.	Would not meet chemical-specific ARARs. Groundwater with contaminant levels above MCLs would remain at the site. Would comply with all Federal and State location-specific and action-specific ARARs.	Would not meet chemical-specific ARARs. TI waiver will be required. Groundwater with contaminant levels above MCLs would remain at the site. Would comply with all Federal and State location-specific and action-specific ARARs.	Would not meet ARARs unless a waiver is obtained: 1, 2, 3
Long-Term Effectiveness	This alternative would not provide active reduction of long-term risks. There are no long-term controls to provide passive reduction of long-term risk.	Lower long-term risks than Alternative 1 but higher than Alternative 3 because even though contained (if necessary), the contaminated source area soils/shallow bedrock would be left in place.	Minimal long-term risks for the source area soils because the soils would be treated to below the cleanup goals. Groundwater monitoring would provide means to monitor the long-term risk from contaminant plume migration. Soil monitoring would confirm soil remediation. Would not provide active reduction of long-term groundwater risks.	Ranked from alternative that would provide the most long-term effectiveness to least long-term effectiveness: 3, 2, 1
Reduction of Toxicity, Mobility, and Volume	It is not expected that reductions of the toxicity, mobility, or volume of the contaminants in the groundwater or soil would occur. Would not provide mechanisms to monitor contamination levels.	Mobility of the heavily contaminated head of the plume minimized by containment. Treatment would reduce the toxicity and volume of contaminated extracted groundwater. Reduction of the mobility of the contaminants in the source area soils/shallow bedrock through physical containment and hydraulic containment. Spent GAC would be only treatment residual. Does not meet the statutory preference for treatment as a principal element.	Volume and toxicity of the soil contaminants reduced through in situ chemical oxidation. Meets statutory preference for treatment as a principal element. It is not expected that reductions of the toxicity, mobility, or volume of the contaminants in the groundwater would occur. Would provide mechanisms to monitor groundwater and soil contamination levels.	Ranked from alternative that would provide the most reduction of toxicity, mobility, and volume to least: 3, 2, 1
Short-Term Effectiveness	The only remedial action that would be conducted is well closure, which can be conducted with only minimal increases in the short-term risks to the community, the environment, and workers. The time to achieve cleanup goals is unknown but anticipated to be significantly longer than 30 years.	Risks to community would be low and risk to workers would be moderate but would be minimized by following proper precautions. The time to implement is estimated to be between 12 and 18 months. The time to reach cleanup goals is anticipated to be longer than 30 years.	Risks to the community from soils would be low and risk from soils to workers would be moderately low. Risks would be minimized by following proper precautions. Soil cleanup goals would be reached in approximately 5 years. Risk to community and workers from the groundwater would be low because action would be limited to installation of monitoring wells. The time to achieve the cleanup goals for the groundwater is unknown but anticipated to be longer than 30 years.	Ranked from alternative that would provide the most short-term effectiveness to least short-term effectiveness: 1, 3, 2
Implementability	Technically and administratively feasible. The only remedial action that would be conducted is well closure. There are many vendors providing well closure services.	Technically feasible. Soil remedy would be more difficult to implement than Alternatives 1 and 3. Groundwater remedy would also be more difficult to implement than Alternatives 1 and 3. Administratively feasible. Would require utility relocates during and after soil remediation and coordination with some private citizens, MDNR, and City of New Haven.	Technically feasible. Few technical problems would be anticipated. Administratively feasible.	Ranked from alternative that would be the easiest to implement to the hardest to implement: 1, 3, 2
Cost (Total Present Worth)	$121, 100	$2,563,000	$1,401,000	Ranked from least expensive to most expensive: 1, 3, 2

1.0 Introduction

The United States Environmental Protection Agency (USEPA) has initiated a remedial investigation and feasibility study (RI/FS) for Operable Unit (OU) 4 at the Orchard Street/Maiden Lane Subsite in New Haven, Missouri. The RI/FS process is the methodology authorized by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980 as amended by the Superfund Amendments and Reauthorization Act (SARA) of 1986 (i.e., the Superfund program) for characterizing the nature and extent of risks posed by uncontrolled hazardous waste sites and for evaluating potential remedial options. Subpart E of the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) establishes methods and criteria for determining the appropriate extent of response authorized by CERCLA, as amended by SARA, and it outlines procedures for determining the nature and extent of contamination at a site as well as the appropriate extent of remedy for the site.

This feasibility study was prepared by Black & Veatch Special Projects Corp. (BVSPC) for the USEPA Region VII, under contract number EP-S7-05-06 (Architect Engineering Services [AES] Contract), USEPA task order number 0063. This report was written in accordance with the guidance documents: *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA (Interim Final),* Office of Solid Waste and Emergency Response (OSWER) Directive 9355.3-01 (USEPA, 1988a), *Guidance on Remedial Actions for Contaminated Groundwater at Superfund Sites,* OSWER Directive 9283.1-2 (USEPA, 1988b), and other OSWER directives including 9355.4-03 (USEPA, 1989a) and 9283.1-06 (USEPA, 1992).

The RI report for OU4 at the Riverfront Site was prepared for USEPA by the United States Geological Survey (USGS) with input from BVSPC (USGS, 2008). The Human Health Risk Assessment (HHRA) for OU4 was prepared by BVSPC (BVSPC, 2008). This FS is based on the information presented in the RI, the HHRA, and previous site investigation reports. The methodology used in this report allows step-by-step assessments of technologies and assembled alternatives by progressing through a series of evaluations. Initially, general qualitative information is used. Subsequently, more refined and quantitative information is used to eliminate unfeasible or otherwise unacceptable actions from consideration. This methodology provides a systematic procedure for identifying and evaluating alternatives, specifies criteria for determining the magnitude of effects resulting from the implementation of an alternative, and considers measures to mitigate the adverse effects from contaminated soil and groundwater at OU4 at the Riverfront Site.

The FS report contains an executive summary and six parts. The executive summary provides a brief overview of the report and identifies key concepts, ideas, and conclusions. Section 1.0 provides an introduction to the project by describing the purpose of the report, subsite background, previous removal actions, and summarizes the findings of previous investigations. Section 2.0 presents a description of the method that will be used for screening remedial actions (RAs), including potential applicable or relevant and appropriate requirements (ARARs), remedial actions objectives (RAOs), and areas and volumes of contamination. Section 2.0 also presents and screens potential remedial technologies and process options. Section 3.0 presents the descriptions of alternatives developed to remediate the subsite. Section 4.0 presents detailed evaluation of the alternatives, and Section 5.0 presents a comparative analysis of the alternatives for each media. Section 6.0 lists the references used to prepare this report.

1.1 Site Location and Description

New Haven (population estimated at 2,000 in 2007) is located along the southern bank of the Missouri River in Franklin County, Missouri, about 50 miles west of St. Louis, Missouri (Figure 1-1). The New Haven downtown business district is located along a narrow strip of the floodplain and is surrounded by a flood protection levee. The principal road in the city is State Highway 100, which runs along an east-west trending ridge about one mile south of the Missouri River. The ridge forms a topographic divide between the Missouri River valley to the north and the Boeuf Creek valley to the south.

In 1986, the volatile organic compound (VOC) tetrachloroethene (PCE) was detected in two public supply groundwater wells (Wells W1 and W2) in the northern part of New Haven. Following the discovery of contamination, two new public supply wells were installed in the southern part of the city, and several investigations were conducted by the Missouri Department of Natural Resources (MDNR) and USEPA. The site became known as the Riverfront Site and, in December 2000, the PCE contamination prompted the listing of the Riverfront Site on the National Priorities List (NPL) for environmental clean-up under Superfund.

The Riverfront Site consists of six OUs within and near the City of New Haven, Missouri. OU1, known as the Front Street Subsite, encompasses approximately 2 acres and was an industrial area in downtown New Haven. OU1 is located near the intersection of Front Street and Cottonwood Street in downtown New Haven. OU2, known as the Kellwood Subsite, is located south of State Highway 100 in southwestern New Haven. OU3, known as the Old City Dump, is located just north of State Highway 100 on the eastern side of New Haven. OU4, known as the Orchard Street/Maiden Lane Subsite, includes the City of New Haven sanitary sewer system within the OU4 area. OU4 is

located in east-central New Haven, north of State Highway 100. OU5 is located just south of downtown New Haven, on the corner of Maupin Avenue and Wall Street. OU5 is located within the boundaries of OU4. OU6 was designated in 2002 by USEPA to encompass removal actions addressing groundwater contamination in domestic wells south of OU2. Figure 1-2 provides a detailed location map for OUs 1 through 6.

The scope of this FS addresses only OU4, the Orchard Street/Maiden Lane Subsite, and as such, the other OUs will not be discussed any further in this document except as they relate to OU4. Discussion of the remedial alternatives for OU1 can be found in Volume 1 of the OU1/OU3 FS Report (BVSPC, 2003), while the remedial alternatives for OU3 are discussed in the second volume of the 2003 FS Report. The Final FS for OU5 was provided to USEPA under separate cover by BVSPC (BVSPC, 2006). The investigations of OU2 and OU6 are ongoing.

The boundaries of OU4 have expanded and changed over the course of the investigation. Currently (2008), the OU boundaries cover a 192-acre area. The boundaries of the OU are approximately Maupin Avenue to the west, Circle Drive to the south, and the Missouri River to the north. The eastern boundary runs through undeveloped land east of Miller Street. OU4 is mostly residential and the topography is steep. A topographic divide runs east to west through the southern portion of the OU. The slopes are less steep to the south of the divide and more steep to the north. Most of the homes were built in the early 1900s, although some were built in the late 1800s and one small development was built in the 2000s. Many of the homes are built on land from the Bagby Nursery, a 500-acre fruit tree nursery that closed in the 1920s, before PCE began to be used. Other landmarks within OU4 include the Assumption Catholic Church, the former Kellwood Research facility (now a private residence), the Sunfield Nursery (a smaller nursery that operated on some of the Bagby Nursery land after the Bagby closed), and the abandoned New Haven Public School. See Figure 1-3.

At OU4, the surficial soils are loess (wind deposited) and thin, ranging from 3 to 10 feet thick. Throughout most of the subsite, a layer of residual deposits several feet thick underlies the soils. Below the residual layer are the bedrock layers of the Ozark aquifer. The top two bedrock layers of the Ozark aquifer below OU4 are the Cotter and Jefferson City Dolomite units. The Cotter contains two sandstone beds, the "upper sandstone" and the Swan Creek sandstone. Where the upper sandstone is exposed along creek beds in OU4, there are often small seeps or springs, indicating that the sandstone is more permeable then the rest of the Cotter. Because of erosion, the thickness of the Cotter varies from 85 feet in the north area of OU4 to 330 feet in the south. The Jefferson City Dolomite, the next unit in the Ozark aquifer, is approximately 150 feet thick below New Haven. These two units are poor water-producing formations, with low

vertical and horizontal conductivities. Below the Jefferson City Dolomite is the Roubidoux Formation, which is approximately 115 feet thick below New Haven. The Roubidoux is a reliable water producing formation, producing sufficient water for domestic supply and even some industrial use (a well in the Pepsi-Cola plant in New Haven draws from the Roubidoux). Monitoring well results have detected PCE contamination in all three of these units. Below the Roubidoux is the Gasconade Dolomite unit, which averages about 300 feet thick below New Haven. The upper portions of this unit are less permeable than the Roubidoux above or the rest of the Gasconade below. As of 2007, samples from the Gasconade unit were not contaminated by PCE or other OU4 contaminants.

At New Haven, there are two groundwater flow systems. In the soils and shallow bedrock units (the units within 400 feet of the surface), groundwater flows with the topography. Therefore, in the southern portions of OU4, which lie south of the topographic divide, the shallow groundwater flows to the south, towards Boeff Creek. In the north, shallow groundwater flows north to the Missouri River. Because the northern side of the OU is steeper, the shallow groundwater on the north migrates faster than the groundwater to the south. The deep groundwater is controlled by the northward regional flow down from the uplands of the Ozarks, which are south of New Haven. The regional flow acts as recharge for the Missouri River (for example, the RI detected upward flow from the bedrock units in the regional aquifer at well W2). Because the groundwater is located in limestone rock units, groundwater tends to migrate along zones of higher permeability, such as bedding planes or units such as the upper sandstone unit and Swan Creek member of the Cotter Dolomite.

1.2 Subsite History of OU4

In 1986, two public supply wells (W1 and W2) for the City of New Haven were found to be contaminated with the VOC PCE. Two new public supply wells (W3 and W4) were installed in uncontaminated groundwater and the two contaminated wells were removed from service. During the rest of the 1980s and 1990s, the MDNR and the USEPA investigated to determine the source of the contamination. See Section 1.3 for a more detailed discussion of the investigation activities. By 1994 the investigations had determined that PCE had been released at OU4 (then known as the Riverfront Site), but it was unclear if this release was the source of the contamination that closed wells W1 and W2.

In 1998, the USEPA requested that the USGS provide assistance in determining groundwater flows at New Haven. The USGS assisted the USEPA in conducting RI activities for the Riverfront Site. By 2000, the USEPA had placed the Riverfront Site on

the NPL and had divided the Site into four OUs. In 2002, based on the initial results of the RI, two additional OUs were designated; OU5, the Old Hat Factory and OU6, which addressed PCE contamination of several individual home supply wells south of OU2.

As the RI progressed, it became clear that while OU1 was contaminated with PCE, it was down- and side-gradient to the two contaminated City wells and was not the source of the contamination that closed them. From 2000 to 2002, based on the initial RI investigation results and unconfirmed reports of possible dumping of PCE and other industrial wastes, the OU4 investigation concentrated on an area east of Miller Street. At the same time, the investigation was systematically installing bedrock monitoring wells in a "walk upgradient" of the two contaminated City wells. By 2003, the investigations east of Miller Street had not found significant contamination, while the monitoring well investigation was leading to a focus on an area around Maiden Lane, which is located west of Miller Street. At that time, USEPA was concerned that PCE disposed of into the City sewer system at OU2 may have leaked from the sewer lines around Maiden Lane and created the PCE plume. However, by sampling various media (soils, tree cores, in-door vapor from homes, sewer water, surface water, and groundwater) and from discussions with residents, the investigation found that most likely a private citizen had disposed of significant amounts of PCE into his home's grey water (sewer) line, which discharged into a low area behind (south of) Maiden Lane. Here the PCE migrated through the soils into the bedrock and then into the bedrock aquifer.

At this time (2008), the PCE soil contamination is nearly all confined to this small (less than 0.2 acre) area south of Maiden Lane. The groundwater plume extends from the shallow groundwater at the soil-rock interface below the source area soils through the bed-rock to the north, possibly as far as the Missouri River. Groundwater contamination also extends slightly south of the soil source area, due to local topography. Overall, the PCE plume extends from the source area to wells W1 (approximately 3,800 ft downgradient) and W2 (approximately 3,000 ft downgradient) and possibly to the Missouri River (approximately 4,000 ft downgradient).

1.3 Investigation Activities and Removal Actions at OU4

From November 2000 through 2007, the USGS conducted a variety of sampling activities as part of the RI for OU4. During these various sampling efforts, the USGS collected vegetation (tree-core sampling), surface water, groundwater, soil, and sanitary sewer samples from OU4 (USGS, 2008). The USEPA collected indoor vapor samples. These sampling efforts are discussed in detail in the RI (USGS, 2008). The USEPA has also conducted a removal action at the OU4 source area soils. The efforts are

summarized in the following sections and the results of these investigations and the removal action are discussed in Section 1.4.

1.3.1 Vegetation (Tree-Core) Reconnaissance Sampling

The USGS conducted four tree-core sampling efforts at OU4. The first was conducted during April 2000 at suspected dump site A, east of Miller Street and along residential fence lines along the east side of Miller Street. The USGS also conducted three rounds of tree-core sampling at the Maiden Lane area. The first effort occurred in September 2001, the second in July 2003, and the last in October 2003.

Tree core samples were collected by boring a core sample from trees in the investigation area and placing the core into a standard volatile organic analysis (VOA) vial. The cores were generally taken from trees with diameters greater than three inches. If available in the investigation area, trees that were fast growing and had deep root systems (mulberry, poplar, or cottonwood) were sampled first. The samples were held overnight to allow equilibrations between the vial headspace and the core material. After equilibration, a sample of the headspace was analyzed using a gas chromatograph (GC). Overall, 148 tree core samples were collected from OU4.

1.3.2 Surface Water Sampling

Four small creeks flow through and out of OU4. The 710 tributary flows south, towards Boeff Creek, since it is located on the south side of the topographic high that runs along the southern portion of OU4. The 210 tributary runs along the eastern side of OU4, while the 300 tributary drains the north portion. A part of the 400 tributary drains the northwestern portion of the OU.

The USGS collected 132 samples from streams and springs in OU4 during the RI. Streams were sampled by walking upstream and sampling each stream segment and just below each stream junction. All three springs in the OU4 area were also sampled. The usual method of sampling was to submerge an empty VOA vial in the stream or spring and cap it below the water's surface, thus avoiding any contact with the atmosphere. While most samples were analyzed within 12 to 16 hours, all the samples were analyzed with 48 hours. In general, any locations with PCE or other VOA detections were resampled for confirmatory analysis.

1.3.3 Groundwater Sampling

During the course of the investigations of the various New Haven OUs, the USEPA has installed 38 bedrock monitoring wells. Of these, 24 are in OU4 or were useful in the investigation of OU4. Groundwater samples were also collected from three

industrial wells near OU4: the "Pepsi" well, which is located south of OU4 in the Pepsi warehouse along Highway 100; well JS-30 east of OU4 on Orchard Street, and; JS-34, north of OU4 in downtown New Haven, just west of public supply well W1. In addition, three shallow (from ground surface to the top of bedrock, all three 11.5 feet or shallower) monitoring wells were installed at the OU4 source area to monitor the RA (see Section 1.3.5). Finally, the sample results from public supply wells W1 and W2 were also used during the OU4 RI.

Many of these wells were installed using cable tool drilling for all or some of their depth. Cable tool drilling does not inject air or water into the formation during drilling, allowing representative samples of the groundwater to be collected during drilling and allowing the well to sample representative water from the formation much sooner than if air rotary drilling (which injects large volumes of air into the bore hole during drilling that strip the volatile contaminants from the groundwater near the well) had been used. To minimize costs, 18 of the wells are pairs installed in the same bore hole. In these wells, two depths of interest were isolated from each other by installing a packer, then placing a grout plug on top of the packer.

The USGS collected over 200 groundwater samples during the investigation of OU4. In general, monitoring wells have been sampled at least annually since they were installed. In addition, because cable tool drilling was used for many of the wells, over 600 samples were collected from drill cuttings or from groundwater collected from the boreholes as the boreholes for the monitoring wells were being drilled.

The vertical distribution of PCE in the bedrock aquifer at OU4 was examined by portable GC analysis of drill cuttings at the time of drilling and from comparison of PCE concentrations in samples from completed monitoring well clusters. Selected samples were sent to an off-site laboratory for confirmatory analysis.

1.3.4 Soil Sampling

The USGS conducted six soil sampling efforts at OU4. The first was conducted during December 2000 and the last was conducted in January 2007. The table below lists the dates of the sampling efforts, the number of soil borings, and the location of the borings.

Table 1-1
Summary of Soil Sampling Efforts
Operable Unit 4, Orchard Street/Maiden Lane Subsite
New Haven, Missouri

Date of Effort	Location of Sampling	Number of Borings	Comments
December 2000	East Miller St	17	16 borings in Area A and one at the future location of BW-08.
March 2003	Circle Drive	6	Two shallow groundwater samples were also collected from the boreholes.
June 2003	Assumption Church	10	
September and October 2004	Kellwood Research Center and S. Maiden Lane	21 total	11 borings were installed at the former Kellwood Research Center and 10 along South Maiden Lane.
November 2005	S. Maiden Lane	11	The borings were installed around the old garage behind 104 Maiden Lane.
January 2007	S. Maiden Lane	3	3 borings were installed around the garage at 104 Maiden Lane to support the Removal Action conducted later in 2007.

The soil samples from the last four efforts were collected using a GeoProbe rig. Samples would be collected every 4 feet from the surface to the desired depth for the boring. The December 2000 samples were collected by advancing a hand auger to the desired depth (3 ft. below ground surface (bgs) for all the samples) and then removing the auger. The samples were collected from core tubes driven to the 3 ft. sample depth inside the borehole made by the auger. The March 2003 sampling effort also used an auger rig to sample, because the area to be sampled was very soft. After the boreholes had been installed in this area they were allowed to remain open for 4 hours to see if they would collect sufficient shallow groundwater to obtain a sample. Two of the six boreholes did collect sufficient water and were sampled.

1.3.5 Sanitary Sewer Sampling

Earlier sampling efforts by the USGS had confirmed that the sanitary sewers in New Haven were contaminated with PCE (USGS, 2005). The USGS conducted five sewer sampling efforts during the OU4 RI. The first was done in September 2001. The

other efforts were conducted in October 2001, April 2002 (both on the 1st and 29th and 30th), November 2003, and February 2004. Eleven sewer manholes were sampled over the course of these five events.

1.3.6 Indoor Air Sampling

During the investigations of the various OUs, the USEPA conducted three rounds of indoor air sampling. Five homes and one public building in OU4 had indoor air samples collected. Samples were collected by placing vacuum canisters with a special sampling valve in two locations within each building. One location was usually a basement, where the sampler would not be disturbed. The other location was a high-use area such as a living room or bedroom. The sampling valve collected a sample over 24 hours. If possible, two samples were collected on consecutive days.

The public building in OU4 was sampled in September 2002 as part of an initial reconnaissance sampling of indoor air samples at OU1, OU2, and OU4. It was sampled again in May 2003, in a second wide scale sampling of properties in OU1, OU2, and OU4. In February 2004, as a result of the detection of PCE in samples from tree-cores, soils, and shallow groundwater in the Maiden Lane area (discussed earlier in sections 1.3.1, 1.3.2, and 1.3.3), the USEPA collected indoor-air samples from five residences in the Maiden Lane area.

1.3.7 In-Situ Chemical Oxidation Removal Action

In 2007, the USEPA conducted a removal action at the OU4 source area soils south of Maiden Lane. The treatment selected was in-situ chemical oxidation using sodium permanganate ($NaMmO_4$). A treatment chemical solution containing sodium permanganate was injected into the contaminated soils, where the solution would oxidize the PCE and other contaminants to carbon dioxide, water, and salts.

The treatment effort was conducted in two phases, one in May and one in October of 2007. The May 2007 effort treated an area primarily southwest and adjacent to the east side of the old garage, while the October effort treated a smaller area east of the old garage. The May effort was hampered by very high perched groundwater levels. At some locations, the injected chemical mixture was forced to the surface by the pressure of the groundwater. By the time of the October effort, shallow groundwater levels in the source area had decreased and the treatment proceeded without complications.

Before mobilization for the permanganate injection effort, the USEPA determined permanganate solution strength and injection volumes based on analysis of potential soil oxidant demand (PSOD) soil samples from three borings. In addition, three temporary

monitoring wells (T1, T2, and T3) were installed to monitor the effect of the treatment injection on PCE concentrations in the perched groundwater below the injection area.

1.4 Nature and Extent of Contamination at OU4

A full discussion of the nature and extent of contamination at OU4 of the Riverfront Site can be found in the USGS's RI report for OU4 (USGS, 2008). The following subsections and figures provide a brief summary of sample results.

1.4.1 Vegetation (Tree Core) Sampling Results

The USGS collected approximately 140 tree core samples during four sampling efforts for the OU4 RI. See Section 1.3.1 for more details of the sampling locations, schedule, and methods.

During the first vegetation sampling effort (east of and along Miller Street), approximately 50 samples were collected and very little contamination was found (only eight samples even had detectable levels of PCE and the highest level was less than 5 micrograms per kilogram (ug/kg)). Most (five) of the detections occurred just downstream of the junction of the 214 and 210 tributaries. This information was helpful in determining where to sample the 210 tributary during the stream sampling (see Section 1.4.2).

During the three efforts at Maiden Lane, very high levels of contamination were detected along Maiden Lane and especially in the area south of (behind) Maiden Lane. During the first effort, 37 trees were sampled. Four samples along Maiden Lane had PCE levels between 5 and 49 ug/kg, while three trees near a detached garage behind 104 Maiden Lane had even higher levels. The highest PCE level detected in this round was 117 ug/kg, from a tree next to the garage behind 104 Maiden Lane. The second effort investigated the trees near the former Kellwood research facility. Fifteen trees were sampled but only four had detectable levels of PCE and all the levels were 4.99 ug/kg or less. The third effort sampled 41 trees in and around Maiden Lane. Only two samples had PCE levels over 50 ug/kg (the highest was 100 ug/kg) and both of these samples were from behind (south of) 104 Maiden Lane. The order of magnitude larger detections behind 104 Maiden Lane, compared to the levels detected in the first effort and the low levels detected around the Kellwood research facility were very helpful in focusing the investigation into the Maiden Lane area.

1.4.2 Surface Water Sampling Results

Four small creeks flow through and out of OU4. The 710 tributary flows south, towards Boeff Creek, since it is located on the south side of the topographic high that

runs along the southern portion of OU4. The 210 tributary runs along the eastern side of OU4, while the 300 tributary drains the north portion. A part of the 400 tributary drains the northwestern portion of the OU.

See Section 1.3.2 for more details of the surface water sampling locations, schedule, and methods.

The 710 tributary is dry except during rain events, so no samples were collected from the stream segments in OU4. Farther down stream, the 710 tributary becomes perennial. Samples collected in these segments were all non-detect for PCE or other OU4 contaminants. Samples from the portions of the 400 tributary that drain OU4 were also non-detect for PCE and other OU4 contaminants.

The 300 tributary is fed by a small (> 0.3 gallon per minute [gpm]) perennial spring, called the Bates Spring in the RI. The 300 tributary and Bates Spring were sampled in November 2000 and April 2001. In November 2000, PCE was detected in Bates Spring at 5.4 micrograms per liter (ug/L), just barely over the PCE maximum contaminant level (MCL) of 5 ug/L. The PCE rapidly dissipated, so that a sample collected just 50 ft downgradient had a PCE level of 0.5 ug/L and all the other samples, collected from farther down stream, were non-detect for PCE and other OU4 contaminants. In April 2001, the PCE level in Bates Spring was 3.8 ug/L and all three downstream samples were non-detect for PCE and the other OU4 contaminants. Three more samples collected from the 300 tributary in February 2005 were all non-detect for PCE and the other OU4 contaminants, confirming the earlier results.

A very small spring, discharging between 40 and 100 milliliters per minute (ml/min) or (approximately 1.5 gallons per hour at maximum [100 ml/min] flow) was discovered in the 210 tributary. This spring has been sampled 19 times between April 2000 and September 2006. PCE levels in the spring have ranged from 3.0 ug/L to 30.3 ug/L, averaging 17.2 ug/L. Only six of the spring's PCE results were less than 10 ug/L. trichloroethene (TCE) and cis-1,2-dichloroethene (cis-DCE) have also been detected in the spring. The contamination in the spring dissipates as it flows downstream. By the time the flow reaches the junction with the small, un-numbered stream to the west of the 210 segment, the PCE levels have declined to below MCLs.

Both of these contaminated springs occur where groundwater flowing along the upper sandstone bed seeps out into the streams. These seep samples confirmed that the groundwater at the upper sandstone bed was contaminated upgradient of the seeps. This information was useful in the placing of monitoring wells farther upgradient and, combined with the vegetation data, focused the investigation effort up the slopes towards the Maiden Lane area.

1.4.3 Groundwater Sampling Results

Analysis of the groundwater samples collected for the OU4 RI shows that a plume of PCE contamination in the bedrock aquifer extends from just south of the Maiden Lane source area near the old garage northeast to the Missouri River. The plume is more than 3,800 ft long and nearly 3,000 ft wide at the downgradient edge near the Missouri River (see Figure 1-4). Within the plume, PCE concentrations range from less than 1 ug/L in shallow well BW-08A (on the western edge of the OU4 plume) to more than 9,000 ug/L in well BW-13 (located immediately downgradient of the source area soils). Concentrations of PCE decrease from thousands of ug/L in wells less than 700 ft downgradient from the source area soils (BW-10 and BW-13) to several hundred ug/L approximately 2,100 ft downgradient (wells BW-02 and BW-05) and continue to decrease farther downgradient. For example, wells BW-01 and JS-34 have PCE levels less than 30 ug/L. These two wells are approximately 3,000 ft downgradient of the source area, near the Missouri River.

The PCE results from monitoring wells and drill cuttings indicate that the PCE contamination from the Maiden Lane source area migrates to deeper bedrock units as groundwater from the source area soils flows generally northward toward the Missouri River. The contaminant migration is driven by the steep downward vertical gradients and uncontaminated recharge downgradient (north) of the source area. In addition, the PCE plume is probably not a homogenous plume. Instead, just as the groundwater migrates along zones of higher permeability, such as bedding planes or within units such as the upper sandstone unit and the Swan Creek member of the Cotter Dolomite, the dissolved PCE plume in the bedrock probably resembles "fingers" of contamination oriented along zones of higher permeability. This would explain why two of the upper sandstone springs in OU4 were seeping contaminated water. Near the source area, the dissolved phase contamination appears restricted to the Cotter Dolomite but further downgradient migrates into the deeper Jefferson City Dolomite and Roubidoux Formation units. The maximum depth of contamination is probably limited by the extent of vertical migration of pure phase PCE in the bedrock and by upward flow as groundwater from deeper units in the Ozark aquifer discharge into the Missouri River. At city well W2, borehole measurements made during the expanded site investigation/remedial investigation (ESI/RI) indicated upward flow in the borehole from units beneath the Roubidoux Formation and that groundwater was migrating out of the borehole into the Roubidoux Formation (USEPA, 2001). Based on these measurements, the RI hypothesized that unless dense non-aqueous phase liquid (DNAPL) migration has carried pure phase PCE contamination into the deeper Roubidoux Formation, the dissolved PCE contamination

migrating from the Maiden Lane source area probably migrates no deeper than the Roubidoux Formation.

1.4.4 Soil Sampling Results

The USGS collected 296 soil samples from 68 soil borings during six sampling efforts for the OU4 RI. See Section 1.3.4 for more details of the soil sampling locations, schedule, and methods.

The first five sampling efforts found that the soils east of Miller Street, around the former Kellwood Research facility, and the Assumption Church were not contaminated with PCE or the other OU4 contaminants. As discussed in Sections 1.3.2 and 1.3.1, surface water sampling had indicated that the source of the PCE plume was upgradient of the two contaminated springs (Bates Spring and the 210 tributary spring), and vegetation sampling had indicated that the soils around the old garage behind 104 Maiden Lane were heavily contaminated with PCE. The soil sampling in the South Maiden Lane area confirmed the indications of the other media samples. The soil samples from Maiden Lane were very heavily contaminated. In some samples from the Maiden Lane area, pure PCE product was detected. A summary of the soil sampling results at Maiden Lane is provided on Figure 1-5. Once the degree of contamination at Maiden Lane was established, USEPA scheduled an in-situ treatment of the soils (this type of action is known as a removal action, even though the soils were treated in place). See Section 1.3.6. The January 2007 sampling effort (see Table 1-1) was conducted to provide information to support the removal action.

1.4.5 Sanitary Sewer Water Sampling Results

The USGS conducted five sewer sampling efforts during the OU4 RI. Eleven sewer manholes were sampled over the course of these five events.

The sample results showed that while there were low levels of PCE and TCE in the sewer gray water, in all but one case the levels were less than upstream levels. A "walk upstream" through the sewer system found that the highest PCE levels were occurring just downstream of OU2 and that the contaminant levels decreased as the grey water moved downstream and was diluted by new flows. In one case, a trace amount of PCE (0.44J ug/L) was detected in the east inflow to manhole 113. This inflow only serves the Assumption Catholic Church and the four homes along Maiden Lane. Overall, the sewer sampling at OU4 confirmed that nearly all the PCE in the grey water was arriving from upstream and that the Kellwood research facility in particular, and the rest of OU4 in general, were not sources of the PCE detected in the sewers.

1.4.6 Indoor Air Sampling Results

The USGS conducted three indoor air sampling efforts during the OU4 RI. Approximately 25 samples were collected over the course of these events.

PCE was detected in every sample while TCE was detected in all but one sample. However, because of their wide use in many industrial and consumer compounds, the detection of trace (less than 1 ug/m^3 [micrograms per cubic meter]) levels of PCE and TCE inside homes is commonplace and not indicative of contamination from soil vapor intrusion. Only four of the PCE and four of the TCE detections exceeded 1 ug/m^3. The highest detections were 6.4 ug/m^3 PCE and 7.4 ug/m^3 TCE. None of the other detections exceeded 1.7 ug/m^3.

1.4.7 Results of the Removal Action

In 2007, the USEPA conducted a removal action at the OU4 source area soils south of Maiden Lane. The treatment selected was in-situ chemical oxidation. In January 2007, the USGS collected soil samples that were used to determine the permanganate soil oxidant demand (PSOD). Once these samples had been analyzed, the removal action was designed such that the treatment would be sufficient to treat the contaminant levels and the PSOD in the soils. The treatment effort was conducted in two phases, one in the May and one in the October of 2007. A treatment chemical solution was injected into the contaminated soils, where the solution would oxidize the PCE and other contaminants to carbon dioxide, water, and salts.

Confirmatory sampling to determine the effectiveness of the in-situ treatment is scheduled to be conducted during the Remedial Design (RD) phase of the alternatives (see Section 3).

1.5 Media and Contaminants of Concern

Because this FS is for OU4, the media of concern are the contaminated soils behind Maiden Lane and the contaminated groundwater plume that extends from the contaminated soils to the Missouri River.

For this FS, the contaminants of concern (COCs) have also been categorized into two groups: soil COCs and groundwater COCs. The primary soil COCs are PCE, TCE, and vinyl chloride (VC). The primary groundwater COCs are nearly the same, PCE and TCE along with cis- and trans-DCE. VC is not a COC for groundwater. The indicator contaminant for both soil and groundwater is PCE. The following is a list of all the COCs and other contaminants at OU4:

- COCs:
  - Soil:
    VOCs - PCE, TCE, and VC
  - Groundwater:
    VOCs - PCE, TCE, cis-DCE, and trans-1,2-Dichloroethene (trans-DCE)

- Other Contaminants:
  - Soil:
    None
  - Groundwater:
    None

1.6 Contaminant Fate and Transport

Previously, detailed assessments of the contaminant fate and transport of the chlorinated VOCs (PCE, TCE, cis-DCE, trans-DCE, and VC) in the soils and groundwater at OU4 were provided in the RI (USGS, 2008). The fate and transport predictions provided in this assessment were based on data collected during the RI. The major fate and transport processes are listed below in the order of their effects on the contaminants. The effects on the soil contamination are listed first, then the effects for the groundwater.

Soil processes:

1) Dispersion, (the migration of a contaminant from soils to groundwater or soil gas), is currently the major transport process. Chlorinated VOCs (nearly all PCE) are desorbing from the soils and dispersing into the groundwater and soil gas. The annual rise and fall of the groundwater table (the source area soils are located in a small local depression that fills with perched groundwater) causes the soil contamination to diffuse into a new volume of perched groundwater every year. However, the very slow groundwater velocity once the contaminated groundwater migrates into the bedrock means that much of the groundwater around the contaminated soils has already been contaminated, so the amount of soil contamination that disperses to the groundwater each year is low. Dispersion is probably the controlling transport process for any DNAPL in the soil and shallow bedrock. DNAPL films and globules disperse downward through the voids in the soil and shallow bedrock, pulled by gravity and pushed by the hydrostatic head of the perched groundwater.
2) Volatilization, (the migration of a contaminant from being adsorbed onto a solid to the gaseous phase or from an aqueous solution to the gaseous phase), is not a

major contributor to the attenuation of the VOC contaminant mass in the soils when compared to dispersion. Because most of the contamination in the soils is deep, the contaminated soils are essentially capped by the much less contaminated surface soil. This capping makes the soil gas exchange rate low. In addition, volatilization is a two or three step process. First the VOCs must desorb from the soils into the soil gas or soil pore moisture. Next, the contaminated soil gas must make its way to the surface. If the VOCs disperse into the soil pore moisture, there is a third step because the VOCs must strip out of the soil moisture into the soil gas. All these factors minimize the amounts of VOCs being volatilized from the soils. It is likely that in the past, as the PCE was being disposed of in the shallow soils, volatilization was as important, or even more important, than dispersion in controlling the fate of the PCE contamination. Volatilization certainly played a significant role in removing the contaminants from the upper shallow soils.

3) Sorption (the tendency of a contaminant to be adsorbed or absorbed on the subsurface media, which typically reduces the rates of dispersion and volatilization) does not appear to have retarded the migration of the chlorinated VOCs, especially in the soils and shallow rock below the source area soils. This conclusion is based on the RI soil sampling data, which found that the deeper soils were substantially contaminated with PCE (possibly up to pure product [DNAPL]) compared to the shallow soils. Given the age of the contamination (40+ years), it is likely that the chlorinated VOC contamination in the vadose zone below the source area is at equilibrium with the perched water and groundwater. The VOC contaminant mass in these soils will act as a source of groundwater contamination for a very long (100+ years) time.

Groundwater processes:

1) Dispersion, (the lateral migration of contaminants within an aquifer), is the major transport process affecting the VOCs in the groundwater. This conclusion is supported by comparing the length (the north to south extent) of the plume to its width (the east to west extent). The ratio of the contaminant plume's length to its width is approximately four to three, as shown on Figure 2-1. It is likely that the groundwater flow velocity (assumed to be approximately 30 to 60 feet/year) is not sufficient to limit dispersion.
2) Advection, (moving the contaminants downgradient along with the groundwater in an aquifer), is not as large a contributor to the attenuation of the plume as dispersion, primarily because of the low groundwater velocity. While the plume ends when it intersects the Missouri River, the low groundwater velocity limits

the amount of the plume that enters the river in any given year. On average, approximately one percent of the plume flows into the Missouri River each year.

3) Sorption, (the tendency of a contaminant to be adsorbed or absorbed on the subsurface media, which typically reduces the rates of advection and dispersion) does not appear to have retarded the migration of the contaminants. This conclusion is based on the relatively low levels of organic carbon in the bedrock and vadose zone soils. While it is likely that some contaminants are sorbed to the vadose zone soils of the source area and possibly to elements in the bedrock below the source area soils, there is also evidence that there is DNAPL in the deep soils and possibly the bedrock. Because there is pure product in the soils, the sorption capacity of the soils must have been exceeded at the source area. Given the plume's age (40+ years) and the low groundwater velocity, it is likely that farther downgradient the sorption/desorption rates from the groundwater to the bedrock (and vice-versa) are approximately equal.
4) Volatilization, (the migration of a contaminant from an aqueous solution to the gaseous phase), is not as large a contributor to the attenuation of the plume as the previous fate mechanisms. Volatilization is a multi-step process for these contaminants to actually escape from the vadose zone, (see the volatilization discussion for contaminants in soils). For the contaminants deep within the plume, volatilization is impossible. Also, the entire source area of the plume is covered by vegetation, buildings, and roads, all of which act to limit the amount of air exchanged with the subsurface, while the bulk of the plume is located in bedrock, which also minimizes the amount of volatilization possible.
5) Biodegradation, (transformation of chemical compounds through the action of microorganisms), does not appear to contribute to contaminant degradation in the downgradient areas of the plume. Sampling results from these areas of the aquifer have detected some of PCE's degradation (daughter) products: TCE, cis-DCE, trans-DCE, and VC. However, the levels of daughter products are very low. As low levels these compounds also occur as contaminants in the original PCE solvent, it is not clear that the levels of the daughter products being detected in the plume are due to biodegradation. They may simply be contaminants that were shipped in the PCE solvent.
6) Hydrolysis, (chemical reactions between the contaminants and water), is not a significant fate (degradation) process for any of the primary COCs (e.g., chlorinated VOCs) within the plume.

1.7 Risk Assessment

BVSPC prepared a HHRA simultaneously with the USGS RI to determine the risks posed by contamination at OU4 to human receptors. The HHRA was completed in July 2008. A complete assessment of the human health risk associated with OU4 at the Riverfront Site can be found in the *Final Human Health Risk Assessment Report, Riverfront OU4, City of New Haven, Franklin County, Missouri (*BVSPC, 2008). A complete assessment of the ecological risks for the Riverfront Site can be found in the *Ecological Risk Assessment Riverfront Superfund Site, City of New Haven, Franklin County, Missouri,* (BVSPC, 2002). The following subsections provide summaries of the conclusions of the HHRA and the ecological risk assessment.

1.7.1 Human Health Risk Assessment at OU4

BVSPC evaluated exposure to carcinogenic and non-carcinogenic contaminants at OU4. USEPA considers a risk unacceptable when the total excess lifetime cancer risk for a reasonable maximum exposure exceeds $1x10^{-4}$ (1 in 10,000). Total excess lifetime cancer risks below $1x10^{-6}$, (1 in one million), are considered to be acceptable. Risk management decisions are required when total excess lifetime cancer risks are in the $1x10^{-4}$ to $1x10^{-6}$ range (risks may be acceptable or unacceptable, depending on the site conditions and other factors). Non-carcinogenic human health risks may exist when the total hazard index calculated for a target population exceeds 1.0.

The calculated excess cancer risks for soil exposures were $2.2x10^{-3}$ for future residents and 4.8×10^{-4} for current/future industrial workers. Soil risks were also greater than 1 in a million ($1x10^{-6}$) for current/future construction workers ($2.3x10^{-5}$) and current residents ($3.4x10^{-6}$). Except for future residents, all non-carcinogenic risks from soils had total hazard indexes less than 1. The non-carcinogenic risk from soils for future residents was 4. Therefore, because the soils at OU4 do pose significant risks for future residents, the soil contamination risk is unacceptable and the soil contamination will be addressed in the remedies prepared in Section 3.0.

The calculated excess cancer risks for outdoor air exposures ranged from $2.5x10^{-3}$ to $1.7x10^{-4}$ for current and future residents, industrial workers, and construction workers. Except for industrial workers, all non-carcinogenic risks from outdoor air exposure had total hazard indexes greater than 1. With regard to these estimated risks, the outdoor air exposure concentrations were modeled from soil and groundwater at OU4. As discussed in the HHRA, considerable uncertainty is associated with these estimated outdoor air concentrations, and it is likely that these risks are overestimated. However, even with these uncertainties, because the soils at OU4 are the source of significant risks from outdoor air exposures for current and future residents, construction workers, and

industrial workers, the soil contamination risk will be addressed in the remedies prepared in Section 3.0.

Because all residences and businesses in OU4 are currently supplied with potable water by the City, there is no current carcinogenic or non-carcinogenic risk from groundwater. However, it is possible that groundwater may be used by residents in the future. Future carcinogenic risks for residents ranged from 4.8×10^{-1} to 5.4×10^{-1} (4.8 to 5.4 excess cancers in 10 people). Therefore, because the groundwater at OU4 poses significant risks for future residents, the groundwater contamination risk is unacceptable and the groundwater contamination will be addressed in the remedies prepared in Section 3.0.

The HHRA identified cancer risks from surface water due to the groundwater contamination in the range of 1.6×10^{-7} to 6.9×10^{-6} for workers and residents. These estimates are at the lower boundary of USEPA's target cancer risk range (1×10^{-4} to 1×10^{-6}). Remediation efforts that affect groundwater will also ultimately protect against the risk from the contaminants in surface water. Therefore, except for additional sampling of the contaminated springs in OU4, surface water will not be discussed in the remedies prepared in Section 3.0.

The HHRA identified cancer risks from vapor intrusion due to the soil contamination in the 1.1×10^{-4} to 2.4×10^{-6} range. These estimates fall within USEPA's target cancer risk range (1×10^{-4} to 1×10^{-6}) and are barely above the upper boundary of the target risk range (1×10^{-4}). Since all hazard indices are less than 1, non-carcinogenic health effects from vapor intrusion are not expected. With regards to vapor intrusion due to soil contamination, the HHRA concluded in its Uncertainties Section that based on site conditions, "it is likely that except for the homes around the source area, the HHRA overestimates the exposure point concentration (EPC) from soil vapor intrusion." Given that even when assuming reasonable maximum scenarios the health risks from vapor intrusion exposure fall right at the upper boundary of USEPA's target risk range, the vapor intrusion pathway is likely not a concern. Therefore, except for additional confirmatory sampling around the source area soils, vapor intrusion will not be discussed in the remedies prepared in Section 3.

The various populations, exposure pathways, and associated risks are summarized on Table 1-2.

1.7.2 Ecological Risk Assessment

The Ecological Risk Assessment concluded that OU4 poses minimal risk to ecological receptors (BVSPC, 2002). Environmental risks at OU4 will be addressed in

the discussion of ARARs, which include all of the standards set to protect the environment under Federal law and under Missouri State law.

1.8 Identification of Preliminary Remediation Goals

Preliminary Remediation Goals (PRGs) have been developed for the COCs in the groundwater at OU4. Based on the risk assessment, the only COCs for OU4 are PCE, TCE, cis-1,2-DCE, trans-1,2-DCE and VC. While groundwater from beneath OU4 is not currently used for drinking water, PRGs have been set at federal MCLs for PCE and the other COCs because groundwater from the aquifer that is below OU4 has been and may be used as a drinking water source. Table 1-3 lists the PRGs for each of the COCs at OU4.

Table 1-2
Summary of Human Health Risks
Operable Unit 4, Orchard Street/Maiden Lane Subsite
New Haven, Missouri

Carcinogenic Risks at OU4			
Population Scenario	**Exposure Pathways**	**Total Excess Lifetime Cancer Risk**	**Contaminant(s) Driving Risk**
Current Resident	Surface Water Soil Indoor Air Outdoor Air	6.9×10^{-6} 3.4×10^{-6} 8.1×10^{-5} 2.5×10^{-3}	PCE and TCE in outdoor air
Future Resident	Surface Water Soil Groundwater Indoor Air Outdoor Air	6.9×10^{-6} 2.2×10^{-3} 5.4×10^{-1} 8.1×10^{-5} 2.5×10^{-3}	PCE in soil; PCE and TCE in groundwater; PCE and TCE in outdoor air
Current/Future Industrial Worker	Surface Water Soil Indoor Air Outdoor Air	1.2×10^{-6} 4.8×10^{-4} 3.8×10^{-5} 1.2×10^{-3}	PCE in soil; PCE in outdoor air
Current/Future Construction Worker	Surface Water Soil Outdoor Air Sewer Water Sewer/Trench Vapors	1.6×10^{-7} 2.3×10^{-5} 1.7×10^{-4} 6.9×10^{-8} 2.8×10^{-5}	PCE in outdoor air
Note 1: Human health risks may exist when the total lifetime excess cancer risk exceeds $1.0 \times 10^{-6.}$ The USEPA considers risks greater than 1.0×10^{-4} to be unacceptable. From BVSPC, 2008.			

Table 1-2, *Continued*
Summary of Human Health Risks
Operable Unit 4, Orchard Street/Maiden Lane Subsite
New Haven, Missouri

Non-Carcinogenic Risks at OU4			
Population Scenario	**Exposure Pathway**	**Total Hazard Index**	**Contaminant(s) Driving Risk**
Current Resident	Surface Water Soil Indoor Air Outdoor Air	0.008 0.02 0.1 3	PCE in outdoor air
Future Resident	Surface Water Soil Groundwater Indoor Air Outdoor	0.008 4 900 0.1 3	PCE in soil; cis-DCE, PCE and TCE in groundwater; PCE in outdoor air
Current/Future Industrial Worker	Surface Water Soil Indoor Air Outdoor Air	0.001 0.3 0.03 0.9	None
Current/Future Construction Worker	Surface Water Soil Outdoor Air Sewer Water Sewer/Trench Vapor	0.005 0.2 10 0.001 1	PCE in outdoor air
Note 1: Human health risks may exist when the total hazard index for non-carcinogenic effects exceeds a value of 1.0. From BVSPC, 2008.			

Table 1-3
Preliminary Remediation Goals for Groundwater and Soil
Operable Unit 4, Orchard Street/Maiden Lane Subsite
New Haven, Missouri

Soil					
Analyte	Sample Dates On-site	Maximum On-site Detection ug/kg	Sample Dates Off-site	Maximum Off-site Detection ug/kg	Preliminary Remediation Goal ug/kg
PCE	11/07/2005	8,000,000	11/08/2005	6,100,000	550 *
TCE	11/07/2005 /	42,800	11/07/2004	7,700	43 *
VC	NA	NAF	NA	NAF	43 *
Groundwater					
Analyte	Sample Dates On-site	Maximum On-site Detection ug/L	Sample Dates Off-site	Maximum Off-site Detection ug/L	Preliminary Remediation Goal ug/L
PCE	9/29/2005	9,100	9/21/2003	9,100	5 ^
TCE	9/11/2007	100	NA		5 ^
cis-DCE	2/06/2006	210	NA		70 ^^
trans-DCE	9/22/2006	30	NA		100 ^^

Notes
NA = Not Applicable
NAF = Not Analyzed For
On-site results from USGS on-site screening with portable GC. Off-site results from off-site verification laboratory.
* U. S. Environmental Protection Agency Region 6 Human Health Medium- Specific Screening Levels 2008 at http://www.epa.gov/Region06/6pd/rcra_c/pd-n/screen.htm.
^ Federal MCL.
^^ Federal maximum contaminant level goal (MCLG).

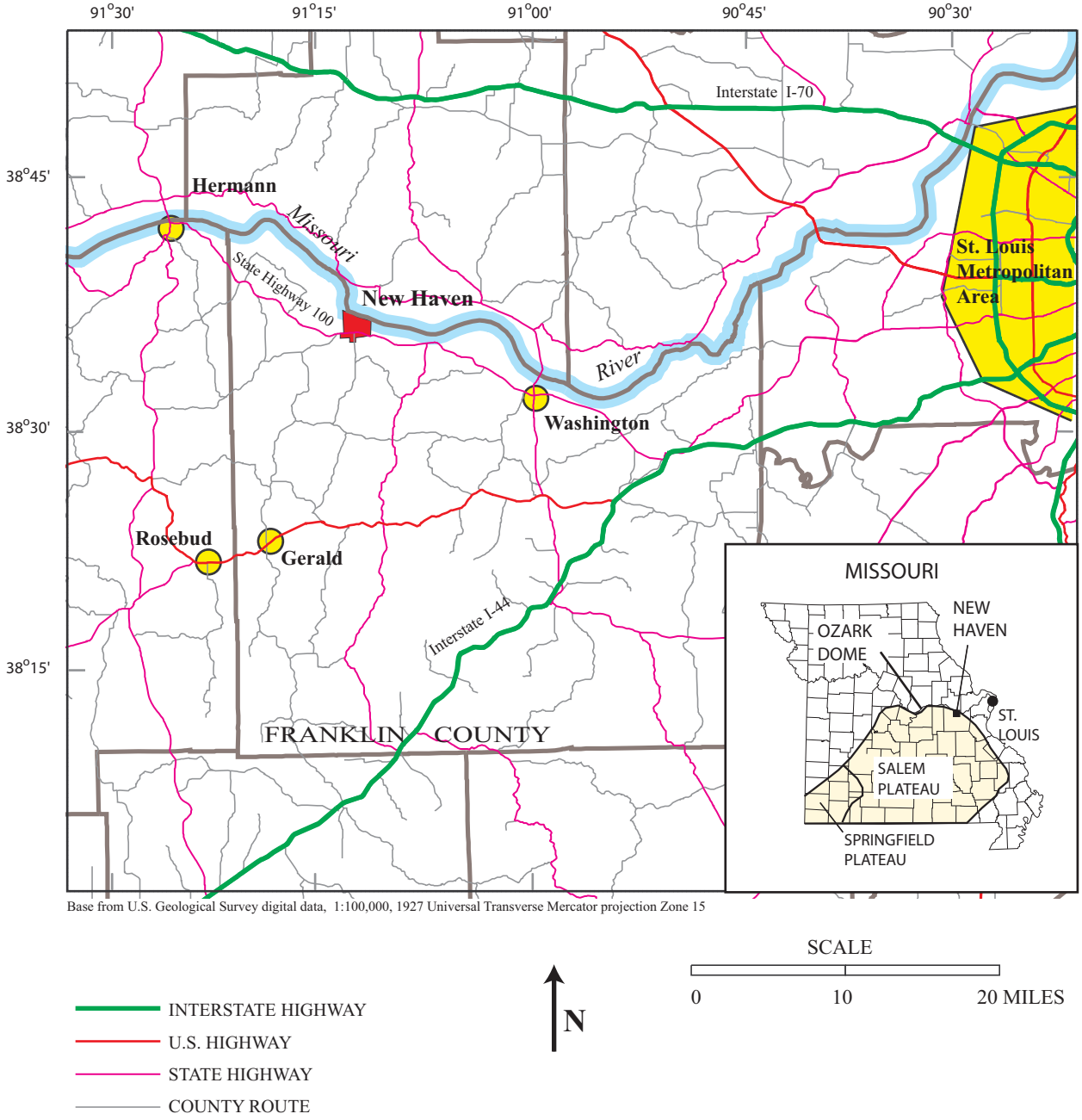
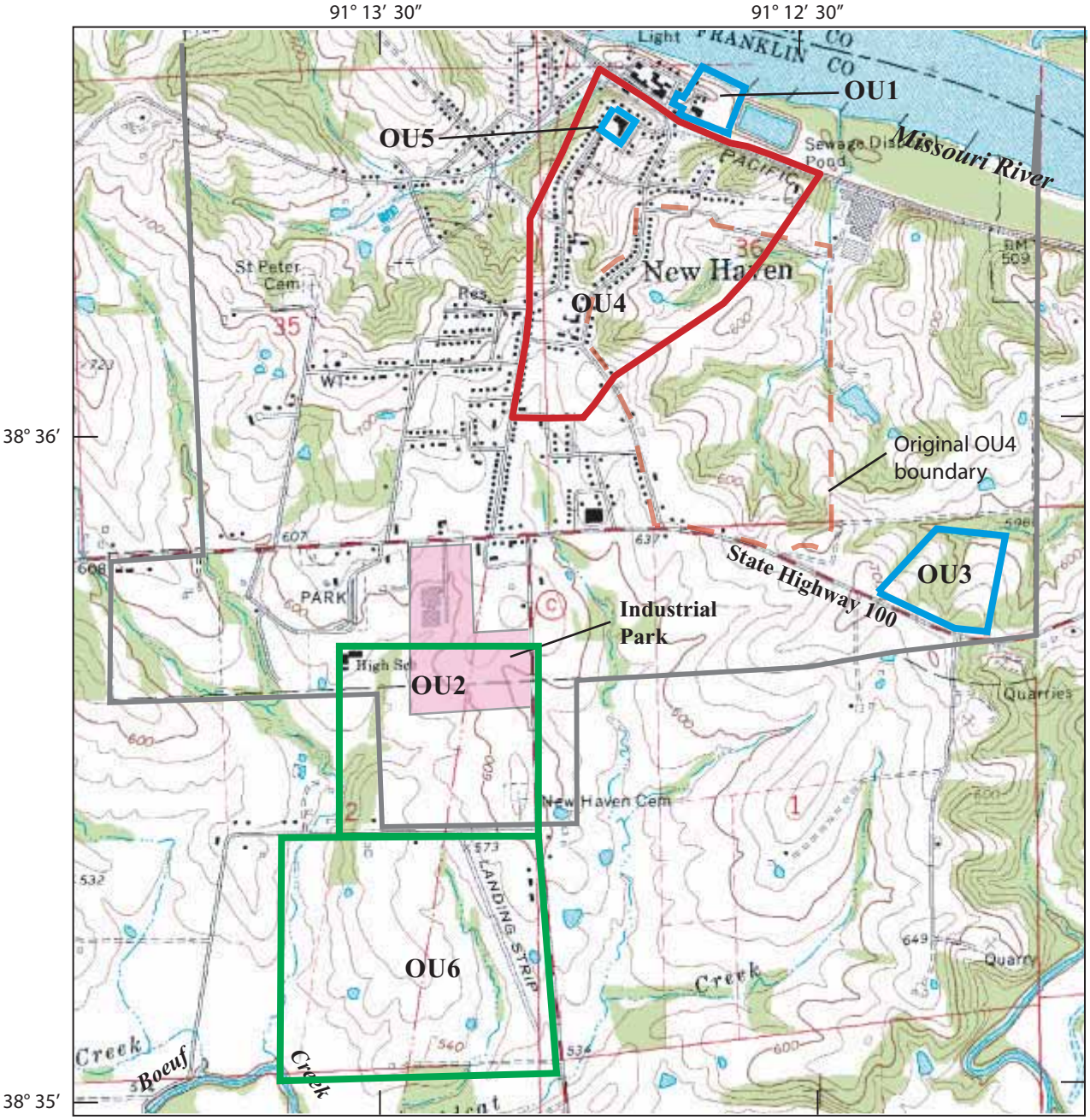


FIGURE 1-1
RIVERFRONT SITE LOCATION MAP
RIVERFRONT SUPERFUND SITE
OPERABLE UNIT 4 FS

SOURCE: USGS OU4 RI, 2008
Z:\044706\C0008320.ai 7/18/2008



Base from U.S. Geological Survey digital raster graphic, New Haven, Missouri Quadrangle, 1:24,000, 1927 Universal Transverse Mercator projection Zone 15

SCALE

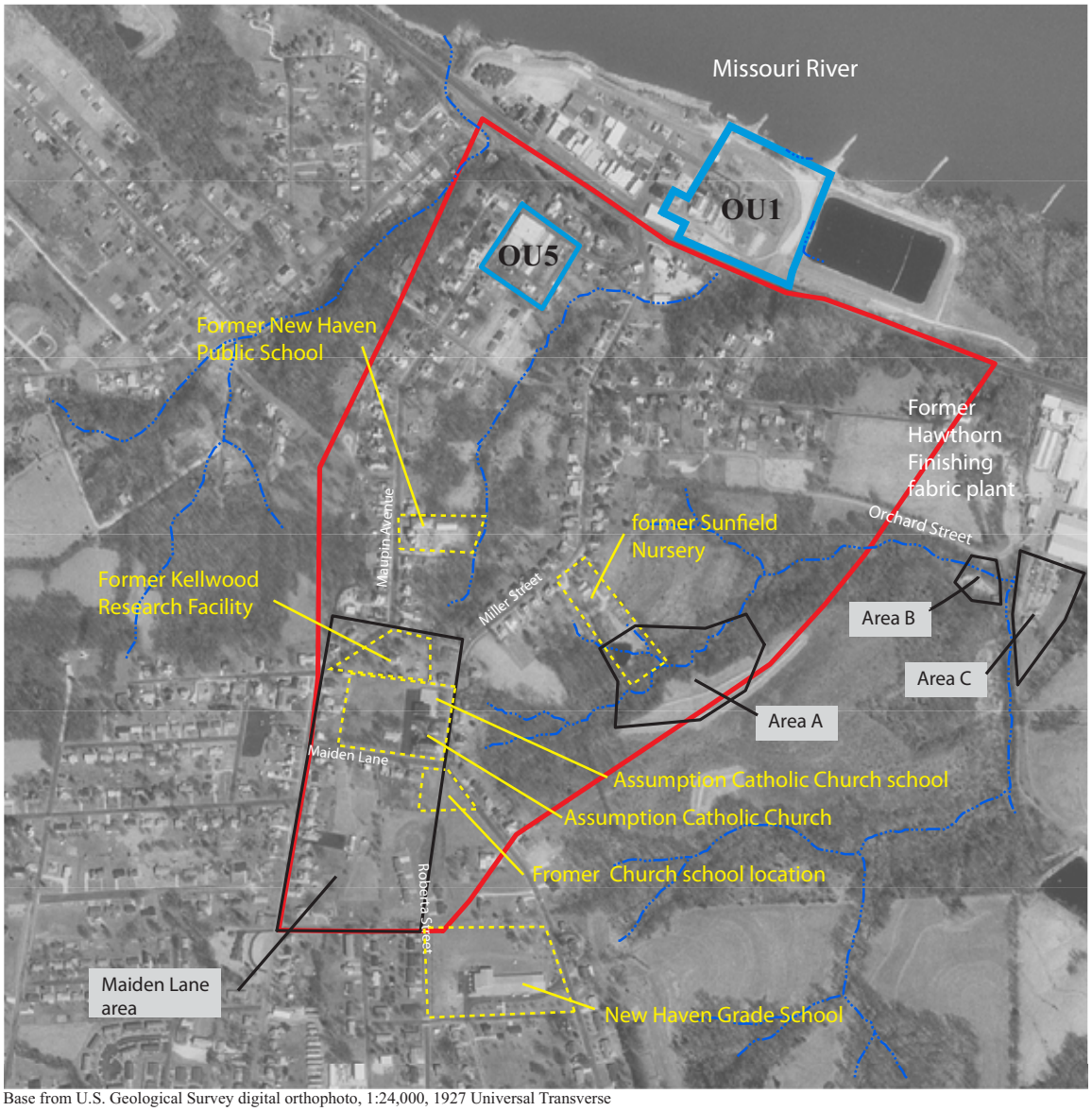
0 2,000 4,000 FEET

NEW HAVEN CITY LIMIT

OPERABLE UNIT (OU). RED INDICATES CURRENT (2008) USEPA INVESTIGATION, BLUE INDICATES USEPA INVESTIGATION COMPLETED, AND GREEN INDICATES PRP LEAD INVESTIGATION.

FIGURE 1-2
RIVERFRONT OPERABLE UNITS 1 TO 6 LOCATION MAP
RIVERFRONT SUPERFUND SITE
OPERABLE UNIT 4 FS

SOURCE: USGS OU4 RI, 2008
Z:\044706\C0008321.ai 7/18/2008



Base from U.S. Geological Survey digital orthophoto, 1:24,000, 1927 Universal Transverse Mercator projection Zone 15

OPERABLE UNIT BOUNDARY

FOCUS AREA OF OU4 INVESTIGATION

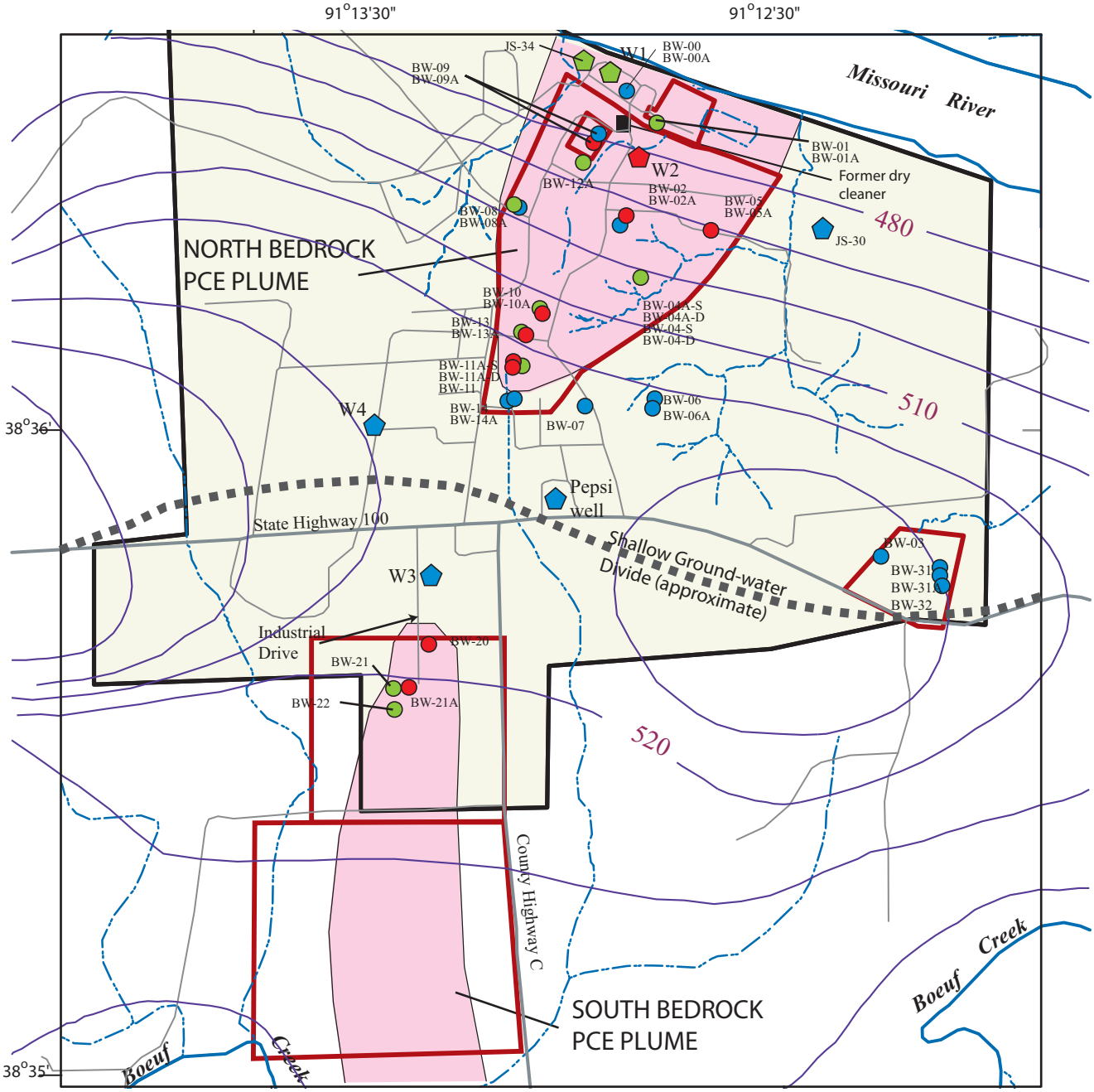
NON-RESIDENTIAL LAND-USE PARCEL IN OU4

SCALE

0 750 1,500 FEET

FIGURE 1-3
OPERABLE UNIT 4 SUBSITE DETAIL
RIVERFRONT SUPERFUND SITE
OPERABLE UNIT 4 FS

SOURCE: USGS OU4 RI, 2008
Z:\044706\C0008322.ai 7/18/2008



Base from U.S. Geological Survey digital data, 1:100,000, 1927 Universal Transverse Mercator projection Zone 15

SCALE

0 2,000 4,000 FEET

EXPLANATION

NEW HAVEN CITY LIMIT

ROAD

HIGHWAY

STREAM

MAJOR STREAM

A A′ LINE OF HYDROGEOLOGIC SECTION (fig. 1-10)

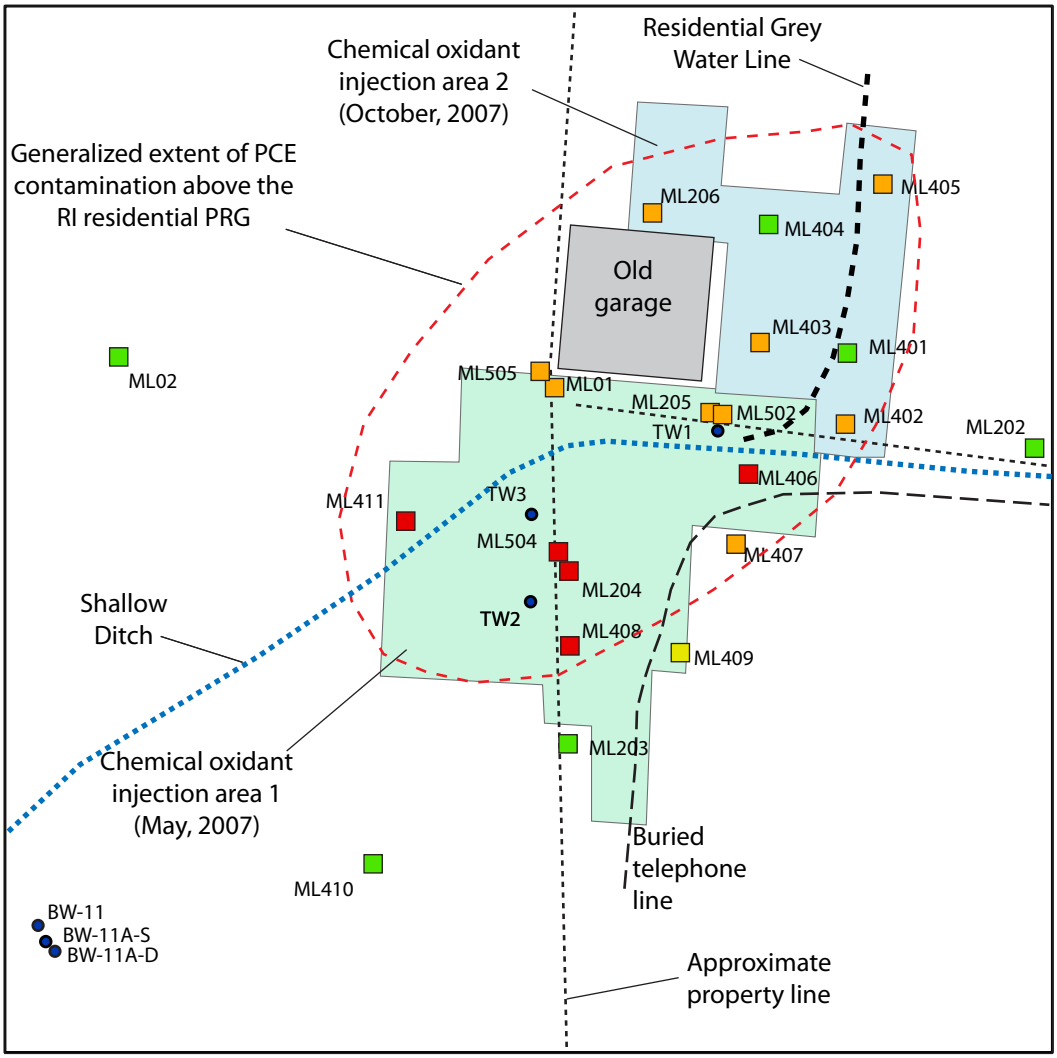
OPERABLE UNIT 4

BW-22 MONITORING WELL IN BEDROCK AND IDENTIFIER. RED INDICATES WELL SAMPLE CONTAINED MORE THAN 100 ug/L (MICROGRAMS PER LITER) TETRACHLOROETHENE (PCE). GREEN INDICATES PCE DETECTED BETWEEN 5.0 AND 100 ug/L. BLUE INDICATES PCE LESS THAN 5.0 ug/L.

W3 PUBLIC-SUPPLY OR INDUSTRIAL WELL AND IDENTIFIER. BLUE INDICATES NO PCE DETECTED, GREENE INDICATE PCE DETECTED BETWEEN 5.0 AND 100 MICROGRAMS PER LITER.

FIGURE 1-4
LOCATION OF OU4 PLUME AND MONITORING WELLS
RIVERFRONT SUPERFUND SITE
OPERABLE UNIT 4 FS

SOURCE: USGS OU4 RI, 2008
Z:\044706\C0008332.ai 7/18/2008



EXPLANATION

0 12.5 25 50 Feet

TW3 Monitoring well and number

RI PCE PRG IS 483 ug/kg

Maximum PCE concentration detected by the laboratory or portable gas-chromatograph in samples from soil boring. Concentrations in micrograms per kilogram (ug/kg) kilogram

- Less than 1
- 1.0 to 239.9
- 240 to 479.9
- 480 to 479,999
- 480,000 to 8,000,000

FIGURE 1-5
SUMMARY OF OU4 MAXIMUM PCE CONCENTRATIONS IN SOIL SAMPLES
RIVERFRONT SUPERFUND SITE
OPERABLE UNIT 4 FS

SOURCE: USGS OU4 RI, 2008
Z:\044706\C0008333.ai 8/6/2008

2.0 Identification and Screening of Technologies

Results of the RI investigative efforts and the HHRA at OU4 indicate that contaminants are present at OU4 in the groundwater and soil at concentrations that pose potential risks to human health and the environment. This section presents the remedial action objectives (RAOs), general response actions (GRAs), remedial technologies, and process options for remediation of OU4.

The first step in the remedial process is to establish the RAOs. An RAO is an OU-specific goal for protecting human health and the environment. RAOs are based on the nature and extent of contamination identified at each OU. Next, ARARs are reviewed to determine which may apply to the remediation of OU4. GRAs are then selected to satisfy the RAOs at OU4. Each GRA consists of specific remedial technologies and process options. These remedial technologies and process options are screened by evaluating their applicability to the nature and extent of the contamination and the physical characteristics of the OU. Finally, the technologies and process options are screened according to their effectiveness, implementability, and cost. The technologies and process options that survive the screening process are retained for assembly into the remedial action (RA) alternatives. These alternatives are described in Section 3.0 and evaluated in Section 4.0.

2.1 Remedial Action Objectives

CERCLA, as amended by Section 121(b) of SARA, requires selection of remedial actions that: attain a degree of cleanup that ensures protection of human health and the environment; are cost effective; and use permanent solutions and alternative treatment technologies or resource recovery technologies to the maximum extent practicable.

To satisfy CERCLA requirements, RAOs were developed for OU4 of the New Haven Site. RAOs will be used to develop GRAs for the operable units. The RAOs developed for OU4 groundwater and soil are discussed below and are presented in Tables 2-1 and 2-2, respectively. All the tables discussed in this section are located at the end of this section. Tables 2-1 and 2-2 also include a preliminary list of GRAs and remedial technology types for groundwater and soils, respectively. The specific technologies within the technology types are evaluated in Sections 2.4 through 2.7.

The following RAOs were developed for OU4 groundwater:

- For protection of human health, prevent exposure to groundwater with contaminant levels greater than MCLs or maximum contaminant level goals (MCLGs).
- For protection of the environment, minimize further degradation of the local groundwater by the containment plume.

The following RAOs were developed for the OU4 soils:

- For protection of human health, prevent exposure to soil with contaminant concentrations which result in an excess cancer risk of greater than 1×10^{-6}, or a Hazard Quotient greater than 1.0, whichever is less.
- For protection of the environment, reduce the soil contaminant levels, or prevent migration of soil contaminants, to provide protection of the groundwater.

Current regulatory drinking water standards include:

- MCLs, which are the maximum permissible levels established by the Safe Drinking Water Act (40 Code of Federal Regulations [CFR] Part 141) for contaminants in water that is delivered to any user of a public water system. MCLs are discussed further in Section 2.2.1.1.

2.2 CERCLA Compliance with ARARs

Section 121(d) of CERCLA, as amended, requires that remedial actions comply with ARARs. ARARs include the requirements of federal environmental laws and promulgated state environmental laws that are more stringent than the equivalent federal law. Applicable requirements include federal or state cleanup standards, standards of control, and other substantive requirements, criteria, or limitations that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at OU4. Relevant and appropriate requirements include federal and state cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations that, while not applicable, address problems or situations sufficiently similar to those at OU4 that their use is well suited (USEPA, 1987). USEPA's Interim Guidance on Compliance with Applicable or Relevant and Appropriate Requirements (USEPA, 1987) and CERCLA Compliance with Other Laws Manual Part II (USEPA, 1989b) establish how requirements of federal and state laws are generally identified and applied to remedial actions at CERCLA sites. ARARs are determined by

applying a two-tiered test. First, a determination is made as to whether the requirement is applicable. If the requirement is not applicable, a determination is made as to whether the requirement is relevant and appropriate. The interim guidance defines "applicable" and "relevant and appropriate" as follows:

- Applicable requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under Federal or State law that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA subsite (USEPA, 1987).
- Relevant and appropriate requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under Federal or State law that, while not "applicable" to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA subsite, address problems or situations sufficiently similar to those encountered at the CERCLA subsite that their use is well suited to the particular subsite (USEPA, 1987).

There are three types of ARARs: chemical-specific, location-specific, and action-specific. Chemical-specific ARARs establish health or risk-based contaminant concentration limits for various media. Chemical-specific ARARs may set cleanup levels for specific chemicals or discharge limits. Action-specific ARARs establish controls or restrictions on the remedial activities that are part of the remedial activity. Action-specific ARARs are triggered by the specific remedial activity rather than the contaminants present. Location-specific ARARs set limitations on remedial activities as a result of the subsite's location or characteristics.

The following subsections present the ARARs identified for OU4. These determinations are based on the RI and MDNR's letter identifying State ARARs for the Riverfront Site (MDNR, 2002).

In addition, USEPA guidance documents also identify non-promulgated advisories or guidance documents issued by federal or state governments as "to-be-considered" materials (TBCs) for OU4. TBCs are not considered legally enforceable and, therefore, are not considered to be applicable or relevant and appropriate for OU4, but are evaluated along with ARARs as part of the risk assessment to set protective cleanup level targets. TBCs should be used in the absence of ARARs, when ARARs are not sufficiently protective to develop cleanup goals, or when multiple contaminants may be posing a cumulative risk (USEPA, 1987).

2.2.1 Chemical-Specific ARARs

Chemical-specific ARARs set contaminant treatment levels that are considered protective of human health and the environment. The levels are media specific. Chemical-specific ARARs may also set acceptable levels for the contaminants in discharged media if discharge occurs as part of a remedial activity. A state requirement is an ARAR only if it is more stringent than the corresponding federal requirement.

The COCs in OU4 are discussed in Section 1.4. The indicator COC is PCE. Table 2-3 lists potential chemical-specific ARARs and their applicability or relevance and appropriateness to OU4. The numerical values in the chemical-specific ARARs for the contaminants in OU4 are listed in Table 2-4. The requirements that may be ARARs are discussed below.

If necessary, EPA may waive attainment of ARARs. CERCLA (in section 121(d)(4)) specifies six reasons for waiving ARARs, including technical impracticability from an engineering perspective (a TI waiver). TI waivers usually apply to ARARs that set cleanup standards or levels. These standards are usually chemical-specific ARARs, especially Federal MCLs or State groundwater quality critera.

2.2.1.1 Federal Maximum Contaminant Levels

Federal MCLs have been adopted as enforceable standards for public drinking water systems. MCLs are based on the allowable lifetime exposure for a 70 kg adult who is assumed to consume 2 liters of water per day. MCLs take into account the technical and economic feasibility of removing the contaminant from the water and must be set as close as possible to the Maximum Contaminant Level Goal (MCLG), given the best available technology and treatment techniques. MCLGs are discussed in Section 2.2.1.2. The primary jurisdictional requirement to determine applicability is that MCLs apply to public water systems having at least 15 service connections or serving at least 25 persons.

MCLs would be applicable to water delivered to customers of a public drinking water system. Promulgated Federal MCLs are relevant and appropriate to groundwater that is a current or potential drinking water source (see 40 Code of Federal Regulations [CFR] 300.430(e)(2)(i)(C)) which requires that the MCL "shall be attained" where it is relevant and appropriate).

2.2.1.2 Federal Maximum Contaminant Level Goals

The Federal MCLGs are non-enforceable health goals for public water systems. MCLGs are set at levels that should result in no known or anticipated adverse health effects and that provide an adequate margin of safety. MCLGs for substances considered to be probable human carcinogens are set at zero. MCLGs for other substances are based upon chronic toxicity and are often set at levels equivalent to the MCLs.

MCLGs are relevant and appropriate for the subsite if the MCLG is greater than zero, or if the USEPA determines a level more stringent than the MCL is appropriate [see 40 CFR 300.430(e)(2)(i)(B)].

2.2.1.3 National Pollutant Discharge Elimination System (NPDES) Standards

The NPDES standards determine the maximum concentrations of contaminants that can be discharged from a point source (such as a treatment plant's effluent pipe) to the "waters of the United States". These standards are applicable to any remedial alternatives that discharge treated groundwater to surface waters.

2.2.1.4 National Pretreatment Standards

The national pretreatment standards determine the maximum concentrations of contaminants that can be discharged from a point source (such as a treatment plant's effluent pipe) to a publicly owned treatment works (POTW). These standards are applicable to any remedial alternatives that discharge treated groundwater to a POTW.

2.2.1.5 Missouri Waste Characterization Requirements

This requirement, which appears in 10 Code of State Regulations (CSR) 25-3.260(1)(H), provides that the wastes at OU4 must be characterized to determine if they meet the definition of hazardous waste found in that regulation.

2.2.1.6 Missouri Identification and Listing of Hazardous Waste Requirements

This requirement defines those solid wastes which are subject to regulations as hazardous wastes under 10 CSR 25. This requirement appears in 10 CSR 25-4.261.

2.2.2 Action-Specific ARARs

Action-specific requirements control or restrict the activities that are selected to accomplish the remedy, not a specific contaminant. Action-specific ARARs may establish performance levels, actions, or technologies as well as specific levels for discharged or residual contaminants. Table 2-5 presents the potential action-specific ARARs for OU4. The action-specific ARARs for each alternative will vary depending on the technologies employed by the alternative. The actual requirements for each alternative are determined during the FS process for OU4 and are presented in Section 4.0. A discussion of when the ARAR would be applicable or relevant and appropriate is included in Table 2-4.

2.2.3 Location-Specific ARARs

Location-specific ARARs set restrictions on contaminant concentrations or on remedial activities because the contaminants or activities are in, or affect, specific locations, such as wetlands, flood plains, historical places, or sensitive habitats. Table 2-6 presents the potential location-specific ARARs for OU4 and a discussion of when the ARAR would be applicable or relevant and appropriate. The applicability or relevancy and appropriateness of the location-specific ARARs for each alternative will be evaluated in Section 4.0.

2.3 Delineation of Areas and Volumes of Contaminated Media and Contaminant Travel Velocities

These subsections delineate the areas and volumes of contaminated soil and groundwater at OU4. The delineation is based on information obtained during the RI (USGS, 2008).

2.3.1 Area and Volume of Contaminated Soil

The USEPA has already conducted two rounds of in-situ soil treatment (see Section 1.4.7) but has not yet conducted confirmatory sampling to determine the post-treatment contaminant levels. The soil treatments were designed to treat the contaminant levels found in the RI soil sampling and the PSOD so it is likely that much of the existing soil contamination has been remediated. Therefore, when generating the soil treatment alternatives for this FS, it has been assumed that the soils will only require additional treatment to remediate any remaining hot spots. The containment and soil treatment alternatives (see Section 3) will conduct soil sampling to confirm the effectiveness of the soil treatments.

While generating the active soil remediation and containment alternatives for this FS it has been conservatively assumed that the soil volume that will require treatment in the remediation alternatives is the same as the contaminated soil volume calculated in the RI. This assumption was made because confirmatory soil sampling has not yet been conducted. As discussed above, the actual contaminated soil volume (if any) should be less, due to remediation from the in-situ soil treatments. For the active soil remediation and containment alternatives, confirmatory soil sampling would be conducted during the Remedial Design (RD) phase for the alternatives. These soil sampling results would be used to design the soil treatment or containment portions of the remedial action.

In addition, the RI estimated the volume of contaminated soil using a PRG of 483 ug/kg PCE. The HHRA used the USEPA Region VI Medium-Specific Screening Level of 550 ug/kg PCE to calculate the risks from the soils and this slightly higher cleanup level is identified as the soil PRG for this FS. It is not expected that the slightly higher FS soil PRG will substantially change the volumes of contaminated soil identified in the RI. Therefore, the RI soil volume estimates were used when generating the active soil remediation and containment alternatives for this FS.

The RI found that most of the contamination (99 percent by mass) was deeper than 10 ft bgs. For the in-situ treatment technology, it may be possible to only treat the soils deeper than 10 ft bgs. In general, however, the alternative in Section 3 that provides for in-situ soil remediation assumes that the entire volume of contaminated soil will be treated (from the ground surface to the top of bedrock). The RI found that the surface soils (0-2 ft bgs) contained essentially no contamination and the soils from 2 to 10 ft bgs contained approximately 3 kg of PCE in more than 1,100 cubic yards of soil. When the removal action in-situ soil treatments were conducted, they treated the heavily contaminated deep soils. The contaminant levels in the upper 10 feet of soil may have been treated as the treatment solution flooded the soils. Therefore, given that the very low contaminant levels in the upper 10 feet of the soil may have been treated, it is not necessary to place institutional controls on the soils until soil sampling has been conducted and the results evaluated. It is reasonable to assume that even deep work, such as placing footings or laying a utility line, will be done in the upper 10 feet of the soil, which was not significantly contaminated even before 2007 treatments.

For the active soil remediation and containment alternatives, the RI estimated that the volume of soil contaminated above the RI's PRG was approximately 2,300 yd^3 (see Figure 2-1). The RI calculated the contaminated soil volume by dividing the soil into five layers, from 0 to 1.9 feet, 2 to 5.9 feet, 6 to 9.9 feet, 10 to 14.9 feet, and 15 to 19 feet, and estimating the volume of soil contaminated above the PRG in each layer. The bottom layer is the soil-bedrock interface and is quite irregular. The RI assumed that this

layer actually averaged about 1.5 feet thick, instead of 4 feet. The area of each of the layers is different, with the deeper layers being larger than the shallower layers. The actual volume that must be contained is the area of the largest contaminated depth times the total contaminated depth. By containing the area of the largest layer, all the contaiminated soil above the cleanup goals will be inside the containment. The volume that must be contained is approximately 3,700 yd^3. The surface area to be contained is approximately 600 yd^2.

For any above-ground treatment or removal alternatives, the volume of soil that must be excavated is larger than the volume that must be contained or treated in-situ, because the excavation's slopes must be cut back to reach the deeper contaminated soils. The RI found that the largest contaminated volume was between 10 and 14.9 feet bgs. Assuming that the amount of soil that must be removed for each of the layers used in the RI volume calculations is 25% greater than the one below, and using the 10 to 14.9 foot layer as the base, the volume that needs to be excavated is approximately 6,200 yd^3. This volume includes approximately 500 yd^3 from the heavily contaminated 15 to 19 foot layer, which is approximately double the RI volume estimated for this layer. The additional volume from the deepest layer was assumed to be weathered rock that could be excavated with standard soil excavation equipment (no rock teeth or other special equipment needed). The upper soils (from 0 to 15 feet) are much less contaminated than the deep layer. Therefore, the FS alternatives assumed that only about one third (2.000 yd^3) of the excavated volume would require treatment or disposal. The non-contaminated soils (approximately 4,200 yd^3) could be used as backfill for the remediated excavation.

2.3.2 Area and Volume of Contaminated Groundwater

The RI estimated that the area of the contaminated plume with detectable PCE levels was approximately 164 acres (7.1 million square feet) and the area of the plume above the PCE MCL of 5 ug/L was approximately 82 acres (3.6 million square feet) (see Figure 2-2). The RI calculated the contaminated groundwater volume by separating the plume into three sections. Zone A is directly below the source area soils and was estimated to be 100 feet thick. Zone B was the contaminated bedrock in the Maiden Lane area and was estimated to be 10 feet thick. Zone C was the remaining portion of the plume from Maiden Lane to the Missouri River and was estimated to be 25 feet thick. The groundwater volume in the three zones is approximately 120 million gallons (16,000,000 cubic feet). This volume of contaminated groundwater is contained within approximately 160 million cubic feet of bedrock. Most of the contamination is traveling within higher permeability zones such as the sandstone layers, chert beds, or along bedding planes and fractures.

2.4 General Response Actions

2.4.1 General Response Actions for Groundwater

GRAs have been identified for the groundwater contamination at OU4 of the Riverfront Site. The GRAs for groundwater include:

- No action
- Institutional controls
- Natural attenuation
- Containment
- Removal
- Treatment
- Disposal

Under the no action response, the subsite would be left "as is," and no provisions would be made for groundwater monitoring, control, or remediation of the aquifer. Institutional controls would involve the implementation of legal, administrative, and/or informational devices to minimize public and environmental contact with the groundwater contaminants. Natural attenuation involves the remediation of the contaminant plume by natural means. Containment involves physically restricting groundwater contaminant mobility. Removal involves the direct physical removal of the contaminated groundwater. Treatment involves on-site and off-site measures to render the contaminated groundwater less hazardous. Disposal involves measures to relocate treated groundwater and treatment residue in a manner that will reduce their interaction with the public and the environment.

Remedial technologies and process options have been identified for each GRA. Remedial technologies refer to general categories of technology types, and process options refer to specific processes within each technology type.

Table 2-1 lists the RAOs, GRAs, and the remedial technology types for the groundwater remediation at OU4. Technical experience and a variety of technical sources, including USEPA documents and professional journals, were used to identify the technologies.

2.4.2 General Response Actions for Soil

GRAs have been identified for the soil contamination at OU4 of the Riverfront Site. The GRAs for soil include:

- No action
- Institutional controls
- Natural attenuation
- Containment
- Removal
- Treatment
- Disposal

Under the no action response, the subsite would be left "as is," and no provisions would be made for soil monitoring, control, or remediation of the aquifer. Institutional controls involve the implementation of legal, administrative, and/or informational devices to minimize public and environmental contact with the soil contaminants. Natural attenuation involves the remediation of the soil contamination by natural means. Containment involves physically restricting the mobility of the soil contaminants to minimize migration to uncontaminated soils or to the groundwater. Removal involves the direct physical removal of the contaminated soils. Treatment involves on-site and off-site measures to render the contaminated soil less hazardous. Disposal involves measures to relocate treated soils and treatment residue in a manner that will reduce their interaction with the public and the environment.

Remedial technologies and process options have been identified for each GRA. Remedial technologies refer to general categories of technology types, and process options refer to specific processes within each technology type.

Table 2-2 lists the RAOs, GRAs, and the remedial technology types for the soil remediation at OU4. Technical experience and a variety of technical sources, including USEPA documents and professional journals, were used to identify the technologies.

2.5 Initial Screening of Technologies and Process Options for Groundwater and Soil

The remedial technologies and process options identified were first screened on the basis of technical implementability. The technologies and process options for groundwater were screened in Table 2-7, while the technologies and process options for soil were screened in Table 2-8. These initial screenings eliminate technologies that are clearly ineffective or unworkable on the basis of the subsite and contaminant

characteristics. Table 2-7 summarizes the initial technology screening for the remediation of groundwater at the subsite and Table 2-8 summarizes the initial screening for soil remediation. These tables present the general response actions, remedial technologies, process options, descriptions of each process option, and screening comments. A brief description of each process option is included in the tables to facilitate understanding of each option and to assist in evaluating its technical implementability. The screening comments address the technical feasibility and ability of the process option to serve its intended purpose. The screening comments include a statement of whether the process option is retained or rejected. Retained process options are further evaluated in Section 2.6 on the basis of effectiveness, implementability, and cost.

2.6 Further Evaluation of Process Options for Groundwater and Soil

The process options for groundwater and soil that were retained during the initial screening (Section 2.5) were evaluated in greater detail for effectiveness, implementability, and cost. Process options were evaluated on their effectiveness relative to other options within the same technology type. The evaluation focused on three main points:

- The potential effectiveness of the process options in handling the estimated volume of contaminated groundwater and meeting the goals identified in the general response actions.
- The effectiveness of the process options in protecting human health and the environment during the construction and implementation phases.
- The reliability and certainty of process options with respect to the contaminants and conditions at OU4.

The implementability of a process option encompasses both the technical and institutional feasibility of implementing a process. Because technical feasibility of the process options was considered during the initial screening, the primary emphasis during this more detailed evaluation was institutional feasibility. Institutional feasibility includes consideration of the ability to obtain the necessary permits for off-site actions; the availability of treatment, storage, or disposal facilities; and the availability of the necessary equipment and workers.

The cost evaluation included a qualitative estimation of the capital and operation and maintenance (O&M) costs associated with the process options. Because more detailed cost estimates will be included in the screening and detailed evaluation of alternatives, costs are not greatly emphasized at this point. The greatest costs during

subsite remediation are usually associated with the degree to which the different technology types are used, not the specific process options.

The results of the process options evaluations are summarized on Tables 2-9 and 2-10, for groundwater and soil, respectively.

2.7 Retained Technologies and Process Options for Groundwater

The GRAs, remedial technologies, and process options that were retained for the groundwater and soil in Section 2.6 are listed in Tables 2-11 and 2-12, respectively, and are further described in this subsection. These GRAs, technologies, and process options represent a pool from which remedial alternatives will be developed in Section 3.0. The rejected process options have been eliminated from consideration and further discussion. The process options that were not retained fall into three groups: process options that have been eliminated from further consideration and discussion; process options that were rejected but should be re-evaluated during the remedial design phase; and process options that would be used to support other process options. Process options that were rejected but should be re-evaluated have the statement "should be evaluated during remedial design. Not retained as a representative process option" in the screening column of Table 2-10. Process options that were not retained but would be used to support a retained process option have the statement "Would be used …. Not retained as a primary process option" in the screening column of Table 2-10.

2.7.1 Groundwater Technologies and Process Options

The GRAs, remedial technologies, and process options that were retained for the groundwater are described in this subsection.

2.7.1.1 No Action

A no action alternative is required for consideration in accordance with the NCP. This option will serve as a baseline against which the other technologies can be compared. Under this alternative, no additional groundwater use restrictions would be implemented, and treatment of contaminated groundwater would not be performed. This option would not provide any protection to the public or the environment and would be the least protective of all actions. The no action alternative usually requires no capital expenditures; however, this alternative would have periodic O&M costs associated with

the 5-year regulatory reviews that would be required in accordance with CERCLA and costs for closing the existing groundwater monitoring wells.

2.7.1.2 Institutional Controls

This subsection discusses institutional controls such as well construction standards and public education.

2.7.1.2.1 Well Construction Restrictions

Pursuant to the Missouri Water Well Drillers' Act (sections 256.600 – 256.940 RSMo), an area encompassing OU4 has been designated as "Special Area 3". Strict well construction standards have been imposed by the State of Missouri on the construction or extension of wells in that area. These standards, found at 10 CSR Division 23, Chapter 3, create enforceable, stringent standards throughout OU4, and provide a reliable and durable control on groundwater exposures. These well construction standards would be effective in protecting human health if properly enforced. These well construction standards would have low capital costs because the Special Area 3 regulations have already been promulgated.

2.7.1.2.2 Public Education/ Information

Public education and informational devices, such as notices to residents, can be used effectively to protect public health. Key components include informing the public about the potential risks associated with using the contaminated groundwater and discouraging the use of it for drinking or bathing.

2.7.1.3 Groundwater Monitoring

This subsection discusses periodic groundwater monitoring.

This technology would involve continued periodic monitoring of the groundwater to detect changes in the migration of contaminants and to assess the effectiveness of any RAs. This technology would not treat or reduce the contamination at OU4. Monitoring wells would be added to the existing monitoring well network to provide additional definition of the contaminant plume. In addition, a sampling and chemical analysis program would be implemented. Additional wells could be installed using conventional techniques. Because OU4 is very steep and rugged terrain and is also completely developed as a residential area, installation of additional monitoring well will be more

difficult than at many locations. Costs for installing monitoring wells are relatively low and are typically a small portion of the total cost of any alternative. The capital costs would depend on the depth and number of new wells required. The O&M costs would depend on the frequency and magnitude of sampling. Groundwater sampling is a proven technology for monitoring groundwater contamination.

2.7.1.4 Containment

Containment technologies would control the migration of contaminated groundwater from within OU4. Two containment technologies were retained: hydraulic controls using vertical wells and hydraulic controls using angle drilled wells.

2.7.1.4.1 Hydraulic Containment, Vertical and Angled-Drilled Wells

Hydraulic controls consist of installing one or more extraction wells. The extraction well creates a cone of depression in the water table which alters the water table's hydraulic gradient to control contaminant migration. The extraction wells would be strategically located within the OU4 plume to prevent further migration of the plume at the source area. Hydraulic controls are used in conjunction with treatment and disposal response actions; however, groundwater would only be removed at a rate to control further migration of the plume.

The location, size, spacing, and pumping capacity of the containment well or wells would be determined by hydrogeological analysis. Usually, the wells installed are vertical wells. However, given the steep topography of OU4 and that the area above the plume is fully developed for residential uses, it may be necessary to drill angled wells to be able to place some wells in the correct location for containment.

Typically, submersible electric or pneumatic pumps are used to withdraw water from the wells. Piping would connect the well pump to a central location for treatment or disposal. If necessary, multiple, smaller treatment or disposal locations might be used. Extraction wells are easy to install, are effective in containing groundwater plumes, and are low in capital and maintenance costs.

2.7.1.5 Treatment

One process option was retained for treatment of groundwater. The technology, granular activated carbon (GAC) adsorption, involves the physical ex-situ treatment of contaminated groundwater. A discussion of this treatment process is included in the following subsection.

If above-ground, ex-situ treatment of the groundwater is selected, the following technologies should be further evaluated during the remedial design phase:

- Air Stripping with tray aeration;
- Air Stripping with packed columns;
- Ion Exchange;
- Chemical Oxidation, and;
- Ultraviolet/Chemical Oxidation.

2.7.1.5.1 GAC Adsorption

This process option involves the passage of groundwater through a treatment system that contains canisters of GAC. Activated carbon has a large volume of very small pores (micropores), which create a large surface area in each grain of carbon. Groundwater contaminants adsorb to the GAC, leaving contaminant-free groundwater to proceed through to the discharge of the process system. The adsorption of VOCs occurs in the micropores of the carbon, and the macropores act as a conduit for groundwater movement.

GAC adsorption is an effective and proven technology for the removal of VOCs from groundwater. The adsorption capacity of the carbon is finite, so the GAC canisters must be changed-out when the carbon is "spent". Therefore, there are O&M costs associated with this treatment process.

2.7.1.6 Disposal

Disposal of groundwater will be necessary if ex-situ treatment of the groundwater is conducted. The two remedial technologies retained are on-and off-site, treated effluent disposal.

Treated groundwater from OU4 would be piped to the Missouri River for discharge. The discharge point may either be within OU4 (on-site discharge) or outside OU4 (off-site discharge).

The substantive requirements of an NPDES permit would have to be met for on-site discharge, and it would be necessary to meet NPDES limitations on discharge flow rate, daily maximum concentrations of contaminants, and maximum average concentrations of contaminants.

An NPDES permit would be required for off-site discharge, and it would be necessary to meet NPDES limitations on discharge flow rate, daily maximum concentrations of contaminants, and maximum average concentrations of contaminants.

For either type of discharge, monitoring by sampling and analysis of the discharge water would be performed.

2.7.2 Soils Technologies and Process Options

The remedial technologies and process options that were retained for soil are further described in this subsection.

2.7.2.1 No Action

A no action alternative is required for consideration in accordance with the NCP. This option would serve as a baseline against which other technologies can be compared. This option would not provide any protection to the public or environment and would be the least protective of all actions. Under this alternative, activity and use limitations would not be implemented, excavation and/or treatment of contaminated soil would not be performed, and the soil would not be monitored. This option would not provide any protection to the public or environment and would be the least protective of all actions. The no-action alternative does not require any capital expenditures. However, five-year regulatory reviews would be required in accordance with CERCLA, so the alternative does have some periodic costs.

2.7.2.2 Institutional Controls

This subsection discusses institutional controls. Public education and informational devices were the only process options retained from this GRA group. Fencing was not retained as a primary treatment option but could be used to support some primary soil process options, such as excavation.

Public education and informational devices can be used effectively to protect public health. Key components include informing the public about the potential risks associated with very deep (10+ ft bgs) soil excavations, which might result in workers encountering soils that are still contaminated despite the removal action soil treatments. After the soil confirmation sampling results are evaluated, it may be possible to discontinue public education/information about the soil contamination, assuming that the results show that, as expected, the soils have been treated to less than the PRGs.

2.7.2.3 Containment

Capping, sheet piling, and rock grouting, were the only remedial technologies retained for the containment GRA. Due to its high effectiveness, multi-layer capping was the favored process option for horizontal containment. Native soil caps, revegetation/stone covers, and drainage controls were not retained as primary treatment options but would be used to support some primary soil process options, such as excavation. Sheet piling and rock grouting were retained as primary vertical containment options.

2.7.2.3.1 Capping

Multi-layer capping involves the covering of the contaminated soils with an impermeable liner, a drainage layer and a native soil layer. These layers work together to prevent surface water migration into the contaminated soils and to prevent contact with the contaminated soils. The multi-layer cap would be several feet thick. A multi-layer cap would need to be maintained, since the native soil layer can become overgrown with weeds, which will decrease the effectiveness of the cap's surface drainage, or trees, whose roots can clog the drainage layer or pierce the impermeable barrier, and the drainage layer can become clogged. Also, a multi-layer cap would require the imposition of activity and use limitations on future use of the land at OU4, which might cause public acceptance issues.

2.7.2.3.2 Sheet Piling

Due to its cost, effectiveness and the ability to be installed with less disruption than other vertical containment technologies, sheet piling was the favored process option for vertical containment of the soils. Sheet piling involves driving metal sheets down from ground level to the bedrock below the contaminated soils. The metal sheets have interlocking edges and create a wall or box around the contaminated soils to prevent groundwater migration through the contaminated soils. The sheet pile enclosure usually has a groundwater extraction well inside to lower the groundwater head within the box. The lower head in the containment enclosure ensures that the direction of groundwater flow is into the enclosure, thereby preventing the flow of contaminated groundwater out of the enclosure.

2.7.2.3.3 Rock Grouting

Because the contamination may extend into the shallow bedrock below the source area soils, rock grouting was selected to complete the containment of the shallow contaminants. Due to its effectiveness in bedrock, rock grouting was the favored process option for vertical containment of the contamination in the shallow bedrock. Rock grouting involves installing injection wells in the bedrock below the contaminated soils. Grout is injected into the bedrock and fills the solution voids, faults, vugs, and channels in the rock. The volume of grout needed at each well depends on the number and size of the channels the well has intersected. After the grout sets, the permeability of the bedrock would be reduced and the available paths for contaminant migration would be minimized.

2.7.2.4 Treatment

One remedial technology, in-situ chemical oxidation was retained for soil remediation at OU4.

If above-ground treatment of the soil is selected, the following technologies should be further evaluated during the remedial design phase:

- Solvent Extraction;
- Soil Venting;
- Soil Washing;
- Thermal Desorption, and;
- Bioslurry Reactors.

In addition, mechanical excavation will have to be conducted to remove the soils for the above-ground treatments. The above-ground treatment technologies may be necessary if the soil contamination proves to be recalcitrant to in-situ chemical oxidation treatment or if DNAPL is detected in the deep soils.

If in-situ treatment of the soil is selected, the following technology should be further evaluated during the remedial design phase:

- Thermally Enhanced Soil Vapor Extraction

The thermally enhanced soil vapor extraction technology may be necessary if the soil sampling and DNAPL investigations find that there is DNAPL and that it is located in the shallow bedrock at depths that can not be excavated.

2.7.2.4.1 In-situ Chemical Oxidation

In-situ chemical oxidation is a proven technology for remediating VOCs in soils. In-situ chemical oxidation uses shallow, vadose zone wells to allow the injection of a solution of water and a chemical oxidant into the soils. The oxidant can be hydrogen peroxide, potassium permanganate, or others. As the solution permeates the soils, the VOC contaminants are destroyed by the oxidant. Vertical or horizontal wells may be installed and variable screen lengths may be used to provide a variety of injection patterns, depending on site characteristics. In-situ chemical oxidation is a cost-effective treatment option but depending on site characteristics require several applications to be completely effective. In-situ oxidation and will take substantially longer than excavation followed by disposal or treatment. This option should be less costly than excavation followed by treatment and substantially less costly than off-site disposal.

Table 2-1
Groundwater Remedial Action Objectives, General Response Actions,
and Remedial Technology Types
Operable Unit 4, Orchard Street/Maiden Lane Site
New Haven, Missouri

Remedial Action Objectives
For protection of human health:
Prevent exposure to groundwater with contaminant levels greater than MCLs and MCLGs.
For protection of the environment:
Minimize further migration of the groundwater contaminant plume.

General Response Actions	Remedial Technology Types
No Action	No Action
Institutional Controls	Activity and Use Limitations
Other Controls	Alternative Drinking Water Source Relocation
Monitoring	Monitoring
Natural Attenuation	Natural Attenuation Focused Monitoring
Containment	Containment Vertical Barriers Horizontal Barriers Surface Controls
Removal	Removal Technology Groundwater Extraction Enhanced Groundwater Extraction
Treatment	Treatment Technologies Physical Treatment Chemical Treatment Biological Treatment In-Situ Treatment Off-site Treatment
Disposal	Disposal Technologies On-site Treated Effluent Discharge Off-site Treated Effluent Discharge

Table 2-2
Soils Remedial Action Objectives, General Response Actions,
and Remedial Technology Types
Operable Unit 4, Orchard Street/Maiden Lane Site
New Haven, Missouri

Remedial Action Objectives
For protection of human health: Prevent exposure to soil containing contaminants at concentrations which result in an excess cancer risk greater than 1×10^{-6} or a Hazard Quotient greater than 1.0, whichever is less. For protection of the environment: Reduce the soil contaminant levels, or prevent migration of soil contaminants, to provide protection of groundwater.

General Response Actions	Remedial Technology Types
No Action	No Action
Institutional Controls	Activity and Use Limitations
Monitoring	Monitoring
Containment	Containment Capping Surface Controls Vertical Barriers Horizontal Barriers
Removal	Removal Technology Excavation Building Demolition
Disposal	Disposal Off-site Disposal On-site Disposal
Treatment	Treatment Technologies Physical Ex-Situ Treatment Physical/Chemical Ex-Situ Treatment Physical/Thermal Ex-Situ Treatment Biological Ex-Situ Treatment In-Situ Treatment

Table 2-3
Potential Chemical-Specific ARARs
Operable Unit 4, Orchard Street/Maiden Lane Site
New Haven, Missouri

Standard, Requirement, Criteria, or Limitation	Citation	Description	Comment
Federal			
Safe Drinking Water Act (SDWA)	42 United States Code (USC) §§ 300f – 300j-26		
National Primary Drinking Water Standards	40 CFR Part 141, Subpart B and G	Establishes MCLs, which are health-based standards for public water systems.	The MCLs for organic contaminants are relevant and appropriate to groundwater contamination in a potential or actual drinking water aquifer. Use of these standards is required by the NCP.
National Secondary Drinking Water Standards	40 CFR Part 143, Subpart F and G	Establish secondary maximum contaminant levels (SMCLs), which are non-enforceable guidelines for public water systems to protect the aesthetic quality of the water.	SMCLs may be relevant and appropriate if treated groundwater is used as a source of drinking water.
Maximum Contaminant Level Goals (MCLGs)	PL No. 99-339, 100 Stat. 642 (1986) 40 CFR Part 141, Subpart F	Establishes non-enforceable drinking water quality goals. The goals are set to levels that produce no known or anticipated adverse health effects. The MCLGs include an adequate margin of safety.	MCLGs for organic constituents may be relevant and appropriate if a more stringent standard is required to protect human health and the environment. Where they exist, non-zero MCLGs are relevant and appropriate to potential drinking water sources in lieu of MCLs.

Table 2-3, Continued
Potential Chemical-Specific ARARs
Operable Unit 4, Orchard Street/Maiden Lane Site
New Haven, Missouri

Standard, Requirement, Criteria, or Limitation	Citation	Description	Comment
Clean Water Act	33 USC §§ 1251-1387		
Water Quality Criteria	40 CFR Part 131 Quality Criteria for Water, 1976, 1980, and 1986	Establishes non-enforceable standards to protect aquatic life.	May be relevant and appropriate to surface water discharges, or may be a TBC. Also may be applicable or relevant and appropriate to groundwater remediation in Missouri based on the Water Quality Standards, 10 CSR 20-7.031.
Toxic Pollutant Effluent Standards	40 CFR Part 129	Establishes effluent standards or prohibitions for certain toxic pollutants: aldrin/dieldrin, DDT, endrin, toxaphene, benzidine, and PCBs.	Not applicable or relevant and appropriate because these contaminants are not present in the OU4 source area soils or in the groundwater below OU4.
National Pollutant Discharge Elimination System (NPDES)	40 CFR Parts 122, 125	Determines maximum concentrations for the discharge of pollutants from any point source into waters of the United States.	If an alternative involved discharge to surface water on-site, these standards would be applicable. Discharge limits would be established for the effluent discharged to the surface water body.
National Pretreatment Standards	40 CFR Part 403	Sets standards to control pollutants that pass through or interfere with treatment processes in POTW or that may contaminate sewage sludge.	If an alternative involved discharge to a POTW off-site, these standards would be applicable.
Clean Air Act	42 USC §§ 7401 – 7671q		
National Primary and Secondary Ambient Air Quality Standards	40 CFR Part 50	Establishes standards for ambient air quality to protect public health and welfare.	These standards are discussed in the action-specific ARARs table.

Table 2-3, Continued
Potential Chemical-Specific ARARs
Operable Unit 4, Orchard Street/Maiden Lane Site
New Haven, Missouri

Standard, Requirement, Criteria, or Limitation	Citation	Description	Comment
Superfund Removal Action Levels	USEPA's Office of Solid Waste and Emergency Response, March 1995	Levels used for Superfund removal actions.	These standards are not ARARs, but may be TBC.
State			
Waste Characterization	10 CSR 25-3.260(1)(H)	Requires that the wastes at the subsite be characterized to determine if the wastes meet the definition of hazardous waste in the citation.	These standards would be applicable or relevant and appropriate.
Identification and Listing of Hazardous Waste	10 CSR 25-4.261	Defines those solid wastes which are subject to regulations as hazardous wastes under 10 CSR 25.	These standards would be applicable or relevant and appropriate.
Missouri Risk-Based Corrective Action (RBCA)	RBCA Technical Guidance, April 2006, June 2006, and June 2008	Outlines a process for determining cleanup goals at sites with known or suspected hazardous substance contamination.	The MDNR is in the process of promulgating these standards, but as yet they have not been formally accepted by USEPA. Therefore, these standards are not ARAR, but are TBC for the soil at OU4.

Table 2-3, Continued
Potential Chemical-Specific ARARs
Operable Unit 4, Orchard Street/Maiden Lane Site
New Haven, Missouri

Standard, Requirement, Criteria, or Limitation	Citation	Description	Comment
Anti-degradation	10 CSR 20-7.031(2)(A)	Requires that for waters that just maintain a level of water quality that protects public health and existing in-stream water uses there be no impairment or loss of existing uses.	The Tier One standard would be applicable to the groundwater at OU4.

Table 2-4
Numerical Values of Chemical-Specific ARARs for
Groundwater and Soil Contaminants of Concern
Operable Unit 4, Orchard Street/Maiden Lane Subsite
New Haven, Missouri

Groundwater			
Contaminant		ARAR Value	
Volatile Organic Compounds			
*	cis-1,2-Dichloroethene	70 Φg/L	1
*	trans-1,2-Dichloroethene	100 Φg/L	1
*	Tetrachloroethene	5 Φg/L	2
*	Trichloroethene	5 Φg/L	2
Soils			
Contaminant		Soil Cleanup Goal Value	
Volatile Organic Compounds			
*	Tetrachloroethene	550 ug/kg	3
*	Trichloroethene	43 ug/kg	3
*	Vinyl Chloride	43 ug/kg	3

Notes:
* Contaminant of Concern (COC).
1 National Primary Drinking Water Standards, 40 CFR Part 141, Subpart F, Maximum Contaminant Levels Goals. These standards are ARARs because non-zero MCLGs for these contaminants have been promulgated.
2 National Primary Drinking Water Standards, 40 CFR Part 141, Maximum Contaminant Levels. These standards are ARARs because non-zero MCLGs for these contaminants have not been promulgated.
3 USEPA Region 6 Human Health Medium-Specific Screening Levels, 2008.

Table 2-5
Potential Action-Specific ARARs
Operable Unit 4, Orchard Street/Maiden Lane Site
New Haven, Missouri

Standard, Requirement, Criteria, or Limitation	Citation	Description	Comments
FEDERAL			
Solid Waste Disposal Act (SWDA), Subtitle C as amended by the Resource Conservation and Recovery Act of 1976	40 USC §§ 6901-6992k		
Criteria for Classification of Solid Waste Disposal Facilities and Practices	40 CFR Part 257	Establishes criteria for determining which solid waste disposal facilities and practices pose a reasonable probability of adverse effects on health, and thereby constitute prohibited open dumps.	If a remediation alternative is developed that involves land disposal of solid waste on-site, this part would be applicable or relevant and appropriate.
Hazardous Waste Management Systems General	40 CFR Part 260 to 268	Establishes procedures and definitions pertaining to solid and hazardous waste.	May be applicable or relevant and appropriate to on-site generation, treatment, storage, or disposal of hazardous wastes.
Identification and Listing of Hazardous Wastes	40 CFR Part 261	Defines those solid wastes that are subject to regulations as hazardous wastes under 40 CFR Parts 262-265 and Parts 124, 270, and 271.	Would be applicable in identifying if a substance in the soils or groundwater at OU4 is identified as a hazardous waste. Any wastes identified as hazardous wastes would have to be handled as such.
Standards Applicable to Generators of Hazardous Waste	40 CFR § 262.11	Waste determination.	The requirements for determining whether a waste is a hazardous waste (in most instances if generated after 1980) are applicable or relevant and appropriate.

Table 2-5, Continued
Potential Action-Specific ARARs
Operable Unit 4, Orchard Street/Maiden Lane Site
New Haven, Missouri

Standard, Requirement, Criteria, or Limitation	Citation	Description	Comments
Standards Applicable to Transporters of Hazardous Waste	40 CFR Part 263	Establishes standards that apply to persons transporting hazardous waste within the U.S. if the transportation requires a manifest under 40 CFR Part 262.	If an alternative involved off-site transportation of hazardous wastes, these standards would be complied with.
Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities	40 CFR Part 264 and 265	Establishes minimum national standards which define the acceptable management of hazardous waste for owners and operators of facilities that treat, store, or dispose of hazardous waste.	May be applicable or relevant and appropriate to on-site and off-site RAs if they involve the treatment, storage, or disposal of a RCRA regulated hazardous waste, or materials that are sufficiently similar.
Land Disposal	40 CFR Part 268	Establishes a ban or restrictions on burial of wastes and other hazardous materials.	If an alternative involves land disposal of any restricted wastes, this part may be applicable or relevant and appropriate.
Hazardous Waste Permit Program	40 CFR Part 270	Establishes provisions covering RCRA permitting requirements.	A permit is not required for on-site CERCLA response actions.
Underground Storage Tanks	40 CFR Part 280	Establishes regulations related to underground storage tanks.	Would be applicable or relevant and appropriate if underground storage tanks are used or addressed in an alternative.
Safe Drinking Water Act	42 USC §§ 300f – 300j-26		
Standards for Owners and Operators of Public Water Supply Systems	40 CFR Part 141	Provides treatment (water quality) requirements for public water supply systems.	MCLs and MCLGs are relevant and appropriate to the establishment of cleanup goals for groundwater contamination.

Table 2-5, Continued
Potential Action-Specific ARARs
Operable Unit 4, Orchard Street/Maiden Lane Site
New Haven, Missouri

Standard, Requirement, Criteria, or Limitation	Citation	Description	Comments
Underground Injection Control (UIC) Regulations	40 CFR Parts 144 – 147	Provides for protection of underground sources of drinking water.	If an alternative involved underground injection, this part would be applicable or relevant and appropriate.
Clean Water Act	33 USC §§ 1251 – 1387		
National Pollutant Discharge Elimination System (NPDES)	40 CFR Parts 122 – 125	Requires permits for the discharge of pollutants from any point source into the waters of the United States.	A permit is not required for on-site CERCLA response actions, but the substantive requirements are applicable if an alternative involved discharge into a creek or other surface water on-site. A permit would be required if the discharge is to a creek or other surface water off-site.
Water Quality Criteria	40 CFR Part 131 Quality Criteria for Water, 1976, 1980, and 1986	Establishes non-enforceable standards to protect aquatic life.	May be relevant and appropriate to surface water discharges, or may be a TBC. Also may be applicable or relevant and appropriate to groundwater remediation in Missouri as per the Water Quality Standards in 10 CSR 20-7.031.
National Pretreatment Standards	40 CFR Part 403	Sets standards to control pollutants that pass through or interfere with treatment processes in POTW or that may contaminate sewage sludge.	If an alternative involves discharge to a POTW, these standards would be applicable or relevant and appropriate.
Toxic Pollutant Effluent Standards	40 CFR Part 129	Establishes effluent standards or prohibitions for certain toxic pollutants: aldrin/dieldrin, DDT, endrin, toxaphene, benzidine, and PCBs.	These standards are not applicable or relevant and appropriate because these contaminants have not been detected in the groundwater at OU4, the Orchard Street/Maiden Lane Subsite.

Table 2-5, Continued
Potential Action-Specific ARARs
Operable Unit 4, Orchard Street/Maiden Lane Site
New Haven, Missouri

Standard, Requirement, Criteria, or Limitation	Citation	Description	Comments
Clean Air Act	42 USC §§ 7401 – 7671q		
National Ambient Air Quality Standards/ NESHAPS/NSPS/ BACT/PSD/LAER	40 CFR 50.1-.17. .50-.54; .150-.154 .480-.489; 40 CFR 53.1-.33; 40 CFR 61.01-.18 .50-.112, .240-.247	Treatment technology standards for emissions to air from: incinerators, surface impoundments, waste piles, landfills, and fugitive emissions.	If an alternative involves emissions governed by these standards then the requirements would be applicable.
Noise Control Act of 1972	42 USC §§ 4321 – 4370f	Federal activities must not result in noise that will jeopardize the health or welfare of the public.	If an alternative's activities, such as drilling, were to take place close to a public access point, this act may be applicable.
Hazardous Materials Transportation Act	49 USC § 5101 et seq.		
Hazardous Materials Transportation Regulations	49 CFR Parts 107, 171-177	Regulates transportation of hazardous materials.	If an alternative involved transportation of hazardous materials, these requirements would be applicable.
STATE			
Missouri Air Pollution Control Program	10 CSR 10-6.010 - 6.300	Ambient concentrations of VOCs should be less than their respective Acceptable Ambient Levels at the subsite boundary.	If an alternative involved discharge of contaminants to the air, these requirements may be relevant and appropriate.

Table 2-5, Continued
Potential Action-Specific ARARs
Operable Unit 4, Orchard Street/Maiden Lane Site
New Haven, Missouri

Standard, Requirement, Criteria, or Limitation	Citation	Description	Comments
Wastewater Treatment Plant Permit Regulations	10 CSR 20-6.010	These rules establish the administrative and substantive requirements for wastewater treatment permits.	The administrative requirements are not ARARs for on-site Superfund actions. The substantive requirements may be applicable or relevant and appropriate.
Water Quality Effluent Regulations or Water Quality Standards.	10 CSR 20-7.010	Regulates any potential discharges to losing streams.	If an alternative involved discharge to the Missouri River, these requirements may be applicable or relevant and appropriate.
Water Quality Standards.	10 CSR 20-7.031	These regulations establish the classification and beneficial uses of surface water and groundwater in Missouri.	If an alternative involved discharge to surface water or groundwater, these requirements may be applicable or relevant and appropriate.
Water Supply Well Construction Code	10 CSR 23-3	Domestic supply wells must be installed or abandoned in accordance with the Code.	Because none of the alternatives required installation or abandonment of domestic wells, these requirements are not applicable or relevant and appropriate. However, see the entry for Special Area 3, below.
Special Area 3 Well Installation and Review Requirements	10 CSR 23-3.100(7)	These requirements, a subset of Chapter 3 of the Missouri Well Construction Rules, specifically address domestic supply wells construction standards in and around New Haven.	Because none of the alternatives required installation of domestic wells, these requirements are not applicable or relevant and appropriate. However, any new domestic supply wells installed in OU4 must comply with these standards.
Monitoring Well Construction Code	10 CSR 23-4	Monitoring wells must be installed or abandoned in accordance with the Monitoring Well Construction Code.	If an alternative required installation or abandonment of monitoring wells, these requirements would be applicable.

Table 2-5, Continued
Potential Action-Specific ARARs
Operable Unit 4, Orchard Street/Maiden Lane Site
New Haven, Missouri

Standard, Requirement, Criteria, or Limitation	Citation	Description	Comments
Federal Regulations Incorporated by Reference	10 CSR 25-4.261, 5.262, 6.263, 7.264(2)(B), 7.264(2)(D), 7.264(2)(E), 7.264(2)(I), 7.264(2)(J), 7.264(2)(X), 7.264(2)(CC), and 7.268.	These regulations govern off-site disposal of excavated wastes, excavation and transportation of wastes from a site, bulking of wastes, handling of wastes in containers, and storing of wastes or contaminated soils in tanks or containers.	These requirements are not applicable or relevant and appropriate because they are not more stringent than the Federal requirements.
Sanitary Landfill Regulations	10 CSR 80-3.010 (2) & (3)	Regulated quantities of hazardous waste are excluded from disposal at permitted solid waste landfills. Hazardous waste must be tested to determine its handling and disposal.	If an alternative required disposal of wastes in a sanitary landfill, these requirements may be applicable or relevant and appropriate.
Professional Geologist – Code of Professional Conduct	20 CSR 2145-4.020	Any site-specific geological interpretations that affect human health and safety must be regulated.	If an alternative involved geological interpretation, these requirements may be applicable.
Missouri Clean Water Law	Chapter 644, RSMo	Establishes requirements relating to water pollution control.	If an alternative required on- or off-site disposal of treated groundwater, this Law may be applicable or relevant and appropriate.
Protection of Caves	L. 1981 H.S.H.B. 1192	The act relates to the protection of caves (including sinkholes) and cave life from vandalism and pollution.	These requirements are not applicable or relevant and appropriate because none of the alternatives involve caves.

Table 2-5, Continued
Potential Action-Specific ARARs
Operable Unit 4, Orchard Street/Maiden Lane Site
New Haven, Missouri

Standard, Requirement, Criteria, or Limitation	Citation	Description	Comments
Groundwater Tracing Regulations	L. 1991 S.B. 221, RSMo 256.621	The act and the associated revised statute relate to surface and groundwater tracing.	If an alternative required use of tracers in groundwater, these requirements may be applicable or relevant and appropriate.

Table 2-6
Potential Location-Specific ARARs
Operable Unit 4, Orchard Street/Maiden Lane Site
New Haven, Missouri

Standard, Requirement, Criteria, or Limitation	Citation	Description	Comment
FEDERAL			
Executive Order on Flood Plain Management	Executive Order No. 11,988; 16 USC 661 et seq.; 40 CFR Part 6, Appendix A and 40 CFR 6.302	Requires Federal agencies to evaluate the potential effects of actions they may take in a flood plain. The intent is to avoid, as much as possible, adverse impacts associated with direct and indirect development of a flood plain.	Because OU4 is not located below the 100-year flood plain, these requirements are not applicable or relevant and appropriate.
100-Year Flood Plain Management	40 CFR 264.18(b)	RCRA treatment, storage, or disposal facilities in the 100-year flood plain must be designed, constructed, operated, and maintained to avoid washout.	Because OU4 is not located below the 100-year flood plain, these requirements are not applicable or relevant and appropriate.
Executive Order on Protection of Wetlands	Executive Order No. 11,990; 40 CFR 6.302(a) and Appendix A	Requires Federal agencies to avoid, as much as possible, adverse impacts associated with the destruction or loss of wetlands and to avoid new construction in wetlands if a practicable alternative exists.	Because there are no wetlands on or near OU4, these requirements are not applicable or relevant and appropriate.
Clean Water Act	33 USC §§ 1251 - 1387		
Dredge or Fill Requirements (Section 404)	40 CFR Parts 230 and 231	Requires permits for discharge of dredged or fill material into navigable waters.	Not applicable or relevant and appropriate because no alternatives would require discharge of dredge or fill material into navigable waters.

Table 2-6, Continued
Potential Location-Specific ARARs
Operable Unit 4, Orchard Street/Maiden Lane Site
New Haven, Missouri

Standard, Requirement, Criteria, or Limitation	Citation	Description	Comment
Rivers and Harbors Act of 1899	33 USC § 401 et seq.		
Section 10 Permit	33 CFR Parts 320-330	Requires permits for structures or work in or affecting navigable waters.	Not applicable or relevant and appropriate because no alternatives would affect navigable waters.
Wilderness Act	16 USC 1311 et seq.; 50 CFR 35.1 et seq.;	Requires that federally owned wilderness areas be administered to leave them un-impacted.	Not applicable or relevant and appropriate because no wilderness areas exist on or adjacent to OU4.
National Wildlife Refuge System	16 USC 668dd et seq.; 50 CFR 27	Restricts activities within a National Wildlife Refuge to those activities allowed under 16 USC 666dd(c).	Not applicable or relevant and appropriate because there are no wildlife refuge areas adjacent to OU4.
National Historic Preservation Act	16 USC § 470 et seq. 36 CFR Part 65	Requires federal agencies to take action to recover and preserve artifacts in areas where alteration of terrain threatens significant scientific, prehistorical, historical, or archaeological data.	These requirements may be applicable or relevant and appropriate because available information indicates that OU4 may have areas that contain significant scientific, prehistorical, historical, or archaeological data.
National Historic Preservation Act	16 USC § 470 et seq.; 40 CFR Part 6.301 (b) 36 CFR Part 800	Requires federal agencies to take into account the effect of any federally-assisted undertaking or licensing on any district, site, building, structure, or object that is included in, or eligible for inclusion in, the National Register of Historic Places.	These requirements may be applicable or relevant and appropriate because the New Haven Residential Historic District is located in OU4.

Table 2-6, Continued
Potential Location-Specific ARARs
Operable Unit 4, Orchard Street/Maiden Lane Site
New Haven, Missouri

Standard, Requirement, Criteria, or Limitation	Citation	Description	Comment
Endangered Species Act	16 USC § 1531 et seq.; 50 CFR Parts 200 and 402	Requires action to conserve endangered species within critical habits upon which the endangered species depend, including consultation with the Department of Interior.	These requirements are not applicable or relevant and appropriate because no threatened or endangered species or critical habitats have been identified in or near OU4.
Fish and Wildlife Coordination Act	16 USC §§ 661-666; 33 CFR Parts 320 - 330; 40 CFR 6.302	Requires consultation when a Federal department or agency proposes or authorizes any modification of any stream or other water body and adequate provision for protection of fish and wildlife resources.	These requirements may be applicable or relevant and appropriate if an alternative would modify a stream or river at or near OU4.
Wild and Scenic River Act	16 USC § 1271 et seq.; Section 7, 40 CFR 6.302(e)	Prohibits adverse effects on any of the scenic rivers listed in 16 USC 1276(a).	These requirements are not applicable or relevant and appropriate because there are no scenic rivers in the area of OU4.
Historic Site, Buildings, and Antiquities Act	16 USC §§ 461-467 40 CFR Sect. 6.301(a)	Requires Federal agencies to consider the existence and location of landmarks on the National Registry of Natural Landmarks to avoid undesirable impacts on such landmarks.	These requirements are not applicable or relevant and appropriate because no current National Landmark is in or adjacent to OU4.
Migratory Bird Treaty Act	16 USC § 703 et seq.	No federal action may jeopardize the habitat of birds with migratory pathways through the area.	These requirements are not applicable or relevant and appropriate because none of the alternatives would affect any migratory pathways.

Table 2-6, Continued
Potential Location-Specific ARARs
Operable Unit 4, Orchard Street/Maiden Lane Site
New Haven, Missouri

Standard, Requirement, Criteria, or Limitation	Citation	Description	Comment
USEPA Regulations on sole-source aquifers	40 CFR Part 149	No activities, including drilling, in an area designated a sole-source aquifer may take place without permission of the USEPA.	The aquifer below OU4 has not been designated by USEPA as a sole-source aquifer. Therefore, this regulation is not applicable or relevant and appropriate.
Seismic Considerations	40 CFR § 264.18(a)	New RCRA hazardous waste treatment, storage, or disposal facilities are prohibited within 61 meters of a fault displaced in Holocene time.	This requirement is not applicable or relevant and appropriate because no treatment, storage, or disposal facilities located in OU4 would be within 61 meters of a Holocene Age fault.
Salt Dome Formations, Salt Bed Formations, Underground Mines and Caves	40 CFR § 264.18	Placement of non-containerized or bulk liquid RCRA hazardous waste is prohibited within salt dome formations, underground mines, or caves.	This requirement is not applicable or relevant and appropriate because none of these types of formations are present on or in the vicinity of OU4.
STATE			
Missouri Well Construction Rules	10 CSR 23-3	Domestic supply wells must be installed or abandoned in accordance with the Rules.	Because none of the alternatives required installation or abandonment of domestic wells, these requirements are not applicable or relevant and appropriate.

Table 2-7
Remedial Technologies and Process Options for Groundwater, Initial Screening
Operable Unit 4, Orchard Street/Maiden Lane Site
New Haven, Missouri

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	RETAINED/ Not Retained	SCREENING COMMENTS
No Action	None	None	No action	RETAINED	Required to be carried through to detailed analysis of alternatives.
Institutional Controls	Activity and Use Limitations	Deed and Zoning Restrictions	A restrictive covenant or other appropriate proprietary control is placed on property within potentially contaminated areas to restrict groundwater use.	RETAINED	Potentially viable.
		Permits	Regulations are promulgated to require a permit for drilling into contaminated aquifers.	Not Retained	Not necessary, Special Area 3 Regulations already in place.
		Well Construction Restrictions	Restrictions are promulgated to prevent the installation of substandard water supply wells in the contaminated plume.	RETAINED	Special Area 3 Regulations completed in 2006.
		Public Education/ Information	Educate/inform residents on appropriate (non-potable) uses of the groundwater.	RETAINED	Potentially viable.
Other Controls	Alternative Drinking Water Source	Home Treatment Units	Treatment units such as carbon filtration units are installed on the service line at each residence.	Not Retained	City water supply currently available for all homes.
		Bottled Water	Drinking water obtained from a commercial vendor.	Not Retained	City water supply or home treatment units are currently available.
		New Public Water Supply	Public water supply is available from the City of New Haven.	Not Retained	Already implemented.

Table 2-7, Continued
Remedial Technologies and Process Options for Groundwater, Initial Screening
Operable Unit 4, Orchard Street/Maiden Lane Site
New Haven, Missouri

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	RETAINED/ Not Retained	SCREENING COMMENTS
Other Controls (Continued)	Relocation	None	Persons affected by groundwater contamination are relocated, usually in cases where there is high risk or an immediate health threat to residents.	Not Retained	Not necessary, other control options are available.
Monitoring	Monitoring	Groundwater Monitoring	Short and/or long-term monitoring is implemented to record aquifer conditions and contamination levels.	RETAINED	Potentially viable.
Natural Attenuation	Focused Monitoring	Focused Groundwater Monitoring	Specific parameters are measured to evaluate natural attenuation. Short and/or long-term monitoring is implemented to evaluate site conditions and contamination levels.	Not Retained	Contaminant levels are too high, source area soils are not completely remediated, and the plume is not located in groundwater conducive to natural attenuation of the contaminants.
Containment	Vertical Barriers	Soil-Bentonite or Cement-Bentonite Slurry Wall	A trench would be excavated around the contaminated area and kept open with a bentonite or cement-bentonite slurry. The trench would be backfilled with a soil-bentonite or with the cement-bentonite mix. The slurry sets up and forms the walls.	Not Retained	Plume is too deep and most of the plume is located in bedrock, where this option cannot be used.
		Vibrating Beam	Vibratory force is used to advance a steel beam into the ground; a relatively thin wall of cement or bentonite is injected as the beam is withdrawn.	Not Retained	Plume is too deep and most of the plume is located in bedrock, where this option cannot be used.

Table 2-7, Continued
Remedial Technologies and Process Options for Groundwater, Initial Screening
Operable Unit 4, Orchard Street/Maiden Lane Site
New Haven, Missouri

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	RETAINED/ Not Retained	SCREENING COMMENTS
Containment (Continued)	Vertical Barriers (Continued)	Chemical Grouting	A chemical grout or organic polymer is injected into the soil or bedrock to reduce permeability.	Not Retained	Plume is too deep and too large for this option to be used to contain the groundwater plume.
		Rock Grouting	Grout is injected into bedrock to seal fractures, solution cavities, and voids.	Not Retained	Plume is too deep and too large for this option to be used to contain the groundwater plume.
		Grout Curtains	Grout is pressure-injected along contamination boundaries in a regular overlapping pattern of drilled holes.	Not Retained	Plume is too deep and most of the plume is located in bed rock, where this option can not be used.
		Sheet Piling	Steel sheet piling is driven along contamination boundaries.	Not Retained	Plume is too deep and most of the plume is located in bed rock, where this option can not be used.
		Hydraulic Controls, Vertical Wells	A series of wells is installed to control groundwater flow.	RETAINED	Potentially viable for the shallow portion of the Plume in Zones A and B. Not practicable for Zone C.
		Hydraulic Controls, Horizontal/Angle-Drilled Wells	A series of wells is installed to control groundwater flow.	RETAINED	Potentially viable for the shallow portion of the Plume in Zones A and B. Not practicable for Zone C.

Table 2-7, Continued
Remedial Technologies and Process Options for Groundwater, Initial Screening
Operable Unit 4, Orchard Street/Maiden Lane Site
New Haven, Missouri

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	RETAINED/ Not Retained	SCREENING COMMENTS
Containment (Continued)	Horizontal Barriers	Capping	An impermeable barrier such as clay, soil/synthetic membrane, asphalt, asphaltic concrete, concrete, multi-layer, and chemical sealants/stabilizers placed over area to minimize infiltration of surface water.	Not Retained	Plume is too large and OU4 is too steep and too developed to successfully implement capping of the plume.
	Surface Controls	Drainage Controls	New drainage patterns are established to minimize infiltration through areas of contaminated soil.	Not Retained	Effectiveness would be limited because new drainage patterns are difficult to build in developed areas.
		Revegetation	A vegetative cover is re-established in areas which have been regraded or capped to reduce erosion and increase integrity of other control measures.	Not Retained	Plume is too deep to be affected by revegetation. Effectiveness would be limited because revegetation is difficult in developed areas.
Removal	Groundwater Extraction	Vertical Wells	Wells are installed to extract contaminated groundwater.	Not Retained	Plume is located in deep bedrock and the surface is very rugged and completely developed, making Plume-wide implementation impracticable.
		Horizontal/Angle-Drilled Wells	A series of wells is installed to extract the groundwater flow.	Not Retained	Plume is located in deep bedrock and the surface is very rugged and completely developed, making Plume-wide implementation impracticable.

Table 2-7, Continued
Remedial Technologies and Process Options for Groundwater, Initial Screening
Operable Unit 4, Orchard Street/Maiden Lane Site
New Haven, Missouri

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	RETAINED/ Not Retained	SCREENING COMMENTS
Removal (Continued)	Groundwater Extraction (Continued)	Interceptor Trenches	Underground gravel-filled trenches generally equipped with tile or perforated pipe installed to collect contaminated groundwater.	Not Retained	Not technically implementable due to subsite conditions, especially the close proximity to developed areas and the migration of the plume into bedrock.
	Enhanced Groundwater Extraction	Hydraulic/ Pneumatic Fracturing	Injection of a highly pressurized fluid to extend existing fractures in bedrock and/or create a new secondary network of fractures, channels, and fissures.	Not Retained	Not technically practicable, as plume is too deep, is located in bedrock, and is too large.
		Explosive Fracturing	Explosives are used in a well to create an extensively fractured volume in bedrock, which increases the yield of the extraction well.	Not Retained	Not technically implementable due to subsite conditions, especially the close proximity to developed areas.
Treatment	Physical Treatment	Pretreatments	Treatments such as equalization, oil/water separation, or aeration, that are used to control problem conditions, such as contaminant variability, free product, or dissolved iron, that might interfere with treatment of the primary contaminants.	Not Retained	These technologies were not retained as primary treatment technologies. The need for these types of technologies will be evaluated during the Remedial Design Phase. Other technologies that would be evaluated include clarification and dewatering.
		Filtration/ Microfiltration/ Ultrafiltration	Use of filters to separate particles from the groundwater. Micro- and ultra- filters have progressively smaller openings in the filters.	Not Retained	Contaminants are either pure product or are dissolved in the groundwater, so they can not be removed by filtration.

Table 2-7, Continued
Remedial Technologies and Process Options for Groundwater, Initial Screening
Operable Unit 4, Orchard Street/Maiden Lane Site
New Haven, Missouri

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	RETAINED/ Not Retained	SCREENING COMMENTS
Treatment (Continued)	Physical Treatment (Continued)	Reverse Osmosis	High pressure is used to force water through a selective membrane, leaving the contaminants behind.	RETAINED	Potentially viable.
		Pervaporation	A polymeric membrane based ultra filtration process is used to remove organics from groundwater.	Not Retained	Innovative technology, not fully demonstrated.
		Distillation	The groundwater and contaminants are vaporized and then condensed at different temperatures to separate the contaminants from the water.	Not Retained	Plume contaminants are dissolved in water and are too dilute to be separated cost effectively by distillation.
		Incineration	Incineration uses high temperature oxidation under controlled conditions to degrade substances.	Not Retained	Plume contaminants are dissolved in water and are too dilute to be cost effectively incinerated.
		Wet Air Oxidation	Organic and oxidizable inorganic contaminants in water are oxidized by addition of dissolved air under pressures of up to 3000 pounds per square inch at temperatures under 650 Fahrenheit.	Not Retained	Plume contaminants are dissolved in water and are too dilute to be treated cost effectively by wet air oxidation.

Table 2-7, Continued
Remedial Technologies and Process Options for Groundwater, Initial Screening
Operable Unit 4, Orchard Street/Maiden Lane Site
New Haven, Missouri

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	RETAINED/ Not Retained	SCREENING COMMENTS
Treatment (Continued)	Physical Treatment (Continued)	Thermal Oxidation	Hydrocarbons transferred from aqueous to vapor phase are incinerated by admixture with a fuel and combustion air in a suitable combustion chamber. The combustion gases may be used to generate steam for energy recovery.	Not Retained	Plume contaminants are dissolved in water and are too diluted to be combusted. Not retained as a primary treatment option. May be used as secondary treatment for contaminated vapor.
		Granular Activated Carbon (GAC) Adsorption	Contaminated water is passed over activated carbon (an adsorbent) that removes contaminants.	RETAINED	Potentially viable.
		Air Stripping/ Packed Columns	Large volumes of air flow counter current to the contaminated groundwater in a packed column to promote transfer of volatile contaminants to air.	RETAINED	Potentially viable. The contaminated vapor may require further treatment.
		Air Stripping/Tray Aeration	Air forced across a series of aeration trays to promote transfer of volatile contaminants to air.	RETAINED	Potentially viable. The contaminated vapor may require further treatment.
		Steam Stripping	Similar to air stripping except steam is pumped into the stripper to add heat, which promotes the transfer of volatile contaminants to air.	RETAINED	Potentially viable. The contaminated vapor may require further treatment.
		Evaporative Ponds	Shallow ponds are used to allow natural evaporation of water to occur.	Not Retained	Not technically implementable due to subsite conditions, especially climate and proximity to developed areas.

Table 2-7, Continued
Remedial Technologies and Process Options for Groundwater, Initial Screening
Operable Unit 4, Orchard Street/Maiden Lane Site
New Haven, Missouri

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	RETAINED/ Not Retained	SCREENING COMMENTS
Treatment (Continued)	Physical Treatment (Continued)	Spray Evaporation	Contaminated groundwater is sprayed in a fine mist to promote evaporation.	Not Retained	Not technically implementable due to subsite conditions, especially climate and proximity to developed areas.
		Electro-Chemical Precipitation	A direct current across consumable electrodes generates an insoluble ion matrix that adsorbs and precipitates heavy metals and other contaminants from the water. The precipitate is then separated from the water.	Not Retained	Used for removal of metals, not viable for the removal of dissolved organics.
	Chemical Treatment	Chemical Precipitation/ Flocculation	Addition of chemicals for ion precipitation.	Not Retained	Not effective for removal of organics.
		Ion Exchange	Contaminated water passes through a bed or ion exchange resin in which contaminants are exchanged for other less toxic ions on the surface of the resin particles.	RETAINED	Can be effective for removal of organics.
		Dechlorination	Extraction of halogenated ions.	Not Retained	Typically used for treating PCBs. Not effective for removal of volatile chlorinated contaminants.
		Chemical Oxidation	Strong electron donors such as ozone, hydrogen peroxide, or permanganate are used to rupture molecular bond in contaminant molecules.	RETAINED	Potentially viable. Some contaminants may require chemical reduction before oxidation treatment.

Table 2-7, Continued
Remedial Technologies and Process Options for Groundwater, Initial Screening
Operable Unit 4, Orchard Street/Maiden Lane Site
New Haven, Missouri

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	RETAINED/ Not Retained	SCREENING COMMENTS
Treatment (Continued)	Biological Treatment	Ultraviolet/ Chemical Oxidation	Oxidation of organic contaminants by UV light and chemical oxidation.	RETAINED	Potentially viable.
		Aerobic Processes	Organic wastes are oxidized in a reactor through the use of a mixed culture or organisms in aerobic conditions.	RETAINED	Potentially viable. May need to be combined with anaerobic processes to treat all the contaminants.
		Anaerobic Process	Organic wastes are reduced in a reactor through the use of a mixed culture or organisms in anaerobic conditions.	RETAINED	Potentially viable. May need to be combined with aerobic processes to treat all the contaminants.
		Anaerobic Lagoon	Microbial growth is promoted in a lagoon that is kept anaerobic.	Not Retained	Not technically implementable due to proximity to developed areas.
		Trickling Filter	Contaminated water is sprayed on a bed of crushed rock which is coated with biological films.	RETAINED	Potentially viable. May need to be combined with anaerobic processes to treat all the contaminants.
		Rotating Biological Contractors (RBCs)	An RBC consists of a shaft of circular plastic disks revolving partly submerged in a contoured-bottom tank. As disks are rotated out of the tank, air enters spaces between disks and liquid trickles out over films of biological growth attached to the disks.	RETAINED	Potentially viable. May need to be combined with anaerobic processes to treat all the contaminants.
		Aerated Lagoon	Microbial growth is promoted in a well-mixed lagoon that is fully aerated.	Not Retained	Not technically implementable due to proximity to developed areas.

Table 2-7, Continued
Remedial Technologies and Process Options for Groundwater, Initial Screening
Operable Unit 4, Orchard Street/Maiden Lane Site
New Haven, Missouri

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	RETAINED/ Not Retained	SCREENING COMMENTS
Treatment (Continued)	In-Situ Treatment	Solidification/ Stabilization	The contaminants are immobilized by mixing with materials such as portland cement to solidify the soil matrix and associated contamination.	Not Retained	Solidification can not be reliably conducted below the groundwater table or in bedrock.
		Aerobic Bioremediation	A system of injection wells or direct push injection points are used to introduce oxygen, and, if necessary, nutrients and bacteria to degrade the contaminants.	Not Retained	Anaerobic bioremediation can treat all the contaminants, so aerobic bioremediation is not necessary.
		Anaerobic Bioremediation	A system of injection wells is used to introduce an oxygen scavenger, nutrients, and, if necessary, bacteria to degrade contamination.	Not Retained	No evidence that anaerobic biodegradation is occurring. Would be difficult to establish and maintain anaerobic conditions throughout the aquifer.
		Air Sparging/Soil Vapor Extraction (SVE)	A system of wells injects air into the groundwater to remove volatiles by air stripping. Volatiles would be transferred to the air and removed with SVE wells.	Not Retained	Would be difficult to install due to the plume's depth and location (in bedrock).
		Steam Sparging	Injection of steam into groundwater to remove volatiles by steam stripping.	Not Retained	Not as cost effective as air sparging.
		Reactive Barrier Wall	Downgradient trenches backfilled with treatment media to remove contaminants from the groundwater.	Not Retained	Would be difficult to install due to the developed areas above the plume and the plume's location in bedrock.

Table 2-7, Continued
Remedial Technologies and Process Options for Groundwater, Initial Screening
Operable Unit 4, Orchard Street/Maiden Lane Site
New Haven, Missouri

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	RETAINED/ Not Retained	SCREENING COMMENTS
Treatment (Continued)	In-Situ Treatment (Continued)	Chemical Oxidation	A system of wells is used to apply oxidizers such as hydrogen peroxide, sometimes combined with a catalyst, to degrade contaminants. May require close spacing of application points. Oxidizer could also be introduced through existing monitoring wells.	Not Retained	Plume is located in deep bedrock, making application, especially adequate contact between oxidant and contaminants, impracticable. Would also require a large numbers of injection wells, which are also impracticable.
		Chemical Reduction	A system of wells is used to apply a reducing agent, to degrade contaminants. May require close spacing of application points. The reducing agent could also be injected through existing monitoring wells.	Not Retained	Not retained as a primary treatment technology. Should be evaluated during Remedial Design to see if it can be used instead of chemical oxidation in the treatment of the plume.
		Pressure Pulse Enhanced Remediation	A system is placed in a well to impart a pulse to the water in the well and on into the aquifer. Used to enhance recovery of contaminants and/or to speed up and homogenize mixing treatment chemicals into the aquifer.	Not Retained	Not retained as a primary treatment technology. Should be evaluated during Remedial Design to see if it can be used to enhance contaminant recovery or in-situ treatment.

Table 2-7, Continued
Remedial Technologies and Process Options for Groundwater, Initial Screening
Operable Unit 4, Orchard Street/Maiden Lane Site
New Haven, Missouri

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	RETAINED/ Not Retained	SCREENING COMMENTS
Treatment (Continued)	In-situ Treatment (Continued)	In Well Aeration (IWA)	Each well has two hydraulically separated screened intervals. Air lift pumping in the lower section causes in-situ vapor extraction within the well casing. The contaminated vapor is drawn out of the well to treatment or disposal. Groundwater re-infiltrates into the aquifer through the upper screen section, setting up a recirculation pattern in the surrounding aquifer.	Not Retained	Not viable. Re-infiltration of treated water would be difficult because shallower rock beds are less permeable than deeper beds.
		Advanced Remedial Technology (ART) IWA Stripping	Well combines SVE, in well aeration, and groundwater pumping.	Not Retained	Not viable. Re-infiltration of treated water would be difficult because shallower rock beds are less permeable than deeper beds.
		Phytoremediation	Plants are used to remove and/or treat contaminants in the soils. There are several mechanisms, such as accumulation of contaminants in the plant or degradation in the plant.	Not Retained	The effectiveness is limited to the shallow soils (i.e., root depth) and most of the contaminated groundwater is in bedrock, too deep for roots to reach.

Table 2-7, Continued
Remedial Technologies and Process Options for Groundwater, Initial Screening
Operable Unit 4, Orchard Street/Maiden Lane Site
New Haven, Missouri

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	RETAINED/ Not Retained	SCREENING COMMENTS
Treatment (Continued)	In-situ Treatment (Continued)	Polymerization	A catalyst is injected into the aquifer to convert a monomer of a contaminant to a larger chemical multiple of itself, which has greater chemical, physical, or biological stability.	Not Retained	Would not be effective in treating the subsites contaminants.
	Off-site Treatment	Public Owned Treatment Works (POTW)	Contaminated groundwater is treated at a nearby POTW.	Not Retained	Would be difficult to implement for the volume of water required. Extraction of the plume is also impracticable.
		Resource Conservation and Recovery Act (RCRA) Treatment Facility	Contaminated groundwater is transported to an off-site RCRA-approved facility for treatment.	Not Retained	Would be difficult to implement for the volume of water required.
Disposal	On-site Treated Effluent Discharge	Reinjection	Treated groundwater is reinjected through wells.	Not Retained	Impracticable as the treated water would have to be injected below its extraction depth as shallower rock layers are less permeable than the deeper layers.
		Infiltration Basins	Surface impoundments are used to contain treated or untreated wastewater or groundwater until it evaporates or percolates into the ground.	Not Retained	Would be difficult to install in the developed areas above the plume and would be difficult to operate given the shallow depth to bedrock across OU4.
		Discharge to Floodway	Treated groundwater is discharged to a drainage ditch or stream on-site.	RETAINED	Potentially viable.

Table 2-7, Continued
Remedial Technologies and Process Options for Groundwater, Initial Screening
Operable Unit 4, Orchard Street/Maiden Lane Site
New Haven, Missouri

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	RETAINED/ Not Retained	SCREENING COMMENTS
Disposal (Continued)	Off-site Treated Effluent Discharge	POTW	Treated effluent is discharged to a POTW.	RETAINED	Potentially viable.
		Discharge to Floodway	Treated groundwater is discharged to a drainage ditch or stream.	RETAINED	Discharge water quality would need to meet National Pollution Discharge Elimination System (NPDES) requirements.
		Deep Well Injection	Aqueous wastes are injected into permitted injection wells. Recent guidance may further regulate this practice.	Not Retained	No local access to permitted facility.
		Land Application/ Irrigation	Treated groundwater is applied to nearby farmland for disposal and irrigation purposes.	Not Retained	Difficulty of implementation would depend on the identification of willing users. Would only be viable during the growing season.
		Beneficial Use	Treated groundwater will be used for beneficial uses such as the public water supply designated by the community representatives.	Not Retained	Difficulty of implementation would depend on the identification of willing users. Questionable public acceptance.

Table 2-8
Remedial Technologies and Process Options for Soil, Initial Screening
Operable Unit 4, Orchard Street/Maiden Lane Site
New Haven, Missouri

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	RETAINED/ Not Retained	SCREENING COMMENTS
No Action	None	None	No actions are taken to meet remedial action objectives.	RETAINED	A No Action Alternative is required in accordance with the NCP.
Institutional Controls	Land Use Restrictions	Deed and Zoning Restrictions	Enforceable activity and use limitations are placed in the chain of title on all properties where contaminated soil is present. Typically accomplished through an environmental or restrictive covenant. Place restrictive zoning on all properties where contaminated soil is present.	Not Retained	Not necessary as surface soils (0-2 ft bgs) and subsurface soils to 10 ft bgs were barely contaminated above PRGs even before treatment. May be used as a secondary process option for protection of caps or other containment structures. More restrictive zoning is not possible as OU4 is already zoned residential – the most restrictive zoning available.
	Access Restrictions	Fencing	Contaminated areas are surrounded with a fence to control access.	RETAINED	Effective means of reducing public access to the subsite, therefore limiting contact with surface soils.
		Security Guard Service	Use of an around the clock, on-site security service to minimize trespasser access to OU4.	Not Retained	Effective means of reducing public access to the subsite, however, soil source area is small enough that fencing is more easily implemented.
		Public Education/ Information	Educate/inform residents on appropriate (shallow) uses of the soil.	Not Retained	The most heavily contaminated soils are sufficiently deep (15 ft bgs) that public education is not needed to minimize contact with the contaminants.

Table 2-8, Continued
Remedial Technologies and Process Options for Soil, Initial Screening
Operable Unit 4, Orchard Street/Maiden Lane Site
New Haven, Missouri

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	RETAINED/ Not Retained	SCREENING COMMENTS
Monitoring	Monitoring	Groundwater Monitoring	Periodic groundwater monitoring is conducted to determine migration of contaminants.	RETAINED	Monitoring of groundwater would indicate migration of contaminants from the soils.
		Soil Monitoring	Periodic monitoring of surface and/or subsurface soils is conducted to determine the concentration of contaminants.	RETAINED	Effective as a means of determining current contaminant levels and the effectiveness of treatment.
Containment	Capping	Native Soil	Contaminated soil is covered with compacted clean native soil cap to reduce direct contact and ingestion of contaminated soil. May also be used in areas where contaminated soils are excavated or treated to reduce risk associated with any residual contamination.	Not Retained	Cap is subject to cracking due to freeze-thaw cycles. Not as effective as other cap types.
		Clay	Contaminated soil is covered with a compacted clay cap to reduce direct contact and ingestion of contaminated soil.	Not Retained	Cap is subject to cracking, but has some self-healing properties. Direct contact with contaminated soil is minimized.
		Soil/Synthetic Membrane	Contaminated soil is covered with a synthetic membrane and then by a layer of compacted soil to reduce direct contact and ingestion of contaminated soil.	Not Retained	Membrane is susceptible to tearing. Subject to cracking due to freeze-thaw cycles.

Table 2-8, Continued
Remedial Technologies and Process Options for Soil, Initial Screening
Operable Unit 4, Orchard Street/Maiden Lane Site
New Haven, Missouri

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	RETAINED/ Not Retained	SCREENING COMMENTS
Containment (Continued)	Capping (Continued)	Asphalt or Asphaltic Concrete	Contaminated soil is covered with sprayed asphalt or asphaltic concrete to reduce direct contact and ingestion of contaminated soil.	Not Retained	If not maintained, asphalt has poor weathering characteristics, is susceptible to cracking, is photosensitive, and becomes brittle with age.
		Concrete	A concrete slab is installed over contaminated soil to reduce direct contact and ingestion of contaminated soil.	Not Retained	Potential for cracking as a result of settling and freeze-thaw cycles. A concrete cap would harm the aesthetic quality of residential New Haven.
		Multi-layer	Contaminated material is covered with a cap conforming to RCRA regulations to reduce direct contact and ingestion of contaminated soil.	RETAINED	Layering provides greater protection from cracking and infiltration than other caps. Effective in reducing direct contact with soil.
		Chemical Sealants/ Stabilizers	Contaminated soil is treated with a chemical agent to reduce or immobilize contaminants.	Not Retained	Used primarily for short-term protection because the sealants are sensitive to UV light and may become water soluble. Sealants become less effective when disturbed, especially by pedestrian or vehicular traffic.

Table 2-8, Continued
Remedial Technologies and Process Options for Soil, Initial Screening
Operable Unit 4, Orchard Street/Maiden Lane Site
New Haven, Missouri

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	RETAINED/ Not Retained	SCREENING COMMENTS
Containment (Continued)	Surface Controls	Soil Stabilization	Chemical stabilizers are sprayed on bare soils or mulched to coat, penetrate, and bind together the soil particles. Chemical stabilizers include latex emulsions, plastic films, oil-in-water emulsions, and resin in water emulsions.	Not Retained	Much of the contamination is subsurface. Long-term effectiveness is uncertain.
		Revegetation or Stone Covers	A vegetative or stone cover would be reestablished in areas that have been regraded or capped to decrease erosion and protect the integrity of the cap.	RETAINED	May be used in conjunction with other containment technologies, such as drainage controls and capping.
		Drainage Controls	New drainage patterns are established to prevent migration of contaminants in soil.	RETAINED	Might be used in conjunction with other containment technologies.
	Vertical Barriers	Slurry Wall	A soil-cement or soil-bentonite slurry is pumped into a trench as excavation proceeds and is used to create a wall of low permeability.	Not Retained	Would not prevent downward migration of contaminants from the soils unless capping was also implemented.
		Grout Curtain	Grout is injected or mixed into soil with auger-like blades to create a wall of low permeability.	Not Retained	Would not prevent downward migration of contaminants from the soils unless capping is also implemented.

Table 2-8, Continued
Remedial Technologies and Process Options for Soil, Initial Screening
Operable Unit 4, Orchard Street/Maiden Lane Site
New Haven, Missouri

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	RETAINED/ Not Retained	SCREENING COMMENTS
Containment (Continued)	Vertical Barriers (Continued)	Sheet Piling	Sheet piling is installed around contaminated soil to prevent migration of contaminants.	RETAINED	Might be used in conjunction with other treatment technologies. Proximity to developed areas would make driving sheet piles difficult at OU4. Would not prevent downward migration of contaminants from the soils unless capping is also implemented.
		Vibrating Beam	A variation of a grout curtain in which a vibrating force is used to advance a steel beam into the ground. Grout is injected as the beam is withdrawn.	Not Retained	Integrity of the barrier may be unsatisfactory due to the difficulty in creating a reliable continuous wall. Will not prevent downward migration of contaminants from the soils unless capping is also implemented. Proximity to developed areas would make using vibration difficult at OU4.
		Rock Grouting	Grout is injected into bedrock to seal fractures, solution cavities, and voids.	RETAINED	At OU4, contamination is in soil and may be in shallow bedrock. Would not be effective without another vertical barrier within the overlying soil.
	Horizontal Barriers	Grout Injection	Grout is pressure injected through drilled holes in a pattern to provide a low permeable barrier beneath the contaminated soil.	Not Retained	Technology is designed to be implemented in soil. At OU4, contamination may be in the shallow bedrock as well as soil.

Table 2-8, Continued
Remedial Technologies and Process Options for Soil, Initial Screening
Operable Unit 4, Orchard Street/Maiden Lane Site
New Haven, Missouri

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	RETAINED/ Not Retained	SCREENING COMMENTS
Containment (Continued)	Horizontal Barriers (Continued)	Block Displacement	After the contaminated area is isolated by a vertical barrier, grout is injected through holes bored through contaminated area. Continued grout pumping causes vertical displacement of the contaminated block of earth.	Not Retained	Would require use of a vertical barrier. OU4 is in a developed area. Vertical block displacement is not acceptable. In addition, much of the contamination is within the bedrock, which can not be displaced at reasonable cost.
Removal	Excavation	Mechanical Excavation	Contaminated soil and wastes are removed by common excavation equipment, and disposed of or treated.	RETAINED	Effective and well-established technology. Conventional equipment could easily excavate contaminated soils and shallow rock.
	Building Demolition	Demolition	A contaminated building is demolished and disposed of.	Not Retained	May be used in conjunction with other containment technologies, such as capping or excavation.
Disposal	Off-site Disposal	RCRA-permitted Landfill	Contaminated soil is transported and placed in a RCRA Part C permitted commercial landfill.	RETAINED	Landfilling is a well-established technology for the containment of contaminated soils.
		Solid Waste Landfill	Contaminated soil and/or treated soil is transported and placed in a permitted commercial solid waste landfill.	RETAINED	Landfilling is a well-established technology for the containment of contaminated and treated soils.

Table 2-8, Continued
Remedial Technologies and Process Options for Soil, Initial Screening
Operable Unit 4, Orchard Street/Maiden Lane Site
New Haven, Missouri

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	RETAINED/ Not Retained	SCREENING COMMENTS
Disposal (Continued)	On-site Disposal	RCRA-compliant Landfill	Contaminated soil is excavated and placed in a landfill located on-site that meets the substantive requirements of RCRA.	Not Retained	The contaminated source area is too small to allow construction of a RCRA compliant landfill. A landfill would harm the aesthetic quality of residential New Haven.
		Solid Waste Landfill	Contaminated soil and/or treated soil is transported and placed in a permitted commercial solid waste landfill.	Not Retained	The contaminated source area is too small to allow construction of a solid waste landfill. A landfill would harm the aesthetic quality of residential New Haven.
		Waste Piles	Contaminated soil and wastes are placed on an impermeable base. May be covered or left open.	RETAINED	Waste piles would be temporary storage, not ultimate disposal. Might be required for temporary stockpiling of wastes.
		Reusable Products	Contaminated soil is processed and waste products are reclaimed.	Not Retained	The OU4 soils do not contain contaminants with commercial value.
Treatment	Physical, Ex-Situ Treatment	Mechanical Separation	After excavation, contaminated soil is treated by common soils handling equipment, such as screens, to remove debris, roots, large rocks, et.	RETAINED	Would not be used as a primary treatment option. May be used with mechanical excavation.
		Soil Venting	Contaminated soils are excavated and placed in waste piles on top of perforated piping. A vacuum is placed on the piping to remove the contaminated vapor from the piles.	RETAINED	Would require excavation and separation. Contaminated vapor may require further treatment. The amount of soil being treated at any one time may be limited by the area available for soil piles and the treatment equipment.

Table 2-8, Continued
Remedial Technologies and Process Options for Soil, Initial Screening
Operable Unit 4, Orchard Street/Maiden Lane Site
New Haven, Missouri

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	RETAINED/ Not Retained	SCREENING COMMENTS
Treatment (Continued)	Physical/ Chemical, Ex-Situ Treatment	Solvent Extraction	Excavated soil is washed with sufficient quantities of an organic solvent to extract the contaminants. The washed soil is separated from the solvent, dried, and returned to excavated areas. Spent solvent is treated (by distillation, sedimentation, etc.) to remove and concentrate the contaminants. The treated solvent is reused. Concentrated organic residuals require further treatment or disposal.	RETAINED	Established, commercially-available technology effective for removal of organic contaminants from soils. Debris would have to be removed prior to treatment. Process is similar to soil washing.
		Soil Washing	Water and appropriate chemical additives or surfactants are used to extract the contaminants. Treated soil is dewatered. Process water is treated and reused. Concentrated residuals require further treatment or disposal.	RETAINED	Commercially-available technology effective for removal of inorganic compounds and some organic compounds from soils. Debris would have to be removed prior to treatment. Process is similar to solvent extraction.

Table 2-8, Continued
Remedial Technologies and Process Options for Soil, Initial Screening
Operable Unit 4, Orchard Street/Maiden Lane Site
New Haven, Missouri

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	RETAINED/ Not Retained	SCREENING COMMENTS
Treatment (Continued)	Physical/ Chemical, Ex-Situ Treatment (Continued)	Solidification/ Stabilization	Contaminated soils are excavated and combined with pozzolanic ingredients, water, and/or proprietary reagents. The wet slurry is replaced in the excavated areas to harden. Pozzolanic materials used can include Portland cement, fly ash, alumina, and silicates. Solidification occurs when the contaminants are bound into the stabilized soils. Stabilization occurs when the contaminants react chemically with the pozzolanic reagents.	Not Retained	This process is effective for soils contaminated with metals. It provides permanent isolation of the contaminants from the environment. Might also be effective for soils contaminated with low levels of organics. Contaminant levels are too high for this process option to be effective. Debris might have to be removed prior to treatment. The treated soils would be covered by clean soil and revegetated.
		Asphalt Batching	The contaminated soils would be excavated and blended into new asphalt, using either the hot mix or cold mix process. The contaminants are encapsulated into the asphalt when it hardens.	Not Retained	This process is effective for soils contaminated with petroleum hydrocarbons, which are not the contaminants of concern at this OU. It provides permanent isolation of the contaminants from the environment. Debris might have to be removed prior to treatment. The treated soils would be covered by clean soil and revegetated.

Table 2-8, Continued
Remedial Technologies and Process Options for Soil, Initial Screening
Operable Unit 4, Orchard Street/Maiden Lane Site
New Haven, Missouri

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	RETAINED/ Not Retained	SCREENING COMMENTS
Treatment (Continued)	Physical/ Thermal, Ex-Situ Treatment	Off-site Incineration	Soils would be excavated and transported to an off-site incinerator. Incinerators use high temperature oxidation under controlled conditions to degrade the organic contaminants in the soils. Multiple incinerator types (rotary kiln, fluidized bed, etc.) available.	RETAINED	Would be effective for treating organic contamination. Commercially available. Might require acid gas scrubbing. Debris removal might be required.
		On-site Incineration	Soils would be excavated and treated by an on-site incinerator. The incinerator would use high temperature oxidation under controlled conditions to degrade the contaminants in the soils. Multiple incinerator types available.	RETAINED	Would be effective for treating organic contamination. Commercially available. Might require acid gas scrubbing. Debris removal might be required.
		Thermal Desorption	Excavated soils are heated at temperatures less than combustion temperatures to desorb organic contaminants from the soils. Low-temperature (200 to 600 ^{o} F) desorption is used for VOCs. High-temperature (600 to 1000 ^{o} F) is used for SVOCs, such as PAHs.	RETAINED	Would be effective for treating organic contamination. Commercially available. Desorbed contaminants might require further treatment. Debris removal might be required.
	Biological, Ex-Situ Treatment	Bioslurry Reactors	Excavated soils are kept in suspension in a reactor with microorganisms, nutrients, and possibly oxygen. The treated soil would be dewatered.	RETAINED	Would require mechanical excavation and separation. The treated soil could be used as backfill. The amount of soil being treated at any time would be limited by the number of reactors.

Table 2-8, Continued
Remedial Technologies and Process Options for Soil, Initial Screening
Operable Unit 4, Orchard Street/Maiden Lane Site
New Haven, Missouri

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	RETAINED/ Not Retained	SCREENING COMMENTS
Treatment (Continued)	Biological, Ex-Situ Treatment (Continued)	Composting	Organic compounds in the soil undergo aerobic decomposition by microorganisms. Bulking agents (sawdust or woodchips) are added to obtain proper porosity. Heat produced during decomposition serves to keep temperature in the proper range to promote pathogen inactivation and drying.	Not Retained	Ability of composting to promote biological oxidation of all the organic contaminants at OU4 is questionable.
		Landfarming	Organic wastes or wastewaters are applied to agricultural lands for treatment and disposal. The soil promotes bacterial growth which results in biological oxidation of the organics. Crops grown on the subsite consume nutrients. Some metals are captured in the soil complex.	Not Retained	Most applicable to municipal and industrial sludges and wastewaters. Large volume of soil to be treated/disposed would require large land area. Ability of soil to promote biological oxidation of all organic contaminants is questionable.
		Biopiles	Excavated soil would be placed in piles on an impermeable barrier. Pipes to add water, air, and nutrients and to capture excess water would be incorporated into the soil piles. The piles would be covered and conditions optimized for biological treatment of the contaminants within the piles.	RETAINED	Would require mechanical excavation and separation. The treated soil could be used as backfill for the excavations. The amount of soil being treated at any one time would be limited by the area available for soil piles and the treatment equipment.

Table 2-8, Continued
Remedial Technologies and Process Options for Soil, Initial Screening
Operable Unit 4, Orchard Street/Maiden Lane Site
New Haven, Missouri

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	RETAINED/ Not Retained	SCREENING COMMENTS
Treatment (Continued)	In-situ Treatment	Bioreclamation/ Aerobic Respiration	A solution containing microorganisms, nutrients, and oxygen is injected into the contaminated areas.	Not Retained	Would not be effective for treating all the organic contaminants at the OU4 subsite.
		Soil-Vapor Extraction (SVE)	A system of wells applies a vacuum to the soil vapor. As the soil vapor is removed, volatile contaminants are also removed. Contaminated soil vapor may require treatment.	RETAINED	The chlorinated organic contaminants are sufficiently volatile for viable removal. The soil type may require a large number of SVE wells.
		Thermally Enhanced SVE	The contaminated soil is heated (by wells and/or thermal blankets for surface soils, by radio frequency heating or hot air or steam for subsurface soils) to increase the capture rate of VOCs and some SVOCs by SVE.	RETAINED	May be useful in accelerating the remediation of the soils.
		Bioventing	Injection of air or pure oxygen into the subsurface stimulates natural biodegradation of contaminants.	Not Retained	Most of the organic contaminants at OU4 are not aerobically degradable.
		Chemical Oxidation	Hydrogen peroxide, permanganate, or other oxidizer is injected into the soil to detoxify the contaminants.	RETAINED	Has already been used at OU4 in the Removal Action. May require multiple applications of chemical.

Table 2-8, Continued
Remedial Technologies and Process Options for Soil, Initial Screening
Operable Unit 4, Orchard Street/Maiden Lane Site
New Haven, Missouri

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	RETAINED/ Not Retained	SCREENING COMMENTS
Treatment (Continued)	In-situ Treatment (Continued)	Stabilization	Pozzolanic ingredients and water are blended with soil in place often using proprietary equipment. The treated soil forms a monolithic, stabilized mass which remains isolated from the environment.	Not Retained	While commercially available and effective for the depths required at the subsite to stabilize low levels of organics, would be difficult to implement due to the high contaminant levels in the OU4 soils.
		Soil Flushing	Soil is flushed with water or other detergent solutions to mobilize contaminants. The contaminated water is intercepted, collected, and pumped to the surface for separation of contaminants.	Not Retained	It would be difficult to collect the contaminated treatment water, which could lead to further groundwater contamination.
		Vitrification	Electrodes are used to create an electric current in the contaminated soil which melts. Soil has to contain significant levels of silicates. Inorganic and some organics are trapped in the melt which forms obsidian or very strong glass as it cools.	Not Retained	Would not be feasible in the developed area around OU4.
		Phyto-remediation	Plants are used to remove and/or treat contaminants in the soils. There are several mechanisms, such as accumulation of the contaminant in the plant or degradation in the plant.	Not Retained	May not be effective or timely for treating the VOCs in the soils. Also, the effectiveness is limited to the shallow soils (i.e., root depth) and much of the contamination is in the bedrock.

Table 2-9
Remedial Technologies and Process Options for Groundwater, Second Screening
Operable Unit 4, Orchard Street/Maiden Lane Site
New Haven, Missouri

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTION	EFFECTIVE-NESS	IMPLEMENTABILITY	RELATIVE COST* (CAPITAL / O&M)	RETAINED /Not Retained	SCREENING COMMENTS
No Action	None	None	Does not meet RAOs	Easily Implemented	None / Very Low	RETAINED	Required by the NCP.
Institutional Controls	Activity and Use Limitations	Deed and Zoning Restrictions	Moderate	Difficult to Implement	Low / Low	Not Retained	Would be too difficult to implement given the number of properties.
		Well Construction Restrictions	Moderate	Special Area 3 regulations completed in 2006.	Low / Low	RETAINED	Would prohibit the installation of substandard water supply wells in the contaminated plume.
		Public Education/ Information	Low	Easily Implemented	Low / Low	RETAINED	Could be easily implemented.
Monitoring	Monitoring	Groundwater Monitoring	Moderate	Easily Implemented	Low / Low to Moderate	RETAINED	Could be used to support other process option.
Containment	Vertical Barriers	Hydraulic Controls, Vertical Wells	Low to Moderate	Difficult to Implement	Moderate to High/ Moderate to High	RETAINED	Moderate to high costs because the plume is deep and in bedrock.
		Hydraulic Controls, Horizontal/ Angle-Drilled Wells	Low to Moderate	Difficult to Implement	Moderate to High/ Moderate to High	RETAINED	Angled wells may be needed due to OU4 topography and access issues.

Table 2-9, Continued
Remedial Technologies and Process Options for Groundwater, Second Screening
Operable Unit 4, Orchard Street/Maiden Lane Site
New Haven, Missouri

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTION	EFFECTIVE-NESS	IMPLEMENTABILITY	RELATIVE COST* (CAPITAL / O&M)	RETAINED /Not Retained	SCREENING COMMENTS
Treatment	Physical Treatment	Reverse Osmosis	Moderate to High	Moderately Difficult to Implement	High/ High	Not Retained	Difficult and costly to keep the membranes clean and effective.
		Granular Activated Carbon (GAC) Adsorption	Moderate to High	Implementable	Moderate/ Low	RETAINED	Retained as the representative process option for low flows.
		Air Stripping/ Packed Columns	High	Implementable	Low to Moderate/ Low	Not Retained	Higher costs than tray aeration. Not retained as the representative process option. Should be evaluated in the RD.
		Air Stripping/Tray Aeration	High	Implementable	Moderate to High/ Moderate to High	Not Retained	Not retained as the representative process option. Pretreatment costs could move O&M costs to moderate. Should be evaluated during RD.
		Steam Stripping	High	Moderately Difficult to Implement	Moderate to High/ High	Not Retained	Not retained as the representative process option. More costly than air stripping.

Table 2-9, Continued
Remedial Technologies and Process Options for Groundwater, Second Screening
Operable Unit 4, Orchard Street/Maiden Lane Site
New Haven, Missouri

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTION	EFFECTIVE-NESS	IMPLEMENTABILITY	RELATIVE COST* (CAPITAL / O&M)	RETAINED /Not Retained	SCREENING COMMENTS
Treatment (Continued)	Chemical Treatment	Ion Exchange	Moderate	Implementable	Moderate to High/ Moderate to Low	Not Retained	Higher capital costs than GAC adsorption. May have lower O&M costs than GAC; not retained as representative process option - should be evaluated during RD
		Chemical Oxidation	Moderate	Moderately Difficult to Implement	Moderate / Moderate	Not Retained	Higher costs than air stripping. Not retained as representative process option - should be evaluated during RD.
		Ultraviolet/ Chemical Oxidation	Moderate to High	Moderately Difficult to Implement	Moderate / Moderate	Not Retained	Higher costs than air stripping; should be evaluated during RD - not retained as a representative process option.
	Biological Treatment	Aerobic Processes	Moderate to High	Difficult to Implement	High / High	Not Retained	Requires disposal of residual waste. Higher costs than air stripping. Not able to treat all the COCs at the subsite. Would also require anaerobic processes.

Table 2-9, Continued
Remedial Technologies and Process Options for Groundwater, Second Screening
Operable Unit 4, Orchard Street/Maiden Lane Site
New Haven, Missouri

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTION	EFFECTIVE-NESS	IMPLEMENTABILITY	RELATIVE COST* (CAPITAL / O&M)	RETAINED /Not Retained	SCREENING COMMENTS
Treatment (Continued)	Biological Treatment (Continued)	Anaerobic Process	Moderate to High	Very Difficult to Implement	High / High	Not Retained	Requires disposal of residual waste. Anaerobic processes are usually batch processes and require large numbers of tanks.
		Trickling Filter	Moderate to High	Very Difficult to Implement	Moderate / Moderate	Not Retained	Requires disposal of residual waste. Requires a large surface area.
		Rotating Biological Contractors (RBCs)	Moderate	Difficult to Implement	High / Moderate	Not Retained	Requires disposal of residual waste. Higher costs than air stripping. Not able to treat all the COCs at the subsite. Would also require anaerobic processes.
Disposal	On-site Treated Effluent Discharge	Discharge to Floodway	Moderate	Difficult to Implement	Low / Low	RETAINED	Treated water would be discharged to the Missouri River.
	Off-site Treated Effluent Discharge	Public Owned Treatment Works (POTW)	High	Very Difficult to Implement	Low / Low	Not Retained	Would use too much of the local POTW's spare capacity.
		Discharge to Floodway	Moderate	Difficult to Implement	Low / Low	RETAINED	Treated water would be discharged to the Missouri River.

Table 2-10
Remedial Technologies and Process Options for Soil, Second Screening
Operable Unit 4, Orchard Street/Maiden Lane Site
New Haven, Missouri

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTION	EFFECTIVE-NESS	IMPLEMENTABILITY	RELATIVE COST* (CAPITAL / O&M)	RETAINED /Not Retained	SCREENING COMMENTS
No Action	None	None	Low	Easily Implemented	None / Very Low	RETAINED	Required by the NCP.
Institutional Controls	Activity and Use Limitations	Fencing	Moderate	Moderately Difficult to Implement	Low / Low	Not Retained	Would be used to support soil containment. Not retained as a primary treatment option.
Monitoring	Monitoring	Groundwater Monitoring	Moderate	Easily Implemented	Low / Low	Not Retained	Not retained as a primary soil process option.
		Soil Monitoring	Moderate	Easily Implemented	Low / Low	Not Retained	Would be used to support excavation. Not retained as a primary treatment option.
Containment	Capping	Multi-Layer	High	Difficult to Implement	Low to Moderate/ Low	RETAINED	Would be used over the source area only.
	Surface Controls	Revegetation or Stone Covers	Low to Moderate	Difficult to Implement	Low / Low	Not Retained.	Not retained as a primary process option. Would only be used near the source area.
		Drainage Controls	Low to Moderate	Difficult to Implement	Low / Low	Not Retained	Not retained as a primary process option. Would only be used near the source area.

Table 2-10, Continued
Remedial Technologies and Process Options for Soil, Second Screening
Operable Unit 4, Orchard Street/Maiden Lane Site
New Haven, Missouri

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTION	EFFECTIVE-NESS	IMPLEMENTABILITY	RELATIVE COST* (CAPITAL / O&M)	RETAINED /Not Retained	SCREENING COMMENTS
Containment (Continued)	Vertical Barriers	Sheet Piling	Moderate	Difficult to Implement	High/ Very Low	RETAINED	Retained as a primary process option to contain source area soil. Could also be used to support excavation.
		Rock Grouting	Moderate	Difficult to Implement	Moderate / Low	RETAINED	Retained as a primary process option to contain shallow contamination in bedrock.
Removal	Excavation	Mechanical Excavation	Moderate to High	Difficult to Implement	Moderate / Very Low	Not Retained	Would be used for source area soils and shallow bedrock only. Access to remove soils difficult. Excavation would likely have to be dewatered. Excavated soils would likely require treatment before any disposal. Would only be used if ISCO is found to be ineffective.

Table 2-10, Continued
Remedial Technologies and Process Options for Soil, Second Screening
Operable Unit 4, Orchard Street/Maiden Lane Site
New Haven, Missouri

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTION	EFFECTIVE-NESS	IMPLEMENTABILITY	RELATIVE COST* (CAPITAL / O&M)	RETAINED /Not Retained	SCREENING COMMENTS
Disposal	Off-site Disposal	RCRA-permitted Landfill	High	Difficult to Implement	Moderate/ Low	Not Retained	Would be used for soils contaminated above soil cleanup levels. Some contamination might remain in the shallow bedrock. Temporary storage locations for sorting difficult to obtain, as area is completely developed. Access during the Work would also be difficult to manage, as area is completely developed. Should be evaluated during RD if excavation is required.

Table 2-10, Continued
Remedial Technologies and Process Options for Soil, Second Screening
Operable Unit 4, Orchard Street/Maiden Lane Site
New Haven, Missouri

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTION	EFFECTIVE-NESS	IMPLEMENTABILITY	RELATIVE COST* (CAPITAL / O&M)	RETAINED /Not Retained	SCREENING COMMENTS
Disposal (Continued)	Off-site Disposal (Continued)	Solid Waste Landfill	High	Difficult to Implement	Low to Moderate/ Low	Not Retained	Would be used for soils contaminated above soil cleanup levels, but below RCRA TCLP Land Ban limits. Some contamination might remain in the shallow bedrock. Temporary storage location for sorting difficult to obtain, as area is completely developed. Access during the Work would also be difficult to manage, as area is completely developed. Should be evaluated during RD if excavation is used.
	On-site Disposal	Waste Piles	Low	Difficult to Implement	Low / None	Not Retained	Not retained as a primary process option. Would be used for temporary storage for ex-situ treatment or disposal.

Table 2-10, Continued
Remedial Technologies and Process Options for Soil, Second Screening
Operable Unit 4, Orchard Street/Maiden Lane Site
New Haven, Missouri

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTION	EFFECTIVE-NESS	IMPLEMENTABILITY	RELATIVE COST* (CAPITAL / O&M)	RETAINED /Not Retained	SCREENING COMMENTS
Treatment	Physical, Ex-Situ Treatment	Mechanical Separation	Moderate	Easily Implemented	Low / None	Not Retained	Not retained as a primary process option. Would be used as the first step for ex-situ treatment or off-site disposal.
		Soil Venting	Moderate	Moderately Difficult to Implement	Low / None	Not Retained	Not retained as a primary process option. Would be used as the second step for ex-situ treatment or off-site disposal. Should be evaluated during RD if excavation is necessary.
	Physical / Chemical, Ex-situ Treatment	Solvent Extraction	Moderate	Difficult to Implement	High / None	RETAINED	Contaminated solvent will require treatment or disposal. Excavated soils will probably require mechanical separation. Temporary storage and treatment locations for difficult to obtain, as area is completely developed. Access during the Work would also be difficult to manage, as area is completely developed. Should be evaluated during RD if excavation is necessary.

Table 2-10, Continued
Remedial Technologies and Process Options for Soil, Second Screening
Operable Unit 4, Orchard Street/Maiden Lane Site
New Haven, Missouri

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTION	EFFECTIVE-NESS	IMPLEMENTABILITY	RELATIVE COST* (CAPITAL / O&M)	RETAINED /Not Retained	SCREENING COMMENTS
Treatment (Continued)	Physical / Chemical, Ex-situ Treatment (Continued)	Soil Washing	Moderate	Moderately Difficult to Implement	Moderate / None	Not Retained	Less effective than solvent extraction, so not retained as the representative process option. Should be evaluated during RD if excavation is necessary.
	Physical / Thermal, Ex-situ Treatment	Off-site Incineration	High	Easily Implemented	High / None	Not Retained	Not as cost effective as disposal in an off-site RCRA landfill.
		On-site Incineration	High	Very Difficult to Implement	High / None	Not Retained	Difficult to implement in the developed area around OU4.
		Thermal Desorption	High	Difficult to Implement	Moderate / Moderate	Not Retained	More costly and difficult to implement than solvent extraction, so not retained as a representative process option. Should be evaluated in the RD if excavation is necessary.
	Biological, Ex-situ Treatment	Bioslurry Reactors	Moderate	Difficult to Implement	Moderate to High / None	Not Retained	More costly and difficult to implement than solvent extraction, so not retained as a representative process option. Should be evaluated in the RD if excavation is necessary.

Table 2-10, Continued
Remedial Technologies and Process Options for Soil, Second Screening
Operable Unit 4, Orchard Street/Maiden Lane Site
New Haven, Missouri

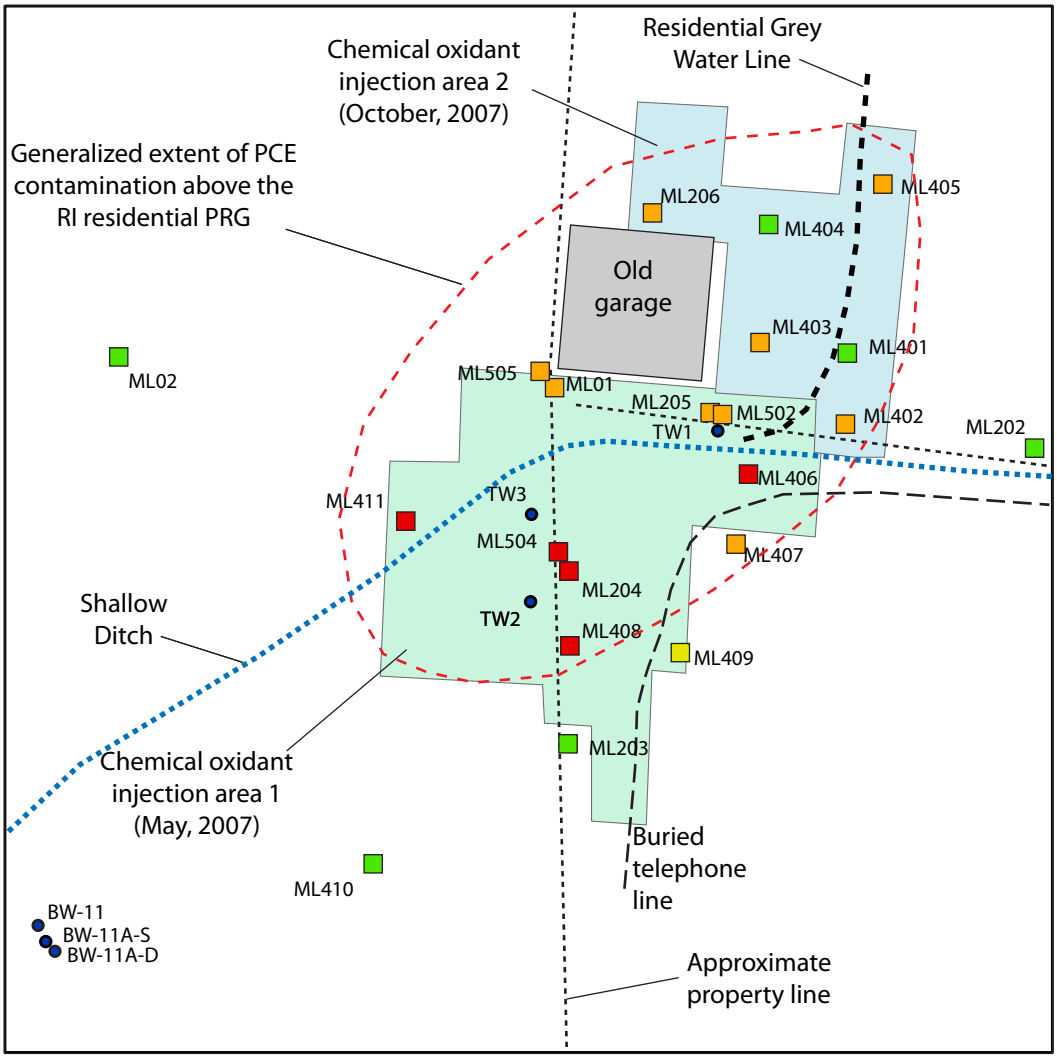
GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTION	EFFECTIVE-NESS	IMPLEMENTABILITY	RELATIVE COST* (CAPITAL / O&M)	RETAINED /Not Retained	SCREENING COMMENTS
Treatment (Continued)	Biological, Ex-situ Treatment (Continued)	Biopiles	Moderate	Difficult to Implement	Low to Moderate / None	Not Retained	Less effective than bioslurry reactors and more difficult to implement than solvent extraction. Not retained as a representative process option.
	In-situ Treatment	Soil-Vapor Extraction (SVE)	Moderate	Moderately Difficult to Implement.	Moderate / Moderate	Not Retained	Less effective than TE-SVE in the soil and rock types present at the site, so not retained as a representative process option.
		Thermally Enhanced SVE	Moderate	Difficult for Source Area Soils	Very High / Low	Not Retained	May not be more effective than in-situ chemical oxidation. Would require installation of over 100 wells to implement. Could treat DNAPL in shallow bedrock. Should be evaluated during RD if DNAPL is present in the bedrock.
		Chemical Oxidation	Moderate	Moderately Difficult to Implement.	Low to Moderate / Moderate	RETAINED	O&M costs moderate because several applications of chemical may be necessary.

Table 2-11
Groundwater Process Options Retained for the Development of Remedial Alternatives
Operable Unit 4, Orchard Street/Maiden Lane Subsite
New Haven, Missouri

General Response Action	**Process Options**
No Action	None
Institutional Controls	Well Construction Restrictions
	Public Education/ Information
Monitoring	Groundwater Monitoring
Containment	Hydraulic Controls, Vertical Wells
	Hydraulic Controls, Horizontal/Angle-Drilled Wells
Treatment	Granular Activated Carbon (GAC)
Disposal	On-Site Discharge of Treated Effluent to Floodway
	Off-site Discharge of Treated Effluent to Floodway

Table 2-12
Soil Process Options Retained for the Development of Remedial Alternatives
Operable Unit 4, Orchard Street/Maiden Lane Subsite
New Haven, Missouri

General Response Action	**Process Options**
No Action	None
Institutional Controls	Public Education/ Information
Monitoring	Groundwater Monitoring
	Soil Monitoring
Containment	Multi-Layer Cap
	Sheet Piling
	Rock Grouting
Treatment	In-situ Chemical Oxidation



EXPLANATION

0 12.5 25 50 Feet

TW3 Monitoring well and number

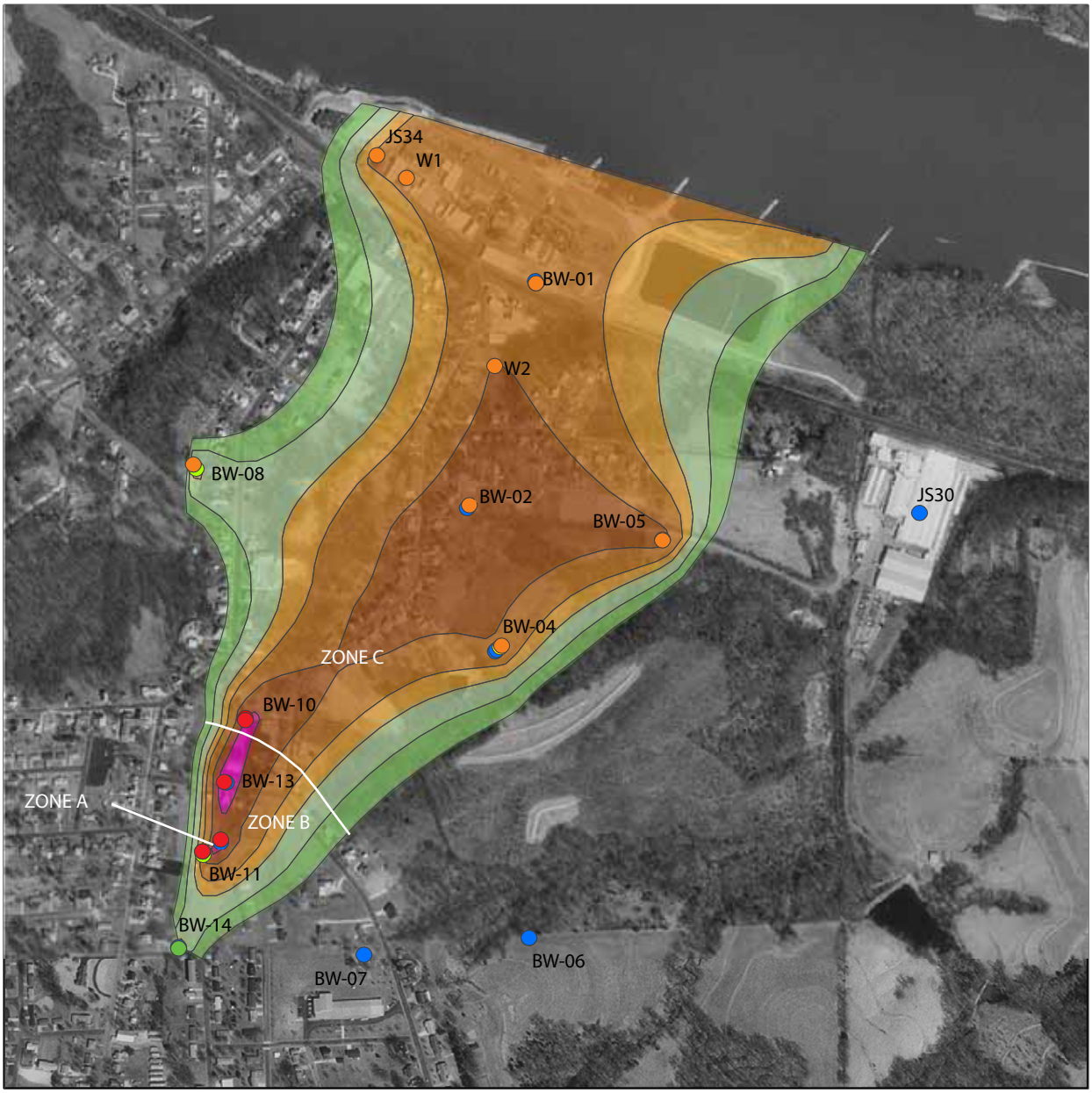
RI PCE PRG IS 483 ug/kg

Maximum PCE concentration detected by the laboratory or portable gas-chromatograph in samples from soil boring. Concentrations in micrograms per kilogram (ug/kg) kilogram

- Less than 1
- 1.0 to 239.9
- 240 to 479.9
- 480 to 479,999
- 480,000 to 8,000,000

FIGURE 2-1
APPROXIMATE EXTENT OF SOIL PCE CONTAMINATION ABOVE THE RESIDENTIAL PRG
RIVERFRONT SUPERFUND SITE
OPERABLE UNIT 4 FS

SOURCE: USGS OU4 RI, 2008
Z:\044706\C0008334.ai 8/6/2008



Base from U.S. Geological Survey digital orthophoto, 1:24,000, 1927 Universal Transverse Mercator projection Zone 15

0 375 750 1,500 Feet

EXPLANATION

MAXIMUM TETRACHLOROETHENE (PCE) CONCEN - TRATION IN MONITORING WELL CLUSTER -Concen - trations in micrograms per liter

- Not detected
- Less than 5.0 ug/l
- 5.0 to 499
- Greater than 500

ESTIMATED TETRACHLROETHENE (PCE) CONCENTRATION IN GROUND-WATER -Concentrations in micrograms per liter

- Less than 0.1
- 0.1 to 0.99
- 1.0 to 4.99
- 5.0 to 49.9
- 50 to 499
- 500 to 4,999
- Greater than 5,000

NOTE: WESTERN EDGE OF PLUME NOTE FULLY DEFINED.

FIGURE 2-2
LATERAL EXTENT OF THE OU4 GROUNDWATER PCE PLUME
RIVERFRONT SUPERFUND SITE
OPERABLE UNIT 4 FS

SOURCE: USGS OU4 RI, 2008
Z:\044706\C0008335.ai 8/6/2008

3.0 Development of Alternatives

The process options that appear to be the most applicable for the subsite conditions at OU4 were identified in Section 2.0. The individual process options have been combined to develop possible solutions for the contamination problem at OU4. These possible solutions are referred to as remedial alternatives. The *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA*, (USEPA, 1988a) indicates that each alternative shall combine the technologies and the media to which they apply into an alternative that addresses site-wide contamination.

3.1 Basis for Alternative Development

This section discusses the basis used to formulate remedial alternatives for the contaminated groundwater and soils at OU4. In this section, the retained process options described in Section 2.0 are developed into viable remedial alternatives. These alternatives were formulated in accordance with USEPA guidance criteria (USEPA, 1988a; USEPA 1988b; USEPA, 1989a; and USEPA, 1992).

The goals in developing the preliminary remedial alternatives are to provide both a range of cleanup options and sufficient detail to adequately compare alternatives. The USEPA guidance document for remedial actions for contaminated groundwater at Superfund sites (USEPA, 1988a) recommends that alternatives be developed that achieve cleanup levels with varying time frames using different methodologies. The guidance document suggests three general types of response actions: a no action response, plume containment, and active remediation. The groundwater portions of the remedial alternatives include the first two general types of response actions so as to provide ranges in the time and costs required for practicable remediation activities. No active remediation alternatives have been prepared because active remediation of the plume would be impracticable. See Appendix B, which contains the Groundwater Technical Impracticability Evaluation Report.

For soils, in conformance with the NCP and the FS guidance, alternatives were developed that fit into five general compliance categories: (1) no action, (2) attaining ARARs, (3) exceeding ARARs, (4) meeting CERCLA criteria without attaining all ARARs and (5) off-site treatment or disposal.

The operational period for each of the alternatives was determined by the process options used in the alternative, subsite conditions, and the amounts of contamination. The operational periods were used to calculate the costs, especially the O&M costs, for the alternatives. The operational period selected was 30 years, for the no action, limited action, and containment alternatives. While it is likely that these alternatives would have

to continue to operate beyond 30 years, the operational period was limited to 30 years because of general uncertainties concerning conditions beyond 30 years.

The RI (USGS, 2008) concluded that significant contamination had already migrated from the source area soils through the groundwater and probably on to the Missouri River. The HHRA found that there was soil contaminated with COCs at levels that caused unacceptable risks to human health and would continue to cause contamination of groundwater at levels above MCLs and that the groundwater was contaminated with COCs at levels that posed unacceptable risks to future residents and that exceeded MCLs. However, because the contaminant plume is located in deep bedrock, the surface topography is very rugged, and the area above the plume fully developed as residences, remediation of the plume is impracticable. See Appendix B, which contains the Groundwater Technical Impracticability Evaluation Report. Therefore, the remedial alternatives in this FS were developed to remediate the remaining soil contamination in OU4 and monitor the groundwater contamination. Figure 2-1 summarizes the extent of the soil contamination while Figure 2-2 shows the lateral extent of the PCE groundwater plume.

The remedial alternatives have been grouped into three categories, no action, containment, and active remediation, based on the soil remedy selected. The categories and the alternatives are briefly discussed in the following subsections. For the groundwater plume, no action, monitoring, and containment alternatives have been prepared. The soil no action and containment alternatives have been paired with the groundwater no action and containment alternative, respectively. The soil treatment alternative has been paired with the groundwater monitoring alternative, as treatment of the groundwater plume is impracticable.

Table 3-1 summarizes the alternatives by illustrating which process options are included in each alternative. All tables are located at the end of this section.

The following sections discuss the soil remedial alternatives and the groundwater remedial alternatives.

3.1.1 Soil Remedial Alternatives

The following sections provide general descriptions of the alternatives. For detailed descriptions, see Section 3.2.

3.1.1.1 No Action

The no action response would not attempt to remediate or monitor the contamination in the soils. One No Action Alternative has been developed for the OU4 soils. Soil Alternative 1 (S1) would involve no on-site actions. The no action alternative

is discussed in Section 3.2.1. As discussed above, a 30-year life was assumed for the no action alternative.

3.1.1.2 Containment

Soil containment refers to preventing the migration of soil contaminants to the groundwater contaminant plume by using various technologies. As discussed above, a 30-year life was assumed for the containment alternatives. To develop the containment alternatives and their costs, current subsite data and various assumptions were used. Different decisions could be made at the time of remedial design and during the course of the remedy based on the most current available data.

Alternative S2 would contain the contaminated soils. The soils would be contained by installing a cap over the contaminated soils, a sheet pile enclosure around the perimeter of the contaminated soils, and conducting rock grouting in the shallow bedrock below the contaminated soils. With the source of the plume isolated, natural attenuation processes (dispersion and advection) should begin to restore the plume. As discussed in Section 2.3.2, for this alternative it was conservatively assumed that the volume of soil that would require containment would be equal to the volume of contaminated soil provided in the RI. Because the soils have been treated, it is probable that the remaining soil volume that would require containment is less than the RI estimate. This alternative is further discussed in Section 3.2.1.

3.1.1.3 Active Remediation

Active remediation refers to alternatives that use treatment to reduce the contaminated soil contaminant levels to the required cleanup levels in the minimal time feasible. Unlike the 30-year operational period assumed for the no action and containment alternatives, the operational periods for the active soil remediation alternatives vary. To develop the active remediation alternatives and their costs, current subsite data and various assumptions were used. Different decisions could be made at the time of remedial design and during the course of the remedy based on the most current available data. As discussed in Section 2.3.2, for these alternatives it was conservatively assumed that the volume of soil that would require treatment would be equal to the volume of contaminated soil provided in the RI. Because the soils have been treated, it is probable that the remaining soil volume that would require remediation is less than the RI estimate.

Based on the RI, several observations can be made about the soil contamination in OU4: there was residual contamination at the vadose zone of the source area soils and the

shallow bedrock; the source area soils and the contaminated bedrock both have low permeability; the possibility of DNAPL contamination in the deep soils and shallow bedrock must be investigated, and; the degree of soil remediation from the two removal actions has not been determined. Because of these observations, considerable uncertainty exists about the time frame of the remediation of the remaining soil contaminants. While most of the soil contaminants are in the deep soils and residuum above the bedrock, it is possible that DNAPL has migrated into the shallow bedrock below the soils. Therefore, the active soil remediation alternative is designed to determine the location and levels of remaining contamination in the source area soils and shallow bedrock first, then concentrate on remediating the contamination.

Active remediation alternatives generally reduce soil contaminant levels more rapidly than containment alternatives and much more rapidly than the no action alternative. However, active remediation alternatives generally entail higher costs. Active remediation alternatives have higher costs because the active remediation alternatives generally require more equipment (such as treatment chemical injection equipment) and have higher fees (such as off-site disposal fees), which results in higher capital costs and they usually treat more aggressively, which results in higher O&M costs.

One alternative has been developed that would provide active soil remediation. Alternative S3 would use in-situ chemical oxidation to treat the contaminated soils. This alternative is discussed in Section 3.2.1.

If the soil contamination proves to be recalcitrant to the in-situ treatment, it may be necessary to excavate the soils and either dispose of them offsite or treat them on-site and use the treated soils as backfill. As discussed in Section 2.7.2.4, various above ground treatment technologies should be evaluated if above ground treatment is found to be necessary. Likewise, if substantial amounts of DNAPL are found at depths were excavation is impracticable, other in-situ treatment technologies may need to be evaluated.

3.1.2 Groundwater Remedial Alternatives

The following sections provide general descriptions of the alternatives. For detailed descriptions, see Section 3.2.

3.1.2.1 No Action

The no action response would not attempt to remediate or monitor the contamination in the groundwater. One No Action Alternative has been developed for the OU4 groundwater plume. Groundwater Alternative 1 (GW1) would involve no on-

site actions. The no action alternative is discussed in Section 3.2.2. As discussed above, a 30-year life was assumed for the no action alternative.

3.1.2.2 Monitoring

Groundwater Alternative 2 (GW2), the monitoring alternative, would monitor the plume to determine if the plume was migrating beyond its current location, the plume's current contaminant levels, and if any new sensitive receptors were threatened. Alternative GW3 would also use institutional controls to minimize contact with the contaminated groundwater. The limited action alternative is discussed in Section 3.2.2. As discussed above, a 30-year life was assumed for the limited action alternative.

3.1.2.3 Containment

Plume containment refers to preventing the migration of a contaminant plume by using various technologies. Groundwater Alternative 3 (GW3) would use hydraulic controls (groundwater extraction wells) to minimize further contaminant migration. The extracted groundwater would require treatment and disposal by other technologies retained in Section 2.0. This alternative is further discussed in Section 3.2.2. To develop the containment alternative and its costs, current subsite data and various assumptions were used. Different decisions could be made at the time of remedial design and during the course of the remedy based on the most current available data. As discussed above, a 30-year life was assumed for the containment alternative, GW3.

3.1.3 Five-Year Review

For all the alternatives, 5-year reviews would be required pursuant to CERCLA and the NCP because contamination above MCLs would be present in the groundwater for the operational period of the alternative. It should be noted that the operational period for the groundwater no action, limited monitoring, and containment alternatives has been assumed to be 30 years. The operational period for the soil RA alternatives has been assumed to be between 1 and 5 years.

3.2 Description of Alternatives

Three soil and three groundwater alternatives have been developed for OU4. They are discussed below. Section 3.2.1 describes the soil alternatives, while Section 3.2.2 describes the groundwater alternatives. The alternatives developed include: a no action alternative for both the soil and groundwater, which is required as a baseline for comparison; an on-site soil containment alternative; an active soil remediation

alternative; a groundwater monitoring alternative, and; a groundwater containment alternative. No active groundwater remediation alternatives have been developed, as active remediation of the groundwater plume is impracticable. See Appendix B, which contains the Groundwater Technical Impracticability Evaluation Report.

3.2.1 Soil Alternative Descriptions

The following sections describe the three soil remedial alternatives.

3.2.1.1 Alternative S1 -- No Action

Alternative 1 would not involve any RAs, and the subsite would remain in its present condition. This alternative, required by the NCP and CERCLA, is a baseline alternative against which the effectiveness of the other alternatives can be compared. Under the no action alternative, the subsite is left "as is" and no funds would be expended for monitoring, control, or cleanup of the remaining contaminated soils. However, a 5-year review of the subsite would be required under CERCLA, so funds would have to be expended to conduct the review. The 5-year reviews for OU4 would actually be conducted on the 5-year review schedule for OU1, because the long term remedial action (LTRA) of OU1 has already begun. The 5-year review would be a site-wide review, with OU4 being one of the OUs reviewed.

3.2.1.2 Alternative S2 – On-Site Containment Using Capping, Sheet Piling, and Rock Grouting

Alternative S2 would isolate the contaminated soils from the groundwater by containing them inside a capped, sheet piling enclosure with a rock grout “floor”.

Soil sampling and a DNAPL investigation would be conducted to determine the edge of the soil volume contaminated above the soil cleanup goals. The cleanup goals used to determine the limits of the sheet piling enclosure and cap would be based on the soil COCs for OU4. The cleanup goals are summarized in Table 3-2.

The soil monitoring would consist of direct push sampling of the source area soils and a DNAPL investigation of the shallow bedrock during installation of the two new monitoring wells in the source area. The direct push sampling of the source area soils would be conducted to determine the effectiveness of the two in-situ treatment efforts conducted in 2007 (Section 1.4.7). Direct push sampling would be conducted in a grid within the contaminated volume. The cleanup goals used to determine the effectiveness of the treatment would be based on the three soil COCs for OU4 and are listed in Table 3-2. The DNAPL investigation would consist of sampling the shallow bedrock during

installation of the two new monitoring well nests in the source area. The DNAPL sampling would determine the extent and depth, if any, of DNAPL into the bedrock. The wells would be installed in the boreholes after the DNAPL investigation had been completed. During the installation of the well nests in the boreholes, care would be taken to seal off any DNAPL zones detected in the boreholes to prevent migration of DNAPL to deeper zones. If necessary, the well boreholes would be abandoned to ensure that any DNAPL zones are sealed off and the new well nests would be installed at nearby offset locations.

The USEPA has conducted two rounds of in-situ soil treatment (see Section 1.4.7) of the source area soils but has not yet conducted confirmatory sampling to determine the post-treatment contaminant levels. The soil treatments were designed to treat the contaminant levels found in the RI soil sampling and the PSOD so it is probable that except for recalcitrant hotspots the soil contamination has been remediated. Therefore, the USEPA and MDNR will evaluate the source area soil confirmation sample results and the DNAPL results to determine the remediation status of the source area soils and the shallow bedrock. After the current soil contamination levels are determined by the soil/DNAPL sampling efforts, the soil contamination activities would be planned.

In addition to the soil and DNAPL sampling, in-door air sampling of the residences around the source area soils would be conducted in the first year of the alternative. After access was granted by the homeowner, in-door air samples would be collected twice, once during a season when the home was closed up (Winter or Summer) and once during a season when the home was open (Spring or Fall).

A detailed sampling and quality assurance plan would be written before the soil monitoring activities began. The sampling and quality assurance plans would include sample locations, sampling frequency, sampling procedures, sample analysis methods, and sample documentation procedures. This sampling could also be conducted during the RD. See Table 3-2.

Based on the information obtained during the DNAPL investigation, rock grouting would be conducted below the depth of any DNAPL contamination in the shallow bedrock. If DNAPL is not found in the shallow bedrock, the rock grouting will be conducted in the layer of competent rock below the soils. The rock grouting could be conducted before or after the sheet piling installation.

The building that covers part of the contaminated soils (the old garage) would be demolished and the debris disposed of in a construction landfill.

Next, sheet piling would be driven from the ground surface to the Cotter dolomite formation below the subsite (15 to 20 feet below ground surface [bgs]) to enclose the soil contaminated above the soil cleanup levels. At least one electric power pole would have

to be moved before the sheet piling could be installed.

The multi-layer cap would then be placed to cover the area defined by the direct push sampling. It would direct surface water runoff to the edges of the cap and would be laid so as to prevent water from pooling on the cap.

After the sheet piling had been installed, three extraction wells and three piezometers would be installed within the containment volume. Their installation would be coordinated with the cap installation to minimize the amount of repairs (from trenching and well installation) to the cap.

The multi-layer cap would require regular maintenance to check for vegetation growth (especially trees), blockages of the drainage channels, or subsidences. These types of damage would have to be regularly repaired to maintain the integrity of the cap.

Institutional controls for the soils would consist of proprietary controls in the form of environmental covenants on the properties where the containment structures were built. These controls would restrict activities that could damage the cap or the sheet piling enclosure and would allow USEPA, MDNR, or their contractors access to maintain the cap, the enclosure's pumping wells, and the pipe from the wells to the treatment system.

The groundwater inside the enclosure would be pumped to keep the groundwater table inside the enclosure lower than the surrounding perched groundwater. The extraction wells in the enclosure would only be pumped at the minimum rate to ensure that groundwater flow would be into the enclosure. This would minimize further migration of PCE from the soils to the groundwater plume. For this alternative, is has been assumed that three extraction wells within the soil containment volume would be sufficient to control the groundwater flow gradient. The wells would be pumped at between 0.5 and 2.5 gpm, for an approximate total of 3 gpm combined. Five piezometers, three inside and two outside the enclosure would be installed to monitor the groundwater flow gradient and groundwater table elevation inside the enclosure.

The groundwater would be pumped to a treatment system through double contained piping with a leak detection system. This treatment system would be similar to the system described in Alternative GW3. See Section 3.2.2.3 for the detailed description of the treatment system. The proposed locations of the underground piping between the wells and the treatment system and of the discharge piping from the treatment system are shown on Figure 3-1. The final location of the piping, the treatment system, and the discharge point would be determined during the RD.

The cost estimate for this alternative includes costs for discharging the treated water into one of the storm drains that go through the United States Army Corps of Engineers (USACE) flood control levee to the Missouri River. During the RD, the costs

of installing a dedicated pipeline to carry the treated water over the levee should be investigated.

The continuing source of the groundwater plume should be removed once the contaminated soils are enclosed within the sheet piling and rock grouting and capped. Future contaminant migration from the soils to the groundwater should be minimized, both by the sheet piling/rock grouting and by the extraction wells within the sheet piling/rock grouting enclosure. As discussed above, the RI found that most of the downgradient plume is dissolved (very little contaminant mass is sorbed to the aquifer materials). Therefore, once the source of the groundwater contamination is removed by containment of the source area soils, NA processes should begin to restore the aquifer. The time necessary for NA processes to restore the aquifer is unknown due to many complicating factors. The primary uncertainties include the distribution of contaminants in the bedrock (including the possibility that there may be some amount of DNAPL outside the containment), the rates of dispersion and advection of these contaminants in the downgradient plume groundwater, and the degree of success in isolating the source area soils from the aquifer. However, Alternative S2 should restore the downgradient portion of the aquifer (essentially, Zone C) more quickly than Alternative S1.

3.2.1.3 Alternative S3 - In-Situ Chemical Oxidation Treatment

Alternative S3 would use in-situ chemical oxidation to treat the contaminated soils.

Soil sampling and a DNAPL investigation would be conducted as described in Alternative S2 to determine the edge of the soil volume contaminated above the soil cleanup goals. The cleanup goals used to determine the limits of the treatment volume would be based on the soil COCs for OU4. The cleanup goals are summarized in Table 3-2.

Indoor air monitoring of the residences near the source area soils would also be implemented as described in Alternative S2.

To develop this alternative and provide cost estimates, a combination of engineering judgment, assumptions, and technical information were used. Different decisions about the application rate and application quantities could be made at the time of RD based on the most current available data.

One primary reason for the selection of chemical oxidation is that when PCE is chemically oxidized, it is not oxidized sequentially into its biodegradation products. Instead it degrades in one step into carbon dioxide, water, and salt. If the PCE was degraded sequentially (as occurs during biodegradation, for example), it would degrade into TCE, then cis-DCE, and finally VC. As PCE's degradation products all pose as

great a threat to human health and the environment as PCE itself, having PCE degraded in one step would be preferable, and would minimize the time needed to remediate the soils.

The contaminated source area soils would be treated in-situ by chemical oxidation. The treatments would be very similar to the two in-situ chemical oxidation treatment efforts conducted during the RA. The 2007 source area treatments are shown on Figure 2-2. During the RD, the source area soils would be sampled on a grid pattern using direct push technology to determine the current extent of contamination. The injection efforts would be conducted during the period with the lowest perched water table levels (late summer or early fall). For costing purposes, it was assumed that one more injection effort covering the entire source area would be necessary. This effort would be conducted in Year 1. Direct push sampling would be conducted in Year 2 to evaluate the effectiveness of the injection. It was assumed that in Year 3 an additional effort over half the source area would be needed and that in Year 5 the final injection effort would be conducted, on 25% of the source area (the volume that contained the 8,000,000 ug/kg of PCE). Direct push sampling efforts (appropriately scaled down) would be conducted in Year 4 to determine the locations of the residual soil contamination and in Year 6 to confirm that the soils have been remediated. As a final confirmation that no rebound contamination has occurred, the soils will be sampled again in Year 9, just before the second 5-year review. The sample results would be used to plan the chemical injection efforts during remediation and to confirm that no additional treatment is necessary (Years 6 and 9).

Institutional controls for the soils would consist of public education/ information. Institutional controls would only be necessary until the soil treatment had been completed and sampling had confirmed that no soil contamination above cleanup goals remained.

3.2.2 Groundwater Alternative Descriptions

The following sections describe the three groundwater remedial alternatives.

3.2.2.1 Alternative GW1 -- No Action

Alternative GW1 would not involve any RAs, and the subsite would remain in its present condition. This alternative, required by the NCP and CERCLA, is a baseline alternative against which the effectiveness of the other alternatives can be compared. Under the no action alternative, the subsite is left "as is" and no funds would be expended for monitoring, control, or cleanup of the contaminated groundwater. However, a 5-year review of the subsite would be required under CERCLA, so funds would have to be expended to conduct the review. The 5-year reviews for OU4 would actually be

conducted on the 5-year review schedule for OU1, because the long term remedial action (LTRA) of OU1 has already begun. The 5-year review would be a site-wide review, with OU4 being one of the OUs reviewed. In addition, the monitoring wells currently being used to monitor OU4 must at some time be properly closed, so capital costs for this work have been included because the wells would not be used in the future under this alternative.

3.2.2.2 Alternative GW2 – Monitoring

Alternative GW2 would use groundwater monitoring and institutional controls to address the potential health risks associated with the contaminated groundwater. This alternative would not actively restore the aquifer, but would monitor the plume to ensure that any migration of the plume towards sensitive receptors would be detected.

For the purpose of developing this alternative, it was assumed that five new monitoring wells would be installed. Two wells would be installed in or near the source area soils; one would be installed at the downgradient edge of the plume, to determine the depth of the plume at that location; one additional well would be installed west of BW-08, and; the last additional well on the eastern side of the plume. The five proposed well sites are shown on Figure 3-2. The final locations and depths of the wells would be determined during design and would be contingent on current data results from the existing wells and upon access agreements with the property owners and the City of New Haven.

It was assumed that nineteen existing wells (with 29 sampling depths) and the five new wells (with ten sampling depths) would be sampled quarterly for 2 years, twice a year for 3 years, and annually thereafter or until RAOs are attained. The frequency of the monitoring could be reevaluated and modified after the five-year reviews or after review of monitoring data by the USEPA and MDNR. The groundwater samples would be sampled for the following parameters:

- VOCs
- Dissolved oxygen (DO) (field parameter)
- Specific conductance (field parameter)
- pH (field parameter)
- Oxidation reduction potential (ORP) (field parameter)
- Temperature (field parameter)

Given the depth of the wells that must be sampled, the samples would have to be collected using pumps.

The results of the sample analysis would be used, possibly with aquifer screening models, to evaluate the rate and direction of groundwater contaminant migration. If the monitoring results indicate that the plume is migrating towards new receptors, further RAs could be initiated.

A detailed sampling and quality assurance plan would be written before the groundwater monitoring activities began. The sampling and quality assurance plans would include sample locations, sampling frequency, sampling procedures, sample analysis methods, and sample documentation procedures. Wells from the existing monitoring well network would be used as much as possible to avoid duplication of effort and to minimize the number of new monitoring wells installed. New monitoring wells would be added to the existing monitoring well network to provide further definition of the plume and to provide data on especially important areas of the plume, such as the western edge of the plume near BW-08.

Alternative GW2 would include well construction restrictions and public education/ information to prevent human use of the groundwater at OU4. Well construction restrictions would prevent the construction of substandard wells, which could spread contamination at or near OU4. The rules for Special Area 3, which includes all of OU4, have been finalized by the State of Missouri. Therefore, any new wells installed within OU4 will have to comply with the well construction standards in the Area 3 rules as well as the Missouri New Water Supply Well requirements. Public education/ information would be performed to inform the city officials and land owners residing in OU4 of the restrictions on well drilling within the boundaries of OU4. Public education would be conducted through informational meetings and flyers. As in Alternative GW1, 5-year reviews would be required under CERCLA 121(c).

3.2.2.3 Alternative GW3 – Hydraulic Containment and Above Ground Treatment

Alternative GW3 would use hydraulic containment, above ground groundwater treatment, groundwater monitoring, and institutional controls to address the potential health risks associated with the contaminated groundwater. This alternative would contain the contaminant plume and minimize contaminant migration from the source area soils and the shallow bedrock. It would not actively restore the aquifer, but would rely on the aquifer's ability to lower contaminant concentrations by natural attenuation processes. The extracted groundwater would be treated by GAC to meet discharge standards. At this time, the only identifiable discharge location is the Missouri River.

Alternative GW3 would pump sufficient groundwater to establish a hydraulic barrier to control further migration of the heavily contaminated portion of the plume

(Zones A and B of the plume [see Section 2.3.2]). The barrier would be established by using extraction wells. The extraction wells would be pumped at rates sufficient to overcome the existing groundwater flow gradient around the wells. Given the steep topography and highly developed character of OU4, it may be necessary to drill some of the extraction wells as angle wells to reach the necessary locations to establish the barrier. The amount of contaminated groundwater removed would be the minimum required to contain the migration of the plume. The well locations and pumping rates would not be designed to actively restore the plume. The extraction wells would be located so that their radii of influence overlap the width of the contaminant plume. For this alternative, it has been assumed that seven extraction wells would be sufficient to contain the heavily contaminated portion of the plume. Preliminary locations for the extraction wells are shown on Figure 3-1. The wells would be pumped at between 0.5 and 2.5 gpm each, for an approximate total of 7 gpm. Monitoring wells would be installed to monitor the extraction wells' hydraulic performance. In addition, five monitoring wells would be installed during the RD, as described in Alternative 2. Overall, it is anticipated that eight new monitoring wells would be installed (four wells for the RD investigation and four for the hydraulic monitoring).

As discussed above, five new monitoring wells would be installed, during the RD before the extraction wells were installed. Sampling of the new and existing monitoring wells would be conducted before the extraction wells were installed to confirm the depth of the contaminant plume, the approximate center line of the plume, and the eastern and western edges of the plume along the line where the extraction wells would be installed. The actual number, location, pumping rate, depth, and size of the extraction wells and monitoring wells would be determined during the RD and would be contingent upon access agreements with the property owners and the data from the new monitoring wells. This effort is necessary to ensure that the capture radius of the wells is sufficient to contain the entire width of the plume.

A submersible electric or pneumatic pump would be installed in each well and the pump controls would be housed at the top of the well casing. Automatic shut-off controls would be installed with each pump to shut it off if predetermined low water levels were reached in the extraction wells. These level controls would prevent damage to the well pumps during low water levels. The pumps' controls might also include a high water level to stop pumping during heavy rains or high Missouri River flood stages.

The groundwater would be pumped to a treatment system through double contained piping with a leak detection system. The proposed locations of the underground piping between the wells and the treatment system and of the discharge piping from the treatment system are shown on Figure 3-3. The final location of the

piping, the treatment system, and the discharge point would be determined during the RD. For this alternative, it has been assumed that one treatment system and building would be constructed and that the water extracted by the plume barrier wells would be combined and treated by one system.

The groundwater treatment system would be a package system that would be delivered to the subsite. The treatment system would be housed in a building to reduce noise, improve appearance, insulate the treatment process, and protect equipment. The building would be heated for freeze protection. The above-ground pumps would have individual high-temperature overloads, but the building would not be cooled. Controls for the treatment system and for the wells, valves, and pumps would be housed within the building for year-round operation. Power lines would be connected and wiring and controls would be installed to operate the process pumps, lighting, and other equipment (i.e., heating and ventilation equipment). Control wiring (on/off controls) to the wells would also be installed. Signs would be posted to prevent unauthorized entry into the building and security measures, such as alarms and a fire department key box, would also be implemented to be consistent with local codes and best practice. The building would also be locked to limit general accessibility to the facility and the potential for public exposure.

The groundwater would be pumped through a GAC adsorption system to remove the contaminants. The GAC system would have at least two absorber vessels, piped so that either vessel could be the lead or the lag vessel. Normally, the system would be operated with one vessel as the lead and the other as the lag. When operational sampling data indicated that the carbon in the lead vessel was spent (no longer adsorbing contaminants), it would be taken out of service. A new carbon vessel or replacement carbon would be put in place, the lag vessel would be set up as the lead vessel, and the new carbon would be used as the lag vessel. Operating the system in this manner ensures that the full adsorption capacity of the lead vessel is used before the carbon is replaced. A flow schematic for the treatment system is shown on Figure 3-3. It was assumed that the spent GAC would be transported off-site for disposal in a RCRA-permitted facility.

The cost estimate for this alternative includes costs for discharging the treated water into one of the storm drains that go through the USACE flood control levee to the Missouri River. During the RD, the costs of installing a dedicated pipeline to carry the treated water over the levee should be investigated.

Groundwater monitoring would be included under this alternative. The performance of the extraction wells must be monitored to ensure that the plume is contained. The performance of the extraction wells would be monitored by collecting groundwater samples for chemical analysis and by collecting groundwater levels to

determine the groundwater flows around the extraction wells. Wells from the existing monitoring well network would be used as much as possible to avoid duplication of effort and to minimize the number of new monitoring wells installed. The number and location of any new monitoring wells necessary to monitor the extraction well's performance would be reevaluated during the RD.

In addition to the four new monitoring wells installed for plume definition during the RD, monitoring wells would be installed during the remedy's construction phases to monitor the performance of the extraction wells. The general location of the plume was confirmed during the RI, so the purpose of the four new plume definition monitoring wells is to confirm the depth of the plume and the western edge of the plume, while the other four monitoring wells will be used to monitor the performance of the extraction wells. The final location of the wells and the depths of the wells would be determined during RD and would be contingent upon access agreements with the property owners and the City of New Haven.

For all the soil alternatives except S1, it is expected that the contaminant levels in the downgradient extraction wells would decrease steadily, since the contaminants in the source area soils and shallow bedrock would have been contained or treated. Depending on the rate of contaminant flushing from the plume in the bedrock between the source area soils and the downgradient extraction wells, the levels may decrease to less than MCLs. However, the containment alternative would be functioning correctly as long as no contaminants from Zones A and B of the plume were migrating downgradient of the extraction well line.

Natural attenuation (NA) occurs to some degree in all groundwater systems. However, the rate of the process varies widely for different classes of contaminants and for different hydrogeologic systems. Even though some natural attenuation always occurs, the RI (USGS, 2008) determined that the rates of the processes in the OU4 plume are not protective of human health and the environment. The RI examined most of the issues required to evaluate the effectiveness of NA, especially the relative rates of degradation and contaminant transport. The RI found that:

1) Except for dispersion and advection (essentially dilution processes), very little natural attenuation (especially biodegradation) was occurring within the plume.
2) While disposal of PCE ended over twenty years ago, the contaminant levels for PCE and its degradation products still exceed MCLs from the source area to where the plume joins the Missouri River.
3) The likely presence of DNAPL at the source area and the very slow rates of destructive or sorptive NA processes in the OU4 plume make it unlikely that NA processes would lower the concentrations of the groundwater COCs sufficiently

as the contamination migrates to the current downgradient edge of the plume (assumed to be the Missouri River).

The continuing source of the groundwater plume should be removed once the contaminated soils are remediated by one of Alternatives S2 or S3. As discussed above, the RI found that most of the downgradient plume is dissolved (very little contaminant mass is sorbed to the aquifer materials). Therefore, once the source of the groundwater contamination is removed by treatment or containment of the source area soils, NA processes should begin to restore the aquifer. The time necessary for NA processes to restore the aquifer is unknown due to many complicating factors. The primary uncertainties include the distribution of contaminants in the bedrock, the rates of dispersion and advection of these contaminants in the downgradient plume groundwater, and the degree of success in isolating the source area soils from the aquifer. However, Alternative GW3 should restore the downgradient protion of the aquifer (essentially, Zone C) more quickly than Alternative GW1.

A detailed sampling and quality assurance plan would be written before the groundwater monitoring began. The sampling and quality assurance plans would include sample locations, sampling frequency, sampling procedures, sample analysis methods, and sample documentation procedures. Wells from the existing monitoring well network would be used as much as possible to avoid duplication of effort and to minimize the number of new monitoring wells installed. New monitoring wells would be added to the existing monitoring well network to provide further definition of the plume; data on especially important areas of the plume, such as the eastern and western edges at the extraction well line; and data regarding the hydraulic performance of the extraction wells.

It was assumed that eight new and the existing monitoring wells and the seven extraction wells (for a total of 34 wells with approximately 50 sampling depths) would be sampled quarterly for 2 years, twice a year for 3 years and annually thereafter or until RAOs are attained. The frequency of the monitoring could be reevaluated and modified after the 5-year reviews or after review of monitoring data by the USEPA and MDNR. The groundwater samples would be sampled for the following parameters:

- VOCs
- DO (field parameter)
- specific conductance (field parameter)
- pH (field parameter)
- ORP (field parameter)
- Temperature (field parameter)

The results of the sample analysis would be used, along with water level data and aquifer flow models, to evaluate the rate of contaminant migration, the degree of plume

containment in Zones A and B, and the rate of natural attenuation in Zone C. If the monitoring results indicate that Zones A and B of the plume are not being contained, further RAs could be initiated.

The treatment plant's influent and effluent would be monitored as required to meet NPDES requirements. For the purpose of developing this alternative, it was assumed that the influent and effluent would be monitored quarterly for VOCs until RAOs were met.

The institutional controls for groundwater would be the same as those described in Alternative GW2.

3.3 Combined Soil and Groundwater Remedial Alternatives

Because both the soils and groundwater at OU4 are contaminated, the remedial alternatives need to address both media. In order to limit the analyses in Chapters 4 and 5 to a manageable number of alternatives, while still meeting the requirements for generating specific alternatives (especially the No Action and the containment alternatives), the soil and groundwater alternatives will be paired. The following combined alternatives will be analyzed:

1) Alternative 1 - No Action/ No Action
2) Alternative 2 - Capping, Sheet Piling, and Rock Grouting/ Containment by Hydraulic Control
3) Alternative 3 - In Situ Chemical Oxidation Treatment/ Monitoring

Table 3-3 summarizes the combined alternatives by illustrating which process options are included in each alternative. The periodic costs and the present worth cost of Alternatives 1, 2, and 3 are shown in Appendix A, Table A-1, A-2, and A-3, respectively.

Table 3-1
Development of Soil and Groundwater Alternatives
Operable Unit 4, Orchard Street/Maiden Lane Subsite
New Haven, Missouri

General Response Actions	Remedial Technology	Process Option (C – Soil and Groundwater, S – Soil, GW – Groundwater)		Alternative S1 – No Action	Alternative S2 – Capping, Sheet Piling, & Rock Grouting	Alternative S3 – In Situ Chemical Oxidation Treatment	Alternative GW1 – No Action	Alternative GW2 - Monitoring	Alternative GW3 – Containment by Hydraulic Control
No Action	None	None	C	•			•		
Institutional Controls	Access Restrictions	Well certification, especially the Special Area 3 Regulations	GW					•	•
		Environmental Covenants	S		•				
		Public Education	C		•			•	•
Monitoring	Monitoring	Groundwater Monitoring	GW					•	•
	Monitoring	Soil Monitoring	S		•	•			
Containment	Vertical Barriers	Hydraulic Control, Extraction Wells	GW		•				•
		Sheet Piling	S		•				
		Rock Grouting	C		•				
	Capping	Multi-Layer	S		•				
Removal	Excavation	Excavation	S						
Treatment	Physical	GAC Adsorption	GW		•				•
		Chemical Oxidation	S			•			
Disposal	Off-Site Treated Effluent Disposal	Discharge to Floodway (the Missouri River)	GW		•				•

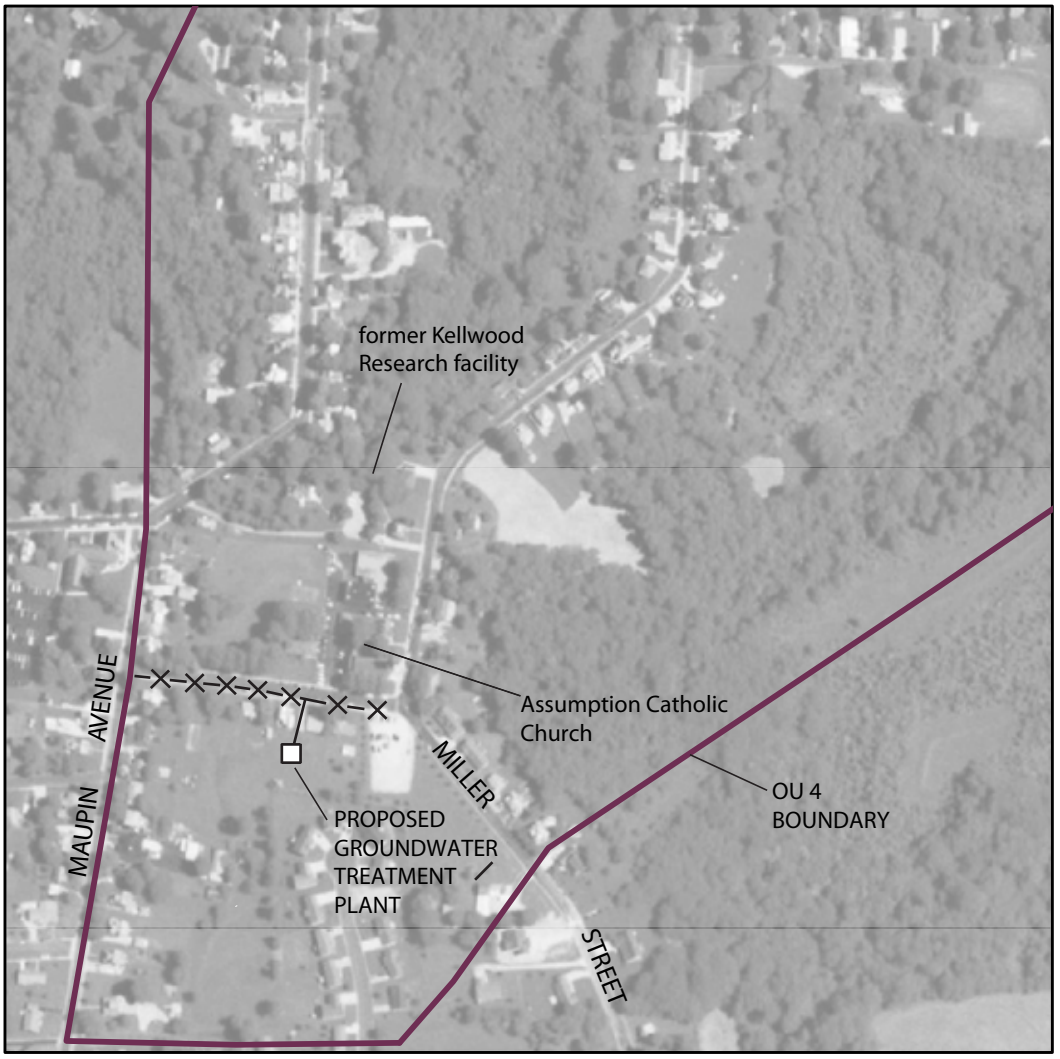
Table 3-2
Contaminant Soil Cleanup Limits and Disposal Limits
Operable Unit 4, Orchard Street/Maiden Lane Subsite
New Haven, Missouri

Contaminant	Soil Cleanup Limit * (ug/kg)	Maximum Level for Disposal at a Solid Waste Facility ** (ug/kg)
PCE	550	14,000
TCE	43	10,000
VC	43	4,000

All soils with contaminant levels greater than the maximum level acceptable to the solid waste disposal facility would be disposed of in a RCRA permitted facility.
* USEPA Region 6 Human Health Medium-Specific Screening Levels, 2008.
** Based on the "20 times the TCLP limits" rule of thumb for determining disposal requirements.

Table 3-3
Development of Combined Soil and Groundwater Alternatives
Operable Unit 4, Orchard Street/Maiden Lane Subsite
New Haven, Missouri

General Response Actions	Remedial Technology	Process Option (C – Soil and Groundwater, S – Soil, GW – Groundwater)		Alternative 1 – No Action / No Action	Alternative 2 – Capping, Sheet Piling, & Rock Grouting/ Hydraulic Control	Alternative 3 – In Situ Chemical Oxidation/ Monitoring
No Action	None	None	C	•		
Institutional Controls	Access Restrictions	Well certification, especially the Special Area 3 Regulations	GW		•	•
		Environmental Covenants	S		•	
		Public Education	C		•	•
Monitoring	Monitoring	Groundwater Monitoring	GW		•	•
	Monitoring	Soil Monitoring	S		•	•
Containment	Vertical Barriers	Hydraulic Control, Extraction Wells	GW		•	
		Sheet Piling	S		•	
		Rock Grouting	C		•	
	Capping	Multi-Layer	S		•	
Treatment	Physical	GAC Adsorption	GW		•	
	In Situ Treatment	Chemical Oxidation	S			•
Disposal	Off-Site Treated Effluent Disposal	Discharge to Floodway (the Missouri River)	GW		•	



Base from U.S. Geological Survey digital orthophoto, 1:24,000, 1927 Universal Transverse Mercator projection Zone 15, 2003 photograph

0 250 500 1,000 Feet

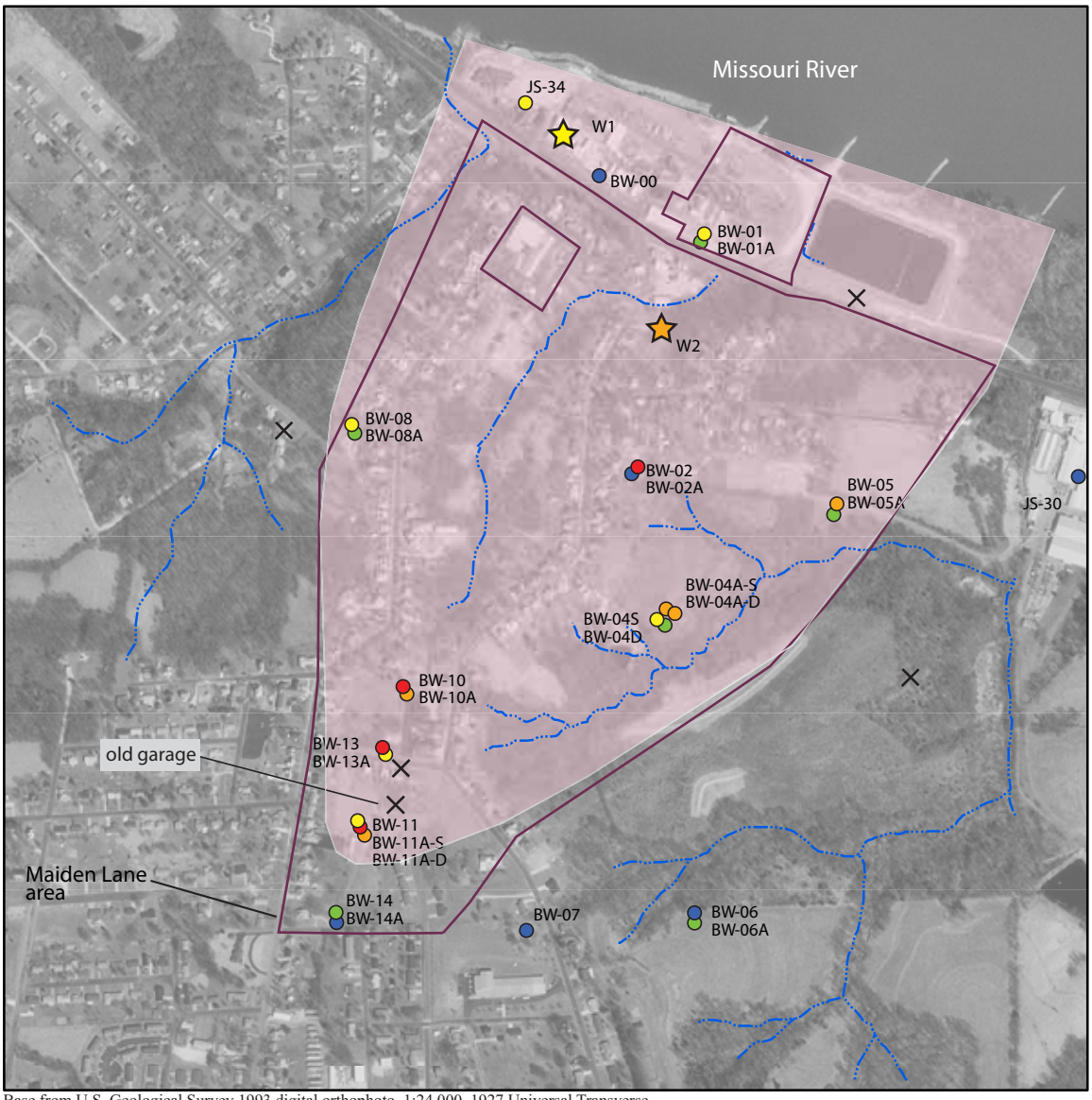
EXPLANATION

X PROPOSED BARRIER EXTRACTION WELLS

— PROPOSED PIPING

FIGURE 3-1
ALTERNATIVES S2 AND GW3
BARRIER EXTRACTION WELL LOCATIONS
RIVERFRONT SUPERFUND SITE
OPERABLE UNIT 4 FS

SOURCE: USGS OU4 RI, 2008
Z:\044706\C0008348.ai 10/03/2008



Base from U.S. Geological Survey 1993 digital orthophoto, 1:24,000, 1927 Universal Transverse Mercator projection Zone 15

SCALE

0 750 1,500 FEET

EXPLANATION

ESTIMATED EXTENT OF PCE CONTAMINATED GROUND WATER AT OPERABLE UNIT 4

BEDROCK MONITORING WELL CLUSTER AND MAXIMUM PCE CONCENTRATION DETECTED IN MICROGRAMS PER LITER

- Not detected
- Less than 5
- 5 to 49.99
- 50 to 499
- Greater than 500

× PROPOSED MONITORING WELLS

FIGURE 3-2
ALTERNATIVE GW2
PROPOSED MONITORING WELL LOCATIONS
RIVERFRONT SUPERFUND SITE
OPERABLE UNIT 4 FS

SOURCE: USGS OU4 RI, 2008
Z:\044706\C0008349.ai 10/03/2008

PLOTTER: ???? PEN TABLE: Half PLOT SCALE: 1=1 Original dwg size 11 x 8.5 Revised By: ON Oct 02, 2008 @ 4:09pm
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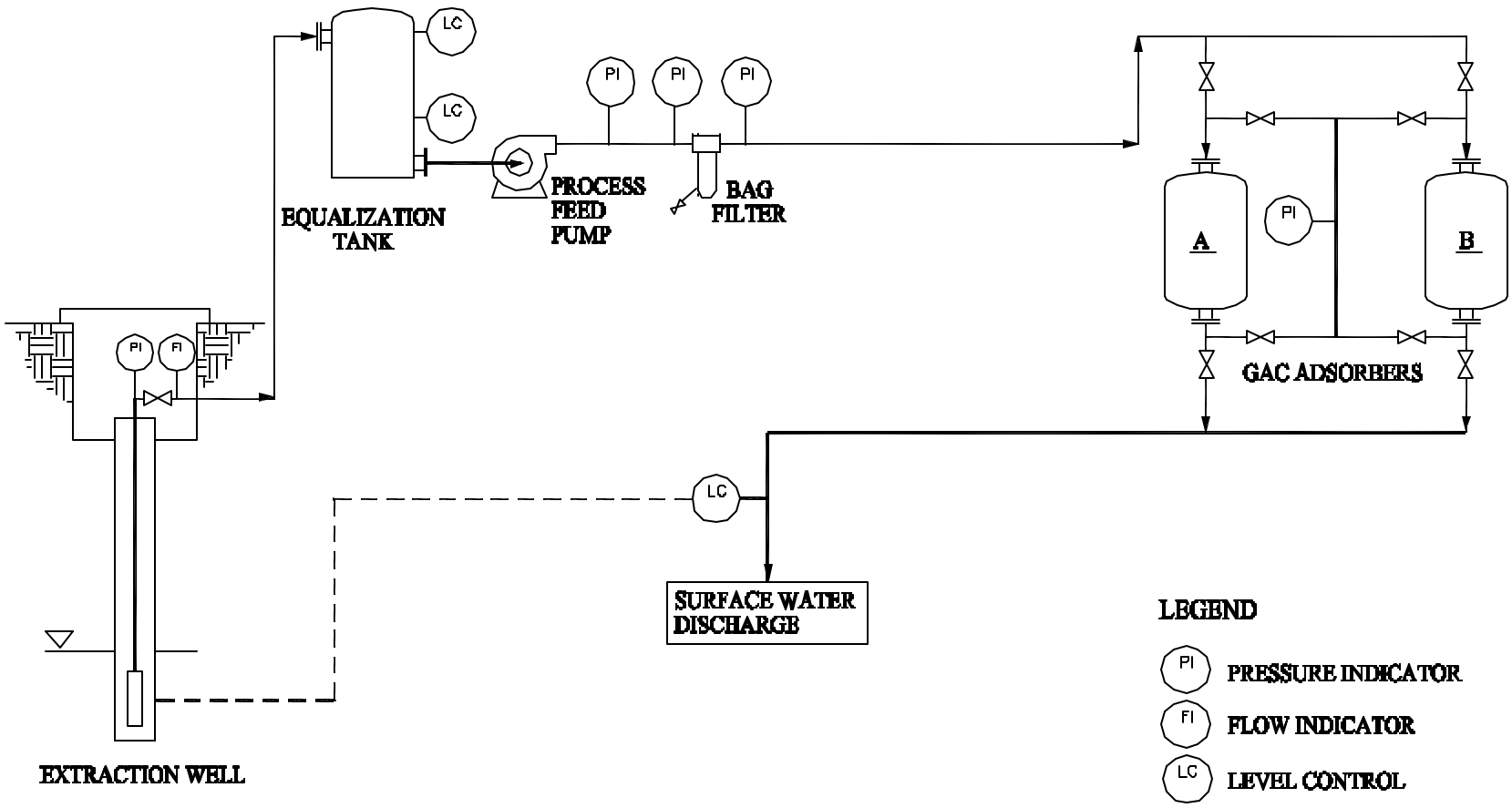

FIGURE 3-3
ALTERNATIVE GW3, GAC TREATMENT SCHEMATIC
RIVERFRONT SUPERFUND SITE
OPERABLE UNIT 4 FS

4.0 Detailed Evaluation of Alternatives

In this section, the remedial alternatives were evaluated in detail to provide enough relevant information about each alternative so that an appropriate remediation measure can be selected for OU4 at the Riverfront Site. Each alternative is evaluated against the NCP-required criteria.

The remedial alternative evaluation criteria have evolved as a result of statutory requirements that must be addressed in the ROD. CERCLA requires that RAs meet the following criteria:

- Be protective of human health and the environment.
- Attain ARARs (or provide grounds for invoking a waiver).
- Be cost-effective.
- Use permanent solutions and alternative treatment technologies or resource recovery technologies to the maximum extent practicable.
- Satisfy the preference for treatment that reduces toxicity, mobility, or volume as a principal element or provide an explanation in the ROD of why it does not.

The NCP and the "Interim Final Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA" (USEPA, 1988a) provide nine evaluation criteria to address the CERCLA statutory requirements considerations:

- Overall protection of human health and the environment.
- Compliance with ARARs.
- Long-term effectiveness and permanence.
- Reduction of toxicity, mobility, or volume through treatment.
- Short-term effectiveness.
- Implementability.
- Cost.
- State acceptance.
- Community acceptance.

Table 4-1 describes the evaluation factors for each of the nine criteria. In this section, each individual alternative is evaluated against seven of the nine criteria. State and community acceptance criteria cannot be adequately addressed until after the FS report is released for regulatory and public review. These criteria should, therefore, be assessed in the ROD responsiveness summary.

The following discussion presents the primary components of each of the seven criteria that will be used to complete the detailed evaluation of alternatives. The first two criteria, overall protection of human health and the environment and compliance with ARARs, are considered threshold criteria. These criteria must be met for an alternative to

be considered a remedy for the site. The five remaining criteria are considered balancing criteria. Tradeoffs can be made between the alternatives with respect to the balancing criteria. State acceptance and community acceptance are considered modifying criteria and are used to identify the preferred alternative after the public comment period.

- Overall Protection of Human Health and the Environment
  This criterion provides an overall assessment of whether each alternative would adequately protect human health and the environment. The overall protectiveness focuses on whether an alternative would achieve adequate protection and how site risks would be eliminated, reduced, or controlled through treatment, engineering, or institutional controls. This criterion is considered a threshold criterion; that is, overall protection must be provided for an alternative to be considered a remedy for the site.
- Compliance with ARARs
  This criterion, also a threshold criterion, assesses whether an alternative would meet all federal and state ARARs for the site.
- Long-Term Effectiveness and Permanence
  This balancing criterion assesses the residual risk that would remain at the site after the RAOs are achieved. The extent and effectiveness of the controls needed to manage any treatment residuals or untreated media would be assessed by qualitatively determining the magnitude of any residual risk remaining at the site at the conclusion of remedial activities. Also, the adequacy and reliability of the controls that would be used to manage any treatment residuals or monitor untreated media remaining at the site would be assessed.
- Reduction of Toxicity, Mobility, or Volume Through Treatment
  This balancing criterion assesses the degree to which site media would be treated to permanently and significantly reduce the toxicity, mobility, or volume of site contaminants. This is accomplished by analyzing the destruction of toxic contaminants, the reduction of the total mass of toxic contaminants, the irreversible reduction in contaminant mobility, or the reduction in total volume of contaminated material.
- Short-Term Effectiveness
  This balancing criterion addresses the effects of an alternative on-site surroundings during the construction and implementation phases of the RA, before RAOs would be achieved. These effects include consideration of the protection of workers and the community during RA implementation, environmental impacts that might result from construction or implementation, and the length of time until the RAOs would be achieved.

- Implementability

  This balancing criterion addresses the technical and administrative feasibility of implementing an alternative and the availability of the various services and materials required during implementation. Technical feasibility encompasses the technical difficulties and the unknowns associated with the alternative, the reliability of the technologies, the ease of undertaking additional RAs if necessary, and monitoring requirements. Administrative feasibility includes the activities required for coordination with other offices and agencies. Availability of services and materials includes the availability of necessary equipment and specialists, the ability to obtain competitive bids, and the availability of prospective technologies.

- Cost

  The cost criterion involves the evaluation of the capital costs, the annual O&M costs, and a present worth analysis. The cost estimates would be order-of-magnitude level estimates, which would be defined by the American Association of Cost Engineers as approximate estimates made without detailed engineering data. It is normally expected that an estimate of this type would be accurate to +50 percent and -30 percent. The actual costs of the project would depend on the final scope of the RA, the schedule of implementation, competitive market conditions, and other variable factors that may impact project costs.

  Direct capital costs include expenditures for the equipment, labor, and materials necessary to implement RAs. Types of capital costs considered direct capital costs are:

  - Installation of wells,
  - Construction of treatment systems, and
  - Implementation of institutional controls.

  Indirect capital costs include expenditures for engineering, permitting, and other services that are not part of actual installation activities but are required to complete the installation of remedial alternatives. Types of capital costs considered in indirect capital costs are bid and scope contingencies, permitting and legal costs, construction services, and engineering design costs.

  O&M costs are the annual or periodic costs necessary to ensure the continued effectiveness of an alternative. These include costs for groundwater monitoring, on-going costs for treatment chemicals or treatment system utilities, preparation of newsletters, and 5-year reviews.

  The present worth analysis of the alternative costs evaluates expenditures that occur over different time periods by discounting all future costs to a common base

year. Costs of the alternatives are then compared on the basis of a single figure representing the amount of money that, if invested in the base year, would be sufficient to cover all costs associated with the alternative over its planned life.

The following sections present discussions of the three RA alternatives developed for OU4 of the Orchard Street/Maiden Lane Site in relation to the first seven evaluation criteria.

4.1 Alternative 1 – No Action/ No Action

The no action alternative would not implement any RAs so OU4 would remain in its present condition. Alternative 1, required by the NCP and CERCLA, is the baseline alternative against which the effectiveness of the other alternatives is compared. More detailed descriptions of the soil and groundwater portions of Alternative 1 were presented in Sections 3.2.1.1 and 3.2.2.1, respectively.

4.1.1 Overall Protection of Human Health and the Environment

Because no remedial or monitoring activities would be conducted as part of Alternative 1, human health and the environment would not be adequately protected by this Alternative.

Currently (August 2008), two subsite-specific factors protect human health from the contaminated soil at OU4. The RI found that the surface soils (0-2 ft bgs) and the subsurface soils to 10 ft bgs were not substantially contaminated. In addition, the USEPA has conducted two rounds of in-situ soil treatment (see Section 1.4.7) but has not yet conducted confirmatory sampling to determine the post-treatment contaminant levels. The soil treatments were designed to treat the contaminant levels found in the RI soil sampling and the PSOD, so it is likely that the existing soil contamination has been remediated.

However, if there is recalcitrant soil contamination, it would continue to migrate into the groundwater and continue to discharge into the Missouri River. Because of the possible presence of DNAPL in the source area soils and shallow bedrock, the slow average groundwater velocity, and the distance of the source area soils from the Missouri River, the potential exists for untreated contaminants (if any) in the source area soils/shallow bedrock to migrate into the groundwater. The current contaminated groundwater plume may migrate into currently uncontaminated volumes of groundwater downgradient of the source area. The concentrations of PCE, TCE, cis-DCE, and trans-DCE in the groundwater currently exceed the MCLs. The concentrations of PCE remaining in the soil may exceed the soil cleanup goals.

Currently (August 2008), two subsite-specific factors protect human health from the contaminated groundwater at OU4. The City of New Haven provides potable water to OU4 and the surrounding area, so no one is currently exposed to the contaminated groundwater. In addition, all of OU4 is within Special Area 3. If any new water supply wells are installed in OU4, they must comply with the well construction requirements listed in the Special Area 3 regulations. However, the potential for future ingestion or direct contact with contaminated soil and groundwater would remain. One existing water supply well in OU4 (JS-34) is contaminated and Alternative 1 does not include any mechanisms for monitoring wells or warning the public of the potential dangers from using the contaminated groundwater.

Because monitoring would not be performed the future location of the contaminants, the levels of contamination in the soil (if any) and groundwater, and the extent of natural attenuation, could not be determined. If this alternative were implemented, it would not be possible to determine if the RAOs were satisfied.

4.1.2 Compliance with ARARs

The potential ARARs are presented in Section 2.2, and set out in Tables 2-3, 2-5 and 2-6. The chemical-specific ARARs specific to the present quality of the groundwater include the National Primary Drinking Water Standards. The concentrations of PCE, TCE, cis-DCE, and trans-DCE in the groundwater currently exceed the MCLs and MCLGs. Thus, the present quality of the groundwater does not meet these standards, so this alternative would not comply with the chemical-specific ARARs. No chemical-specific ARARs were identified for the soils at OU4. The concentrations of PCE and other COCs in the soil may exceed the soil cleanup goals. Because the soil would not be monitored under this alternative, it will not be possible to determine if the soil cleanup goals are being met.

No location-specific ARARs would apply to Alternative 1.

The only RA that would be taken is closure of the existing monitoring wells. The only action-specific ARAR that would have to be complied with is the Missouri Monitoring Well Construction Code (10 CSR 23-4), which would apply to the monitoring well closures.

Any new domestic water supply well installations in or near OU4 would have to comply with the Missouri Well Construction rules (which are under 10 CSR 23-3). In particular, the Special Area 3 regulations (10 CSR 23-3.700(7)), a subset of Chapter 3 of the Well Construction rules, specifically apply to new wells constructed at OU4.

4.1.3 Long-Term Effectiveness and Permanence

The residual risk to human health and the environment associated with Alternative 1 would be the same as the current risk. While there are four subsite-specific factors that minimize current and future human risk from the OU4 contaminants, Alternative 1 does not include any mechanisms of warning the local population of the risks from the OU4 contaminants. The concentrations of PCE, TCE, cis-DCE, and trans-DCE in the groundwater currently exceed the MCLs. In addition, contamination may be present in the soil that results in risks to the environment and at levels that would continue to act as a source of groundwater contamination. The existing groundwater plume may migrate into currently uncontaminated volumes of groundwater. Because monitoring would not be conducted, there would be no mechanism to evaluate the effectiveness of this alternative. Therefore, the long-term effectiveness of the current protective factors is uncertain. An evaluation of the adequacy and reliability of controls is not applicable to this alternative. Because contamination above cleanup goals would remain at the subsite, 5-year reviews would be required.

4.1.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

Because no remedial activities would be conducted, there would be no reduction in the toxicity, mobility, or volume of the contaminants except by natural fate and transport processes. Monitoring would not be conducted and therefore no mechanism would exist to determine the reductions, if any, of the toxicity, mobility, or volume of the contaminants in the soil or groundwater.

4.1.5 Short-Term Effectiveness

Because the only action that would be conducted is well closure, there would be no increase in the short-term risk to the community. There would be very minor increases in risks to workers and the environment as the equipment used to close the wells was decontaminated, but these risks are easily controlled. The amount of time required for the contaminants in the groundwater and soil to degrade or dilute to concentrations at or below the MCLs or risk-based levels is unknown, but is expected to be significantly greater than 30 years.

4.1.6 Implementability

Monitoring well closure, the only on-site activity required in this alternative, is easily implemented. Well closure vendors and the materials needed to close the wells are readily available. Except for closing the wells, services, materials, and activities normally needed to coordinate with other agencies would not be necessary. Five-Year

reviews would be required and the services, materials, and personnel needed to complete the required 5-year reviews are readily available.

4.1.7 Cost

The costs for this alternative are presented in Table A-1 of Appendix A. While no RAs would be conducted, the existing groundwater monitoring wells must be closed. Therefore, capital costs have been included for the wells' closure. Because 5-year reviews of the subsite would be required, there are also O&M costs. Five-year reviews have been assumed to consist of a 2-day subsite visit by two people and the labor and expenses associated with producing a 5-year review report. The cost for the OU4 portion of the 5-year review was assumed to be 25% of the 5-year review cost, as to date only OU1, OU3, OU5, and now OU4 have had their FS completed. Each 5-year review has been estimated to cost $52,000, so costs of $13,000 are listed for the OU4 5-year reviews. In order to generate the cost estimate, the duration of this alternative is assumed to be 30 years. The total present worth of Alternative 1 is estimated to be $121,000.

4.2 Alternative 2 – Capping, Sheet Piling, and Rock Grouting/ Hydraulic Containment, Above Ground Treatment, and Monitored Natural Attenuation

Alternative 2 includes the containment of the contaminated source area soils and shallow bedrock by capping over, sheet piling around, and rock grouting below the contaminated soil/ shallow bedrock volume and extraction of groundwater at a rate to contain the head of the groundwater contaminant plume. It is estimated that ten extraction wells, pumping at a total rate of approximately 10 gpm, would be necessary to contain the groundwater contaminant plume and remove the groundwater from the soil containment volume. Extracted groundwater would be treated by GAC. The treated groundwater would then be discharged to a local tributary or storm drain and ultimately to the Missouri River.

As discussed in Section 2.3.2, for this alternative it was conservatively assumed that the volume of soil that would require containment would be equal to the volume of contaminated soil provided in the RI. Because the soils have been treated, it is probable that some of the soils meet the RAOs and soil containment of the entire RI defined area would not be necessary. After soil monitoring determined the limits of the containment volume, the existing garage on-site would be demolished and the volume of contaminated soil and shallow bedrock would be enclosed by rock grouting to seal off the shallow bedrock, sheet piling keyed into the top of the bedrock and a multi-layer cap over the contaminated soils. The alternative also includes groundwater monitoring to determine

the effectiveness of the plume containment and institutional controls including the existing requirements for new well certification and public education.

The operational life of this alternative is expected to be greater than 30 years. More detailed descriptions of the soil and groundwater portions of Alternative 2 were presented in Sections 3.2.1.2 and 3.2.2.3, respectively.

4.2.1 Overall Protection of Human Health and the Environment

Alternative 2 would protect the public and the environment from the risks posed by the groundwater contamination by preventing the migration of the heavily contaminated portion of the plume (essentially, the portion of the plume in Zones A and B). The contaminated water that is extracted would be treated to levels below the cleanup goals (MCLs and MCLGs). The cap/sheet piling/rock grouting enclosure would eliminate direct contact with the contaminated soil and minimize migration of the contaminants into the groundwater. This is a containment alternative, so some risk would remain because the bulk of the contaminants would not be actively remediated.

No long-term residual risk would be associated with the groundwater that is extracted and treated. GAC adsorption is proven to be effective for the removal of organics from contaminated groundwater. Groundwater monitoring would be implemented to monitor how effectively the groundwater contaminant plume is contained. Discharge of the treated effluent to the Missouri River should not pose a significant risk because contaminant concentrations in the effluent would be regulated by the NPDES program.

Unacceptable cross-media impacts should not occur. The soil currently acts as a source of the groundwater contamination. Contaminants migrate from the soil to the groundwater by two mechanisms: 1) contaminants are carried from the soil to the groundwater by water infiltrating from the surface, through the contaminated soils, to the groundwater below and 2) contaminants in the soil transfer directly to the groundwater when the water table rises and fills contaminated soil in the source. Capping the contaminated soil would minimize the transfer of contaminants through infiltration. Installing sheet piling around the contaminated soil volume would minimize direct transfer of contaminants from the soil to the groundwater. Grouting the bedrock below the contaminated soil and shallow bedrock would minimize migration of contaminated groundwater and possibly DNAPL from the perched water table to the local groundwater aquifer.

4.2.2 Compliance with ARARs

A full spectrum of potential ARARs for the subsite is discussed in Section 2.2, and set out in Tables 2-3, 2-5 and 2-6. The chemical-specific ARARs specific to the present quality of the groundwater include the National Primary Drinking Water Standards., 40 CFR Part 141, Subparts B & G.

No chemical-specific ARARs were identified for the soils at OU4. The concentrations of PCE and other COCs in the soil may exceed the soil cleanup goals. Because the contaminated soils would be contained with the cap/sheet piling/rock grouting enclosure under this alternative, any migration of contaminants in the soil to the groundwater should be minimized.

These cleanup standards are derived from the following chemical-specific ARARs:

- Safe Drinking Water Act.
  - National Primary Drinking Water Standards; 40 CFR Part 141, Subparts B & G.

This alternative would meet ARARs, but would most likely fail to achieve a permanent cleanup. A containment remedy, such as this one, would be limited to preventing migration of contamination above these levels.

The following are the federal and state location-specific and action-specific ARARs that pertain to Alternative 2:

- Clean Water Act.
  - NPDES, 40 CFR Parts 122, 125: These standards would need to be complied with when discharging the treated groundwater.
- Missouri Water Quality Effluent Regulations and Water Quality Standards, 10 CSR 20.7010 and 20-7.031: These standards would need to be complied with for discharge of the treated groundwater to the Missouri River.
- RCRA: Wastes would be evaluated by complying with 40 CFR 260-268. This alternative does not include on-site disposal regulated by RCRA. RCRA would need to be complied with for any off-site disposal of hazardous waste such as drill cuttings.
- Solid Waste Disposal Act, 40 CFR Part 257: These requirements would be applicable to wastes disposed of at a solid waste landfill.
- Missouri Sanitary Landfill Regulations, 10 CSR 80-3.010 (2) & (3): These requirements would be applicable to wastes disposed of at a sanitary landfill.
- Clean Air Act and Missouri Air Pollution Control Program: Fugitive emissions (such as dust) would need to be controlled during the sheet pile driving and cap construction activities.

- Noise Control Act of 1972; 42 USC Sect 4901 et seq. Noise during operation can be addressed by placing systems within a building and adding sound-absorbing insulation if required. Noise during construction (building demolition, capping, well installation, etc.) would have to comply with the Act. Noise during excavation and drilling operations can be addressed by restrictions on when excavation or drilling was performed (no activities early in the morning or after dark, for example).
- Missouri Board of Geological Registration Regulations, 4 CSR 145-1.010: Activities that require interpretation of the subsite geology, including monitoring well installation, would have to comply with these regulations.
- Missouri Monitoring Well Construction Code, 10 CSR 23-4: Extraction and monitoring well installation at the subsite would have to comply with these regulations.
- NHPA, 36 CFR Parts 65, 800: Portions of OU4 are also located in the New Haven Residential Historical District. Monitoring well installations within the Historical District would have to comply with these regulations.

In addition, all remedial activities for the subsite would need to comply with OSHA and USACE requirements.

Any new domestic water supply well installations in or near OU4 would have to comply with the Missouri Well Construction rules (which are under 10 CSR 23-3). In particular, the Special Area 3 regulations (10 CSR 23-3.700(7)), a subset of Chapter 3 of the Well Construction rules, specifically apply to new wells constructed at OU4.

4.2.3 Long-Term Effectiveness and Permanence

The residual risk to human health and the environment from the contaminated soils would be reduced by eliminating the threat of direct contact with the contaminated soils. The cap/sheet pile/rock grout enclosure would minimize infiltration and the transfer of contaminants from the soils and shallow bedrock to the groundwater.

In this alternative, the contaminated groundwater aquifer would not be actively restored, so there would be a long-term risk from the contaminants remaining in the aquifer. Pumping contaminated groundwater is considered an adequate and reliable method of plume hydraulic containment. By containing the heavily contaminated portion of the groundwater plume, controlling further migration of the contaminants, and removing and treating contaminant mass, the long-term risk would be reduced.

Groundwater monitoring would be conducted to evaluate the effectiveness of this alternative. Because contamination above cleanup goals would remain at the subsite, 5-year reviews would be required. The long-term effectiveness of new well certification

requirements are uncertain. However, the Special Area 3 regulations have been finalized, so this institutional control is in place. If the heavily contaminated portion of the plume is not contained under this alternative, the groundwater might have to be extracted at a greater flow rate or additional extraction wells might have to be installed and pumped to contain the plume.

Implementation of this alternative would reduce the long-term risk to health that is associated with potential human use of the contaminated groundwater. However, because contaminated groundwater would remain in the aquifer, a long-term risk would continue to exist for the environment. The environmental risks would remain until natural attenuation processes reduced the groundwater contaminant levels to the MCLs and MCLGs.

Eventually, groundwater contaminants in Zone C would be diluted through natural processes. However, contaminated groundwater would remain at OU4 for a long time. In order to estimate costs, it has been assumed that Alternative 2 will last 30 years. Because groundwater monitoring would be conducted, there would be a mechanism to evaluate the contaminant levels in the plume, future migration of the plume, and the attenuation of contaminants from natural processes (if any).

The long-term risk from the extracted groundwater would be eliminated by the treatment of the extracted water. Treatment of contaminated groundwater with GAC should permanently and effectively lower the contaminant levels in the extracted groundwater to levels less than the NPDES discharge standards. During the remedial design, an evaluation could be conducted to determine if one of the process options not retained as the representative process option (in Section 2.0) should be used instead of or in conjunction with GAC.

Long-term O&M activities associated with this alternative would include repair and maintenance of the extraction and monitoring wells, the groundwater treatment system equipment, and the multi-layer cap. Cap maintenance and sampling and analysis of groundwater and treated effluent would be performed on a regular basis. The O&M activities would be moderate and relatively easy to implement. No difficulties or uncertainties are foreseen during the performance of these activities. The long-term effectiveness of institutional controls are uncertain, but if properly maintained and enforced, should be good. As discussed, the Special Area 3 regulations have been finalized, so this institutional control is in place. The need for unscheduled replacement of major components such as pumps would be minimal if proper maintenance activities are performed regularly.

4.2.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

This alternative meets the statutory preference for treatment as a principal element. Extraction and treatment of contaminated groundwater would effectively reduce the mobility of the contaminants in the groundwater. Capping, sheet piling, and rock grouting would minimize the movement of contaminants from the soil and shallow bedrock to the groundwater. Groundwater extraction and treatment is essentially irreversible. Spent carbon would be the only residual waste generated from the treatment processes.

It is anticipated that the spent GAC from the groundwater treatment system would be non-hazardous wastes. The spent carbon would be disposed of in accordance with applicable State and Federal waste regulations.

4.2.5 Short-Term Effectiveness

Community risk associated with this remedial alternative would be relatively low during construction of this alternative. Proposed activities include building demolition, cap and sheet piling installation, rock grouting, groundwater treatment system construction, and installation of the extraction wells and the new monitoring wells. The risk would be greater for workers, but would be minimized by compliance with OSHA requirements and guidelines for hazardous waste site activities. Installation and maintenance activities would require that workers be trained and certified to perform hazardous waste site activities, and workers would be required to wear Level D personal protective equipment during well installation.

Environmental impacts resulting from installation of the cap, sheet piling, and rock grouting, and the groundwater extraction and treatment system would include noise pollution during building demolition, cap construction, sheet piling installation, and well installation and minimal fugitive dust emissions during construction. During construction, the soil cuttings removed from the contaminated aquifer would be containerized to minimize possible contact with the contaminants. Any contaminated water generated during well installation would be collected and treated in the groundwater treatment facility.

The amount of time required for the contaminants in the groundwater throughout Zone C to dilute to concentrations at or below the MCLs is unknown, but is expected to be greater than 30 years. However, because of uncertainties about the contaminants' migration velocity and about how effectively the contaminated soils would be contained, there is considerable uncertainty about the time required to achieve the groundwater cleanup levels through natural attenuation. For costing purposes, it has been assumed that this alternative would operate for 30 years.

The time to actually construct the alternative would be approximately:

8 months: Engineering design.

8 months: Equipment lead time/installation of monitoring and extraction wells, demolition of building, installation of rock grading and sheet piling, and cap construction.

4 months: Construction, startup, inspections, and related testing of groundwater treatment facility.

Some of these tasks could be performed concurrently. For example, well installation could be conducted concurrently with equipment lead time. However, the soil remediation activities (i.e., building demolition, installation of the sheet piling and cap) would have to be completed after the rock grouting and before new wells are installed in the area to be capped. It is estimated that the time from the notice to proceed with the design to limited startup of the groundwater treatment system would be approximately 12 to 18 months.

4.2.6 Implementability

Implementability of this alternative would be moderately difficult. Demolition of the existing garage could be easily implemented. Installation of the sheet piling would require re-routing of utilities, which would require coordination with state and local entities. Cap construction is readily implemented and contractors are readily available. Installation of wells and rock grouting and construction of a treatment facility are relatively simple activities. Established procedures for well installation are already in use at the subsite. Contractors that specialize in these types of work are readily available. Building demolition, sheet pile installation, capping, rock grouting, and well installation activities would create noise and inconvenience to nearby citizens. Electricity would be required at each extraction well location as well as the treatment plant to implement this alternative. Monitoring and hydraulic control (extraction) well closure, when needed in the future, should also be easy to implement. Technical problems are not expected to lead to schedule delays during remediation because evaluations during the RD would be performed before the RA was implemented.

The use of GAC adsorption to remove organic contaminants is proven and reliable. Caps are proven and effective for minimizing infiltration. Sheet piling with wells installed within the sheet piling and rock grouting would be effective in controlling the movement of groundwater through the contaminated soil. O&M requirements for this alternative would be moderate and easily completed by one individual, supported by subcontractors as needed (for GAC change-out, for example).

Groundwater monitoring, including installation of additional monitoring wells, is easily implementable. Additional coordination activities would be needed to ensure that any monitoring wells installed in the New Haven Residential Historical District comply with the NHPA. Placement of the monitoring wells would have to be coordinated with the private citizens and the City of New Haven. Monitoring well closure, when needed in the future, should also be easy to implement. Technical assistance regarding appropriate safety procedures can be provided by OSHA, which also has the authority to inspect Superfund sites to ensure compliance with OSHA standards.

Frequently, the implementation of institutional controls can be somewhat difficult. However, the implementability of institutional controls at OU4 should be simple. The Special Area 3 well construction regulations have already been finalized for the entire Riverfront Site, not just OU4. New well certifications would be implemented and overseen by the State of Missouri (MDNR's Wellhead Protection Section). Public education/information could be easily implemented through public notices in the newspaper, through direct mailings, and through public meetings. Five-year reviews would be required, and the services, materials, and personnel needed to complete the required 5-year reviews are readily available.

This alternative would not interfere with additional remediation at the site, if required. Additional remedial activities might include excavating the contaminated soil, installing more extraction or monitoring wells, or modifying the treatment system. Sampling the existing and proposed monitoring wells should be sufficient to determine if the extraction system is successfully containing the heavily contaminated portion of the groundwater plume. Placement and design of the extraction and monitoring wells would have to be coordinated with the private citizens and the City of New Haven. In the parts of OU4 that are in the Historical District the design of the placements must comply with the NHPA. Any wells in the floodplain on the land side of the levee would need to have locking valves to prevent the well from becoming artesian when the Missouri River floods.

Technical assistance regarding appropriate safety procedures can be provided by OSHA, which has the authority to inspect Superfund sites to ensure compliance with OSHA standards.

4.2.7 Cost

The detailed cost summary of the capital and O&M costs associated with the implementation of Alternative 2 is presented in Table A-2 of Appendix A.

The capital costs include both direct and indirect capital costs. The direct capital costs include: building demolition; installation of sheet piling and rock grouting, cap

construction; installation of additional monitoring and extraction wells; construction of the treatment facility and associated supply and discharge piping; purchase of process equipment, and; supporting the MDNR Wellhead Protection Section with new well certifications. With the addition of indirect costs, the total capital cost is estimated to be $825,000.

The O&M costs associated with implementing this alternative include groundwater monitoring, maintenance of the groundwater extraction and treatment system, equipment replacement, cap maintenance, and 5-year reviews. O&M costs are divided into two types, yearly and intermittent costs. Yearly costs are those items that do not change over the life of the alternative. An example of a yearly cost is the extraction well treatment plant's NPDES monitoring. Intermittent costs are those periodic costs that differ over the life of the alternative. Examples of intermittent costs are the costs for the groundwater monitoring and 5-year reviews. In addition, costs to close the monitoring wells have been included in the Year 30 costs. While monitoring will probably have to continue beyond 30 years, closure of the wells will be required at some time, so the costs have been included in Year 30 for completeness.

Annual O&M costs for the first year are estimated to be $223,400 and are estimated to be between $110,000 and $229,200 for every year thereafter. The total annual O&M costs for Alternative 2 are $3,921,000. The total present worth of the O&M costs for Alternative 2 is $1,738,000.

The total present worth of Alternative 2 is estimated to be $2,563,000.

4.3 Alternative 3 – In-situ Chemical Oxidation / Monitoring

Alternative 3 includes in-situ chemical oxidation of the contaminated soil. The alternative also includes soil monitoring to determine the effectiveness of the two previous soil remediation efforts.

As discussed in Section 2.3.2, for this alternative it was conservatively assumed that the volume of soil that would require treatment would be equal to the volume of contaminated soil provided in the RI. Because the soils have been treated, it is probable that some of the soils meet the RAOs and additional soil treatment of the entire RI soil volume would not be necessary. A more detailed discussion of soil alternative S3 was presented in Section 3.2.1.5.

Alternative 3 would also include groundwater monitoring and institutional controls to mitigate the effects of the groundwater contamination at OU4. This alternative would not actively restore the groundwater. This alternative would monitor the plume to ensure that any migration of the contaminated groundwater towards sensitive receptors would be detected. Monitoring would be accomplished through the

collection and analysis of groundwater samples. Institutional controls would consist of the existing requirements for new well construction certification, including the Special Area requirements, and public education/information. A more detailed description of groundwater alternative GW3 was presented in Section 3.2.2.3.

4.3.1 Overall Protection of Human Health and the Environment

The long-term residual risk from the soil that is treated in-situ would be substantially less than the current risk. In-situ chemical oxidation is effective for removing the VOCs present in the soils at OU4. In fact, this process option, in-situ chemical oxidation, was used in the 2007 removal action at OU4. Soil sampling would be conducted to determine the degree of soil remediation achieved during the removal action conducted during the RI and by the in-situ soil treatments conducted as part of this alternative. However, if there is DNAPL in the deepest soils or shallow bedrock, it may be difficult to locate and treat. Therefore, some residual risks may remain to the environment.

Human health would be adequately protected from the contaminated groundwater by Alternative 3. Currently (September 2008), two subsite-specific factors protect human health from the contaminated groundwater at OU4. The City of New Haven provides potable water to the residents in OU4 and the surrounding area, so no one is currently exposed to the contaminated groundwater. In addition, all of OU4 is within Special Area 3. If any new water supply wells are installed in OU4, they must comply with the well construction requirements listed in the Special Area 3 regulations. These existing factors, combined with the monitoring of the contaminant plume and the public education/information on the dangers of using the contaminated groundwater that would be conducted under Alternative 3, should prevent current and future human exposure to the contaminated groundwater.

Institutional controls provide no protection to the environment. The existing groundwater plume may migrate into currently uncontaminated volumes of groundwater downgradient of the source area. The concentrations of PCE, TCE, cis-DCE, and trans-DCE in the groundwater currently exceed the MCLs. If there is recalcitrant soil contamination, it could continue to migrate into the groundwater and continue to discharge into the Missouri River. Because of the possible presence of DNAPL in the source area soils and shallow bedrock, the slow average groundwater velocity, and the distance of the source area soils from the Missouri River, the potential exists for untreated contaminants (if any) in the source area soils/shallow bedrock to migrate into the groundwater. The concentrations of PCE in the soil may exceed the soil cleanup goals.

Monitoring would be performed to determine the levels of contamination in the groundwater and would be one of the tools used to determine if the human health RAO had been met. Monitoring would also be performed to confirm that the soil treatments were effective and that the existing soil contamination had been remediated. Monitoring would also provide some protection to the environment, by detecting any expansion of the plume or migration of the plume towards new sensitive receptors. However, overall, this alternative would not meet the RAO for the protection of the environment.

4.3.2 Compliance with ARARs

The potential ARARs are presented in Section 2.2, and set out in Tables 2-3, 2-5 and 2-6. No chemical-specific ARARs were identified for the soils at OU4. The concentrations of PCE and other COCs in the soil may exceed the soil cleanup goals. Because the contaminated soils would be treated in-situ under this alternative, any migration of contaminants in the soil to the groundwater should be minimized. However, contamination, possibly including DNAPL contamination, may remain in the deep soils and shallow bedrock (at depths greater than approximately 18 ft bgs).

The chemical-specific ARARs specific to the present quality of the groundwater include the National Primary Drinking Water Standards., 40 CFR Part 141, Subparts B & G. The concentrations of PCE, TCE, cis-DCE, and VC in the groundwater currently exceed the MCLs and MCLGs. Because the present and probable future quality of the groundwater does not and will not meet all of these standards, this alternative would not comply with the chemical-specific ARARs unless a waiver is received. Any remaining contaminated soils could continue to act as a source of the groundwater contamination.

The Federal and State location-specific and action-specific ARARs that pertain to Alternative 3 include the following:

- RCRA: Wastes would be evaluated by complying with 40 CFR Parts 260-268. This alternative would not include on-site disposal regulated by RCRA. RCRA regulations would need to be complied with for any off-site disposal of hazardous waste, such as soil cuttings from well installations.
- Solid Waste Disposal Act, 40 CFR Part 257: These requirements would be applicable to wastes disposed of at an off-site solid waste landfill.
- Missouri Sanitary Landfill Regulations, 10 CSR 80-3.010 (2) & (3): These requirements would be applicable to wastes disposed of at an off-site sanitary landfill.
- Hazardous Materials Transportation Act, 40 CFR Parts 107, 171-177: Transportation of hazardous soil cuttings to their disposal facility would have to comply with these regulations.

- Clean Air Act: Fugitive emissions (such as dust) would need to be controlled during well drilling and injection activities.
- Noise Control Act of 1972; 42 USC §§ 4901 - 4918. Noise from drilling activities could be addressed through use of hearing protection during drilling activities and restrictions on when drilling was performed (no drilling early in the morning or after dark, for example).
- Missouri Monitoring Well Construction Code, 10 CSR 23-4: Monitoring well installation and closures at the subsite would have to comply with these regulations.
- Missouri Board of Geological Registration Regulations, 4 CSR 145-1.010: Activities that require interpretation of the subsite geology, including monitoring well installation, would have to comply with these regulations.
- National Historic Preservation Act (NHPA), 16 USC § 470 et seq., 36 CFR Parts 65, 800: Portions of OU4 are also located in the New Haven Residential Historical District. Monitoring well installations within the Historical District would have to comply with these regulations.

In addition, all remedial activities for the subsite would need to comply with the Occupational Safety and Health Act (OSHA) requirements.

Any new domestic water supply well installations in or near OU4 would have to comply with the Missouri Well Construction rules (codified at 10 CSR 23-3). In particular, the Special Area 3 regulations (10 CSR 23-3.700(7)), a subset of Chapter 3 of the Well Construction rules, specifically apply to new wells constructed at OU4.

4.3.3 Long-Term Effectiveness and Permanence

In this alternative, the contaminated soils would be actively restored, so there would be a substantial decrease in the long-term risk from the contaminants remaining in either media at OU4. In-situ treatment (by in-situ chemical oxidation) of contaminated soil is considered an adequate and reliable method of contaminant removal. All the contaminated soil exceeding the cleanup goals would be treated by in-situ chemical oxidation. The period for the remediation of the soils is approximately 5 years. Five-year reviews would be conducted until the cleanup goals were met to ensure protection of human health and the environment.

The in-situ soil chemical oxidation would occur by injecting an oxidizing agent into the soils. The oxidizing agent would degrade the PCE and other COCs to carbon dioxide, salt, and water. If the desired results are not achieved in the estimated 5 years for the soils, additional chemical applications might have to be made to remediate the

recalcitrant hot spots. If these measures do not succeed in remediating the soils, other alternatives discussed in Section 3.2.3 would have to be considered.

The long-term risk from the soil contaminants treated in-situ would be minimal because the contaminants would be degraded to harmless by-products. The treatment of the OU4 soil contaminants by in-situ chemical oxidation should permanently and effectively remove the contaminants from the soil.

Implementation of this alternative would reduce the long-term risk to health that is associated with potential human use of the contaminated groundwater. However, because contaminated groundwater would remain in the aquifer, a long-term risk would continue to exist for the environment. The environmental risks would remain until natural attenuation processes reduced the groundwater contaminant levels to the MCLs. While not expected, if recalcitrant to treatment contaminated soils remain in the source area, the soil contaminants may continue to contaminate the groundwater above MCLs.

Eventually, groundwater contaminants would be diluted through natural processes, but because no active remediation would be conducted, contaminated groundwater would remain at OU4 for a long time. In order to estimate costs, it has been assumed that Alternative 3 will last 30 years. Because groundwater monitoring would be conducted, there would be a mechanism to evaluate the contaminant levels in the plume, future migration of the plume, and the attenuation of contaminants from natural processes (if any). The long-term effectiveness of institutional controls are uncertain, but if properly maintained and enforced, should be good. As discussed, the Special Area 3 regulations have been finalized, so this institutional control is in place. Because contamination would remain at the subsite, 5-year reviews would be required. The long-term effectiveness of well construction restrictions and public education/information efforts are uncertain.

O&M activities associated with Alternative 3 would include groundwater and soil monitoring, support of MDNR as it conducts new well certifications, public education activities, and 5-year reviews. No difficulties or uncertainties are foreseen during the performance of these activities.

4.3.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

This alternative meets the statutory preference for treatment as a principal element for the soil. In-situ chemical oxidation of contaminated soil would effectively reduce the toxicity and volume of the contaminants in the source area soils. Chemical oxidation of PCE and the other COCs is an irreversible treatment.

Groundwater monitoring and institutional controls, including the Special Area 3 well construction requirements, would not reduce the toxicity, mobility, or volume of the

contaminants except by natural fate and transport processes. Monitoring would be effective in determining the reductions, if any, of the toxicity, mobility, or volume of the contaminants in the groundwater. Monitoring would be effective in determining the reductions of the toxicity, mobility, or volume of the soil contaminants from the two rounds of soil treatment conducted previously.

4.3.5 Short-Term Effectiveness

Community risk associated with this remedial alternative would be low during the application of the oxidizing chemical to the soil. The risk would be greater for workers, but would be minimized by compliance with OSHA requirements and guidelines for hazardous waste site activities. Direct push point installation activities would require that workers be trained and certified to perform hazardous waste site activities. Workers would be required to wear Level D personal protective equipment during chemical application and well installation activities. Because all treatment would be in-situ, no short-term or cross-media should occur.

Environmental impacts resulting from the groundwater remediation activities would include: noise pollution during well installation and minimal fugitive dust emissions during well construction. During the well installation activities, rods and equipment would be decontaminated after each use. During well construction, the contaminated soil cuttings removed from the aquifer would be containerized to minimize possible contact with the contaminants. Any decontamination water generated during the direct push applications or well installation would be collected and treated.

The time required to achieve the completion of the soil RA portion of this alternative is estimated to be 5 years. The time to actually construct the alternative would be approximately:

8 months:	Engineering design, including direct push sampling to confirm the extent of the soil contamination.
12 months:	Install monitoring wells to monitor the groundwater plume.
60 months:	Conduct in situ treatment of the contaminated soils.
108 months:	Conduct two rounds of confirmation sampling of the remediation of the source area soils.

There would be a minimal increase in the short-term risk to the workers, the community, or the environment during installation of new monitoring wells. The amount of time required for the contaminants in the groundwater to degrade or dilute to concentrations at or below the MCLs or risk-based levels is unknown, but is expected to be significantly greater than 30 years. Design and installation of additional monitoring wells would take a few months to a year.

4.3.6 Implementability

Implementability of the soil remediation efforts would be relatively easy given the source areas location (behind four residences). Chemical oxidation of the COCs at OU4 is technically and administratively feasible. Two in-situ chemical oxidation injection efforts have already been conducted on the source area soils. There are numerous suppliers of several different types of oxidizers and contractors to conduct the in-situ chemical injections are also available.

Technical assistance regarding appropriate safety procedures can be provided by OSHA, which also has the authority to inspect Superfund sites to ensure compliance with OSHA standards.

This alternative would not interfere with additional remediation, if required. This might include installation of additional soil treatment efforts, pumping the oxidizing chemical at a different concentration or a higher volume, or using a different remedial process option. Sampling of the existing and proposed monitoring wells should be sufficient to determine the success of the groundwater's remediation. Implementation of this alternative would also require coordination with the MDNR, the City of New Haven, and several private citizens.

Groundwater monitoring, including installation of additional monitoring wells, is easily implementable. Additional coordination activities would be needed to ensure that any monitoring wells installed in the New Haven Residential Historical District comply with the NHPA. Placement of the monitoring wells would have to be coordinated with the private citizens and the City of New Haven. Monitoring well closure, when needed in the future, should also be easy to implement. Technical assistance regarding appropriate safety procedures can be provided by OSHA, which also has the authority to inspect Superfund sites to ensure compliance with OSHA standards.

Frequently, the implementation of institutional controls can be somewhat difficult. However, the implementability of institutional controls at OU4 should be simple. The Special Area 3 regulations have already been finalized for the entire Riverfront Site, not just OU4. New well certifications would be implemented and overseen by the State of Missouri (MDNR's Wellhead Protection Section). Public education/information could be easily implemented through public notices in the newspaper, through direct mailings, and through public meetings. Five-year reviews would be required, and the services, materials, and personnel needed to complete the required 5-year reviews are readily available.

4.3.7 Cost

The detailed summary of the costs associated with the implementation of Alternative 3 is presented in Table A-3 of Appendix A.

The capital costs include both direct and indirect capital costs. This alternative would have capital costs consisting of installation of five new monitoring wells, soil monitoring, and supporting the MDNR Wellhead Protection Section with new well certifications. With the addition of indirect costs, the total capital cost is estimated to be $223,000.

The O&M costs associated with implementing this alternative include groundwater monitoring and placement of the oxidizing chemical in the soil. The duration of this alternative is assumed to be 30 years. O&M costs are divided into two types, yearly and intermittent costs. An example of a yearly cost is the preparation, publication, and mailing of an annual newsletter. Intermittent costs are periodic costs and those costs that differ over the life of the alternative. Examples of intermittent costs are the costs for the 5-year reviews and the costs for sampling the monitoring wells. In addition, costs to close the monitoring wells have been included in the Year 30 costs. While monitoring will probably have to continue beyond 30 years, closure of the wells will be required at some time, so the costs have been included in Year 30 for completeness. See the cost assumptions in Appendix A, Table A-3 for details on the intermittent costs.

Annual O&M costs for the first year are estimated to be $330,500, and the costs are estimated between $165,500 and $32,200 for every year thereafter. The total present worth of the O&M costs for Alternative 3 is $1,178,000. The total annual O&M costs are $2,081,000.

The total present worth of Alternative 3 is estimated to be $1,401,000.

Table 4-1
Factors for Detailed Analysis of Alternatives
Operable Unit 4, Orchard Street/Maiden Lane Subsite
New Haven, Missouri

Overall Protection	Compliance with Applicable or Relevant and Appropriate Requirements (ARARs)	Long-Term Effectiveness and Permanence	Reduction of Toxicity, Mobility, and Volume	Short-Term Effectiveness	Implementability	Cost	State Acceptance[1]	Community Acceptance[1]
How alternative provides protection to human health and the environment	Compliance with contaminant - specific ARARs Compliance with action - specific ARARs Compliance with location - specific ARARs Compliance with to-be-considereds (TBCs) (appropriate criteria, advisories, and guidance)	Magnitude of residual risk Long-term controls	Treatment process used and media treated Amount of hazardous materials destroyed or treated Degree of expected reductions in toxicity, mobility, and volume Degree to which treatment is irreversible Type and quantity of residuals remaining after treatment	Protection of the community and workers during RAs Environmental impacts Time until RAOs are achieved	Technical feasibility Administrative feasibility Availability of necessary services and materials	Direct capital costs Indirect capital costs Operating and maintenance costs Present worth cost	Aspects of the alternative the State of Missouri supports Aspects of the alternative the State of Missouri has reservations about Elements of the alternative the State of Missouri strongly opposes	Aspects of the alternative the community supports Aspects of the alternative the community has reservations about Elements of the alternative the community strongly opposes

Note:
[1] This criterion cannot be assessed until this FS has been reviewed by the MDNR and the public. It will be fully assessed in the Record of Decision.

5.0 Comparative Analysis of Alternatives

This section compares the groundwater remedial alternatives on the basis of the evaluation criteria developed and discussed in the introduction of Section 4.0. These criteria include protection of human health and the environment; compliance with ARARs; long-term effectiveness and permanence; reduction in toxicity, mobility, or volume through treatment; short-term effectiveness; implementability; and cost. A summary of this detailed evaluation is provided in Table 5-1. A cost sensitivity analysis is presented in Section 5.7.2.

5.1 Criteria 1--Overall Protection of Human Health and the Environment

Alternative 1 would not provide additional protection of the environment from the contaminants in the groundwater. Currently (August 2008), two subsite-specific factors protect human health from the contaminated groundwater at OU4. However, the potential for future ingestion or direct contact with contaminated groundwater would remain. Existing water supply wells in OU4 may be contaminated and Alternative 1 does not include any mechanisms for monitoring wells or warning the public of the potential dangers from using the contaminated groundwater. Currently (August 2008), two subsite-specific factors protect human health from the possibly contaminated soil at OU4. In addition, untreated contaminants in the soil (if any) could continue to migrate into the groundwater and continue to discharge into the Missouri River. Because no RAs would occur under Alternative 1, the groundwater contaminants would continue to migrate and increase the size of the plume and ultimately continue to discharge contaminants into the Missouri River.

Alternatives 2 and 3 would meet the groundwater and soil RAOs for protection of human health. Alternative 1 should meet the soil RAO for the protection of human health and may meet the groundwater human health RAO. However, Alternative 1 does not include any actions to ensure that human health remains protected. Alternatives 1, 2, and 3 would not meet the groundwater environmental protection RAO and would require waivers.

Waivers and the grounds for invoking them are discussed in the NCP, 40 CFR 300.430(f)(1)(ii)(C). As discussed in earlier sections and in Appendix B, it is impracticable to contain or treat the entire groundwater plume. Therefore, all three alternatives would have to have the environmental protection RAO waived.

The soils have been treated and some portion may meet the RAOs. Alternative 1 would not sample the soils, so it would not be possible to determine if they meet the soil

environmental protection RAO. Alternative 2 would sample the soils and contain any contaminated soils so this alternative would also meet the RAO for protection of the environment from soil contamination. Under Alternative 3, the soils would sampled, so it will be possible to determine if the soils were sufficiently remediated during the RA to meet the RAOs.

Alternatives 2 and 3 would be more protective of human health and the environment than Alternative 1. Alternative 2 would provide containment of the most contaminated groundwater and the source area soils and shallow bedrock. Overall, the groundwater protection provided in Alternative 2 would be greater than Alternative 3 because the contamination in the source area soils would be isolated from the groundwater and the heavily contaminated groundwater in Zones A and B would be contained. By minimizing the replenishment of the downgradient plume contaminants from the contaminated soils and the heavily contaminated upgradient portion of the plume, Alternative 2 should allow natural attenuation processes to begin to decrease the groundwater contaminant levels. Alternative 3 would include groundwater monitoring to evaluate the migration, if any, of the plume.

The groundwater extraction and treatment technologies in Alternative 2 are proven effective for removal of VOCs from groundwater and have been used at many sites. However, uncertainties exist concerning the length of time to achieve cleanup goals because of the potential for re-contamination of the groundwater through desorption of contaminants from contaminated portions of the aquifer not enclosed in the containment.

Chemical oxidation (Alternative 3), is a proven effective technology for remediating VOC-contaminated soil. Contractors and materials to perform these activities would be readily available.

5.2 Criteria 2--Compliance with ARARs

Alternative 1 would not comply with the chemical-specific ARARs because groundwater with contaminant levels in excess of the cleanup goals would remain unremediated and unmonitored. Alternative 2 includes containment of the heavily contaminated head of the groundwater plume, treatment of extracted groundwater and groundwater monitoring, while Alternative 3 would include groundwater monitoring to monitor the location and contaminant levels in the plume. However, both Alterntives 2 and 3 would still not comply with ARARs unless a waiver was received. Waivers and the grounds for invoking them are discussed in the NCP, 40 CFR 300.430(f)(1)(ii)(C). As discussed in earlier sections and in Appendix B, it is impracticable to contain or treat the

entire groundwater plume. Therefore, all three alternatives would have to have the requirement to meet the chemical-specific ARARs waived.

The Missouri Well Construction Code would apply to the well closures in all the alternatives.

Alternatives 2 and 3 would comply with all federal and state location- and action-specific ARARs. Alternative 2, a containment alternative, would prevent further migration of the heavily contaminated portions of the contaminant plume and contain soils and shallow bedrock containing contaminants above cleanup levels. By isolating the primary source of the groundwater contamination (the downgradient source area soils and shallow bedrock), Alternative 2 would allow natural attenuation processes to "treat" the plume without new contaminant loading from the source area soils/shallow bedrock or the heavily contaminated groundwater from Zones A and B. Alternative 3 would actively remediate the source area soils (Alternative 7). Both Alternatives 2 and 3 would monitor the contaminated groundwater plume over the operational life of the alternative.

Any new domestic water supply well installations in or near OU4 would have to comply with the Missouri Well Construction rules (codified at 10 CSR 23-3). In particular, the Special Area 3 regulations (10 CSR 23-3.700(7)), a subset of Chapter 3 of the Well Construction rules, specifically apply to new wells constructed at OU4.

5.3 Criteria 3--Long-Term Effectiveness and Permanence

Because Alternative 1 would conduct no RAs, there would be a long-term risk associated with Alternative 1 as long as cleanup goals are exceeded. Under Alternative 1 it is probable that the contaminant plume would continue to migrate downgradient, ultimately discharging into the Missouri River. Any treated source area soils still above the soil cleanup goals could continue to release contaminants into the groundwater. Alternative 1 would provide minimal long-term effectiveness through the well construction and certification requirements. It should be noted that Special Area 3 regulations have been finalized and would provide some protection from future exposure to groundwater through well construction restrictions. Alternative 1 would not include a mechanism (such as monitoring) to determine if: contaminant concentrations are increasing or decreasing; if the plume was migrating towards new receptors, or; if the contaminated soils have been remediated. The risks from Alternative 1 are higher than the current risk because any future excursions by the plume would not be detected and the effectiveness of the 2007 soil treatments would not be determined. In any case, the risks from Alternative 1 would not be less than the current risks.

Alternative 2 would have the least long-term risk because it would contain the source area soils with capping, sheet piling, and rock grouting and the heavily

contaminated portion of the plume (Zones A and B) with hydraulic control. This alternative would also monitor the groundwater plume. Alternative 2 would include monitoring to determine if: groundwater contaminant concentrations are increasing or decreasing; if the plume was migrating towards new receptors, and; the location of contaminated soils above the cleanup goals. Alternative 2 would also provide additional long-term effectiveness through the well construction and certification requirements and public education/information. It should be noted that Special Area 3 regulations have been finalized and would provide some protection from future exposure to groundwater through well construction restrictions.

Alternative 3 would have less long-term risk than Alternative 1 because it would treat the source area soils with in-situ chemical oxidation until they meet the clean up goals and would monitor the groundwater plume. Alternative 3 would include monitoring to determine if: contaminant concentrations are increasing or decreasing; if the plume was migrating towards new receptors, and; the degree the contaminated soils have been remediated. Alternative 3 would also provide additional long-term effectiveness through the well construction and certification requirements and public education/information. It should be noted that Special Area 3 regulations have been finalized and would provide some protection from future exposure to groundwater through well construction restrictions.

Because Alternatives 2 and 3 would monitor the plume, any migration of the plume towards sensitive receptors would be detected, allowing USEPA and MDNR to take appropriate action. The proposed monitoring plans in Alternatives 2 and 3 should also provide adequate and timely information on the effectiveness of the alternatives and the soil and groundwater contaminant levels at OU4.

Five-year reviews would be required for all three alternatives. Alternatives 1, 2, and 3 would require at least six 5-year reviews because they all would last at least 30 years.

Because no active remediation would occur in Alternative 1, and because it is technically impracticable to treat the downgradient portion of the plume (Zone C), it is probable that the RAO for protection of the environment would not be met by any of the alternatives.

Long-term management is required for Alternatives 2 and 3, but not Alternative 1. Long-term management of Alternative 2 would include preparation, publication, and mailing of an annual newsletter and regularly scheduled groundwater monitoring. Maintenance of the groundwater treatment system treating the groundwater extracted from the soil containment and the plume containment wells would need to be performed on a regular basis for Alternative 2. Long-term management of Alternative 3 would also

include preparation, publication, and mailing of an annual newsletter and regularly scheduled groundwater monitoring. The monitoring program for Alternatives 2 and 3 would be extensive but easily implemented. The groundwater treatment system maintenance necessary for Alternative 2 would also be easily implemented. Some components of Alternative 2's treatment systems, such as pumps, may require replacement over the life of the alternative. However, proper maintenance of the equipment should minimize the need for costly repairs and unscheduled replacements.

5.4 Criteria 4--Reduction of Toxicity, Mobility, or Volume Through Treatment

Because Alternative 1 does not include any treatment or source removal, no decreases in the toxicity, mobility, or volume of the soil and groundwater contamination are anticipated. Also, Alternative 1 would not provide mechanisms (such as monitoring) to determine if any reductions are occurring due to natural attenuation, to ensure that the plume is not migrating towards sensitive receptors, or to confirm that the soils have been remediated.

Alternative 2 would significantly reduce the mobility of the contaminants in the soil and shallow bedrock by containing the contamination in the cap/sheet pile/rock grouting enclosure. Alternative 2 would provide reduction in the mobility and volume of some of the groundwater contaminants by extraction and treatment within the source area. Reductions in the volume of the downgradient groundwater contaminants should occur as natural attenuation processes begin to remove more contaminant mass from the downgradient portion plume than is added from the isolated source area soils or through desorption from the downgradient aquifer rock. Alternative 2 would have residual spent carbon from the groundwater treatment system.

Alternative 3 would reduce the volume and toxicity of the soil contaminants by using in-situ chemical oxidation to degrade the contaminants to harmless by-products. Alternative 3 would include monitoring to determine if the plume is migrating towards sensitive receptors and soil monitoring to confirm the remediation of the soils.

The soil (in-situ chemical oxidation) and the groundwater treatment technology (GAC) are irreversible. Residuals should only be generated with Alternative 2. The residual generated by Alternative 2 would be spent GAC. Only Alternative 3 meets the statutory preference for treatment as a principal element although Alternative 2 does treat the groundwater that is extracted to contain the head of the plume.

5.5 Criteria 5--Short-Term Effectiveness

There would be no increased risk to the community or workers with Alternative 1. Minimal increased risks would occur with Alternative 3 from installation of additional monitoring wells and the soil monitoring and treatment. The risks from Alternative 2 would be moderately low, mainly due to the installation of the sheet piling around the source area soils and the demolition of the old garage.

The short-term risks for all alternatives could be controlled by following proper precautions. The risk to construction workers would be controlled by proper use of personal protection equipment, equipment decontamination, monitoring during subsite activities, and enforcing OSHA construction safety standards. The risk to the community would be reduced by limiting access to the areas where construction activities are being conducted. Nearby residents may be exposed to noise during installation of monitoring, treatment, and extraction wells; during the installation of pipelines; during direct push application of oxidizing chemical; demolition of buildings, installation of sheet piling, and rock grouting activities. Noise would be controlled by limiting the hours of work.

The time to achieve clean up levels would be greatest for Alternative 1 and is estimated to be significantly greater than 30 years.

Alternative 2 would encapsulate the source area soils and shallow bedrock with a cap/sheet piling/rock grouting enclosure and hydraulically contain the heavily contaminated head of the groundwater plume. Alternative 2 would likely reach cleanup goals earlier than Alternative 1 and possibly Alternative 3 but it is estimated that it will still take more than 30 years.

Alternative 3 would treat in-situ the remaining contaminated soils, which should remove the source of the groundwater contamination and allow groundwater cleanup levels to be reached through natural attenuation earlier than Alternative 1. Because Alternative 2 would contain the heavily contaminated groundwater at the head of the plume as well as the source area soils, it may reach the groundwater cleanup levels before Alternative 3. Based on the history of the plume, no estimate of the time to achieve the groundwater environmental protection RAO under Alternatives 1, 2, and 3 can be made. Containment of the contaminated soil in Alternative 2 would likely occur within 12 months. It is anticipated that the soil treatment for Alternative 3 would occur over five years, with rebound sampling occurring in Years 6 and 9.

5.6 Criteria 6--Implementability

Implementation of Alternative 1 would be easy to complete. Closure of the existing monitoring wells and 5-year reviews would be required, and the services,

materials, and personnel needed to close the wells and complete the reviews are readily available.

Implementation of Alternative 3 would also be easy to accomplish, but slightly more difficult than Alternative 1. In-situ chemical oxidation treatment of the contaminated soils has already been conducted twice so it can be implemented. The installation of monitoring wells is a common practice which has also been done before at OU4, and technical assistance for health and safety concerns for both the soil treatment and well installation is readily available.

The Special Area 3 regulations have already been finalized for the entire Riverfront Site, not just OU4. The MDNR would enforce the Special Area 3 regulations, including well certifications. Public education/information could be easily implemented through public notices in the newspaper, through direct mailings, and through public meetings. As with Alternative 1, well closure (in Year 30) and 5-year reviews would be required, and the services, materials, and personnel needed to install monitoring wells, conduct sampling, close the wells, and complete the reviews are readily available.

Alternative 2 would be the hardest alternative to implement because it would require installation of extraction wells, the soil enclosure elements (especially the sheet piling and cap) and the groundwater treatment system as well as nearly the same number of monitoring wells as Alternative 3.

As with Alternative 3, well construction standards and certifications and public education/information could be implemented and enforced by the MDNR, and/or the USEPA. Public education/information could be easily implemented through public notices in the newspaper, through direct mailings, and through public meetings. As with both Alternatives 1 and 2, well closure (in Year 30) and 5-year reviews would be required, and the services, materials, and personnel needed to install monitoring wells, conduct sampling, close the wells, and complete the reviews are readily available.

The soil remediation technology, in-situ chemical oxidation, is proven and reliable.

It is anticipated that Alternative 1 would not be effective and would likely require additional RAs.

It is anticipated that Alternatives 2 and 3 would be effective in containing (Alternative 2) or treating (Alternative 3) the contaminated soils. Alternative 2 should also be effective in containing the heavily contaminated head of the plume. However, both Alternatives 2 and 3 would only monitor the downgradient (Zone C) portion of the plume. If the alternative selected is not effective in meeting the RAOs, there would be no technical difficulties in implementing additional RAs. All the alternatives except Alternative 1 would adequately monitor all migration or exposure pathways.

The necessary equipment and personnel required to implement each alternative are available.

5.7 Criteria 7--Cost

A cost comparison for the remediation alternatives is included in this subsection. Also included are the detailed cost estimates for each alternative and the sensitivity analysis that evaluates the impact of changes on the total present worth of each alternative. These estimates are approximate and made without detailed engineering data. The actual cost of the project would depend on the final scope of the RA and on other unknowns. The costs of the alternatives are summarized in Table 5-2.

5.7.1 Individual Cost Comparison

The total present worth of Alternative 1 would be the lowest at a cost of $121,000. The total present worth cost of Alternative 2 would be the greatest at a cost of $2,563,000. The total present worth cost of Alternative 3 are $1,401,000.

5.7.2 Cost Sensitivity Analysis

Cost estimates involve approximation, assumptions, estimations, interpretation, and engineering judgment. The purpose of this sensitivity analysis is to evaluate the effects of varying key parameters on the total present worth of an alternative while holding all other factors constant.

The following changes to the alternatives are evaluated:

- Varying the discount rate used to calculate the present worth of the alternatives from 7 percent to 5 and 10 percent for all alternatives.
- Varying the volume of contaminated soils that must be contained or treated. For Alternatives 2 and 3, the costs to contain or treat the soils were increased doubled or decreased by 50 percent.
- Varying the amount of O&M required by the alternatives. For Alternatives 2 and 3, the effect of quarterly monitoring throughout the life of the alternative was evaluated. For Alternative 2, the O&M costs for the containment were doubled.

A summary of the alternative cost array from varying these parameters is presented in Table 5-3. A summary of the cost sensitivity analysis results for the alternatives is presented in the following paragraphs.

The present worth cost represents the amount of money that would have to be invested at the beginning of a RA at a given interest rate (discount rate) to pay for all expenditures throughout the life of an alternative. Therefore, decreasing the discount rate

would increase the present worth costs of the alternatives and increasing the discount rate would decrease their present worth costs.

Changing the discount rates affected Alternative 2 the most and Alternative 1 the least. Alternative 3 changed nearly as much as Alternative 2. Alternative 2 and 3 showed the greatest percent change in present worth because a large percentage of their total costs are O&M costs. Alternative 1 showed the least percent change because the large majority of its costs are capital costs. When the discount rate is decreased to 5 percent, the present worth of Alternatives 1, 2, and 3 increased 6.8, 14.3, and 11.6, percent, respectively. When the discount rate is increased to 10 percent, the present worth of Alternatives 1, 2 and 3 decreased by 6.5, 14.5 and 12.3 percent, respectively.

Varying the soil or treatment costs affected Alternative 3 more than Alternative 2. Alternative 3 showed the greatest percent change in present worth because a large percentage of its total costs are the costs for the soil treatment, which occur in the early years of the Alternative. Alternative 2 showed the least percent change because a larger percentage of its costs are O&M costs for groundwater treatment. When the soil volume or costs are doubled, the present worth of Alternatives 2 and 3 increased 16.3 and 29.1 percent, respectively. When the soil volume or costs are decreased by 50 percent, the present worth of Alternatives 2 and 3 decreased by 8.5 and 14.9 percent, respectively. This case was not applicable to Alternative 1 because it does not contain or treat the soils.

Doubling and halving the O&M costs (Alternative 2) or continuing quarterly monitoring for the life of the alternative (Alternatives 2 and 3) affected Alternative 3 more than Alternative 2. Alternative 3 showed the greatest percent change in present worth because more of its total costs are monitoring costs. Alternative 2 showed less (but still significant) change because a larger percentage of its costs are costs for soil treatment. When the O&M costs are doubled, Alternative 2's costs increased 35.3 percent. Decreasing O&M costs by 50 percent decreased Alternative 2's costs by 17.6 percent. Continuing quarterly monitoring for the life of Alternatives 2 and 3 increased their costs by 42.8 and 43.8 percent, respectively. This case was not applicable to Alternative 1, because it's only O&M costs were for 5-year reviews.

Table 5-1
Comparative Analysis of Alternatives
Operable Unit 4, Riverfront Superfund Site
New Haven, Missouri

Evaluation Criteria	Alternative 1 No Action/ No Action	Alternative 2 Capping, Sheet Piling, and Rock Grouting / Hydraulic Containment, Above Ground Treatment, and Monitoring	Alternative 3 In Situ Chemical Oxidation / Monitoring	Alternative Rankings
Overall Protection of Human Health and the Environment	Human health protection RAOs currently met by four site-specific factors. Would not prevent future direct contact with contaminated groundwater. Environmental protection RAOs would not be met because contamination above cleanup levels would remain in the groundwater and the soil.	Protective by containing heavily contaminated groundwater and soil/shallow bedrock (if soil/bedrock is still contaminated after earlier treatment). Amount of contamination migrating from soils and shallow bedrock to groundwater would be minimized, which should allow natural processes to reduce the downgradient plume. Human health RAOs currently met by four site-specific factors. Would prevent future direct contact with contaminated groundwater. Groundwater environmental protection RAO would not be met because contamination above cleanup levels would remain in the groundwater. Monitoring would allow determination of whether soil environmental protection RAO had been met and if groundwater plume was threatening new receptors.	Protective by actively remediating the source area soils. Human health RAOs currently met by four site-specific factors. Would prevent future direct contact with contaminated groundwater. Groundwater environmental protection RAO would not be met because contamination above cleanup levels would remain in the groundwater. Monitoring would allow determination of whether soil environmental protection RAO had been met and if groundwater plume was threatening new receptors.	Ranked from alternative that would provide the most overall protection of human health to least overall protection: 3, 2, 1 Ranked from alternative that would provide the most overall protection to the environment to least overall protection: 3, 2, 1
Compliance with Applicable or Relevant and Appropriate Requirements (ARARs)	Present and future groundwater concentrations would not meet chemical-specific ARARs. Location-specific ARARs are not applicable. Would comply with action-specific ARARs.	Would not meet chemical-specific ARARs. Groundwater with contaminant levels above MCLs would remain at the site. Would comply with all Federal and State location-specific and action-specific ARARs.	Would not meet chemical-specific ARARs. TI waiver will be required. Groundwater with contaminant levels above MCLs would remain at the site. Would comply with all Federal and State location-specific and action-specific ARARs.	Would not meet ARARs unless a waiver is obtained: 1, 2, 3
Long-Term Effectiveness	This alternative would not provide active reduction of long-term risks. There are no long-term controls to provide passive reduction of long-term risk.	Lower long-term risks than Alternative 1 but higher than Alternative 3 because even though contained (if necessary), the contaminated source area soils/shallow bedrock would be left in place.	Minimal long-term risks for the source area soils because the soils would be treated to below the cleanup goals. Groundwater monitoring would provide means to monitor the long-term risk from contaminant plume migration. Soil monitoring would confirm soil remediation. Would not provide active reduction of long-term groundwater risks.	Ranked from alternative that would provide the most long-term effectiveness to least long-term effectiveness: 3, 2, 1
Reduction of Toxicity, Mobility, and Volume	It is not expected that reductions of the toxicity, mobility, or volume of the contaminants in the groundwater or soil would occur. Would not provide mechanisms to monitor contamination levels.	Mobility of the heavily contaminated head of the plume minimized by containment. Treatment would reduce the toxicity and volume of contaminated extracted groundwater. Reduction of the mobility of the contaminants in the source area soils/shallow bedrock through physical containment and hydraulic containment. Spent GAC would be only treatment residual. Does not meet the statutory preference for treatment as a principal element.	Volume and toxicity of the soil contaminants reduced through in situ chemical oxidation. Meets statutory preference for treatment as a principal element. It is not expected that reductions of the toxicity, mobility, or volume of the contaminants in the groundwater would occur. Would provide mechanisms to monitor groundwater and soil contamination levels.	Ranked from alternative that would provide the most reduction of toxicity, mobility, and volume to least: 3, 2, 1
Short-Term Effectiveness	The only remedial action that would be conducted is well closure, which can be conducted with only minimal increases in the short-term risks to the community, the environment, and workers. The time to achieve cleanup goals is unknown but anticipated to be significantly longer than 30 years.	Risks to community would be low and risk to workers would be moderate but would be minimized by following proper precautions. The time to implement is estimated to be between 12 and 18 months. The time to reach cleanup goals is anticipated to be longer than 30 years.	Risks to the community from soils would be low and risk from soils to workers would be moderately low. Risks would be minimized by following proper precautions. Soil cleanup goals would be reached in approximately 5 years. Risk to community and workers from the groundwater would be low because action would be limited to installation of monitoring wells. The time to achieve the cleanup goals for the groundwater is unknown but anticipated to be longer than 30 years.	Ranked from alternative that would provide the most short-term effectiveness to least short-term effectiveness: 1, 3, 2
Implementability	Technically and administratively feasible. The only remedial action that would be conducted is well closure. There are many vendors providing well closure services.	Technically feasible. Soil remedy would be more difficult to implement than Alternatives 1 and 3. Groundwater remedy would also be more difficult to implement than Alternatives 1 and 3. Administratively feasible. Would require utility relocates during and after soil remediation and coordination with some private citizens, MDNR, and City of New Haven.	Technically feasible. Few technical problems would be anticipated. Administratively feasible.	Ranked from alternative that would be the easiest to implement to the hardest to implement: 1, 3, 2
Cost (Total Present Worth)	See Table 5-2	See Table 5-2	See Table 5-2	Ranked from least expensive to most expensive: 1, 3, 2

Table 5-2
Alternative Cost Summary Table
Operable Unit 4, Riverfront Superfund Site
New Haven, Missouri

Alternative	Capital Cost	Present Worth of O&M Costs	Total Present Worth	Total Cost of O&M Costs
Alternative 1 - No Action / No Action	$93,000	$28,100	$121,100	$78,000
Alternative 2 - Capping, Sheet Piling, and Rock Grouting / Hydraulic Containment and Above Ground Treatment	$825,000	$1,738,000	$2,563,000	$3,921,000
Alternative 3 - In-Situ Chemical Oxidation / Monitoring	$223,000	$1,178,000	$1,401,000	$2,081,000
7 percent discount rate				

Table 5-3
Cost Sensitivity Analysis
Operable Unit 4, Riverfront Superfund Site
New Haven, Missouri

Cost Sensitivity Parameters	Alternative 1 - No Action/ No Action		Alternative 2 - Capping, Sheet Piling, and Rock Grouting / Hydraulic Containment and Above Ground Treatment		Alternative 3 - In Situ Chemical Oxidation/ Monitoring Action		Cost Sensitivity Parameters
	Total Present Worth	Percent Change	Total Present Worth	Percent Change	Total Present Worth	Percent Change	
Original Present Worth (7 Percent Discount Rate)	$121,000	NA	$2,563,000	NA	$1,401,000	NA	Original Present Worth (7 Percent Discount Rate)
5 Percent Discount Rate	$129,200	6.8%	$2,930,000	14.3%	$1,563,000	11.6%	5 Percent Discount Rate
10 Percent Discount Rate	$113,100	-6.5%	$2,191,000	-14.5%	$1,228,000	-12.3%	10 Percent Discount Rate
Double Soil Containment Costs	NA (1)	--	$2,982,000	16.3%	NA (1)	--	Double Soil Containment Costs
Decrease Soil Containment Costs by 50%	NA (1)	--	$2,344,000	-8.5%	NA (1)	--	Decrease Soil Containment Costs by 50%
Double Soil Treatment and Sampling Costs	NA (2)	--	NA (2)	--	$1,808,000	29.1%	Double Soil Treatment and Sampling Costs
Decrease Soil Treatment and Sampling Costs by 50%	NA (2)	--	NA (2)	--	$1,192,000	-14.9%	Decrease Soil Treatment and Sampling Costs by 50%
Double O&M Costs	NA (3)	--	$3,467,000	35.3%	NA (3)	--	Double O&M Costs
Decrease O&M Costs by 50%	NA (3)	--	$2,111,000	-17.6%	NA (3)	--	Decrease O&M Costs by 50%
Quarterly Sampling for the Life of the Alternative	NA (4)	--	$3,660,000	42.8%	$2,043,000	45.8%	Quarterly Sampling for the Life of the Alternative

Notes
1 - Not applicable because this alternative does not include cost items that would be affected by the containment of contaminated soil.
2 - Not applicable because this alternative does not include cost items that would be affected by soil remediation costs.
3 - Not applicable because this alternative does not include O&M costs.
4 - Not applicable because this alternative does not conduct monitoring.

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Appendix A
Alternative Cost Estimates

Table A-1
Alternative 1 - No Action / No Action
Present Worth Cost Estimate
Riverfront OU4 Site FS Report

Cost Estimate Component	Quantity	Units	Unit Cost	Capital Cost	Annual Cost
CAPITAL COSTS					
Monitoring Well Closures	4,000	FT	$15	$60,000	
DIRECT CAPITAL COST SUBTOTAL				$60,000	
Bid Contingency (15% of Well Closures)				$9,000	
Scope Contingency (15% Well Closures)				$9,000	
TOTAL DIRECT CAPITAL COST				$78,000	
Permitting and Legal (5%)				$3,900	
Construction Services (10% of Well Closures)				$6,000	
CONSTRUCTION COSTS TOTAL				$87,900	
Engineering Design (8% of Well Closures)				$4,800	
TOTAL CAPITAL COST				$93,000	
ANNUAL OR PERIODIC O&M COSTS					
Five-Year Review @ 5, 10, 15, 20, 25, and 30 yrs	1	LS	$13,000		$13,000
TOTAL PRESENT WORTH O&M COST				$28,100	
TOTAL PRESENT WORTH				$121,100	

7 percent discount rate used to calculate present worth.

LS - Lump Sum

FT - Feet

Table A-1
Alternative 1 - No Action / No Action
Present Worth Cost Estimate
Riverfront OU4 Site FS Report

Year	Yearly O&M Cost*	Intermittent O&M Costs	Total Annual O&M Costs	Intermittent O&M Costs Include:
1	$0	$0	$0	
2	$0	$0	$0	
3	$0	$0	$0	
4	$0	$0	$0	
5	$0	$13,000	$13,000	5 yr review
6	$0	$0	$0	
7	$0	$0	$0	
8	$0	$0	$0	
9	$0	$0	$0	
10	$0	$13,000	$13,000	5 yr review
11	$0	$0	$0	
12	$0	$0	$0	
13	$0	$0	$0	
14	$0	$0	$0	
15	$0	$13,000	$13,000	5 yr review
16	$0	$0	$0	
17	$0	$0	$0	
18	$0	$0	$0	
19	$0	$0	$0	
20	$0	$13,000	$13,000	5 yr review
21	$0	$0	$0	
22	$0	$0	$0	
23	$0	$0	$0	
24	$0	$0	$0	
25	$0	$13,000	$13,000	5 yr review
26	$0	$0	$0	
27	$0	$0	$0	
28	$0	$0	$0	
29	$0	$0	$0	
30	$0	$13,000	$13,000	5 yr review
Total Cost of Annual O&M			$78,000	
Present Worth of Annual O&M			$28,100	

* There are no yearly O&M costs for this alternative.

Table A-2

Alternative 2 - Capping, Sheet Piling, and Rock Grouting / Hydraulic Containment and Above Ground Treatment

Present Worth Cost Estimate

Riverfront OU4 Site FS Report

Cost Estimate Component	Quantity	Units	Unit Cost	Capital Cost	Annual Cost
CAPITAL COSTS					
10 Extraction Wells (3 - 4" PVC wells to a depth of 20 ft, 7 - 4" wells at an angle to a length of 150 ft, development, pump installation, and well vault)	1,110	FT	$60	$66,600	
Piezometers (5 -2" PVC piezometers to a depth of 20 ft)	100	FT	$30	$3,000	
Submersible Pump (support wire, flow and control devices, electric service to wellhead)	10	EA	$1,000	$10,000	
Groundwater Collection Piping (includes double contained PVC piping, bedding, and trenching)	800	LF	$260	$208,000	
Prefabricated Structure (30' x 30', slab on grade)	1	LS	$60,000	$60,000	
Purchased Package (GAC vessels, Control Panel, Influent Storage Tank, Discharge pump)	1	LS	$60,000	$60,000	
Discharge Piping to Storm Drain (includes PVC piping, bedding and trenching)	200	LF	$260	$52,000	
Multi-layer Cap (includes grading, placement of cap)	5,400	SF	$5	$30,000	
Install Sheet Piling Around Soil Contamination (400 linear feet, 20 feet deep, 38 psf piling)	260	TONS	$500	$130,000	
Demolish 90 sf garage and dispose of rubble	1	LS	$10,000	$10,000	
Direct Push Sampling to Determine Extent/Levels of Soil Contamination (25 Borings, field analysis for VOCs)	1	LS	$35,000	$35,000	
Removal of Power Pole for Access and Replacement	1	LS	$30,000	$30,000	
Pump cement grout to seal bottom and sides (15 wells to a depth of 70 feet each (3 in the middle and 3 on 4 sides), Shallow wells so assume $40/ft, will have to grout up 50 ft to bottom of sheet pile, assume 100 ft length so each side will be 5,000 sq ft, total of 24,600 sq ft at $6/ft	1	LS	$190,000	$190,000	
Site Restoration	4,600	SF	$0.2	$900	
Monitoring Well Installation (8 wells each with 2 sampling depths)	1,340	FT	$60	$80,400	
Place Deed Restrictions (4 properties)	4	EA	$1,500	$6,000	
Place Zoning Notices (4 properties)	4	EA	$1,500	$6,000	
Assist MDNR Well Head Protection Section with Well Certifications	1	LS	$5,000	$5,000	
Preparation of Health and Safety Plan	80	HR	$100	$8,000	
Preparation of O&M Manual	120	HR	$100	$12,000	
Preparation of RA QA/Sampling Plan	120	HR	$100	$12,000	
DIRECT CAPITAL COST SUBTOTAL				$555,300	
Bid Contingency (10%)				$55,500	
Scope Contingency (15%)				$83,300	
TOTAL DIRECT CAPITAL COST				$694,100	
Permitting and Legal (5%)				$34,700	
Construction Services (5%)				$34,700	
CONSTRUCTION COSTS TOTAL				$763,500	
Engineering Design (8%)				$61,100	
TOTAL CAPITAL COST				$825,000	

Table A-2
Alternative 2 - Capping, Sheet Piling, and Rock Grouting / Hydraulic Containment and Above Ground Treatment
Present Worth Cost Estimate
Riverfront OU4 Site FS Report

ANNUAL OR PERIODIC O&M COSTS					
Electrical Costs	53,000	KWh	$0.09		$4,800
Spent Carbon Replacements	4	YR	$10,000		$40,000
Groundwater Treatment Operator (4 hours/week)	208	HR	$75		$15,600
Groundwater Treatment Plant Maintenance Allowance	1	LS	$3,000		$3,000
Cap O&M (includes inspections every 2 months, annual report)	60	HR	$75		$4,500
Cap Maintenance Allowance (includes patching and maintenance)	1	LS	$3,000		$3,000
EXTRACTION WELL MAINTENANCE					
Acid wash every 2 years except years 10, 20, and 30	1	LS	$2,000		$2,000
Redevelopment every 5 years, except year 30	1	LS	$7,000		$7,000
AIR MONITORING (Analysis Only, Labor included with Groundwater Sampling)					
Years 1 and 2 Semi-annual resident soil gas sampling (6 homes)	12	EA	$150		$1,800
GROUNDWATER MONITORING (Analysis Only) *					
Years 1 and 2 Quarterly sampling of 27 monitoring wells with 2 sampling zones for 22 of 27 wells and 7 extraction wells each for VOCs (standard turnaround+QA/QC) - sample using a submersible pump	260	EA	$95		$24,700
Years 3 through 5 Semi-annual sampling of 27 monitoring wells with 2 sampling zones for 22 of 27 wells and 7 extraction wells each for VOCs (standard turnaround+QA/QC) - sample using a submersible pump	130	EA	$95		$12,400
Years 6 through 30 Annual sampling of 27 monitoring wells with 2 sampling zones for 22 of 27 wells eand 7 extraction wells ach for VOCs (standard turnaround+QA/QC) - sample using a submersible pump	65	EA	$95		$6,200
Years 1 through 30 Groundwater Treatment Plant Influent and Effluent NPDES Monitoring (Quarterly-annual monitoring for VOCs, standard turnaround) For each sampling event, include 1 duplicate, 1 matrix spike/matrix spike duplicate, and 1 trip blank.	20	EA	$95		$1,900

Table A-2
Alternative 2 - Capping, Sheet Piling, and Rock Grouting / Hydraulic Containment and Above Ground Treatment
Present Worth Cost Estimate
Riverfront OU4 Site FS Report

GROUNDWATER MONITORING (Labor only)					
Years 1 and 2 2 Jr. Level person for 7 x 12 hour days per sampling event and 1 Jr. Level person for 5 x 8-hour days per data evaluation	832	HR	$100		$83,200
Quarterly sampling per diem	56	DAY	$730		$40,900
Years 3 through 5 2 Jr. Level person for 7 x 12 hour days per sampling event and 1 Jr. Level person for 5 x 8-hour days per data evaluation	416	HR	$100		$41,600
Semi-annual sampling per diem	28	DAY	$730		$20,400
Years 6 through 30 2 Jr. Level person for 7 x 12 hour days per sampling event and 1 Jr. Level person for 5 x 8-hour days per data evaluation	208	HR	$100		$20,800
Annual sampling per diem	14	DAY	$730		$10,200
INSTITUTIONAL CONTROLS					
Prepare Newsletter @ 5, 10, 15, 20, 25, and 30 yrs	24	HR	$100		$2,400
Newsletter Publication in Local Newspaper and Direct Mailing @ 5, 10, 15, 20, 25, and 30 yrs	1	LS	$500		$500
Public Informational Meeting @ 5, 10, 15, 20, 25, and 30 yrs	1	LS	$5,000		$5,000
Five-Year Review @ 5, 10, 15, 20, 25, and 30 yrs	1	LS	$13,000		$13,000
Monitoring Well Closures (Year 30, only)	6,550	FT	$15		$98,300
TOTAL PRESENT WORTH O&M COST				$1,738,000	
TOTAL PRESENT WORTH				$2,563,000	

7 percent discount rate used to calculate present worth.

* For each groundwater sampling event, include 3 duplicates, 3 matrix spike/matrix spike duplicates, and 3 trip blanks.

CY - Cubic Yard
LS - Lump Sum
HR - Hour
EA - Each
SF - Square foot
FT - Foot
YR - Year

Table A-2
Alternative 2 - Capping, Sheet Piling, and Rock Grouting / Hydraulic Containment and Above Ground Treatment
Present Worth Cost Estimate
Riverfront OU4 Site FS Report

Year	Yearly O&M Cost*	Intermittent O&M Costs	Total Annual O&M Costs	Intermittent O&M Costs Include:
1	$70,900	$152,500	$223,400	Sampling.
2	$70,900	$154,500	$225,400	Sampling and acid wash.
3	$70,900	$76,300	$147,200	Sampling.
4	$70,900	$78,300	$149,200	Sampling and acid wash.
5	$70,900	$104,200	$175,100	Sampling, 5-yr review, informational meeting, and redevelopment.
6	$70,900	$41,100	$112,000	Sampling and acid wash.
7	$70,900	$39,100	$110,000	Sampling.
8	$70,900	$41,100	$112,000	Sampling and acid wash.
9	$70,900	$39,100	$110,000	Sampling.
10	$70,900	$67,000	$137,900	Sampling, 5-yr review, informational meeting, and redevelopment.
11	$70,900	$39,100	$110,000	Sampling.
12	$70,900	$41,100	$112,000	Sampling and acid wash.
13	$70,900	$39,100	$110,000	Sampling.
14	$70,900	$41,100	$112,000	Sampling and acid wash.
15	$70,900	$67,000	$137,900	Sampling, 5-yr review, informational meeting, and redevelopment.
16	$70,900	$41,100	$112,000	Sampling and acid wash.
17	$70,900	$39,100	$110,000	Sampling.
18	$70,900	$41,100	$112,000	Sampling and acid wash.
19	$70,900	$39,100	$110,000	Sampling.
20	$70,900	$67,000	$137,900	Sampling, 5-yr review, informational meeting, and redevelopment.
21	$70,900	$39,100	$110,000	Sampling.
22	$70,900	$41,100	$112,000	Sampling and acid wash.
23	$70,900	$39,100	$110,000	Sampling.
24	$70,900	$41,100	$112,000	Sampling and acid wash.
25	$70,900	$67,000	$137,900	Sampling, 5-yr review, informational meeting, and redevelopment.
26	$70,900	$41,100	$112,000	Sampling and acid wash.
27	$70,900	$39,100	$110,000	Sampling.
28	$70,900	$41,100	$112,000	Sampling and acid wash.
29	$70,900	$39,100	$110,000	Sampling.
30	$70,900	$158,300	$229,200	Sampling, 5-yr review, informational meeting, and monitoring well closures.
Total Costs of Annual O&M			$3,921,000	
Present Worth of Annual O&M			$1,738,000	

Table A-3
Alternative 3 - In-Situ Chemical Oxidation / Monitoring
Present Worth Cost Estimate
Riverfront OU4 Site FS Report

Cost Estimate Component	Quantity	Units	Unit Cost	Capital Cost	Annual Cost
CAPITAL COSTS					
Monitoring Well Installation (5 wells each with 2 sampling depths)	1,500	FT	$60	$90,000	
Direct Push Sampling to Determine Extent/Levels of Soil Contamination (25 Borings, field analysis for VOCs)	1	LS	$35,000	$35,000	
Assist MDNR Well Head Protection Section with Well Certifications	1	LS	$5,000	$5,000	
Preparation of Health and Safety Plan	80	HR	$100	$8,000	
Preparation of RA QA/Sampling Plan	120	HR	$100	$12,000	
DIRECT CAPITAL COST SUBTOTAL				$150,000	
Bid Contingency (10%)				$15,000	
Scope Contingency (15%)				$22,500	
TOTAL DIRECT CAPITAL COST				$187,500	
Permitting and Legal (5%)				$9,400	
Construction Services (5%)				$9,400	
CONSTRUCTION COSTS TOTAL				$206,300	
Engineering Design (8%)				$16,500	
TOTAL CAPITAL COST				$223,000	

ANNUAL OR PERIODIC O&M COSTS					
ISCO INJECTION USING DIRECT PUSH					
Year 1 (Entire source area)	1	LS	$200,000		$200,000
Year 3 (Half the source area)	1	LS	$100,000		$100,000
Year 5 (Quarter of the source area)	1	LS	$50,000		$50,000
SOIL SAMPLING AFTER ISCO TREAMENT (USING DIRECT PUSH)					
Year 2 (Entire source area)	1	LS	$35,000		$35,000
Year 4 (Half the source area)	1	LS	$17,500		$18,000
Year 6 (Quarter of the source area)	1	LS	$8,750		$10,000
Year 9 (Entire Source Area)	1	LS	$35,000		$40,000
AIR MONITORING (Analysis Only, Labor included with Groundwater Sampling)					
Years 1 and 2 Semi-annual resident soil gas sampling (6 homes)	12	EA	$150		$1,800
GROUNDWATER MONITORING (Analysis Only) *					
Years 1 and 2 Quarterly sampling of 24 monitoring wells with 2 sampling zones for 15 of 24 wells for VOCs (standard turnaround+QA/QC) - sample using a submersible pump	212	EA	$95		$20,100
Years 3 through 10 Semi-annual sampling of 27 monitoring wells with 2 sampling zones for 22 of 27 wells each for VOCs (standard turnaround+QA/QC) - sample using a submersible pump	106	EA	$95		$10,100
Years 11 through 20 Annual sampling of 27 monitoring wells with 2 sampling zones for 22 of 27 wells for VOCs (standard turnaround+QA/QC) - sample using a submersible pump	53	EA	$95		$5,000

Table A-3
Alternative 3 - In-Situ Chemical Oxidation / Monitoring
Present Worth Cost Estimate
Riverfront OU4 Site FS Report

GROUNDWATER MONITORING (Labor only)					
Years 1 and 2 2 Jr. Level person for 6 x 12 hour days per sampling event and 1 Jr. Level person for 5 x 8-hour days per data evaluation report	736	HR	$100		$73,600
Quarterly sampling per diem	48	DAY	$730		$35,000
Years 3 through 10 2 Jr. Level person for 6 x 12 hour days per sampling event and 1 Jr. Level person for 5 x 8-hour days per data evaluation report	368	HR	$100		$36,800
Semi-annual sampling per diem	24	DAY	$730		$17,500
Years 11 through 30 2 Jr. Level person for 16 x 12 hour days per sampling event and 1 Jr. Level person for 5 x 8-hour days per data evaluation report	184	HR	$100		$18,400
Annual sampling per diem	12	DAY	$730		$8,800
ANNUAL OR PERIODIC O&M COSTS (Continued)					
INSTITUTIONAL CONTROLS					
Prepare Newsletter @ 5, 10, 15, 20, 25, and 30 yrs	24	HR	$100		$2,400
Newsletter Publication in Local Newspaper and Direct Mailing @ 5, 10, 15, 20, 25, and 30 yrs	1	LS	$500		$500
Public Informational Meeting @ 5, 10, 15, 20, 25, and 30 yrs	1	LS	$5,000		$5,000
Five-Year Review @ 5, 10, 15, 20, 25, and 30 yrs	1	LS	$13,000		$13,000
MONITORING WELL CLOSURE					
Monitoring Well Closures (Year 30, only) (including Contingency, Permitting, Construction Services, and Engineering Design Costs).	5,500	FT	$15		$82,500
TOTAL PRESENT WORTH O&M COST				$1,178,000	
TOTAL PRESENT WORTH				$1,401,000	

7 percent discount rate used to calculate present worth.

* For each groundwater sampling event, include 5 duplicates, 5 matrix spike/matrix spike duplicates, and 5 trip blanks.

CY - Cubic Yard
LS - Lump Sum
HR - Hour
EA - Each
SF - Square foot
FT - Foot
ISCO - In Situ Chemical Oxidation

Table A-3
Alternative 3 - In-Situ Chemical Oxidation / Monitoring
Present Worth Cost Estimate
Riverfront OU4 Site FS Report

Year	Yearly O&M Cost *	Intermittent O&M Costs	Total Annual O&M Costs	Intermittent O&M Costs Include:
1		$330,500	$330,500	ISCO injection and groundwater sampling
2		$165,500	$165,500	ISCO sampling and groundwater sampling
3		$164,400	$164,400	ISCO injection and groundwater sampling
4		$82,400	$82,400	ISCO sampling and groundwater sampling
5		$135,300	$135,300	5-yr review, informational meeting, ISCO injection, and groundwater sampling.
6		$74,400	$74,400	ISCO sampling and groundwater sampling
7		$64,400	$64,400	Groundwater sampling
8		$64,400	$64,400	Groundwater sampling
9		$104,400	$104,400	ISCO sampling and groundwater sampling
10		$85,300	$85,300	5-yr review, informational meeting, and groundwater sampling
11		$32,200	$32,200	Groundwater sampling
12		$32,200	$32,200	Groundwater sampling
13		$32,200	$32,200	Groundwater sampling
14		$32,200	$32,200	Groundwater sampling
15		$53,100	$53,100	5-yr review, informational meeting, and groundwater sampling
16		$32,200	$32,200	Groundwater sampling
17		$32,200	$32,200	Groundwater sampling
18		$32,200	$32,200	Groundwater sampling
19		$32,200	$32,200	Groundwater sampling
20		$53,100	$53,100	5-yr review, informational meeting, and groundwater sampling
21		$32,200	$32,200	Groundwater sampling
22		$32,200	$32,200	Groundwater sampling
23		$32,200	$32,200	Groundwater sampling
24		$32,200	$32,200	Groundwater sampling
25		$53,100	$53,100	5-yr review, informational meeting, and groundwater sampling
26		$32,200	$32,200	Groundwater sampling
27		$32,200	$32,200	Groundwater sampling
28		$32,200	$32,200	Groundwater sampling
29		$32,200	$32,200	Groundwater sampling
30		$135,600	$135,600	5-yr review, informational meeting, groundwater sampling, and monitoring well closure
Total Costs of Annual O&M			$2,081,000	
Present Worth of Annual O&M			$1,178,000	

* There are no yearly O&M costs for this alternative.

Appendix B
Groundwater Technical Impracticability Evaluation Report

As of November 12, 2008 the Final Draft Fractured Bedrock Technical Impracticability Evaluation Report is still being reviewed by MDNR and EPA Headquarters. It will be submitted under separate cover after all comments on the Report are addressed.