FINAL
FEASIBILITY STUDY REPORT

LOCKWOOD SOLVENT GROUNDWATER PLUME SITE

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ACRONYMS AND ABBREVIATIONS

ARAR	Applicable or relevant and appropriate requirement
ATC	ATC Associates, Inc.
ATSDR	Agency for Toxic Substances and Disease Registry
Beall	Beall Trailers of Montana, Inc.
bgs	Below ground surface
Brenntag	Brenntag West, Inc.
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
cfs	Cubic feet per second
COC	Contaminant of concern
COPC	Contaminants of potential concern
DCE	Dichloroethene
DEQ	Montana Department of Environmental Quality
EPA	U.S. Environmental Protection Agency
FS	Feasibility Study
ft/d	Feet per day
ft/y	Feet per year
gpm	Gallons per minute
HHRA	Human health risk assessment
HRC	Hydrogen Release Compound
LSGPS	Lockwood Solvent Groundwater Plume Site
LWSD	Lockwood Water and Sewer District
MCA	Montana Code Annotated
MCL	Maximum contaminant level
MCLG	Maximum contaminant level goal
mg/kg	Milligram per kilogram
mg/L	Milligram per liter
µg/L	Microgram per liter
MIP	Membrane interface probe
MSL	Mean sea level
NAPL	Nonaqueous phase liquid
NCP	National Oil and Hazardous Substances Contingency Plan

ACRONYMS AND ABBREVIATIONS
(Continued)

O&M	Operation and maintenance
OS/SVE	Ozone sparging/soil vapor extraction
ORC	Oxygen Release Compound
PCE	Tetrachloroethene
ppm	Part per million
PRG	Preliminary remediation goal
PRAO	Preliminary remedial action objective
RCRA	Resource Conservation and Recovery Act
RI	Remedial investigation
SSL	Soil screening level
SVE	Soil vapor extraction
TCE	Trichloroethene
TtEMI	Tetra Tech EM Inc.
UV	Ultraviolet
USGS	U.S. Geological Survey
VC	Vinyl chloride
VOC	Volatile organic compound
WQB-7	Water Quality Bureau - Bulletin Circular 7

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1.0 INTRODUCTION

The Montana Department of Environmental Quality (DEQ), Remediation Division conducted a Feasibility Study (FS) for the Lockwood Solvent Groundwater Plume Site (LSGPS), near Billings, Montana. The FS was prepared by Tetra Tech EM Inc. (TtEMI) in accordance with the scope of work under Task Order No. 11, DEQ Contract No. 402014. The FS includes the required elements outlined in Task No. 1 of Task Order 11 and was conducted in accordance with the U.S. Environmental Protection Agency's (EPA) "Guidance for Conducting Remedial Investigations and Feasibility Studies under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), Interim Final" (1988b).

DEQ, with EPA oversight, is the lead agency for implementing the Remedial Investigation (RI) and FS process under CERCLA at the LSGPS. As the lead agency, DEQ, with EPA concurrence, has final approval authority for the selected remedial alternatives. DEQ also has the responsibility to solicit community involvement and comments throughout the CERCLA remediation process.

1.1 REPORT ORGANIZATION

This FS report is organized into seven sections of text, followed by a list of references and then figures and tables, which are followed by appendices. The contents of Sections 1.0 through 6.0 are briefly described below.

Section 1.0, Introduction, describes the report organization, the report purpose and objectives, and the site history, and summarizes previous and ongoing investigations.

Section 2.0, Site Characterization Summary, describes the LSGPS climate, geology, surface water hydrology, hydrogeology, population data and land use, and cultural resources. This section also summarizes the current understanding of the nature and extent of contamination based on field observations, field parameters, and validated analytical data results from soil, surface water, sediment, and groundwater samples. In addition, this section summarizes the fate and transport of contaminants of concern (COC), and human health and ecological risk assessment findings.

Section 3.0, Applicable or Relevant and Appropriate Requirements (ARAR), summarizes FS requirements under CERCLA and the National Oil and Hazardous Substances Contingency Plan (NCP), and identifies chemical-, location-, and action-specific requirements that the remedial action must meet.

Section 4.0, Development and Screening of Remedial Action Alternatives, describes the preliminary remedial action objectives (PRAOs) and goals; identifies the general response actions; provides an evaluation and screening of technology and process options; and summarizes the technologies selected for the development of remedial alternatives.

Section 5.0, Detailed Description of Selected Technology Options, describes the selection of remedial technologies for further evaluation; and provides detailed descriptions of selected options.

Section 6.0, Detailed Analysis of Remedial Alternatives, describes the alternatives considered for remediating the contamination at LSGPS; outlines the NCP criteria for analyzing alternatives; and presents the detailed analysis of alternatives.

Section 7.0, Comparative Analysis of Alternatives, compares the remedial alternatives by considering overall protection of human health and the environment; compliance with ARARs; long-term and short-term effectiveness and permanence; reduction of toxicity, mobility, or volume of contaminants; implementability; cost; and acceptance by the state/support agency and community.

Section 8.0, Summary and Conclusions, presents FS report summary and conclusions, including a description of the remedy selection and remedial action processes.

1.2 PURPOSE AND OBJECTIVES

The purpose of this FS is to develop, screen, and evaluate a range of remedial alternatives to address contamination in soil and groundwater at the LSGPS. In general, the FS includes discussion on the development and screening of remedial alternatives, and the detailed and comparative analyses of alternatives.

The development and screening of remedial alternatives require the following:

(1) identifying federal and state chemical-, location-, and action-specific ARARs;

(2) identifying PRAOs specifying the contaminants and media of interest, exposure pathways, and remediation goals so that a range of treatment and containment alternatives can be developed;

(3) identifying potential treatment and containment technologies that will satisfy these objectives;

(4) identifying volumes or areas of media to which general response actions may be applied;

(5) screening the technologies based on their effectiveness, implementability, and cost; and

(6) assembling technologies and their associated containment or treatment combinations into alternatives for the contaminated media at the site.

A range of remedial alternatives was developed during the FS process that varied primarily in the cost to implement, operate, and maintain the remedial alternative and the time required to meet PRAOs. The upper bound of the range is an alternative that requires the highest overall cost at the LSGPS and achieves PRAOs in the shortest timeframe. The lower bound is an alternative that requires the lowest overall cost, involves long-term management, and requires a longer timeframe to meet PRAOs.

The detailed analysis of alternatives consists of the analysis and presentation of sufficient information to allow decision makers to select a remedy by comparing the alternatives against each other. The detailed analysis of alternatives is required to meet specific statutory requirements for remedial actions that are addressed in a Record of Decision and are supported by the FS report.

Each remedial action must

(1) be protective of human health and the environment,

(2) attain ARARs,

(3) be cost-effective, and

(4) utilize permanent solutions and alternative treatment technologies or resource recovery technologies to the maximum extent practicable.

Remedial actions in which treatment permanently and significantly reduces the volume, toxicity or mobility of the contaminants are to be preferred over those not involving such treatment. If the selected remedial action does not reflect this preference, then the Record of Decision shall explain why it does not. Remedial alternatives were evaluated in detail with respect to nine evaluation criteria that EPA has developed to address the statutory requirements and preferences of EPA guidance (EPA 1988b) and the NCP. The nine evaluation criteria and related discussion are provided in Section 6.0 of this FS.

1.3 SITE DESCRIPTION

The LSGPS is a 580-acre site on the outskirts of Billings, Montana, that has been found to have chlorinated solvent contamination in soil and groundwater. Figure 1-1 presents the general LSGPS location, and Figure 1-2 presents the LSGPS and vicinity. The primary COCs are the chlorinated volatile organic compounds (VOC) tetrachloroethene (PCE), trichloroethene (TCE), cis-1,2-dichloroethene (DCE), and vinyl chloride (VC). On December 1, 2000, the LSGPS was officially placed on EPA National Priorities List.

The LSGPS consists of residential and light industrial commercial facilities. At this time, the primary source of domestic use water in the LSGPS is from the Lockwood Water and Sewer District (LWSD) Public Water Supply. However, several individual wells within the shallow aquifer that underlies the LSGPS are known to supply water for domestic uses (such as whole-house, drinking, and irrigation), commercial use, and nondomestic use. Those wells still used for whole-house domestic purposes are sampled semi-annually and concentrations of VOCs are currently below drinking water standards.

Based on the geography of the LSGPS and DEQ's desire to present site figures on readily reproducible size paper, the LSGPS has been broken into three geographic areas. These three areas are as follows:

- Area A: The northern part of the LSGPS, generally including the area west of Klenck Lane; north of Taylor Place and the Coulson irrigation ditch; and south and east of the Yellowstone River
- Area B: The southeastern part of the LSGPS, generally including the area north of U.S. Highway 87 East and a line south of the Beall Trailers of Montana, Inc. (Beall) property, west of a line extending south from the east end of Gordon Drive, east of the Interstate Highway 90 Lockwood interchange, and south of Taylor Place
- Area C: The southwestern part of the LSGPS, including the area west of the Interstate Highway 90 Lockwood interchange and Steffes Road, south of the Coulson irrigation ditch, east of the Yellowstone River, and north of the lower Lockwood irrigation ditch.

Two primary source areas have been identified at the LSGPS: the Brenntag and Beall source areas. The Brenntag source area is located in Area A at the Brenntag West Inc. (Brenntag) property on Taylor Place and consists of groundwater and subsurface soil contaminated with chlorinated VOCs. The Beall source area is located in Area B at the Beall property on U.S. Highway 87 East and consists of groundwater, surface soil, and subsurface soil contaminated with chlorinated VOCs. The general locations of the source areas are shown on Figure 1-2. The source areas are described in more detail in Section 2 of this FS report.

1.4 SITE HISTORY

This section provides a brief chronology of the history of the LSGPS; further detail on the history of the LSGPS can be found in the RI report (TtEMI 2003a).

In 1986, a petroleum pipeline rupture near the LWSD treatment plant wells (which supplied public water to a portion of the LSGPS) resulted in environmental investigations that showed that a petroleum products, as well as TCE, had been released to groundwater. In June 1998, DEQ performed an integrated assessment of the LSGPS through its multi-site cooperative agreement with EPA. The investigation focused on collecting samples upgradient of the LWSD treatment plant wells and the petroleum release sites. Results from this study and subsequent sampling tentatively identified Beall (Figure 1-2) as a potential source of TCE and its chemical breakdown products in the groundwater. In addition, residential wells, mainly in the Lomond Lane area, exceeded maximum contaminant levels (MCL) for PCE, TCE, cis-1,2-DCE, and/or VC. The MCL is the maximum permissible level of a contaminant in water, which is delivered to any user of a public water system. In September 1998, DEQ initiated a second investigation to identify the source of VOC contamination in the Lomond Lane area.

In September 1999, EPA performed a PCE source investigation in the Lomond Lane area and available data suggested a potential PCE source on the Brenntag property (Figure 1-2). Under EPA direction, Brenntag personnel continued the investigation on their property; however, they were unable to identify a source of the PCE contamination.

In September 1999, the indoor air in two homes in the Lomond Lane area was tested for the presence of chlorinated VOC vapors. EPA returned to the same two homes in January 2000 and sampled again to evaluate wintertime indoor air concentrations. Results of the indoor air sampling indicated a concern with vapor contaminant concentrations in living spaces and EPA provided mitigation for two residences. Based on these results, EPA sampled indoor air at additional homes in the Lomond Lane Area. DEQ continued indoor-air monitoring at residences in the Lomond Lane area in April 2001, in accordance with an indoor air monitoring plan (DEQ 2001).

Groundwater monitoring was conducted in the fall of 1999 as part of EPA's initial investigation, and again in June 2000. DEQ personnel performed groundwater monitoring of the LSGPS in November 2000, and began a monthly groundwater and surface water monitoring and quarterly sampling program in July 2001 in accordance with the final work plan for the LSGPS groundwater monitoring program (Pioneer 2001a). Monitoring under this program continued through September 2002, with additional quarterly sampling conducted in April and July 2002.

The LSGPS was proposed for the National Priorities List in May 2000. The public comment period ended July 11, 2000, and final listing occurred on December 1, 2000.

During the summer of 2002, TtEMI conducted field work pursuant to the RI work plan (TtEMI 2002a). In addition to the collection of groundwater, surface water, and soil samples, 62 monitoring wells were installed as part of RI activities. The groundwater and surface water monitoring program was extended through April 2004 under the final groundwater/surface water monitoring plan (TtEMI 2002c).

1.5 SUMMARY OF PREVIOUS AND ONGOING INVESTIGATIONS

Environmental investigations have occurred at the LSGPS from 1986 to the present. In October 1986, LWSD discovered the presence of benzene and chlorinated VOCs in the groundwater supply. That discovery led to the initiation of a number of investigations and reports by various parties within the LSGPS and regulatory agencies, including the following:

- 1986—CENEX pipe leak investigation (Northern Engineering and Testing, Inc. 1986)
- 1990—EZ Shoppe investigation and remediation conducted by Montana Petroleum Supply and Western States Tank Testing (Pioneer 2001b)
- 1991—CENEX and Conoco pipeline investigation (LSE, Inc. 1991)
- 1991—Phase 1 LUST Trust Program investigation (Chen Northern, Inc. 1991)
- 1991—EZ Shoppe investigation (Matney-Frantz Engineering, P.C. 1991)
- 1992—Ken's Interstate Conoco investigation (Braun Intertec 1992)
- 1992-1993—LUST Trust Program investigation (Tetra Tech, Inc. 1993)
- 1993—Montana Department of Health and Environmental Services/Water Quality Bureau field investigation (MDHES/WQB 1993a, 1993b)
- 1994—EZ Shoppe corrective measures (Resource Technologies, Inc. 1994)
- 1995—Phase IV LUST Trust investigation (MSE/HKM 1995)

- 1998—Billings Lockwood pumping test investigation and groundwater monitoring (MSE/HKM 1998)
- 1998-1999—integrated site assessment (Pioneer 1999a, 1999b)
- 1998—Lockwood-Lomond Lane sampling investigation (Pioneer 1999b)
- 1999—Agency for Toxic Substances and Disease Registry (ATSDR) health consultation (ATSDR 1999)
- 1999—VOC groundwater plume delineation and potential source area assessment (Lockheed Martin Technology Services Group 1999)
- 2000—site investigation, Dyce Chemical Facility (Maxim Technologies, Inc. 2000)
- 2000—November 2000 groundwater monitoring (DEQ 2000)
- 2001—Beall interim action Phase A Data Summary Report (Pentacore Resources, LLC 2001)
- 2001—preliminary residential air sampling (DEQ 2001)
- 2001-2002—July and October 2001 groundwater monitoring (Pioneer 2002a, 2002b)
- 2002—January 2002 groundwater monitoring (TtEMI 2002b)
- 2002—comprehensive indoor air sampling and analytical results report (TtEMI 2002d)
- 2002—remedial investigation work plan (TtEMI 2002a)
- 2002—April 2002 groundwater monitoring (TtEMI 2003b)
- 2003—remedial investigation report (TtEMI 2003a)
- 2003—April 2003 groundwater monitoring (data presented in Appendix A of this FS)
- 2003—ozone sparging/soil vapor extraction (OS/SVE) pilot test at Brenntag property (ATC Associates, Inc. [ATC] 2003a)
- 2003—remedial design investigation at Brenntag facility (ATC 2003b)
- 2003—addendum 01 to the remedial investigation report (TtEMI 2003c)

A detailed description of the individual investigations and findings prior to the 2002 RI sampling event (TtEMI 2003a) can be found in the data summary report for the LSGPS (Pioneer 2001b), and is not repeated here. The results of the RI are presented in the RI report (TtEMI 2003a); a summary of the RI is provided in Section 2.0 of this FS. Data from the following investigations, completed since the 2002 RI sampling event, are included in this FS:

1. Semi-Annual groundwater data collection event by TtEMI in April 2003 (Appendix A)
2. OS/SVE pilot test at Brenntag property by ATC beginning in January 2003 (ATC 2003a)
3. Remedial design investigation at Brenntag facility by ATC in July and August 2003 (ATC 2003b)
4. Addendum 01 to the RI at the Brenntag source area by TtEMI in September 2003 (TtEMI 2003c)

1.5.1 Semi-Annual Groundwater Data Collection in April 2003 – TtEMI

TtEMI performed site-wide groundwater and surface water monitoring during the week of April 21, 2003, at the LSGPS. Eighty-one (81) groundwater samples were collected from monitoring wells, and seven groundwater samples were collected from residential wells. Static water levels were measured in 78 monitoring wells. Figures showing the site-wide alluvial aquifer water levels and groundwater sampling results are provided in Appendix A. Sampling results are further discussed in Section 2.2.2.

Water elevations in April 2003 ranged from 3,119 feet above mean sea level (MSL) at the southeast corner of the LSGPS (Beall property) to 3,089.5 feet above MSL at the southwest corner of the LSGPS (LWSD treatment facility) and 3080 feet above MSL at the northeast end of the LSGPS (AJ Gravel and Corcoran ponds) (Figure A-1). Groundwater flow directions were consistent with previous monitoring events (TtEMI 2003a), which showed flow to the north and west toward the Yellowstone River.

1.5.2 OS/SVE Pilot Test at Brenntag Property, Beginning in January 2003 – ATC

This pilot test was performed to evaluate the effectiveness of OS/SVE extraction at removing chlorinated VOC constituents from groundwater at the northwest corner of the Brenntag property (ATC 2003a). The initial pilot test was conducted for 8 weeks beginning on January 3, 2003. Preliminary results from the pilot test showed concentrations of PCE, TCE, cis-1,2-DCE and VC were reduced in two of five pilot test wells (PT002 and PT006) (ATC 2003a). A summary of the pilot study is provided in Appendix B.

1.5.3 Remedial Design Investigation at Brenntag Facility in July and August 2003 - ATC

The purpose of this investigation was to further delineate PCE impacts to soil and groundwater near monitoring wells PT002 and PT006 at the northwest corner of the Brenntag property and to collect engineering data for the design of an expanded pilot test remedial system to be installed at the facility. Twenty-two (22) soil samples and 25 groundwater samples were collected from soil borings and piezometers installed in the Brenntag property (ATC 2003b). All samples were analyzed for VOCs. PCE was detected in 19 of 22 soil samples; the highest concentrations (ranging from 520 to 1820 milligrams per kilogram [mg/kg]) were detected in soil samples collected from the 4 to 8-foot depth interval in boreholes along the north-south-running fenceline. PCE, TCE, cis-1,2-DCE, and VC were detected in all but 1 of the 25 groundwater samples collected from piezometer and monitoring wells. The highest total VOC concentrations (ranging from 932 to 5,960 micrograms per liter [μg/L]) in groundwater occurred in samples collected from monitoring wells and piezometers. These results confirmed the presence of a source of contamination in subsurface soil at the northwest corner of the Brenntag property. These results are further discussed in Section 2.

1.5.4 Addendum 01 to the RI at the Brenntag Source Area, September 2003 – TtEMI

The purpose of this investigation was to investigate the nature and extent of suspected source areas located in Area A and gather data needed to evaluate likely remedial alternatives. Field screening and sampling were conducted during the first and second weeks of September 2003 in a study area that included the Brenntag, Keller Transport, Inc., and Kuck Trucking, Inc. properties. A membrane interface probe (MIP) was used as a field screening tool to locate potential VOC source areas in soil, and soil samples were collected from boreholes to confirm and quantify the VOC contamination in soil. Forty (40) MIP borings were drilled and 35 soil samples were collected for VOC analysis. At boring locations where a soil sample could not be collected, a groundwater sample was collected instead. Sources of chlorinated VOCs (specifically PCE) consisting of contaminated soil were identified in three areas at the Brenntag property: (1) at the northwest corner of the property; (2) upgradient (southeast) of the main tank farm; and (3) northeast of the acid tank farm. These results are further discussed in Section 2.

2.0 SITE CHARACTERIZATION SUMMARY

This section summarizes the site's physical characteristics and environmental setting, the nature and extent of contamination, contaminant fate and transport characteristics, and environmental risks to human health and ecological receptors.

2.1 PHYSICAL CHARACTERISTICS AND ENVIRONMENTAL SETTING

Physical characteristics of the LSGPS pertinent to the FS include the climate, geology, hydrogeology, surface water hydrology, land use, and cultural resources. The following sections describe those characteristics, focusing on the Brenntag and Beall source areas. Additional detail regarding site-wide physical characteristics and environmental setting can be found in the RI report (TtEMI 2003a). Existing wells at the LSGPS are shown on Figure 2-1.

2.1.1 Climate

The climate at Billings, Montana (including the LSGPS), is classified as semiarid. About one-third of the annual precipitation falls during May and June, with June being the wettest month. The period of least precipitation is from November through February; less than 20 percent of the annual precipitation occurs in these 4 months. Billings has an average annual temperature of 47.1 °F. The maximum monthly average temperature of 77.85 ^{o}F was reported in July 1960, and the minimum monthly average temperature of 5.05 ^{o}F was reported in January 1950.

2.1.2 Geology

Alluvial braided channel deposits at the Brenntag source area consist primarily of a sequence of mixed silt, clay, and to a lesser degree, silty sands underlain by a thicker sequence of bedload deposits composed of sand and gravel. These deposits overlay the eroded, Cretaceous-age, gray sandstone bedrock (Eagle sandstone).

The Beall source area is located on an upper terrace of the Yellowstone River floodplain. Alluvial deposits at the Beall source area consist primarily of a sequence composed of fine-graded, brown sands and light tan-to-brown silts underlain by a thinner sequence of bedload deposits composed of sand and gravels. These deposits overlie the eroded Eagle sandstone bedrock. Bedrock is exposed southwest of the Beall source area at the interchange of Interstate Highway 90 and U.S. Highway 87 East.

2.1.3 Hydrogeology

This section describes hydrogeologic characteristics at the Brenntag and Beall source areas. Hydrogeologic information is summarized from data collected during previous investigations, including the RI and supplemental RI addendum.

2.1.3.1 Brenntag Source Area

Hydrogeologic units at the Brenntag source area are composed of three principal units: the silty clay and silty sand unit, the sand and gravel unit, and bedrock. These units are displayed graphically in a southeast-northwest oriented cross-section (Figure 2-2).

The vadose zone thickness at the Brenntag source area generally decreases in the groundwater flow direction. Vadose zone thickness upgradient of the Brenntag property (MW001) is approximately 15 feet, decreasing to approximately 10 feet at the main tank farm, and decreasing to approximately 7 feet in the Montana Terrazzo and Kuck Trucking properties (Figure 2-2). Moderate- to low-permeability silty clays and silty sand units were identified in the vadose zone throughout the area, and thin discontinuous gravels were observed in some borings.

Five to 6 feet of impermeable compacted fly ash fill material is present in the vicinity of the acid tank farm (Figure 2-2). This material was placed as a base material for the acid tank farm, which was constructed in the 1980s.

The upper portion of the saturated interval over the majority of the Brenntag source area is in the silty clay and silty sand unit. This unit is underlain by an alluvial sand and gravel unit that varies in thickness from approximately 12 to 25 feet. The sand and gravel unit is derived from bed-load channel deposition of the Yellowstone River and is composed of silty sands with gravels and cobbles. Average thickness of the sand and gravel unit in the area is approximately 15 feet. Significant increases of unit thickness were observed at boring MP131 (Figure 2-2) and likely represent localized scouring of the older bedrock surface. The sand and gravel unit is saturated throughout the area. Permeability characteristics of the unit are variable, but monitoring wells generally exhibit little or no drawdown during purging and sampling activities.

An alluvial aquifer water-level map (Figure 2-3) prepared for the July 23, 2003, measurement event indicated a general northwest flow of groundwater at the Brenntag source area. The groundwater flow gradient was approximately 0.007 feet per foot.

The bedrock hydrostratigraphic unit is composed of the Eagle Sandstone and associated interbedded shale units. Groundwater within the bedrock aquifer is likely contained within a system of interconnected fractures and joints and possibly connected with preserved primary and secondary porosity. One bedrock well (MW128) (see Figure 2-1) was completed to 61 feet below ground surface (bgs) northwest and downgradient of the Brenntag source area during the RI. No VOCs have been detected in the three groundwater samples collected in August and October 2002 and April 2003 (Appendix A) from the bedrock monitoring well. Well hydraulic testing information indicates that the bedrock exhibits moderate permeability; however, consistent vertical gradients between the bedrock and the sand and gravel unit have not been observed.

2.1.3.2 Beall Source Area

The Beall source area is located on an upper alluvial terrace of the Yellowstone River floodplain. Hydrostratigraphic units in this area are composed of a silt and silty clay unit, a sandy gravel and gravelly sand unit, and bedrock. These units are presented graphically in a southeast-northwest oriented cross-section (Figure 2-4).

The thickness of the vadose zone at the Beall source area ranges from 42.5 to 49 feet and generally decreases along the groundwater flow direction to the north and west. Vadose zone thickness is about 47.5 feet upgradient of the Beall source area, 46 to 49 feet west of the steam clean bay, 43 feet at the west edge of the property, and decreases to 35 feet northwest of the property. Moderate- to low-permeability silts and silty clay units were identified in the vadose zone throughout the Beall source area, and layers of discontinuous sands were observed in some borings.

The alluvial aquifer unit at the Beall source area consists of a saturated sand and gravel unit that was derived from bed load channel deposits of the Yellowstone River. The sand and gravel unit is composed of fine to coarse silty sands with gravels and cobbles and overlies the Eagle Sandstone bedrock. The thickness of the sand and gravel unit decreases in the direction of groundwater flow and ranges from 24 feet upgradient, to 20 feet at the Beall source area, and to 16 feet downgradient of the source area. Although the water table generally coincides with the top of the sand and gravel unit north and downgradient of the Beall source area, fine sediments that are found in the vadose zone also comprise the upper saturated portion of the alluvial aquifer at and upgradient of the Beall source area. Permeability characteristics of the sand and gravel unit are variable, but water levels in monitoring wells generally exhibit little or no drawdown during purging and sampling activities.

An alluvial aquifer water-level map (Figure 2-3) prepared for the alluvial aquifer for the July 23, 2003, measurement event indicated a general north and west radial flow of groundwater from the Beall source area toward the Yellowstone River. The groundwater flow gradient at the Beall source area was approximately 0.001 feet per foot for July.

The bedrock hydrostratigraphic unit at the Beall source area is composed of Eagle Sandstone and associated interbedded shale units. Groundwater within the bedrock aquifer is likely contained within a system of interconnected fractures and joints and possibly some preserved primary and secondary porosity. The bedrock slopes to the north in the vicinity of the alluvial aquifer boundary near the interchange of Interstate Highway 90 and U.S. Highway 87 East and at the Beall source area.

Recharge from the bedrock aquifer is likely occurring along the alluvial aquifer boundary immediately upgradient of the Beall source area. Groundwater from this area enters the alluvial aquifer at the contact with the bedrock aquifer (alluvial aquifer boundary) and flows downgradient toward the Yellowstone River.

A monitoring well pair (MW205/MW219) (see Figure 2-1) was installed in the Eagle Sandstone bedrock at the Beall property to monitor water quality and evaluate the hydraulic gradient between the alluvial and bedrock aquifers. Water elevations in the monitoring well pair were measured in August 2002 and initially showed a positive (downward) gradient, indicating groundwater flow or discharge from the alluvial aquifer to the bedrock aquifer. Measurements made in September and October 2002 indicated a negative (upward) gradient from the bedrock aquifer to the alluvial aquifer. Measurements made in April and July 2003 indicated a positive gradient. Bedrock monitoring well (MW219) had low-level detections of VOCs in three groundwater samples collected in August and October 2002 and April 2003. The contaminant concentration data, in combination with the gradient measurements, generally support an overall downward gradient from the VOC-contaminated alluvial aquifer that is contributing to detectable VOC contamination in the upper portion of the bedrock aquifer.

2.1.4 Surface Water Hydrology

Six surface water features are located downstream or downgradient of the Brenntag and Beall source areas: the Coulson irrigation ditch, AJ Gravel pond, Corcoran pond, Lower Lockwood irrigation ditch, a wetland area, and the Yellowstone River (Figure 1-2).

Coulson Irrigation Ditch. The Coulson irrigation ditch supplies irrigation water for the Coulson Water Users Association, downriver from the LSGPS. The ditch originates at a diversion structure on the Yellowstone River south (upriver) from the LWSD treatment plant and flows by gravity to the northeast through the Auto Auction property, and then continues northeast, passing along the north boundary of the Brenntag property. The ditch exits the LSGPS beneath Klenck Road and continues through open fields east of the LSGPS.

Groundwater influx or seepage into the Coulson irrigation ditch occurs during periods of no flow, where the bottom of the ditch intercepts the water table. Comparison of water elevation data in the Coulson irrigation ditch to water elevations in monitoring wells adjacent to the ditch indicate that portions of the Coulson irrigation ditch are below the water table.

Ponds. Two ponds, the AJ Gravel pond and the Corcoran pond, are located south of the Yellowstone River, at the north end of the LSGPS (Figure 1-2). The ponds are about 1,500 and 1,800 feet downgradient of the Brenntag source area. The ponds are the result of former aggregate mining activities, and the water elevations in the ponds are a reflection of water table elevations. Corcoran Pond was mined in the 1960s, and no recent mining operations have taken place. Mining at the AJ Gravel site continued through the year 2000.

Lower Lockwood Irrigation Ditch. The Lower Lockwood irrigation ditch lies above the water table and may provide some seasonal recharge to groundwater, depending on leakage rates and flow within the ditch. Sections of the Lower Lockwood irrigation ditch are piped in subsurface culverts where they cross under Interstate Highway 90, U.S. Highway 87 East, and the Beall property. The Lower Lockwood irrigation ditch originates at a pump intake located at the Coulson diversion structure on the Yellowstone River, south (upriver) from the LWSD treatment plant (Figure 1-2). The ditch is pumped approximately

40 feet higher than the river to a point where it discharges on the Eagle Equipment property. From there it flows eastward, under Interstate Highway 90, and eventually through the Beall property. The ditch flows through moderately permeable sediments approximately 40 to 50 feet above the water table and is likely losing water at variable rates along the length of the channel. The Lower Lockwood Irrigation Ditch parallels the contact of the alluvial aquifer and bedrock.

Wetland Area. A permanent wetland area with small open ponds is located in the west portion of the LSGPS about 4,300 feet downgradient of the Beall property. The wetlands extend from east of Cerise Road and northeast toward the Sandy-Lomond Lane area (Figure 1-2). The morphology of the wetlands indicates they were formed in a former chute channel originating from the Yellowstone River, and some portions of the wetlands have year-round open water and likely receive groundwater flux.

Yellowstone River. The Yellowstone River is the main surface water feature in the LSGPS, and the centerline of the channel marks the western and northern boundaries of the LSGPS(Figure 1-2). A U.S. Geological Survey (USGS) gauging station is located within the LSGPS and has been used since 1904. The Yellowstone River at the point of the gauging station (river mile 360.3) drains approximately 11,795 square miles. The Yellowstone River has an average flow of approximately 7,000 cubic feet per second (cfs) and a base flow of 3,700 cfs. The lowest mean monthly flow for the 76-year period of record is 2,491 cfs (USGS 2003). The river is approximately 2,000 feet downgradient of the Brenntag source area and 4,600 feet downgradient of the Beall source area. The Yellowstone River is expected to intercept the groundwater discharging from the LSGPS.

2.1.5 Human Population and Land Use

The LSGPS is located outside the city limits of Billings, Montana, and south of the Yellowstone River. The area is zoned controlled industrial (minor industry) according to the Yellowstone City/County Planning Department. The current land use within the LSGPS includes residential, commercial, and "light" industrial operations. There are 81 commercial and light industrial businesses within the boundaries of the LSGPS, including trucking companies, a chemical repackaging facility, an automobile auction facility, automobile repair shops, construction companies, a water treatment plant, open agricultural land, a lumber yard, and three active gas stations. An estimated 75 residential single family residences, two trailer parks, and one apartment complex are currently located within the boundaries of the LSGPS.

The north and west boundaries of the LSGPS are bordered by the Yellowstone River, which is used for drinking water supply, irrigation and industrial supply, and recreational activities including fishing, boating, and swimming. The Coulson irrigation ditch is used for seasonal irrigation. The Lower Lockwood irrigation ditch runs eastward near the southern boundary of the LSGPS and is used for seasonal irrigation. There are no drinking water intakes in surface water bodies within the boundaries of the LSGPS; intakes for the LWSD public water supply system are located on the Yellowstone River, upstream of the LSGPS.

At the time of the initial investigations, the primary source of drinking, domestic, commercial, and non-domestic water for the residences and businesses in the northern portion of the LSGPS came from the shallow aquifer, from private wells. During the environmental investigations, however, residences with private wells that were found to contain contaminant concentrations above MCLs or Montana numeric water quality standards, Circular Water Quality Bulletin-7 (WQB-7) (DEQ 2004) were placed on the LWSD public water supply system. DEQ has confirmed that all businesses within the LSGPS boundaries are either connected to the public water supply or provide an alternative drinking water supply for their employees. The LSGPS does not have a community-wide sanitary sewer system. Residences and businesses are served by individual septic systems.

2.1.6 Cultural Resources

There are four (4) previously recorded historic and archaeological sites within the LSGPS that are listed in the database of the Montana Historical Society, State Historic Preservation Office (2003). Identified historic and archaeological sites within the boundary of LSGPS are shown in Table 2-1. They include the Coulson irrigation ditch, the Lockwood irrigation project pumping plant, a railroad overpass over the Yellowstone River, and a vehicular and foot bridge over the Yellowstone River. The Coulson irrigation ditch is the only identified cultural resource within the LSGPS that is located downgradient of a contaminant source area.

2.2 NATURE AND EXTENT OF CONTAMINATION

This section presents a summary of the nature and extent of contamination at the LSGPS, including a summary of contaminant sources and resultant groundwater contamination where COC concentrations are greater than regulatory levels and warrant remedial action. For the purposes of this FS, surface soil samples are considered to be samples taken from ground surface to 2 feet bgs and subsurface samples are considered to samples taken wholly or partially below 2 feet bgs (for example, a sample taken from 0 to 4 feet bgs is considered a subsurface sample). Vadose samples are considered to be subsurface samples above the water table.

Data considered in this FS includes data presented in the RI work plan (TtEMI 2002a), the RI report (TtEMI 2003a), and data from recent investigations described in Sections 1.5.1 through 1.5.4.

2.2.1 Sources of Contamination

Two primary source areas for VOC groundwater contamination have been identified at the LSGPS based on the results of surface water, soil, soil vapor, nonaqueous phase liquid (NAPL) ribbon samplers, MIP, and groundwater sampling from site investigations, including the RI. The two source areas are the Brenntag source area and the Beall source area. No other source areas have been identified. A summary of vadose soil samples with COC concentrations greater than site-specific soil screening levels (SSL) is provided in Table 2-2. SSLs were developed in the RI work plan (TtEMI 2002a) following EPA guidelines (EPA 1996a). Vadose soil with COC concentrations above site-specific SSLs is considered a potential source for groundwater contamination; soil remediation objectives and goals are presented in Section 4.1. No surface or subsurface soil samples from locations outside the Brenntag and Beall source areas contained COCs at concentrations above SSLs.

2.2.1.1 Brenntag Source Area

In Area A, concentrations of COCs above site-specific SSLs were reported in vadose soil samples taken from four pilot test well boreholes (PT001, PT002, PT002B, and PT003), eleven soil borings (SB103, SB104, SB105, SB106, SB-8/PZ-8, SB-10/PZ10, SB-11/PZ-11, SB-19/PZ-19, SB-22, LSS-SS-13B, and LSS-SS-14B), and six MIP boreholes (MP103, MP104, MP109, MP114, MP124, and MP127). See Figure 2-5 and Figure 2-6 for soil sampling locations in the Brenntag source area and Area A. All of these sample locations are either within or downgradient of the Brenntag source area and all are considered associated with this source area. Based on analytical data from previous investigations (ATC 2003b), the RI (TtEMI 2003a), and from a supplemental MIP source investigation (TtEMI 2003c) at the Brenntag property, the Brenntag source area has been further defined as three NAPL-contaminated areas: the northwest corner, the main tank farm, and the acid tank farm. These distinct source areas are described in more detail in the following text.

Northwest Corner of Brenntag Property

From evaluation of soil sample and MIP data, a PCE NAPL-contaminated source area was identified in the northwest corner of the Brenntag property (TtEMI 2003c). The main release area is located in the area of monitoring well PT002. Vadose zone contamination (less than 5 feet bgs) was identified in borings MP114 and MP139 and likely represents the surface release location. NAPL contamination appears to have spread horizontally below the water table in the silty clay and silty sand unit overlying the more permeable sand and gravel unit.

Elevated VOC concentrations were also observed on the MIP logs in four borings (MP119, MP120, MP121, and MP122) completed in the Keller Transport property. Decreasing VOC concentrations in soil were observed further to the west on the Keller property in MP114. Soil sample and MIP data from borings indicate that the NAPL-contaminated soil extends to a depth of 10 to 12 feet bgs, corresponding approximately to the top of the sand and gravel unit. Soil concentrations of PCE ranged up to 2,404 mg/kg, measured in boring PT002 at 6 to 8 feet bgs. Low levels of PCE (0.24 to 1.1 mg/kg) were measured in deeper soil (19 to 31 feet bgs) in PT001, MW105, MW116, MW117, and MW122 (see Figure 2-5). There was no indication of NAPL on the MIP logs deeper in the sand and gravel unit or on top of bedrock.

A smaller release area was detected in the vicinity of PT001 and MP132, approximately 40 feet south of the previously described release area. NAPL was indicated at this location based on the concentration of PCE (304 mg/kg) detected in a soil sample collected from PT001, at a depth interval of 6 to 8 feet bgs (SECOR 2002). Elevated VOC concentrations were also observed on the MIP log from MP 132 from 9.5 to 11.5 feet bgs. A soil sample collected from this interval contained detectable PCE at 1.2 mg/kg.

Main Tank Farm

A PCE NAPL-contaminated source area was identified in boring MP104 (TtEMI 2003c). Soil contamination was encountered in the vadose zone immediately below the pavement. Soil samples were collected at two intervals: 2.0 to 4.0 feet bgs and 6.0 to 8.0 feet bgs. Both samples exhibited a strong solvent odor, and photoionization detector readings in sample headspaces were off-scale (greater than 2,000 part per million [ppm]). PCE concentrations in two soil samples, collected from 2 to 4 and from 6 to 8 feet bgs, were 260 and 4,670 mg/kg, respectively.

A soil sample collected by Maxim (2000) in boring BHM, located next to MP104, contained cis-1,2-DCE at 12 mg/kg at 11 feet bgs. Groundwater samples collected from boring BHM contained cis-1,2-DCE ranging from 173 to 86,000 µg/L as well as high concentrations of toluene (210,000 µg/L). These data suggest that the PCE detected in vadose zone samples in MP104 has undergone biodegradation to cis-1,2-DCE in the saturated zone.

MIP boring logs (MP124 and MP103) and soil sample concentrations adjacent to MP104 did not indicate the presence of NAPL-contaminated soil. The presence of NAPL deeper in boring MP104 could not be evaluated as VOC concentrations were elevated from 2.0 feet bgs to bedrock at 30.2 feet bgs. Subsequent borings and sampling at the main tank farm did not detect additional PCE NAPL sources; however, petroleum contamination was apparent in several areas.

Acid Tank Farm

A PCE NAPL-contaminated source was identified in MIP boring MP105, in the acid tank farm area. The MIP log from the MIP boring indicates elevated VOC concentrations immediately above bedrock in the sand and gravel aquifer. The groundwater sample collected from the interval above bedrock contained a high concentration of PCE (2,960 µg/L), with very low concentrations of TCE and cis-1, 2-DCE. This concentration exceeds 1 percent solubility of PCE (1,500 µg/L) and may indicate the presence of NAPL.

One groundwater sample collected by Maxim (2000) in boring BHF at 14 feet bgs contained PCE at 13,000 µg/L, which also exceeds a 1 percent solubility of PCE. This boring is located immediately southwest of the acid tank farm and may indicate the location of another surface spill of PCE. No other sources have been identified in Area A.

2.2.1.2 Beall Source Area

In Area B, concentrations of COCs above site-specific SSLs were reported in vadose soil samples taken from two monitoring well boreholes (MW200 and MW201), and soil borings (SB200, SB201, SB202, DFSB-6, DFSB-10, and DFSB-12) (Figure 2-7). All of these sample locations are within the Beall source area and all are considered associated with this source area. Source material is likely found beneath the oil-water separator and associated steam-clean bay drainage pipe, based on groundwater concentrations in this area. Maximum detected VOC concentrations of 1,870 µg/L TCE (SB201) and 4,000 µg/L cis-1,2-DCE (DFSB-12) in groundwater samples from the Beall property do not suggest that NAPL is present in the subsurface, as these concentrations are below 1 percent solubility of TCE (11,000 µg/L) and cis-1,2-DCE (8,000 µg/L). Detected PCE is likely the result of PCE as an impurity in the parent TCE product, based on relative concentration ratios. No other VOC sources have been identified in Area B.

2.2.1.3 Area C – No Identified Source Areas

In Area C, no concentrations of COCs above SSLs were reported in subsurface or surface soil samples. No sources have been identified in Area C.

2.2.2 Groundwater Impacts

The highest concentrations of VOC groundwater contamination at the LSGPS have been reported within and downgradient of the Brenntag and Beall source areas. In addition, lower concentrations of VOCs in groundwater have been reported throughout the site. Monitoring wells where samples contained contaminant concentrations greater than MCL/WQB-7 criteria are shown in Table 2-3. Concentrations in Table 2-3 are the maximum concentrations reported for each given well during the April 2003 sampling event. July/August and October 2002 groundwater sampling data were presented in figures provided in the RI report (TtEMI 2003a); April 2003 groundwater sampling data are presented in Appendix A of this FS.

In April 2003, no COCs were detected in background wells at the Brenntag (MW001) and Beall (MW202) facilities (Figures A-2 and A-3). No COCs were detected in a sample collected from the bedrock well MW128, downgradient of the Brenntag source area. Only cis-1,2-DCE (1.2 µg/L) was measured in a sample collected from the bedrock well MW219 at the Beall source area. TCE (12 µg/L) and cis-1,2-DCE (1.8 µg/L) were detected in samples from the same well in October 2002.
Low-level concentrations of COCs were observed in the current, whole-house use, residential wells sampled in April 2003 (Figures A-2 and A-4). These concentrations are comparable to previous sampling results, and none exceeded MCLs.

Overall, COC concentrations across the LSGPS were similar to previous groundwater sampling event results. A comparison of analytical results from the July/August 2002 and October 2002 events with the April 2003 sampling (Appendix A) event showed that TCE and cis-1,2-DCE concentrations appeared to slightly increase in some wells and extended further from the Beall source area during October 2002 and April 2003. A similar phenomenon was observed at and downgradient of the Brenntag source area, where increases in concentrations of COCs were observed between the October 2002 and April 2003 sampling events. Observed variations may indicate flushing of contaminants into the aquifer during higher water table events or seasonal fluctuations in groundwater flow direction. Groundwater sampling locations and analytical results are presented for each COC on Figures A-5 through A-8.

2.2.3 Surface Water and Sediment Impacts

Surface water samples with COC concentrations greater than MCL/WQB-7 criteria are shown in Table 2-4. No COCs were reported in sediment above site-specific SSLs. Concentrations of COCs in surface water above regulatory criteria were reported in samples from stations SW100, SW101, and SW102, all located within the AJ Gravel Pond (Figure 2-8). COCs in the AJ Gravel pond are attributed to contaminated groundwater that discharges into the pond. TCE was detected in the surface water from wetlands at 0.23 µg/L when sampled in May 2002.

COCs were also detected in Coulson irrigation ditch surface water at concentrations below MCL/WQB-7 criteria and are considered the result of contaminated groundwater discharge to the ditch. Coulson irrigation ditch likely receives groundwater discharge when no irrigation flow is present. Contaminated groundwater that discharges to the ditch appears to occur at and below station SW300 during nonirrigation flows (typically in the fall and winter). When irrigation flows are present in the ditch, water levels are elevated above those in adjacent groundwater, and little or no groundwater-to-surface-water discharge is expected. Modeling indicates that discharge of contaminated groundwater has negligible impact to the Yellowstone River.

2.3 SUMMARY OF CONTAMINANT FATE AND TRANSPORT

The fate and transport of COCs released at the Brenntag and Beall source areas were evaluated through (1) the analysis of plume behavior through a geochemical characterization, (2) hydrogeological data analysis, (3) statistical analysis of historical analytical data from the samples of the pre-RI monitoring and residential wells, and (4) modeling of the transport and biodegradation of COCs. These evaluation characteristics are summarized in the following text. A more detailed discussion of the fate and transport characteristics of COCs in groundwater and soil is provided in the RI report (TtEMI 2003a).

2.3.1 Geochemical Characterization

The Brenntag source area is characterized by releases of what are believed to be PCE and possibly TCE NAPLs, as well as petroleum products and other unidentified organic compounds. NAPL-contaminated soil extends below the water table in the Brenntag source area, but mobile NAPL was not detected in groundwater during the RI sampling activities. The VOC plume in the alluvial aquifer extends from the Brenntag source area to the Yellowstone River. The core of the plume is relatively narrow and is generally less than 300 feet wide. The plume exhibits some lateral dispersion and is approximately 1,300 feet wide where it enters the river approximately 2,000 feet from the source area. A portion of the plume discharges into the AJ Gravel pond, and an unknown mass of VOCs is likely lost due to volatilization and degradation in the pond. The bedrock aquifer downgradient from the Brenntag source area does not appear to be impacted by VOCs. Strong lines of geochemical evidence support that reductive dechlorination is actively occurring in the Brenntag tank farm area.

The Beall source area is characterized by a release from the drainfield of wastewater that contained TCE used in tank trailer cleaning operations. Wastewater with higher concentrations of TCE and possibly petroleum components may have been released from a leaking oil-water separator or from subsurface piping exiting the wash bay. No evidence of NAPL release was detected in soil samples or indicated by maximum concentration of COCs in groundwater samples. The Beall plume extends from the source area downgradient, approximately 4,600 feet northwest to the Yellowstone River. TCE concentrations exceeding regulatory limits extend approximately 2,000 feet downgradient to monitoring wells along the Montana Rail Link Railroad corridor. Within the Beall source area and downgradient to Lockwood Road, dissolved oxygen concentrations exceed 1.0 milligrams per liter (mg/L) indicating that reductive dechlorination may not be active in this portion of the plume. Although degradation daughter product cis-1,2-DCE is present in the plume, there is only limited geochemical evidence of ongoing degradation. Degradation of TCE to cis-1,2-DCE in the past is presumed to have consumed the majority of available organic substrate such as matter potentially associated with an on-site septic tank (Pentacore 2001) or organics released from the steam clean bay.

2.3.2 Hydrogeological Data Analysis

Hydrogeologic data was evaluated to determine groundwater flow gradients and directions, to assess water-transmitting properties of the aquifer, to estimate the velocity of groundwater flow, and to estimate the transport of COCs in groundwater. Shallow groundwater flows northwest to the Yellowstone River, according to water-level measurements taken during the RI. The hydraulic conductivity of the alluvial aquifer in the Brenntag source area was estimated to be 0.295 feet per day (ft/d) from slug tests and 70 ft/d from the groundwater model calibration. The hydraulic conductivity of the alluvial aquifer in the Beall source area was estimated to be about 22.4 ft/d from the model calibration. The site-specific seepage (groundwater) velocity for the plume downgradient of the Brenntag source area was estimated to be about 1.7 ft/d or about 625 feet per year (ft/y). The site-specific seepage velocity for the plume downgradient of the Beall source area was estimated to be about 0.489 ft/d or about 179 ft/y. Hydraulic conductivity and seepage values were recalculated for the FS (Appendix E) based on additional groundwater monitoring data available since the RI.

2.3.3 Statistical Analysis of Groundwater Concentration Trends

Mann-Kendall statistical trend analysis was performed for monitoring well data within the Brenntag source area and indicated the concentrations of TCE and cis-1,2-DCE are not decreasing over time at this location. In downgradient monitoring wells, decreasing concentration trends of PCE and TCE coupled with increasing concentrations of daughter products, cis-1,2-DCE and VC, were observed. These observations suggest biodegradation is active in the portion of the plume downgradient of the Brenntag source area. One downgradient monitoring well showed decreasing trends in concentrations over time for both parent compounds and daughter products.

The Beall source area exhibited no decreasing trend in the concentrations of TCE or cis-1,2-DCE over time. Concentrations of TCE and cis-1,2-DCE appear to be stable. Long-term monitoring well data were not available further downgradient; therefore, no statistical analyses were conducted at downgradient locations.

2.3.4 Transport and Biodegradation Modeling

For the portion of the plume downgradient of the Brenntag source area, model results (assuming constant source activity since property development in 1972) suggest that the downgradient edge of the VOC plume may have reached the Yellowstone River as early as model year 5 (calendar year 1977). This portion of the plume appears to have reached a maximum length and width by model year 10 (calendar year 1982), and model results suggest no significant changes in the dimensions of the plume have taken place after that time.

Model results support a conclusion that the portion of the plume downgradient of the Beall source area is slowly increasing in size.

The groundwater-surface water mixing model indicates that the incremental impact of COCs in groundwater on surface water quality in the Yellowstone River at low flow would not be detectable with current laboratory detection limits and therefore would be well below any regulatory standard.

2.4 SUMMARY OF HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENT

The objectives of the risk assessment at the LSGPS were to evaluate risks to human health and the environment. Portions of the groundwater within and downgradient of the Brenntag and Beall source areas contain contaminants at concentrations greater than both federal and state regulatory standards and, were humans to be exposed, would pose unacceptable risks to human health. Where there is no numeric standard available, CERCLA develops a reasonable maximum exposure scenario that describes the current and potential risks posed by the LSGPS in order to determine what cleanup level is necessary to protect against such risks. Under this risk-based approach, the risk assessment for the LSGPS had determined that soil, surface water, and sediment contamination at the LSGPS does not pose unacceptable risks to humans. Soil, groundwater, surface water, and sediment contamination does not pose an unacceptable risk to ecological receptors at the LSGPS or within the Yellowstone River. Summaries of the human health and ecological risk assessments are included in the following sections.

2.4.1 Baseline Human Health Risk Assessment

Cancer risks and noncancer hazard indices were calculated for an array of current and future residential and industrial exposures at the LSGPS. Both the reasonable maximum exposure and a central tendency exposure scenario were considered for each receptor selected for quantitative assessment. Contaminants of potential concern (COPC) were identified for each medium. The primary COPCs include the VOCs PCE, TCE, cis-1,2-DCE, and VC. Because of its considerable size, the LSGPS was divided into nine exposure subareas for the evaluations, resulting in discrete human health risk assessments (HHRA) in nine areas: Area A (source and nonsource areas), Area B (source and nonsource areas), Area C, the AJ Gravel pond, the Coulson irrigation ditch, the wetland area on Cerise Road, and the Yellowstone River (Figure 2-9). The latter three areas had no COPCs retained for quantitative HHRA; therefore, risks and hazards were calculated for the six remaining areas.

During the RI process, a conceptual site model was developed as a planning tool that organized what was known about the site. The conceptual site model was used as a framework for understanding the exposure pathways and receptors included in the HHRA at the LSGPS. Activity patterns for current and future receptors were evaluated under a reasonable maximum exposure scenario and a central tendency exposure scenario based on current and future land and water uses. Figure 2-10 presents the conceptual site model for the LSGPS.

The toxicity assessment for the HHRA included identification of toxicity values used to characterize non-cancer health effects and cancer risk. The most current toxicity information available was used to predict human health risks from exposure to contaminated LSGPS media. The NCP indicates that for the cleanup of known or suspected carcinogens to be protective, the remedial action must achieve a cleanup level that falls within a risk management range (acceptable excess lifetime cancer risk) between one person in ten thousand (1×10^{-4}) and one person in a million (1×10^{-6}).

The HHRA concluded that the following scenarios (see Table 2-5) are within the risk management range such that no additional cleanup is necessary to protect human health:

- Resident adults and children in each of the subareas, assuming only indoor air inhalation exposures as a result of subsurface vapor intrusion.
- Resident adults who use contaminated well water to wash cars or irrigate their lawn in each of the subareas.
- Resident adolescents who recreate with contaminated well water in wading (kiddie) pools or sprinklers in each of the subareas.
- Recreators who fish from, wade in, or dip their arms in the AJ Gravel pond.
- Utility/construction workers in any of the subareas.
- Industrial workers in Area A nonsource, Area B source, Area B nonsource, and Area C subareas who use the public water supply or are supplied an alternative source of drinking water.
- Resident adults and children in Area A nonsource, Area B nonsource, and Area C subareas that use groundwater as a potable water source for whole-house use and/or as a drinking water source.
- Industrial workers in Area A nonsource, Area B nonsource, and Area C subareas that use groundwater as a potable water source for interior use and/or as a drinking water source.

Those scenarios and receptors that had cancer risks that warrant further evaluation or remediation are as follows:

- Industrial workers in Area A source subarea that use groundwater as a potable water source for interior use and/or as a drinking water source and who may spend 4 hours of each workday in contact with Area A source subarea groundwater.

- Resident adults and children in Area A source and Area B source subareas that use contaminated groundwater for whole-house use, including bathing, drinking, and washing.

- Industrial workers in Area A source and Area B source subareas that use contaminated groundwater for unrestricted workplace use, including drinking and washing.

Central tendency, or more "average" risks, were lower than those projected for the high-end reasonable maximum exposure scenarios. Important uncertainties in these reasonable maximum exposure conclusions were summarized in the baseline HHRA. After consideration of these findings and the identification of ARARs for the LSGPS, PRAOs are proposed in Section 4.0 to address these potential human health risks.

2.4.2 Screening-Level Ecological Risk Assessment

The baseline ecological risk assessment included a detailed screening of all detected contaminants in each medium sampled at the LSGPS specifically for ecological effects. The most conservative available ecological screening benchmarks were employed, and an updated toxicity effects literature search was conducted to close data gaps identified in the screening process. The LSGPS ecological risk assessment found the following:

- All surface water concentrations at the LSGPS (including the maximum detected concentrations present in the AJ Gravel pond as well as modeled concentrations in the Yellowstone River) were below conservative direct-contact and food-chain-protective aquatic benchmarks.
- All sediment concentrations at the LSGPS were below sediment benchmarks.
- All soil concentrations at the LSGPS were below soil benchmarks.
- A conservative desktop food model was employed to evaluate top-level avian carnivores, such as the bald eagle, because of that species' special status and possible home range overlap with the LSGPS. Based on an assumption that 100 percent of the eagle's diet was contaminated fish from the AJ Gravel pond (contaminated with the maximum detected concentrations of VOCs in any surface water body at the LSGPS), and that 100 percent of the eagle's daily water intake was contaminated at the maximum VOC concentration, a hazard quotient of 1 was concluded. Because the hazard quotient was not greater than one, no unacceptable risk to bald eagles was concluded.

The results of the ecological risk assessment for the LSGPS indicated the site did not pose an unacceptable risk to ecological receptors. Based on these findings, no action is required to address ecological risk at the LSGPS.

3.0 APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

The goal of the Superfund process at the LSGPS is to delineate the nature and extent of contamination at the site and develop and select remedies in accordance with CERCLA. Section 121(d) of CERCLA [42 U.S.C. § 9621(d)] requires that remedial actions must attain or exceed ARARs. The selected remedy or differing site circumstances may dictate whether an ARAR is applicable or relevant and appropriate to a response action.

Applicable requirements are those environmental cleanup standards, requirements, criteria, or limitations promulgated under federal or state law that specifically address the circumstances at a CERCLA site. If the requirement is not legally applicable, the requirement is evaluated to determine whether it is relevant and appropriate. Relevant and appropriate requirements are those environmental cleanup standards, requirements, criteria, or limitations promulgated under federal or state law that, while not applicable, address problems or situations similar to the circumstances of the proposed response action and are well suited to the conditions of the site.

ARARs may be categorized as chemical-specific requirements that may define acceptable exposure levels and therefore be used in establishing preliminary remediation goals (PRG); as location-specific requirements that may set restrictions on activities within specific locations such as floodplains or wetlands; and as action-specific requirements that may set controls or restrictions for particular treatment or disposal activities for the proposed response. The document “CERCLA Compliance with Other Laws Manual” (U.S. EPA, Draft May 1988a) contains detailed information on identifying and complying with ARARs.

This Section 3.0 provides an outline of ARARs identified for the LSGPS. A more thorough discussion of ARARs is included in Appendix C.

3.1 FEDERAL ARARS

This section presents a brief summary of preliminary federal ARARs identified for contaminant-, location-, and action-specific requirements at the LSGPS. Each requirement is further described in Appendix C.

3.1.1 Federal Contaminant-Specific Requirements

Federal contaminant-specific requirements that are identified for the LSGPS include the following:

- Groundwater Standards -Safe Drinking Water Act[1] (Relevant and Appropriate)
- Surface Water Standards - Ambient and Point Source Discharges - Clean Water Act[2] (Applicable or Relevant and Appropriate)
- Stormwater Runoff Controls - Clean Water Act[3] (Applicable)
- Air standards - Clean Air Act[4] (Applicable)

MCLs and Maximum Contaminant Level Goals (MCLGs) set under the Safe Drinking Water Act are relevant and appropriate as contaminant-specific requirements where either surface water or groundwater is or may be used for drinking water. Private residential and commercial wells already exist within the LSGPS boundaries. The adjacent Yellowstone River is a drinking water source. Table 3-1 provides the MCLs and MCLGs for the COCs at the LSGPS.

There are no federal contaminant-specific soil quality standards.

3.1.2 Federal Location-Specific Requirements

Applicable federal location-specific requirements that are identified for the LSGPS include the following:

- Fish and Wildlife Coordination Act[5]
- Floodplain Management Order[6]
- Protection of Wetlands Order[7]
- Endangered Species Act[8]
- National Historic Preservation Act[9]
- Archaeological and Historic Preservation Act[10]

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[1] 42 U.S.C. § 300f et seq.
[2] 33 U.S.C. §1251 et seq.
[3] 40 C.F.R. Parts 122 and 125
[4] 42 U.S.C. § 7401 et seq.
[5] 16 U.S.C. § 661 et seq.
[6] 40 C.F.R. Part 6, Appendix A, Executive Order No. 11988.
[7] 40 C.F.R. Part 6, Appendix A, Executive Order No. 11990.
[8] 16 U.S.C. §§ 1531-1544.
[9] 16 U.S.C. § 470 et seq.

- Historic Sites, Buildings, and Antiquities Act[11]
- Migratory Bird Treaty Act[12]
- Bald Eagle Protection Act[13]
- Native American Grave Protection and Repatriation Act[14]

3.1.3 Federal Action-Specific Requirements

Federal action-specific requirements that are identified for the LSGPS include the following:

- Resource Conservation and Recovery Act (RCRA)[15] (Applicable or Relevant and Appropriate)
- Surface Mining Control and Reclamation Act[16] (Relevant and Appropriate)
- Clean Air Act[17] (Applicable or Relevant and Appropriate)
- Dredge and Fill Requirements under the Clean Water Act[18] (Applicable or Relevant and Appropriate)
- Underground Injection Controls[19] (Applicable or Relevant and Appropriate)
- Transportation of hazardous waste requirements[20] (Applicable or Relevant and Appropriate)

The primary constituents at the LSGPS consist of PCE, TCE, cis-1,2-DCE and VC with other VOCs formed through the natural breakdown of chlorinated solvents. Soil mixed with chlorinated solvents could qualify as RCRA hazardous waste. RCRA hazardous waste requirements would then be applicable.[21] This contaminated soil may need to be treated, stored, or disposed of in accordance with RCRA Subtitle C (hazardous waste) requirements for waste piles, land treatment, land disposal, corrective action management units and landfills.

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[10] 16 U.S.C. § 469 et seq.
[11] 16 U.S.C. § 461 et seq.
[12] 16 U.S.C. § 703 et seq.
[13] 16 U.S.C. § 668 et seq.
[14] 25 U.S.C. § 3001 et seq.
[15] 42 U.S.C. §§ 6901-6991.
[16] 30 U.S.C. §§ 1201 – 1326.
[17] 40 C.F.R. § 50.6.
[18] 40 C.F.R. Part 230.
[19] 40 C.F.R. Part 149
[20] 40 C.F.R. Part 263.
[21] Federal RCRA Subtitle C hazardous waste regulations are incorporated by reference into applicable state Hazardous Waste Management Act regulations. See Administration Rules of Montana 17.53.801.

In implementing the response action for the LSGPS, solid wastes may be generated activating RCRA Subtitle D (solid waste) requirements. The State of Montana has the lead role in regulating solid waste disposal in the State of Montana.

3.2 STATE OF MONTANA ARARS

As provided by Section 121 of CERCLA, 42 U.S.C. § 9621, only those state standards that are more stringent than any federal standard and that have been identified by the state in a timely manner are appropriately included as ARARs. DEQ has identified specific state standards that are potentially duplicative of federal standards to ensure the timely identification and consideration in the event that the standards are not identified or retained in the federal ARARs. Duplicative or less stringent standards will be deleted as appropriate when the final determination of ARARs is presented.

3.2.1 Montana Contaminant-Specific Requirements

The Montana Water Quality Act and its implementing regulations set standards applicable to Montana's surface and ground waters. Table 3-1 shows the WQB-7 water quality standards for the COCs at the LSGPS. The Montana Air Quality Act sets applicable Ambient Air and Particulate standards. The State of Montana has no contaminant-specific soil quality standards.

3.2.2 Montana Location-Specific Requirements

The Floodplain and Floodway Management Act[22] and regulations (applicable) specify types of uses and structures that are allowed or prohibited in the designated 100-year floodway and floodplain. A floodplain map is provided in Appendix C. The Montana Solid Waste Management Act[23] and regulations (applicable) specify requirements that apply to the location of any solid waste management facility. The Natural Streambed and Land Preservation Act[24] and regulations (applicable) would apply to any remedial action that alters or affects a stream, its banks or tributaries within the LSGPS.

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[22] Section 76-5-401 et seq., MCA

[23] Section 75-10-201 et seq., MCA

[24] Section 75-7-101 et seq., MCA.

3.2.3 Montana Action-Specific Requirements

Storm water requirements under the Water Quality Act are applicable to the LSGPS. Requirements under the Air Quality Act that place controls on open burning, particulate concentrations in ambient air and fugitive dust are also applicable to the LSGPS. Several design, operation, monitoring, closure and post-closure requirements may be applicable under the Solid Waste Management Act to the disposal or active management of solid wastes at the LSGPS. Reclamation requirements under the Montana Strip and Underground Mine Reclamation Act[25] may be relevant and appropriate to any remedial action involving soil disturbance (e.g. clearing and grubbing, stripping and stockpiling topsoil, excavation, backfilling, regarding or revegetation).

3.3 "TO BE CONSIDERED" DOCUMENTS

Additional policies, guidance, or other sources of information may exist that are "to be considered" in the selection of the remedy and implementation of the Record of Decision. Although not enforceable requirements, these documents are important sources of information that EPA and DEQ may consider during selection of the remedy, especially in regard to the evaluation of public health and environmental risks, or they may be referred to, as appropriate, in selecting and developing cleanup actions. Further detail on "to be considered" standards is provided in Appendix C.

3.4 OTHER LAWS

"Other laws" are included in Appendix C to provide a reminder of other legally applicable requirements for actions being conducted at the LSGPS. This does not purport to be an exhaustive list of other legal requirements. These "other laws" are identified in Appendix C because they set out related concerns that must be addressed and, in some cases, may require some advance planning. Health and safety requirements, laws affecting public water supply, water rights and groundwater controls all may be pertinent to the cleanup of the LSGPS, but they are not designated as ARARs because they are not "environmental or facility siting laws" under 42 U.S.C. § 9621 of CERCLA. As applicable laws other than ARARs, they are not subject to ARAR waiver provisions.

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[25] Section 82-4-201 et seq, MCA.

4.0 DEVELOPMENT AND SCREENING OF REMEDIAL OPTIONS

The principal objective of this FS is to develop and evaluate remedial alternatives for the LSGPS that are consistent with CERCLA and the NCP. This FS has been prepared in accordance with EPA's "Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA" (EPA 1988b). This section documents the initial steps involved in developing and screening remediation options for contaminated soil and groundwater at the LSGPS. It presents preliminary remedial action objectives (PRAOs) that will satisfy the threshold criteria of protecting human health and the environment and compliance with ARARs. This section also identifies general response actions and screens viable technology types and process options that will remediate contaminated media and attain PRAOs. Finally, this section summarizes the remedial technologies and process options that will be carried forward into the detailed description of selected technology options (Section 5.0).

Screening and evaluation of remedial options is based on the type, distribution, and volume of contaminants found in soil and groundwater at the LSGPS and on the PRAOs. As described in Section 2, VOC contamination in groundwater at the LSGPS constitutes a risk to human health and requires action to reduce the risk to acceptable levels. The results of the ecological risk assessment for the LSGPS indicated the site did not pose an unacceptable risk to ecological receptors. Based on these findings, no PRAOs were developed for ecological risk at the LSGPS. The VOCs exist as a dissolved phase in groundwater; no mobile NAPL was directly identified in groundwater during site investigations. However, NAPL-contaminated soil was identified at the Brenntag source area. VOCs were found in soil at both the Brenntag and Beall source areas at concentrations that indicate the contaminated soil are sources of contamination to groundwater.

4.1 PRELIMINARY REMEDIAL ACTION OBJECTIVES

PRAOs are established to allow the identification and screening of remedial alternatives that will achieve protection of human health and the environment consistent with reasonably anticipated land use. Preliminary remediation goals (PRGs) are acceptable contaminant levels or range of levels for each exposure route or medium. PRAOs and PRGs for the LSGPS were developed based on the results of human health and ecological risk assessments summarized in Section 2 as well as the preliminary ARARs discussion provided in Section 3 and Appendix C. Final ARARs, compliance with ARARs, and the applicability of any waivers of ARARs will be determined when the remedial action is selected, as described in the Proposed Plan and finalized in the Record of Decision.

4.1.1 PRAOs for Groundwater

The following PRAOs are proposed for groundwater at the LSGPS:

- Prevent exposure of humans to groundwater contaminants in concentrations above regulatory standards.
- Reduce contaminant concentrations in the alluvial aquifer to below regulatory standards.
- Prevent or minimize further migration of the contaminant plume (plume containment).

PRGs for groundwater COCs are presented in Table 4-1.

4.1.2 PRAOs for Surface Water

The following PRAOs are proposed for surface water at the LSGPS:

- Prevent exposure of humans to surface water contaminants in concentrations above regulatory standards.
- Reduce contaminant concentrations in the surface water to below regulatory standards.

PRGs for surface water COCs are presented in Table 4-1.

4.1.3 PRAO for Soil

The following PRAO is proposed for soil at the LSGPS:

- Prevent or minimize further migration of contaminants from source materials (soil) to groundwater (source control).

PRGs for LSGPS soil are presented in Table 4-2. The development of soil PRGs is based on the results of vadose soil modeling presented in Appendix D. EPA and the State of Montana do not have contaminant-specific soil quality standards.

4.1.4 Remediation Volume Estimates

Figure 4-1 illustrates the extent of the contaminated groundwater at and downgradient of LSGPS source areas that is being considered for remediation. These groundwater areas (784,592 square feet at and downgradient of the Beall source area and 1,457,078 square feet at and downgradient of the Brenntag source area) are based on groundwater sampling results. These areas include contiguous groundwater monitoring wells in which the MCL for any individual COC was exceeded in April 2003. The average thickness of the contaminated aquifer is estimated at 25 feet in the Beall source area and 22 feet in the Brenntag source area, and the estimated depth of contamination is based on the lower boundary of the alluvial aquifer. Assuming an aquifer effective porosity of 27 percent, the volume of contaminated groundwater at LSGPS that exceeds MCLs is estimated at 13,951,039 cubic feet (104 million gallons) of which 5,295,996 cubic feet (40 million gallons) is located at and downgradient of the Beall source area and 8,655,043 cubic feet (64 million gallons) is located at and downgradient of the Brenntag source area. In addition, an estimated 667,510 square feet of other site-wide areas had groundwater with individual COCs above MCLs in April 2003 (see Appendix A and Table 2-3). This additional volume of contaminated groundwater is estimated at 4,235,350 cubic feet (32 million gallons).

Figures 4-2 and 4-3 illustrate the extent of known and suspected contaminated soil at the Brenntag and Beall source areas considered for remediation. Lateral and vertical extent of known contaminated soil areas are based on soil sampling results where remediation goals (Table 4-2) are exceeded. Suspected areas of soil contamination above the remediation goals total 7,454 square feet in the Brenntag source area and 9,862 square feet in the Beall source area. These areas are inferred from existing soil and groundwater data and the locations of physical features suspected as release points. Soil contamination is assumed to extend from ground surface to the bottom of the fine grain silty sand formation: an average depth of 14 feet in the Brenntag source area and an average depth of 45 feet in the Beall source area. Based on these assumptions, a total volume of 3,865 cubic yards of contaminated soil is estimated in the Brenntag source area; a volume of 16,437 cubic yards of contaminated soil is estimated in the Beall source area. These estimates include soil beneath structures and foundations.

Data gaps identified for groundwater and soil and recommendations for filling those gaps were outlined in the RI report (TtEMI 2003a). Some additional data were gathered in the Brenntag source area for the RI addendum report (TtEMI 2003c). Any additional data needed to better define soil and groundwater remediation areas will be gathered during the remedial design and prior to remedial action.

4.2 GENERAL RESPONSE ACTIONS

General response actions are broad classes of actions that may satisfy PRAOs for the site. General response action categories for the LSGPS are assembled based on the nature and extent of contamination, as described in Section 2.0. Based on EPA guidance (EPA 1988b), general response actions include treatment, containment, excavation, extraction, disposal, institutional controls, or a combination of these categories. The PRAOs for groundwater and soil are discussed in Section 4.1. The following sections discuss each general response action and its applicability to VOC contamination in soil and groundwater at the LSGPS.

4.2.1 No Further Action

No Further Action implies that no remedial action will be conducted on the LSGPS. The site is allowed to continue in its current state, and no future actions are conducted to remove or remediate the contamination. No access restrictions are put into place, and no deed restrictions are placed on the site. The NCP requires that "no action" be included among the general response actions evaluated in every FS, as detailed in 40 CFR 300 430(e)(6). The no action response provides a baseline for comparison to the other remedial response actions.

4.2.2 Institutional Controls

Institutional controls are nonengineering measures, such as administrative and/or legal controls, that help minimize the potential for human exposure to contamination and/or protect the integrity of a remedy by limiting land or resource use. There are four general categories of institutional controls: governmental controls; proprietary controls; enforcement and permit tools with institutional control components; and informational devices. Examples of institutional controls that may be applicable to VOC contamination at the LSGPS include land use controls, groundwater use restrictions and community awareness. Institutional controls could also include health and safety policies and procedures to limit exposure to groundwater contaminants during construction activities.

4.2.3 Monitored Natural Attenuation

According to EPA guidance (EPA 1999), monitored natural attenuation refers to the reliance on natural attenuation processes to achieve site-specific remedial objectives within a timeframe that is reasonable compared with that offered by other more active methods. The processes, under favorable conditions, act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in soil or groundwater. These in-situ processes include biodegradation; dispersion; dilution; sorption; volatilization; and the chemical or biological stabilization, transformation, or destruction of contaminants.

4.2.4 Containment

Containment actions control or reduce migration of the contaminated materials into the surrounding environment. They could also be used to isolate contaminated soil and groundwater to reduce the possibility of exposure by direct contact. These actions may involve the use of physical barriers to block a contaminant migration pathway. Containment measures for contaminated groundwater typically include caps, hydraulic gradient controls, vertical barriers, and horizontal barriers. Slow contaminant removal (as a consequence of the gradient control system) or natural attenuation may gradually achieve cleanup levels within the contained area.

4.2.5 Groundwater Collection, Treatment, and Discharge

Collection, treatment, and discharge are used to reduce groundwater contaminant levels more rapidly than plume containment or monitored natural attenuation in addition to preventing further plume migration. An extraction system is used to remove contaminated groundwater from the affected aquifer. This step is followed by treatment, if required, and discharge or reinjection of treated water back into the aquifer. Extraction can be achieved by using pumping wells, French drains, or extraction trenches. Pumping may be continuous or pulsed to remove contaminants after they have been given time to desorb from the aquifer material and equilibrate with groundwater. Above-ground treatment may involve physical and chemical processes such as air stripping, carbon adsorption, and biological treatment, depending on the physical and chemical properties of the contaminants.

4.2.6 In-Situ Groundwater and Soil Treatment

In-situ treatment consists of actions that treat contaminants in place. In-situ treatment of contaminated soil or groundwater generally includes methods to separate and remove contaminants or to degrade contaminants in place. In-situ treatment methods to separate and remove contaminants include soil flushing, in-situ thermal treatment, air sparging, and vapor extraction. Soil flushing involves introduction of mixtures of water, chemical surfactants, or cosolvents into the subsurface to strip or dissolve contaminants and then remove them through groundwater extraction. In-situ thermal treatment methods are ways to mobilize contaminants in the subsurface through heating, then removing the contaminants by vapor or water extraction. Air sparging involves injecting air into the aquifer to strip or flush volatile contaminants as the air bubbles up through the groundwater and is captured by a vapor extraction system installed above the water table. Stripped or volatilized contaminants usually are removed through soil vapor extraction (SVE) wells, treated if necessary, and discharged directly to the atmosphere.

Methods of in-situ degradation generally involve adding agents to the subsurface (via wells or treatment walls) that facilitate chemical or biological destruction. The types of in-situ degradation most frequently used at hazardous waste sites include various types of in-situ biological treatment and permeable treatment walls or gates. In-situ groundwater bioremediation involves pumping nutrients and/or an oxygen source (such as air) into the aquifer to enhance biodegradation of contaminants in the groundwater. Passive treatment walls (permeable reactive barriers) act like contaminant treatment zones. Contaminated groundwater comes into contact with the wall, which is permeable, and a chemical reaction takes place. The walls are placed in the subsurface across the natural flow path of the contaminant plume. They can be combined with impermeable flow barriers in a “funnel and gate” arrangement, in which flow is directed through the treatment walls or gates. Contaminants can also be degraded in place using in-situ oxidation. This technology involves pumping a chemical such as hydrogen peroxide, potassium permanganate, or ozone into the subsurface to break down the organic contaminants into compounds such as water and carbon dioxide.

4.2.7 Soil Removal, Transport, Ex-Situ Treatment and Disposal

This action involves complete or partial removal of source material followed by transportation, treatment and disposal. Source materials would be excavated using conventional earth-moving equipment such as front-end loaders and hydraulic excavators. Shoring, sheet piling, or other specialized techniques may be necessary to excavate near buildings or other structures. Excavation below groundwater or to depths below the reach of conventional excavators (approximately 15 feet) may require specialized equipment. Containment and treatment of water encountered during excavation may be necessary. Dust suppression during excavation may also be necessary. Removed source material would be transported to on-site or off-site treatment facilities and/or disposal sites in trucks. Factors affecting the costs and feasibility of truck hauling include haul distances, required road construction, and acceptance by residents and landowners.

Ex-situ treatment consists of actions that treat contaminants after removal from the subsurface. Ex-situ treatment of contaminated soil includes methods to stabilize contaminants, separate and remove contaminants, or to degrade contaminants. Ex-situ treatment methods to stabilize contaminants include solidification or stabilization. Solidification refers to a process that binds the polluted soil or sludge and cements it into a solid block. Stabilization refers to changing the contaminants so they become less harmful or less mobile. Methods to separate and remove contaminants include soil washing, thermal treatment, and mechanical aeration. Soil washing involves introduction of water, chemical surfactants, or cosolvents into the soil to strip or dissolve contaminants and then remove them. Thermal treatment mobilizes contaminants in the soil through heating, then removing the contaminants by vapor extraction. Mechanical aeration involves injecting air or oxygen into the soil while mixing to strip volatile contaminants. Stripped or volatilized contaminants are either discharged directly to the atmosphere or further treated.

Methods of ex-situ degradation generally include thermal, chemical, and biological methods. Thermal destruction (incineration) is similar to thermal treatment, but at temperatures high enough to break down chemicals into elemental constituents. Ex-situ chemical degradation includes chemical oxidation. This technology involves pumping a chemical such as hydrogen peroxide, potassium permanganate, or ozone into the soil to break down the contaminants into less harmful substances like water and carbon dioxide. Ex-situ bioremediation involves adding nutrients and/or an oxygen source (such as air) into the soil to enhance biodegradation of contaminants. Biological treatment methods include land treatment units, biopiles, and composting.

On-site disposal options could be applied to treated or untreated contaminated materials. As materials are excavated and moved during this process, treatment may become a cost-effective option. The design configuration of an on-site repository would depend on the toxicity and type of material requiring disposal. The design could range in complexity from an earthen cap, to an earthen cap with a geomembrane liner, a modified RCRA Subtitle C repository, or a RCRA Subtitle C repository.

Off-site disposal involves placing excavated contaminated material in an engineered, licensed containment facility located outside the LSGPS boundary. Nonhazardous wastes could possibly be disposed of in an off-site permitted solid waste landfill in compliance with applicable laws. Materials that are deemed to be hazardous waste would require disposal in a RCRA-permitted treatment, storage, and disposal facility. These facilities are also known as RCRA Subtitle C facilities.

4.3 IDENTIFICATION AND SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS

This section describes the identification and screening of potential technology types and process options for the remediation of contaminated soil and groundwater at the LSGPS. Technology types and process options are identified for each general response action identified in Section 4.2. VOC contaminated groundwater is present at over 70% of Federal Superfund sites. EPA encourages the use of presumptive remedies (EPA 1993) and historical information to streamline current and future FS processes. Therefore, for the most part, only those technologies and process options that have been proven effective at other, similar sites with equivalent contamination or identified by EPA guidance have been considered in this FS for the LSGPS. Those options have been reviewed relative to site-specific conditions and analyzed based on their effectiveness, implementability, and relative cost. These three criteria are described below.

Effectiveness Evaluation. This evaluation focuses on the potential effectiveness of each process option in remediating the contaminated soil and groundwater and in meeting the PRAOs with regard to protection of human health and the environment. Specific information considered includes types of contamination as well as the concentration, volume, and areal extent of contaminated soil and groundwater, and the timeframe to achieve remediation goals. Each process option was classified as being effective, limited, or not effective.

Implementability Evaluation. This evaluation rates the relative degree of technical implementability and the administrative feasibility of implementing the technology or option. Aspects considered may include any substantive requirements of potential permits for off-site actions, availability of treatment, storage and disposal services, and the availability of necessary equipment and skilled workers to implement the technology. The implementability of options was classified as easy, moderately difficult, difficult, or not implementable.

Cost Evaluation. The cost analysis is made on the basis of engineering judgment, and each process is evaluated in relation to other process options of the same technology type. Both capital costs and operating costs are considered. The costs of options are classified as low, moderate, high, or very high, in relation to other process options in the same technology grouping for each medium of concern.

4.3.1 No Further Action

The No Further Action option, required under CERCLA, provides a baseline for comparing other options and/or alternatives. This option entails no future activities to contain or remediate contaminants at a site, provides no treatment for contaminants, and provides no legal or administrative protection of human health or the environment beyond cleanup criteria. This option assumes that physical conditions at the LSGPS remain unchanged.

Effectiveness. The No Further Action option is not effective in remediating the contaminated soil and groundwater and in meeting the PRAOs with regard to protection of human health and the environment. However, the No Further Action option is retained for detailed evaluation to serve as a baseline for comparison for other options and/or alternatives.

Implementability. The No Further Action option is easy to implement technically, because it does not require any actions to be taken. Administrative implementability is not evaluated in this FS.

Cost. There are no construction or operations and maintenance costs associated with the LSGPS No Further Action option because no actions are taken and no site monitoring is conducted. However, it is anticipated that periodic CERCLA 5-year reviews would be conducted under this option to evaluate conditions at the site as required by the NCP. Costs associated with the 5-year reviews would be included in the LSGPS No Further Action option.

Screening Summary. The No Further Action option will not achieve PRAOs; however, it is retained as a stand-alone alternative to be used as a baseline against which other alternatives will be compared.

4.3.2 Institutional Controls

At the LSGPS, institutional controls may be appropriate to protect human health and the environment in source areas and in areas where groundwater contaminant concentrations exceed PRAOs and to assure continued effectiveness of the response action(s).

4.3.2.1 Land Use Controls

Zoning. Zoning would be implemented to control present and future land uses on or around a source area consistent with the potential hazards present, the nature of remedial measures implemented, and future land-use patterns. The objective of zoning would be to prevent public or private misuse of a source area that could jeopardize the effectiveness of remedial measures taken or pose an unacceptable potential for human exposure to the contaminants present in the source.

Deed Notices. Deed Notices would be used to prevent the transfer of property without the property recipient being notified of limitations on the use of the property, or of requirements related to preserving and protecting the effectiveness of remedial measures that may have been taken. Both elements are intended to limit the potential for human exposure to source contamination.

Environmental Control Easements. Montana recently established environmental control easements (Section 76-7-101 et seq, Montana Code Annotated [MCA]), an enforceable easement mechanism for imposing restrictions on the use of a site and for requiring performance of operation and maintenance activities that may help protect the public health, safety, and welfare, and the environment. The environmental control easement is intended to be used at sites throughout the state that contain or may contain hazardous wastes or substances that may require remediation, reclamation or restoration pursuant to federal, state or local law or regulation. Protection of the public health, safety, or welfare or the environment may be enhanced by the application and enforcement of certain restrictions on the future use of the site or requirements for performance of certain activities.

4.3.2.3 Groundwater Use Restrictions

Controlled Groundwater Areas. Under Section 85-2-506(2)(e-g), MCA, a controlled groundwater area may be designated by the Montana Department of Natural Resources and Conservation through a petition of a state or local public health agency for identified public health risks if (but not limited to): (1) excessive groundwater withdrawals would cause contaminant migration, (2) groundwater withdrawals adversely affecting groundwater quality within the groundwater area are occurring or are likely to occur, or (3) groundwater quality within the groundwater area is not suited for a specific beneficial use. The Montana Department of Natural Resources and Conservation may grant either a permanent or a temporary controlled groundwater area. Restrictions within the controlled groundwater area may include such provisions as prohibition of new wells or special permitting and monitoring requirements for new and existing wells within the designated area.

4.3.2.4 Community Awareness

Information and Education Programs. These programs could include a range of informational and educational programs designed to enhance community understanding and awareness of the potential hazards posed by the source areas and contaminated groundwater, the purpose and effectiveness of remedial actions taken, and the community's and the individual's responsibilities in the maintenance of the remedial actions. Individuals or groups that may be responsible for implementing such educational programs include EPA, DEQ, local health officials, or parties that may be implementing cleanup actions including potentially responsible parties and remediation contractors.

4.3.2.5 Site Administrative Procedures

Health and Safety Programs. Administrative procedures, such as site-specific health and safety requirements, could be used as a mechanism to manage risk at the site. Site-specific health and safety requirements may be used to manage potential risks resulting from exposure to site contaminants by an industrial or construction worker if excavation into potentially contaminated soil and/or groundwater is required. Currently, some businesses located at the LSGPS have administrative health and safety procedures in place to limit contaminant exposure to workers.

Monitoring and Mitigation Programs. Protection of human health is a priority at the LSGPS. Throughout the implementation of remedial actions, the groundwater contamination at the LSGPS will continue to pose a risk to human health. Currently, all residences with groundwater contamination above regulatory standards have been provided the LWSD public water supply. DEQ is monitoring the groundwater quality of all residential wells within the plume boundaries that are used for whole-house domestic purposes. DEQ is also providing bottled water to those residences where the contaminants in the groundwater are near or approaching regulatory standards. At the beginning of the investigations, DEQ confirmed that all businesses within the plume boundaries are either connected to the public water supply or provide bottled water for a drinking water supply for the employees. In addition, two residences have received mitigation to reduce the risk from contaminated vapors entering the homes from the contaminated groundwater.

To ensure the continued protection of human health, each alternative, except No Further Action, will include the provision for continued monitoring and, if deemed necessary by DEQ or EPA, immediate mitigation of risks posed by the contamination present at the site. These mitigation programs may include provision of an alternate water supply, point-of-use groundwater treatment systems, and/or vapor intrusion mitigation.

4.3.2.6 Screening Summary

Although institutional controls do nothing to remediate the contamination at the site, they are effective for managing human exposure to contaminants. The limited effectiveness of institutional controls depends on the mechanisms used and the durability of the institutional control. Institutional controls are considered to be easy to implement and low cost to implement and maintain.

4.3.3 Monitored Natural Attenuation

Natural attenuation is a naturally occurring process in soil and groundwater environments. It acts without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in those media. This in-situ process includes biodegradation, dispersion, dilution, adsorption, volatilization, and chemical or biological stabilization or destruction of contaminants. Naturally occurring biological stabilization or destruction of contaminants (also known as intrinsic bioremediation) can be a dominant process in the fate and transport of contaminants. Natural attenuation takes place when naturally occurring microorganisms consume or otherwise degrade contaminants either aerobically or anaerobically. Natural attenuation ultimately transforms the contaminants into harmless byproducts such as chloride, carbon dioxide, ethane, and water. Natural attenuation processes have been shown to be active in portions of the LSGPS (Section 2.0).

Effectiveness. The limited effectiveness of monitored natural attenuation at the LSGPS depends on-site conditions such as source strength and persistence, pH, temperature, microbial activity, and oxidation-reduction coupling. Natural attenuation has occurred at the LSGPS, as indicated by the presence of PCE and TCE degradation products in groundwater and other geochemical lines of evidence (Section 2.0). A preliminary evaluation of groundwater monitored natural attenuation using analytical groundwater modeling techniques (Appendix E) indicates that monitored natural attenuation alone will not achieve PRAOs within a reasonable timeframe, primarily because monitored natural attenuation is not effective at remediating contamination sources (e.g., high concentrations of VOCs) at either the Brenntag or Beall source areas.

Groundwater modeling also suggests that if the continuing contribution of source in the subsurface was fully remediated or contained, monitored natural attenuation would likely require a relatively long timeframe to meet cleanup goals. For example, the portion of the plume downgradient of the Brenntag source area would continue to discharge to the Yellowstone River for more than 10 years if the subsurface source area was remediated. If the Beall source area were fully remediated, the portion of the plume downgradient of the Beall source area would continue to move as a slug toward the Yellowstone River for more than 30 years, and would contaminate currently uncontaminated portions of the aquifer in Area C. If the continuing contributions of source in the subsurface in the Brenntag and Beall source areas were not remediated, the dimensions of the portion of the plume downgradient of the Brenntag source area would remain the same, indefinitely. The dimensions of the portion of the plume downgradient of the Beall source area would continue to expand and would migrate toward the Yellowstone River.

Implementability. Implementation of monitored natural attenuation as a remediation technology entails a comprehensive groundwater monitoring program to provide data to evaluate biodegradation rates, and to monitor plume extent. A monitoring well network exists at the LSGPS to adequately monitor natural attenuation. Equipment and methods to sample and analyze groundwater are readily available. Monitored natural attenuation is easy to implement.

Cost. Costs to implement and maintain a groundwater monitoring program to monitor natural attenuation are low to moderate, depending upon the number of wells sampled and the frequency of sampling.

Screening Summary. Monitored natural attenuation alone will not achieve PRAOs within a reasonable timeframe. However, monitored natural attenuation may be used as a follow-up to other more aggressive remediation efforts. This option will be considered in conjunction with other options to form alternatives.

4.3.4 Containment

Containment actions control or reduce migration of the contaminated materials into the surrounding environment. They can also be used to isolate contaminated soil or groundwater to reduce the possibility of exposure by direct contact. These actions may involve the use of physical barriers to block a contaminant migration pathway, such as a soil-to-groundwater pathway. Containment actions for contaminated groundwater typically include physical barriers or hydraulic gradient controls.

4.3.4.1 Soil Physical Barriers

For the LSGPS, capping could be used to reduce precipitation infiltration through contaminated soil and potentially to prevent recharge to groundwater in source areas. An impermeable cap over contaminated soil areas could be constructed of clay, asphalt, concrete, or by using synthetic liners such as polyvinyl chloride or polyethylene. The areas above contaminated groundwater at the LSGPS currently include some paved parking lots and building foundations. The integrity of these surface covers is unknown.

Effectiveness. Horizontal barriers or caps at LSGPS could significantly reduce migration of contaminants from soil to groundwater due to infiltration of precipitation. However, sources would remain at and below the groundwater table and would continue to affect groundwater in the source areas; therefore, PRAOs would not be achieved in the source areas using caps alone. Capping could also have the effect of reducing oxygen availability in the area by reducing the infiltration of oxygenated precipitation and by cutting off contact of atmospheric air with the vadose zone and shallow groundwater. As a result, capping could reduce the degree of aerobic degradation occurring in the area and increase the degree of anaerobic degradation. At this time, it is difficult to gauge the net positive effect of a cap in the source areas and is therefore ranked with limited effectiveness.

Implementability. Capping is considered a standard construction practice and easily implemented. Equipment and construction methods associated with capping are readily available, and design methods and requirements are well understood.

Cost. A single-layer cap for the LSGPS source areas would have a moderate cost to construct and low maintenance cost.

Screening Summary. Containment with physical barriers alone would not achieve PRAOs within the source areas. Horizontal barriers or caps are not retained due to potential adverse effects to subsurface and groundwater chemistry.

4.3.4.2 Groundwater Physical Barriers

Physical containment methods to isolate groundwater at the LSGPS could include sheet piling and cutoff walls or curtains. These types of physical barriers could be used in conjunction with in-situ treatment walls or gates commonly referred to as a permeable reactive barrier (see Section 4.3.6.7).

Effectiveness. For a vertical groundwater barrier to be effective at the LSGPS, it would need to fully isolate the contaminated portion of the aquifer, both laterally and vertically. This would require keying the barrier into the top of the bedrock that underlies the alluvial aquifer. The bedrock surface underlying portions of the LSGPS (e.g., the Brenntag source area) appears to contain undulations that could prove problematic to sealing sheet piling and may be better sealed with grout or other flowable sealant. Also, a vertical barrier may need to encircle the source area to preclude any groundwater flow around the barrier. Effective containment of groundwater at the source areas by vertical physical barriers would allow cleanup of downgradient groundwater using other remedial actions; however, containment by itself would not remediate source areas to achieve PRAOs and is therefore ranked with limited effectiveness.

Implementability. Groundwater containment can be difficult to achieve; however, these actions have been successfully implemented at other, similar sites. Groundwater containment using vertical barriers at the Beall source area would be more difficult to implement than in the Brenntag source area due to greater depths to groundwater and bedrock in the Beall area. Changing seasonal flow directions can also interfere with containment of contaminated groundwater. Groundwater containment is ranked moderately difficult to implement at the Brenntag source area and difficult to implement at the Beall source area.

Cost. Vertical groundwater barriers at the Brenntag source area would have a moderate to high cost to construct; vertical groundwater barriers at the Beall source area are expected to be high cost. Maintenance costs of vertical groundwater barriers are considered low.

Screening Summary. Containment with physical barriers alone would not achieve PRAOs within the source areas; however, containment could be an integral part of remedial approach to clean up groundwater downgradient of source areas. Vertical groundwater containment will be considered in conjunction with other options to form alternatives.

4.3.4.3 Hydraulic Barrier

Groundwater containment could also be achieved through the use of hydraulic barriers. Hydraulic containment may include the use of pumping wells, French drains, or extraction trenches to create hydraulic sinks that would collect contaminated groundwater, preventing it from further migration. Hydraulic containment would likely require water treatment prior to on- or off-site disposal or reinjection (see Section 4.3.5 for additional discussion of pump-and-treat technologies).

Effectiveness. Hydraulic containment is expected to be effective at preventing migration of contaminant plumes but does not provide remediation for contaminated groundwater. Screening-level groundwater modeling (Appendix E) indicates that groundwater at and downgradient of the Brenntag and Beall source areas could be effectively contained using hydraulic pumping methods. Alternatively, effective containment of groundwater within source areas would allow cleanup of downgradient groundwater by other remedial actions. Some reduction in source area contaminant mass would be achieved by this approach since hydraulic containment requires the removal of contaminated groundwater; however, containment by itself would not remediate source areas to achieve the PRAOs.

Implementability. Equipment and construction methods associated with hydraulic containment are readily available, and design methods and requirements are well understood. Groundwater containment at the LSGPS is not expected to pose any insurmountable difficulties; these actions have been successfully implemented at other, similar sites. Therefore, hydraulic containment is ranked as easy to implement.

Cost. Groundwater containment at the LSGPS would have a moderate cost to construct and a moderate to high cost to operate and maintain.

Screening Summary. Hydraulic containment alone would not achieve PRAOs within the source areas; however, hydraulic containment could be an integral part of a remedial approach to clean up groundwater downgradient of source areas. Hydraulic containment will be considered in conjunction with other options to form alternatives.

4.3.5 Groundwater Collection, Treatment, and Discharge

A combination of collection, treatment, and discharge, also described as pump-and-treat, is used to provide hydraulic containment and to reduce groundwater contaminant levels in a portion of the plume. An extraction system is used to remove contaminated groundwater from the affected aquifer, which is followed by groundwater treatment, if required, and discharge or reinjection of the groundwater back into the aquifer. Extraction can be achieved by using pumping wells, French drains, or extraction trenches. Pumping may be continuous or pulsed. Pulsed pumping is used to enhance removal of contaminants by providing time for the contaminants to desorb from the aquifer material and equilibrate with groundwater. Treatment may involve physical and chemical processes such as air-stripping, carbon adsorption, and biological treatment, depending on the physical and chemical properties of the contaminants.

In general, pump-and-treat technologies can be used to either (1) remediate or restore an aquifer to original groundwater quality conditions, or (2) maintain hydraulic control to prevent migration of the leading edge of a contaminant plume or prevent future release of source materials beyond a hydraulic barrier. Pump and treat expands on the hydraulic barrier option described in Section 4.3.4.3 by providing for treatment and discharge of the extracted groundwater. Both of these objectives were evaluated using simplified analytical groundwater models (Appendix E).

4.3.5.1 Extraction Wells and Collection Trenches

Two types of collection technologies are considered applicable to the LSGPS source areas: extraction wells and collection trenches. Small-diameter (2- to 6-inch) wells are the most common method of extracting contaminated groundwater and could be used in all areas of the LSGPS. Extraction wells are typically emplaced vertically into the aquifer with a well screen and pump placed below the water table. Design of the extraction wells, including spacing, would be based on aquifer characteristics such as hydraulic gradient and hydraulic conductivity. Computer modeling may be used to predict required well spacing and pumping rate, but pilot testing is recommended to further define system design parameters. Extraction wells could be designed to remove water from specific depths within the aquifer or from across the entire saturated thickness.

Collection trenches or horizontal wells could be used in the Brenntag source area, where depths to the base of the aquifer are generally less than 30 feet. The collection trench would typically be constructed as a gravel filled trench emplaced below the water table containing perforated pipe connected to a collection sump and pump. However, horizontal extraction would be difficult to construct in the Beall source area, where depth to groundwater is 40 to 45 feet bgs and the base of the aquifer is 70 to 75 feet bgs. At the Brenntag source area, where contamination is present at shallow depths, a collection trench may cost less to install than a large number of shallow extraction wells. Collection trenches may also serve as a hydraulic barrier and can be more effective than vertical extraction wells at preventing off-site migration of contamination.

Effectiveness. Extraction wells are considered effective for intercepting and extracting groundwater; collection trenches are considered effective for shallow formations. Appendix E presents an assessment of the technical feasibility of using pump-and-treat technology alone to remediate plumes at the LSGPS. The assessment found that pump-and-treat alternatives would not be effective because of the excessive time required to meet cleanup goals, the concentrations of PCE in the Brenntag source area that approach or exceed 1 percent of solubility, and the predicted rebound and tailing effects after pumping terminates. Based on this analysis and the results of groundwater modeling (Appendix E) pump-and-treat remediation by itself will likely not meet PRAOs within a reasonable timeframe. The technology would provide only minimal source mass reduction (limited by source dissolution rates into groundwater) and would not be expected to achieve PRAOs in the source areas within a reasonable timeframe. However, results of groundwater modeling suggest that pump-and-treat technology could be used to effectively maintain hydraulic control to prevent migration of the leading edge of a contaminant plume, or prevent the future release of subsurface contamination beyond a hydraulic barrier.

Implementability. Extraction wells are easy to construct and are a very well-tested and widely available technology. Collection trenches are considered moderately easy to implement at the Brenntag source area and difficult to implement at the Beall source area.

Cost. Extraction wells, collection trenches, and pumping costs are considered low to moderate and depend on the number of wells or trenches that must be installed and the length of operation.

Screening Summary. Pump-and-treat scenarios using extraction wells and collection trenches are not expected to achieve PRAOs within the source areas or associated contaminated portions of the aquifer. However, the technology will be considered in conjunction with other options that require hydraulic controls for groundwater.

4.3.5.2 Air Stripping

Air stripping is a water treatment process that promotes the volatilization of contaminants from aqueous to vapor phase. For groundwater remediation, air stripping is typically accomplished by pumping the contaminated water through a vertical cylindrical column filled with a prescribed packing material. The packing material consists of plastic shapes with regular geometries that have engineered surface-to-volume ratios; the packing material provides a media for aqueous contaminants to form a film across each individual shape. Clean air is blown across and through the film attached to each shape facilitating the transfer of the contaminant from aqueous to vapor phase. The water is then collected from the column and further treated, if necessary, and discharged. Air and chemical vapor is also collected and treated, if necessary, and subsequently vented.

Effectiveness. Air stripping is one of the most commonly used technologies for remediation of groundwater contaminated with chlorinated VOCs, including those found at LSGPS. The process is most effective for high-volatility contaminants with concentrations of less than 200 mg/L. Influent waste streams with higher contaminant concentrations may be continuously recycled through the air stripping column until the desired effluent concentration is achieved. An air stripping system is effective at removing chlorinated VOCs from an influent waste stream; however, the effectiveness of an air stripper is dependent upon the influent flow rate of the waste stream because contaminated groundwater must be collected using a traditional extraction well or collection trench network, as detailed in Section 4.3.5.1. If necessary to meet discharge limits, liquid and/or vapor effluent from air stripping towers can be treated using a granular activated carbon adsorption system (see Section 4.3.5.3).

Implementability. Air stripping is a simple, well-known, and readily available technology commonly used to treat groundwater in pump-and-treat systems and could be implemented at LSGPS. Air stripping is considered easy to implement at the Brenntag and Beall source areas. The size of the air stripping system depends upon pumping rates, contaminant concentrations, and discharge standards.

Cost. The construction cost of an air stripping system is considered moderate. Costs of operation and maintenance (O&M) are considered moderate.

Screening Summary. Air stripping technology will be retained for further evaluation as a potential remediation option in conjunction with options that rely on extraction wells and collection trenches.

4.3.5.3 Carbon Sorption

Carbon sorption is a simple and well-known technology used to remove VOCs and semivolatile organic compounds from water. Liquid-phase carbon sorption involves pumping groundwater through a series of vessels containing granular activated carbon. Granular activated carbon adsorbs aqueous contaminants to active sites on the surface of each carbon element. As granular activated carbon active sites become saturated with contaminant, “break-through” begins to occur and effluent water quality decreases and contaminant concentrations increase. When the concentrations of contaminants in the effluent from the granular activated carbon exceed a target level, the carbon may be either removed and regenerated (heat treated to remove contaminants) or disposed of and replaced with new granular activated carbon.

Effectiveness. Carbon sorption is one of the most commonly used technologies for remediation of groundwater contaminated with VOCs, including the chlorinated VOCs found at LSGPS. A carbon sorption system is effective at removing chlorinated VOCs from an influent waste stream and is often used as a polishing step to achieve low discharge limits. The effectiveness of a carbon sorption system is directly dependent upon the influent flow rate and contaminant concentrations. Carbon sorption could effectively remediate groundwater to discharge limits at the LSGPS.

Implementability. Carbon sorption is a simple, well-known, and readily available technology commonly used to treat extracted groundwater from pump-and-treat systems and could be implemented at LSGPS. Carbon sorption is considered easy to implement at the Brenntag and Beall source areas. Granular activated carbon systems do require periodic regeneration or replacement. Spent granular activated carbon can be disposed of in a landfill but is typically recycled through a heat treating process that desorbs the collected VOCs.

Cost. The costs associated with liquid-phase carbon sorption depend on waste stream flow rates, types of contaminants, contaminant concentrations, and discharge standards. The cost of constructing a liquid-phase carbon sorption system is considered low to moderate depending upon the complexity of the system. Cost of O&M is considered moderate to high because of regeneration and disposal concerns.

Screening Summary. Carbon sorption technology is expected to be effective in treating groundwater to meet discharge limits and will be retained in conjunction with groundwater extraction and treatment options.

4.3.5.4 Chemical Oxidation/Ultraviolet Reduction

Ex-situ chemical oxidation and ultraviolet (UV) reduction involves a two-stage process in degrading chlorinated VOCs. Contaminated groundwater is exposed to UV radiation, which reduces higher-order chlorinated VOCs such as TCE and cis-1,2-DCE to VC; VC and remaining cis-1,2-DCE is then chemically oxidized to ethane and ethene.

Effectiveness. Chemical oxidation and UV reduction systems have been shown to be moderately effective in remediating groundwaters contaminated with chlorinated VOCs. The effectiveness of chemical oxidation and UV reduction to degrade PCE has been shown to be limited.

Implementability. Chemical oxidation and UV reduction treatment systems have been implemented at numerous sites. Implementation of a chemical oxidation and UV reduction system at the LSGPS is expected to be easy since it is a well known and readily available technology.

Use of a chemical oxidation and UV reduction system is dependent upon the implementation limitations of the extraction well network. Chemical oxidation and UV systems do require periodic maintenance and replenishment and may have a potentially high power input requirement.

Cost. The cost of implementing, operating, and maintaining chemical oxidation and UV reduction is considered moderate to high due to both equipment and power requirements.

Screening Summary. Chemical oxidation and UV reduction will not be retained as a water treatment option because other technologies provide equal or greater effectiveness at lower cost.

4.3.5.5 Engineered Bioreactors

Biodegradation of contaminants in extracted groundwater is achieved by putting contaminants into contact with microorganisms through either attached or suspended biological systems. In suspended biological systems, such as an activated sludge system, contaminated groundwater is circulated in an aeration basin where microbial populations aerobically degrade organic matter. The degradation products may then be concentrated and further treated as sludge. In attached systems, such as rotating biological contractors and trickling filters, microorganisms are cultured on an inert support matrix; as groundwater is passed through the support matrix, contaminants are aerobically degraded when they contact the attached microorganisms.

Effectiveness. Engineered bioreactor for the treatment of chlorinated VOCs are considered an innovative technology. The effectiveness of engineered bioreactors at LSGPS depends upon a variety of factors, including contaminant composition and concentration of the influent waste stream. Full-scale bioreactors are most effective in treating semivolatile organic compounds, fuel hydrocarbons, and other biodegradable organic material; little full-scale information is available on the effectiveness of bioreactors for treatment of chlorinated VOCs. Pilot studies at similar sites have shown that engineered bioreactors can effectively remediate VOCs and a pilot study would be necessary to determine the effectiveness of this technology at LSGPS. Due to the innovative nature of this technology, it is considered to have limited effectiveness at this time.

Implementability. Full-scale bioreactors are well known technologies and are offered as mobile package plants by authorized vendors. Very high contaminant concentrations may be toxic to microorganisms. For sludge processes, air pollution controls may be needed if volatization occurs from the sludge. Residual sludge from aeration and other processes also usually requires additional treatment or disposal. This alternative is considered moderately difficult to implement at the LSGPS, because it is unproven and would require a pilot study.

Cost. The cost of implementing engineered bioreactors is considered moderate to high. Costs for O&M are also considered moderate to high primarily due to expected high labor costs.

Screening Summary. Engineered bioreactor technology will not be retained as a water treatment option because other technologies provide more proven and better effectiveness at lower cost.

4.3.5.6 Discharge

Treated water may be disposed of through direct discharge to surface water, discharge to a storm sewer, discharge to a sanitary sewer, or reinjection to the aquifer. No sanitary or storm sewer system is present at the site. Discharge to surface waters will be required to meet surface water quality standards that are included as ARARs.

Reinjection of treated water into the aquifer will also require that the water be treated to levels that comply with groundwater quality standards that are included as ARARS. Reinjection can increase the hydraulic gradient in the aquifer and increase the effectiveness of downgradient extraction wells or collection trenches. Reinjection can also increase biodegradation of contaminants by increasing dissolved oxygen levels in the aquifer.

Effectiveness. Discharge of treated groundwater to surface water or through reinjection to the aquifer are considered effective means of water disposal. The discharge option selected will depend upon the specific design and hydraulic balance of the remediation system, water quality standards, and whether the system is being used in conjunction with other remedial technologies.

Implementability. Reinjection of treated water to the aquifer or to surface water is expected to be easy to implement.

Cost. The cost of implementing discharge options is considered low to moderate, depending upon the distance to the discharge point. Cost of O&M is considered low.

Screening Summary. Reinjection to groundwater and discharge to surface water will be retained in conjunction with extraction and treatment options. Selection will be based on the design of the remediation system.

4.3.6 In-Situ Groundwater and Soil Treatment

In-situ treatment refers to those actions that treat groundwater and soil contaminants in place. In-situ treatment of VOC contaminated groundwater and soil generally includes methods to separate and remove contaminants or to degrade contaminants in place. Since minimal or no removal or handling of contaminated groundwater or soil is required for these methods, in-situ processes tend to be more economical than ex-situ processes but may require a longer time to meet PRAOs.

In-situ treatment methods to separate and remove VOC contaminants include air sparging and vapor extraction. Methods of in-situ degradation generally involve adding agents to the subsurface (via wells or treatment walls) that facilitate chemical or biological destruction. The types of in-situ degradation most frequently used at chlorinated VOC sites like the LSGPS include various types of in-situ biological treatment and permeable treatment walls or gates.

4.3.6.1 Air Sparging and Soil Vapor Extraction

Air sparging is a process during which air is injected into the saturated zone below or within the areas of contamination. As the injected air rises through the saturated zone, it tends to volatilize and remove adsorbed VOCs in soil as well as strip dissolved contaminants from groundwater. Air sparging also oxygenates the groundwater, thereby enhancing the potential for biodegradation at sites with contaminants that degrade aerobically, such as the LSGPS. When air is first introduced below the water table, mounding of contaminated groundwater and changes to groundwater flow paths may occur; however, these disruptions typically abate once steady-state conditions are attained. Air sparging is most effective at sites with homogeneous, high-permeability soil and unconfined aquifers like the LSGPS. Air sparging can be constructed to treat a specific zone or area of contamination or it may be constructed as a barrier using horizontal or vertical injection wells perpendicular to the flow of groundwater.

Air sparging can be enhanced in a number of ways. In cometabolic air sparging, propane is injected at low concentrations along with air and acts as another nutrient for microorganisms. In biosparging, a well injects a heated mixture of air, water, nutrients, and bacteria. As the air mixture moves across the contaminated zone, bacteria, with the aid of the nutrients, destroy many of the contaminants. Ozone sparging injects an ozone-air mixture. In addition to extracting dissolved VOCs out of contaminated groundwater, the ozone reacts rapidly with the volatile compounds to oxidize them into end products consisting of carbon dioxide, dilute hydrochloric acid, and water.

SVE is an in-situ remediation technique that applies a vacuum to vapor extraction wells (horizontal or vertical) and induces air flow through the contaminated vadose zone soil. Contaminants sorbed onto soil particles, in pure phase, or in soil moisture will desorb from these phases to the vapor phase and be drawn to the extraction points. The exhaust gas may then be treated, if necessary, and discharged. The removal of contaminants can often be increased by enhancing the flow of air through the vadose zone with the addition of a network of buried air-injection piping; SVE by itself does not remove contaminants in saturated soil or groundwater below the groundwater table. SVE effectiveness can be enhanced by heating the soil while venting. Heating effectively raises the vapor pressure of the contaminant, increasing its removal rate. Heating is done by injecting hot air or steam into the soil, or by placing electrodes in the ground (six phase heating).

Air sparging systems typically are coupled with SVE systems to control subsurface airflow and to prevent contaminated soil vapor from migrating to previously uncontaminated areas. These systems are sometimes referred to as in-situ air stripping. The use of SVE during air sparging may be required to minimize the release of untreated VOC vapors from the treatment area. In addition, the treatment area could be sealed with a vapor barrier to ensure that no fugitive vapors escape from the surface of the treatment area and to reduce potential short-circuiting of atmospheric air to the SVE wells.

Effectiveness. Air sparging is an effective and commonly used technology for remediation of a saturated zone (groundwater and soil) contaminated with VOCs, including the chlorinated VOCs found at LSGPS. Likewise, SVE is often used successfully for treatment of vadose zone contaminated soil or in conjunction with air sparging. The ability of air sparging and SVE to meet PRAOs in a reasonable timeframe is dependent upon the nature and extent of contaminant source material. The presence of large quantities of NAPL-contaminated soil may significantly extend remediation timeframes. NAPL-contaminated soil has been found at the Brenntag source area in both the vadose and saturated zones; the presence of this material has not been confirmed at the Beall source area. Air sparging can cause groundwater mounding that could potentially accelerate or alter plume migration.

Implementability. Air sparging and SVE are technologies with extensive full-scale application experience. Large air sparging systems require significant equipment installation, power input, and routine maintenance. Air sparging and SVE are considered to be easy to moderately difficult to implement at the LSGPS, depending upon aquifer depths and the presence of existing structures and other physical constraints that could inhibit component installation. The off-gas extracted as the result of air sparging and SVE may require additional treatment to collect or destroy extracted organic contaminants.

Cost. The cost of implementing air sparging, including installation of air lines, sparge points and equipment shelters, is considered moderate; however, when combined with SVE, the cost of this alternative may increase depending upon the complexity of the air sparge and SVE network. Cost of O&M is considered moderate.

Screening Summary. Air sparging combined with SVE will be retained as a potential remediation option for the LSGPS.

4.3.6.2 Enhanced Aerobic Bioremediation

Biodegradation of chlorinated VOCs in groundwater, such as cis-1,2-DCE and VC, may be accomplished in a highly aerobic environment. Aerobic biodegradation can be promoted by the addition of oxygen into a contaminated area to provide an electron donor to the existing in-situ population of dechlorinating microorganisms (called chlororespirators). Also, organic carbon may be introduced into the contaminated area to provide a growth substrate to culture and enhance the population of chlororespirators. The microbes then use in-situ oxygen or injected oxygen enhancements to aerobically degrade cis-1,2-DCE and VC. Aerobic degradation of TCE only occurs through cometabolism (biological reactions), requiring the addition of a suitable cometabolic growth substrate. PCE degradation occurs anaerobically, and it cannot be degraded or biotransformed aerobically. Oxygen enhancement can effectively enhance complete degradation of VC.

The rate of aerobic biodegradation of petroleum hydrocarbons and lightly chlorinated VOCs is reduced when the concentration of oxygen in the subsurface is limited. Oxygen-enhanced aerobic bioremediation entails the addition of oxygen to the groundwater to facilitate more rapid biological degradation of contaminants. Oxygen enhancement can be accomplished by several methods, including air sparging or the addition of an electron acceptor such as hydrogen peroxide or Regenesis Oxygen Release Compound® (ORC).

Effectiveness. Oxygen enhancement by the addition of ORC is an effective delivery method for small sites with shallow depths to groundwater (less than 60 feet), such as the Brenntag and Beall source areas at LSGPS. Also, ORC does not generate vapor emissions that would need to be collected and treated. Oxygen enhancement may be appropriate to complete degradation of VC. The effectiveness of ORC can be limited by the presence of clay lenses in the aquifer, as a layer of clay will impede the movement of ORC through the contaminant mass in the saturated area. Slow groundwater velocities will also limit its distribution and require a large number of injection points. In general, ORC is expected to reduce the contaminants cis-1,2-DCE and VC to meet PRAOs; however, the time needed to achieve PRAOs varies based upon contaminant concentrations and hydrogeologic conditions. Pilot testing at the LSGPS would help define reaction rates and influence areas of ORC in-situ. Oxygen enhancement may be used as part of a phased approach for in-situ remediation of cis-1,2-DCE and VC. Often, PCE and TCE are treated in-situ using an anaerobic process to degrade to cis-1,2-DCE and VC. The cis-1,2-DCE and VC may then effectively be degraded aerobically.

The use of hydrogen peroxide for oxygen enhancement is limited for in-situ groundwater treatment. Because concentrations of hydrogen peroxide greater than 200 ppm in groundwater inhibit the growth of microorganisms, lower concentrations must be maintained. At these lower concentrations, the achievable degradation rate and the effectiveness of the treatment are limited.

Implementability. Implementation of oxygen enhancement by the addition of ORC is considered to be easy at the both the Beall and Brenntag source areas at LSGPS. In addition, ORC produces minimal residual waste and requires little aboveground equipment and power input. Typically, pilot testing is performed prior to full-scale implementation of ORC at a site. Reaction rates, influence areas, and other design parameters are determined using the results and data from the pilot test.

Cost. The cost of implementing oxygen enhancement via ORC is low to moderate. Factors influencing the cost of ORC include depth of contamination, quantity of injection points needed for areal coverage, and cost of pilot testing. Cost of O&M is considered low for ORC.

Screening Summary. Oxygen enhancement alone is not considered appropriate for LSGPS because groundwater contaminants at the site include the more highly chlorinated VOCs PCE and TCE, which biodegrade more effectively in an oxygen-deficient (anaerobic) environment. However, if continued monitoring at the LSGPS indicates that the more highly chlorinated VOCs are biodegrading to VC, then oxygen enhancement may be appropriate to enhance degradation of VC. Groundwater monitoring at LSGPS has shown that more highly chlorinated VOCs are biodegrading to cis-1,2-DCE and VC. Thus, oxygen enhancement at the LSGPS may be appropriate for use in combination with other in-situ options and will be retained for further consideration.

4.3.6.3 Enhanced Anaerobic Bioremediation

The most important process for the biodegradation of the more highly chlorinated solvents is halorespiration, commonly referred to as reductive dechlorination. Under anaerobic conditions, certain bacteria are able to gain energy for growth by reducing chlorinated VOCs such as PCE, TCE, and cis-1,2-DCE to VC. During this process, the chlorinated VOC is used as an electron acceptor and a chlorine atom is removed and replaced with a hydrogen atom. VC can also be degraded under certain anaerobic conditions (i.e., iron- or manganese-reducing); however the reduction of VC is more effectively accomplished under aerobic conditions.

Because chlorinated compounds are used as electron acceptors during reductive dechlorination, there must be an appropriate electron donor present. The electron donor used by most reductive dechlorinating microbes is molecular hydrogen, which may be produced by fermentation of a variety of organic substrates. Potential sources of molecular hydrogen include natural organic matter, fuel hydrocarbons, or organic substrates. Organic carbon sources that have been added to stimulate dechlorination include:

lactate, butyrate, acetate, molasses, refined sugars (fructose), Regenesis Hydrogen Release Compound® (HRC), edible oils, and plant mulch. The addition of carbon into the contaminated area also provides a substrate to promote and enhance the existing culture of chlororespirator microorganisms. Given a large enough population of chlororespirators, degradation of the chlorinated VOCs PCE, TCE, and cis-1,2-DCE is possible in a reasonable timeframe.

For the purposes of this FS, two commonly used organic substrate additions have been evaluated; lactate and HRC. Lactate and HRC have been successfully used to enhance biodegradation at other similar sites. An evaluation of HRC application at LSGPS is provided in Appendix G. Use of lactate or HRC assumes that the preexisting population of chlororespirators is sufficiently large to degrade chlorinated VOCs if provided a sufficient electron donor.

Effectiveness. Use of either lactate or HRC is expected to be effective at both Brenntag and Beall source areas at the LSGPS. Neither lactate nor HRC generates vapor emissions that would need to be collected and treated. The effectiveness of both lactate and HRC can be limited by the presence of clay lenses in the aquifer, as a layer of clay will impede the movement of the injected material through the contaminant mass in the saturated area. In general, injection of lactate or HRC is expected to reduce the contaminants PCE, TCE, and cis-1,2-DCE to achieve PRAOs; however, the time needed to achieve PRAOs varies based upon contaminant concentrations and hydrogeologic conditions. Pilot testing at the LSGPS will help define reaction rates and influence areas of lactate and HRC in-situ. Anaerobic enhancement using lactate or HRC may be used as part of a phased approach for in-situ remediation of the chlorinated VOCs PCE, TCE, and cis-1,2-DCE. Often, cis-1,2-DCE and VC are treated in-situ using an aerobic oxygen enhancement process, including ORC.

Implementability. Implementation of anaerobic enhancement by the addition of lactate or HRC is considered to be easy at both the Beall and Brenntag source areas at the LSGPS. Lactate and HRC produce minimal residual waste and require little aboveground equipment and power input. Typically, pilot testing is performed prior to full-scale implementation of either lactate or HRC at a site. Reaction rates, influence areas, and other design parameters are determined using the results and data from the pilot test. Limitations involved with the use of lactate or HRC include the possibility of hydrogen sulfide gas production. Hydrogen sulfide is a poisonous, deadly gas that can pool in areas and displace oxygen. The generation of hydrogen sulfide gas is usually only of concern at sites where groundwater sulfate levels are excessively high (>600 mg/L). Some areas of the LSGPS have groundwater sulfate concentrations greater than 600 mg/L.

Cost. The cost of implementing anaerobic enhancement using either lactate or HRC is considered moderate. Factors influencing the cost of lactate or HRC include depth of contamination, quantity of injection points needed for areal coverage, and cost of pilot testing. Cost of O&M is considered low for HRC and moderate for lactate recirculation.

Screening Summary. Anaerobic enhancement alone is not considered appropriate for the Brenntag source area because groundwater contaminants in this portion of the LSGPS include the lesser chlorinated VOC VC, which biodegrades more effectively in an oxygen-rich environment. Currently, groundwater concentration data from the Brenntag source area shows that PCE, TCE, and cis-1,2-DCE are degrading into VC, indicating that anaerobic conditions and a population of chlororespirators exist in-situ at the LSGPS. Reductive dechlorination is not currently active at the Beall source area and could likely be enhanced through the introduction of carbon substrate and electron donors. Like the Brenntag source area, VC that is produced would be more effectively biodegraded in an oxygen-rich environment. Thus, anaerobic enhancement may be appropriate for use in combination with other in-situ options and will be retained for further consideration.

4.3.6.4 In-Situ Thermal Treatment

In-situ thermal treatment methods include steam injection, six-phase heating, and radiofrequency heating of the subsurface. Thermal treatment is typically used in saturated zone areas where high concentrations of NAPL-contaminated soil or mobile NAPL are present. High concentrations of NAPL-contaminated soil are present at the Brenntag source area; however, mobile NAPL has not been confirmed at the LSGPS. The increased temperatures help to volatilize VOCs and enhance in-situ oxidation. Vaporized contaminants rise to the unsaturated zone where they are removed by vacuum extraction and then treated.

Effectiveness. Thermal treatments are effective in removing oily waste accumulations and in retarding downward and lateral migration of organic contaminants. It is most effectively applied to sites with soil containing light to dense NAPLs, including VOCs and could be effective at treating NAPL-contaminated soil at the LSGPS.

Implementability. Thermal treatments are applicable to both shallow and deep contaminated areas. In addition, the components of the technology are readily available. However, the location of NAPL-contaminated soil at the Brenntag source area near operating facilities and structures would make this technology moderately difficult to construct.

Cost. Thermal treatments are expensive technologies and are generally considered cost effective only at sites with very high dissolved contaminant concentrations, mobile NAPL or NAPL pools. The cost of implementing, operating and maintaining thermal treatment at the LSGPS is moderate to high.

Screening Summary. Mobile or recoverable NAPL has not been found at the LSGPS. NAPL-contaminated soil is found primarily in the vadose zone where excavation and ex-situ treatment or other in-situ treatment technologies (SVE) can be applied with similar or greater effectiveness and lower cost; therefore, in-situ thermal treatments are eliminated from further consideration.

4.3.6.5 Chemical Oxidation

In-situ chemical oxidation involves the injection of a chemical oxidant such as ozone, hydrogen peroxide, potassium permanganate, or sodium permanganate into the groundwater to treat both contaminated groundwater and soil. Chemical oxidation of VOCs produces hydrochloric acid and carbon dioxide. Ozone oxidation was previously discussed in Section 4.3.6.1.

Effectiveness. In-situ chemical oxidation is effective at treating chlorinated VOCs. Clay lenses and subsurface chemical reactions can make it difficult to deliver the oxidant to the contaminant. Applied oxidants can be consumed by natural organic matter in the aquifer, other organic contaminants (petroleum), and dissolved iron. The presence of a large mass of other organic materials at the Brenntag source area may limit the effectiveness of chemical oxidation at treating chlorinated VOCs in that source area.

Implementability. Chemical oxidation is applicable to both shallow and deep contaminated areas and is considered to be easy to implement at the LSGPS. In addition, the components of the technology are readily available.

Cost. Cost for in-situ chemical oxidation is directly affected by how many injection wells are required and how much oxidant is injected. The cost of implementing, operating and maintaining chemical oxidation at the LSGPS is moderate to high.

Screening Summary. This technology may be considered at the Brenntag and Beall source areas in conjunction with other options to form alternatives.

4.3.6.6 Phytoremediation

Phytoremediation is a process that uses plants to remove, transfer, stabilize, or destroy contaminants in soil, sediment, and groundwater. The mechanisms of phytoremediation include enhanced rhizosphere biodegradation, which takes place in soil or groundwater immediately surrounding plant roots; phytoextraction, also known as phytoaccumulation, which is the uptake of contaminants by plant roots and the translocation or accumulation of contaminants into plant shoots and leaves; phytodegradation, the metabolism of contaminants within plant tissues; and phytostabilization, the production of chemical compounds by plants to immobilize contaminants at the interface of roots and soil. Depending on the types of trees, climate, and season, trees can act as organic pumps when their roots reach down toward the water table and establish a dense root mass that takes up large quantities of water.

Effectiveness. Phytoremediation can be effective at treating shallow VOC plumes. The U.S. Air Force used poplar trees at one of its sites to contain a groundwater TCE plume (EPA 2002). TCE was shown to be degraded in the tissues of the poplar trees. The trees pumped a sufficient amount of water to produce a cone of depression that limited the spread of the TCE plume. Effectiveness of phytoremediation at the LSGPS would be reduced significantly during the winter due to plant (tree) dormancy and therefore has limited overall effectiveness.

Implementability. Phytoremediation is considered easy to implement at the Brenntag source area, where the groundwater table is shallow (5 to 10 feet). This technology is not considered feasible to implement at the Beall source area, where the depth to water is approximately 40 feet.

Cost. Phytoremediation is low cost. The cost is directly affected by the number and age of trees planted. Larger trees can be more effective in a shorter timeframe than sprigs; however, planting older, larger trees is more expensive. Cost of O&M is also considered low.

Screening Summary. Phytoremediation is not considered effective as a stand-alone option but will be retained and potentially used in conjunction with other options at the Brenntag source area.

4.3.6.7 Permeable Reactive Barrier

Permeable reactive barriers, also known as passive treatment walls, are installed across the flow path of a contaminated groundwater plume, allowing groundwater to flow through the wall. These barriers allow the passage of water while prohibiting the movement of contaminants by employing agents within the wall such as zero-valent metals, chelators, sorbents, and microbes. The contaminants are either degraded or retained in a concentrated form by the barrier material, which may need to be replaced periodically. For the VOC plumes at the LSGPS, a permeable reactive barrier would likely be constructed with a reactive medium such as elemental iron filings or zero-valent iron. As the VOC plume migrates downgradient, it crosses the barrier and reacts with the iron, causing all chlorinated VOCs to be completely and nonselectively oxidized to ethene, ethane, and water. Commercial permeable reactive barriers are currently built in two basic configurations, funnel-and-gate and continuous. The funnel-and-gate design uses physical barrier walls (such as sheet pilings or slurry walls) as a “funnel” to direct the contaminant plume to a “gate” containing the reactive media, whereas the continuous barrier completely transects the plume flow path with reactive media. Due to the funnels, the funnel-and-gate design has a greater impact on altering the groundwater flow than does the continuous permeable reactive barrier. In both designs, it is necessary to keep the reactive zone permeability equal to or greater than the permeability of the aquifer, to avoid diversion of the groundwater around the reactive zone.

Effectiveness. Reactive iron barriers have been successful in dechlorinating VOCs such as those found at the LSGPS. The barrier acts to cut off the flow of contaminated groundwater; however, the barrier does not treat the source area. Effectiveness would require keying the barrier into the top of the bedrock that underlies the alluvial aquifer. The bedrock surface underlying portions of the LSGPS (e.g. the Brenntag source area) appears to contain undulations that would need to be sealed to prevent groundwater bypass. Permeable reactive barriers installed at sites with similar groundwater contaminants have been effective at former Naval Air Station Moffett Field and former Lowry Air Force Base (Naval Facilities Engineering Command 2002). Both permeable reactive barriers are currently performing as designed, removing chlorinated VOCs from groundwater to below detection limits, and are predicted to perform acceptably for at least 30 years. A permeable reactive barrier is expected to be effective at treating VOCs in groundwater at the LSGPS.

Previous studies of zero-valent iron reactive barriers have indicated that precipitates may form over time on the iron as the groundwater passes through the reactive wall, but it is uncertain how much of the precipitate stays in the wall (EPA 1998). These precipitates, as well as the potential occurrence of biofouling, could eventually decrease permeability of the wall and cause water to flow around or under the permeable reactive barrier. Precipitates and potential biofouling also could reduce contact between the groundwater and the reactive media, resulting in incomplete treatment. The current technology for barrier regeneration would be the removal and replacement of the zero-valent iron; however, evidence of fouling has not been found at any installed permeable reactive barrier (some up to 10 years old). Innovative technologies for barrier regeneration are under development, such as flushing of the wall or ultrasound technology to mobilize the precipitates and allow them to pass through the wall (EnviroMetal Technologies, Inc. [ETI] 2003). An evaluation of permeable reactive barrier implementation at LSGPS is provided in Appendix F.

Implementability. More than 80 permeable reactive barriers have been installed around the world. Continuous trenching techniques are commonly used for installation of barrier and other systems, such as drainage trenches and pipe installation. The passive nature of the barrier makes O&M simple. Although reactive barriers are more easily constructed in relatively shallow contaminant plumes, they have been installed to depths of 120 feet bgs. The components of the technology are readily available. This alternative is considered moderately difficult to implement at the Brenntag area due to depths to groundwater and bedrock, and difficult to implement at the Beall source area due to the greater depths of groundwater and bedrock.

Cost. Cost depends on the size of the reactive barrier that must be installed. The length, depth, and thickness of the reactive barrier depend directly upon contaminant concentrations, plume width, and groundwater velocity, size, and migration rate of the groundwater plume. The cost of implementing reactive barriers at the LSGPS is considered high and operational and maintenance costs are considered to be low.

Screening Summary. Because reactive barriers are useful for controlling the migration of contaminants, reactive barriers are retained for consideration as a stand-alone alternative or in combination with other source-remediation options to form alternatives.

4.3.7 Soil Removal, Transport, Ex-Situ Treatment, and Disposal

This action involves complete or partial removal of contaminated soil source material followed by transportation; on- or off-site biological or physical/chemical treatment; and disposal at an on- or off-site location.

4.3.7.1 Removal and Transportation

Source materials could be excavated in the vadose zone or the upper portions of the saturated zone using conventional earth-moving equipment such as hydraulic excavators, backhoes, and front-end loaders. Containment and treatment of water encountered during excavation at or beneath the water table may be necessary.

Removed source material would be transported to a treatment area or disposal site in trucks or rail cars. Factors affecting the costs and feasibility of truck hauling and/or rail cars include haul distances, volume of materials, and container requirements.

Effectiveness. Mechanical excavation is considered an effective means of removing soil source material in the vadose zone at the LSGPS to approximately 30 feet bgs. Mechanical excavation in the saturated zone to similar depths can be accomplished but may be less effective due to physical difficulties (such as sloughing) encountered with saturated materials. The use of trucks and/or rail cars is considered effective means to transport excavated materials.

Implementability. Excavation and transportation of contaminated soil is a common practice that has been implemented successfully at sites with similar contamination. Excavation is expected to be easy to moderately difficult to implement at the Brenntag and Beall source areas. The water table is located at shallower depths at the Brenntag source area than the Beall source area; therefore, it is likely that the more difficult excavation of saturated materials could occur at the Brenntag source area. At both the Brenntag and Beall source areas, facility structures, including buildings and foundations, are located in close proximity to contaminated soil areas and excavation near or beneath these features would be difficult to accomplish. Excavated soil would need to be immediately backfilled at some locations at both the Beall and Brenntag source areas to preclude impacts to industrial activity in these areas.

Cost. The cost of excavation to approximately 15 feet bgs is expected to be low. The cost of excavation is moderate for greater depths and below the water table and where facilities require relocation. Cost of on-site transportation is expected to be low; off-site transportation costs could be high and are dependent upon distance, volume of materials, and means of transportation (rail car or truck).

Screening Summary. Excavation and transportation of contaminated soil will be retained in conjunction with soil treatment and disposal options.

4.3.7.2 Ex-Situ Biological Treatment

Biological treatment of excavated soil consists of cultivating microorganisms that destroy or transform contaminated material and using the contaminated materials as food and an energy source by creating a favorable environment for the microorganisms. This method typically involves the adjustment and control of oxygen, carbon, nutrients, moisture, temperature, and pH. Many times, microorganisms adapted for degradation of the specific contaminants are applied to enhance the process. Not all organic compounds are susceptible to biodegradation; however, bioremediation methods have been successful in remediating soil contaminated by the chlorinated VOCs found at the LSGPS. Biological treatments available today include land farming and composting.

4.3.7.2.1 LAND FARMING

Land farming is a bioremediation technology in which contaminated soil is mixed with soil amendments such as soil bulking agents and nutrients, and then periodically tilled for aeration. Contaminants are degraded, transformed, and immobilized by microbiological processes and by oxidation. Contaminated soil may be applied over and tilled into uncontaminated soil or placed within a lined land treatment unit with the ability to collect and store leachate. An irrigation system is used to control moisture and to add nutrients. Collected leachate can be reapplied to the land farm or treated separately and disposed of. Soil conditions that typically control the rate of contaminant degradation include moisture content, aeration, pH, nutrients, and soil amendments. Also, tilling and exposure to atmospheric air allow VOCs to volatilize. Land farms usually require greater treatment area than composting since the treatment thickness is limited by tilling depth. Treated soil could be backfilled into excavation areas or used as common fill.

Effectiveness. Land farm treatment is an effective process in treating VOCs in the soil; however, treatability testing would need to be conducted prior to full-scale implementation to establish the biodegradability of contaminated soil and efficient oxygenation and nutrient loading rates. Land farms are less effective and require more time to reach PRAOs in colder climates, as biological activity can be significantly reduced during the winter.

Implementability. Land farming of contaminated soil could be moderately difficult to implement at the LSGPS, primarily due to space limitations in some areas.

Cost. Cost of implementing an ex-situ land farm system to remediate contaminated soil is expected to be moderate to high due to the need an engineered treatment facility. Importing and backfilling disturbed areas with clean fill or treated fill are not expected to add significantly to the overall cost of this alternative. Cost of O&M is expected to be moderate.

Screening Summary. Ex-situ land farming of contaminated soil will not be considered further since there is uncertainty if land farming can meet PRAOs and other treatment options provide greater effectiveness. Also, thermal treatment is EPA's presumptive remedy for treatment of VOC contaminated soil.

4.3.7.2.2 COMPOSTING

Composting is a process in which organic wastes are degraded by microorganisms at elevated temperatures under either aerobic or anaerobic conditions. Soil is excavated and mixed with bulking agents and organic amendments, such as wood chips and plant wastes that enhance porosity. Maintaining proper oxygen and moisture content and closely monitoring temperature helps achieve maximum degradation efficiency. Typical compost temperatures range from 54° to 65° Celsius. The increased temperatures result from heat produced by microorganisms during the degradation of the organic material in the waste. Composting produces a byproduct that is stable and in some circumstances results in complete degradation of the contaminant. Composting units may generate leachate waste streams, which may require additional treatment. Treated soil could be backfilled into excavation areas or used as common fill.

There are three major designs used in composting. The first design is an aerobic static pile or biopile. Compost is formed into piles that may be enclosed, such as with a geomembrane liner. The biopile is aerated with blowers or vacuum pumps, and an installed irrigation system provides a means for controlling nutrients and moisture. Soil piles can be up to 20 feet high.

The second design uses a vessel similar to a bioreactor. After being placed in the vessel, the compost is mechanically agitated and aerated.

The third method, called windrow composting, is usually considered the most cost-effective composting alternative. After contaminated soil is excavated, large rocks and debris are removed. Amendments such as straw, alfalfa, manure, and agricultural wastes are then added. The material is layered into long piles, known as windrows. The windrow is thoroughly mixed by turning with a commercially available composting machine. Moisture, pH, temperature, and contaminant concentrations are monitored. At the completion of the composting period, the windrows are disassembled and the compost is taken to the final disposal area.

Effectiveness. Composting is an effective process in treating VOCs in the soil; however it is uncertain if this technology could achieve soil PRAOs within a reasonable timeframe. Treatability testing would need to be conducted during design to establish the biodegradability of contaminated soil and efficient oxygenation and nutrient loading rates. Composting can be less effective and require more time to reach PRAOs in colder climates, like at the LSGPS, as biological activity can be significantly reduced during the winter.

Implementability. Composting is expected to be easy to moderately difficult to implement at the LSGPS. Sufficient area for constructing treatment units appears to be available at both source areas, depending upon the volume of soil requiring treatment.

Cost. Cost of implementing an ex-situ biopile or compost system to remediate contaminated soil is expected to be moderate to high due to the requirement for an engineered treatment facility. Importing and backfilling disturbed areas with clean fill or treated fill are not expected to add significantly to the overall cost of this alternative. Cost of O&M is expected to be moderate.

Screening Summary. Engineered composting units (biopiles and bioreactors) will not be retained because there is uncertainty if composing can meet PRAOs and other treatment options provide greater effectiveness. Also, thermal treatment is EPA’s presumptive remedy for treatment of VOC contaminated soil.

4.3.7.3 Ex-Situ Physical/Chemical Treatment

Ex-situ Physical or chemical treatment remediates contaminated soil by destroying, chemically converting, separating and removing, or immobilizing the contamination. These remediation actions may involve technologies that use chemical reduction or oxidation and dehalogenation techniques. Other treatment actions may involve a separation technique using SVE, thermal treatment, soil washing, and solvent or chemical extraction. Reduction or oxidation treatment chemically converts contaminated materials to nonhazardous materials or less toxic compounds that are more stable, less mobile, and easier to manage. The most commonly used oxidizing agents include ozone, hydrogen peroxide, hypochlorite, chlorine, and chlorine dioxide. Most of these technologies involve batch treatment of materials with no long-term operation and maintenance.

4.3.7.3.1 EX-SITU SEPARATION

Ex-situ separation techniques include gravity separation and physical screening. Gravity separation involves the fluidization of contaminated soil in water; contaminants are partitioned into the aqueous and pure phase, and soil and solid contaminants are allowed to settle for further treatment. Physical separation involves the actual screening of soil particles to remove bulk contaminants. Ex-situ separation is more applicable to solid contaminants rather than VOCs and will not be further addressed.

4.3.7.3.2 EX SITU SOIL VAPOR EXTRACTION

Ex-situ SVE consists of applying contaminated soil into a lined treatment unit that has a preinstalled horizontal aeration pipe network. A pilot study would likely be required to refine design parameters. The SVE uses mass transfer and vapor phase partitioning process in a manner similar to in-situ SVE systems. Vapors may be directly vented to the atmosphere or collected and treated to meet discharge standards. Leachate collection and treatment for the lined facility may need to be to be provided. Depending upon the size of the treatment unit, soil may need to be treated in multiple batches. Treated soil could be backfilled into excavation areas or used as common fill.

Effectiveness. Ex-situ SVE technology is well known and widely available and is expected to be an effective process in removing chlorinated VOCs from the soil, including those found at LSGPS; however, it is unclear if it could achieve PRAOs in all soil. Pilot studies should be conducted to refine design parameters.

Implementability. Ex-situ SVE is expected to be easy to moderately difficult to implement at the LSGPS; difficulties may be encountered due to the need to construct an engineered treatment facility.

Cost. Cost of implementing and operating an ex-situ SVE system to remediate contaminated soil is expected to be moderate. Costs would be higher if treatment of vapors and leachate were required.

Screening Summary. Ex-situ SVE will not be retained since there is uncertainty if this technology can meet PRAOs and other treatment options provide greater effectiveness. Also, thermal treatment is EPA's presumptive remedy for treatment of VOC contaminated soil.

4.3.7.3.3 EX-SITU SOIL WASHING

Soil washing consists of separating contaminated material that has sorbed onto soil particles, using an aqueous process where soil is flushed with water to remove contaminants. The wash water can be supplemented with a basic leaching agent, surfactant, pH adjustment, or chelating agent to help remove organics and heavy metals. Most organic and inorganic contaminants tend to bind and sorb to clay, silt, and organic soil particles that are stuck to larger particles such as sand and gravel. Washing separates the small particles from the large particles by breaking adhesive bonds. The separated material is smaller in volume and is more easily disposed of or treated further. Treated soil could be backfilled into excavation areas or used as common fill.

Effectiveness. Soil washing is expected to be effective at removing chlorinated VOCs from contaminated soil that can be excavated. Chlorinated VOCs will readily partition from the soil-sorbed phase to an aqueous phase as wash water is flushed through. A pilot study would be required to determine if PRAOs could be met.

Implementability. Soil washing is expected to be difficult to implement at the LSGPS due to the expected complexity of the treatment facilities.

Cost. The cost of using soil washing is expected to be high. Importing and backfilling with clean fill are not expected to significantly contribute to the overall cost of this alternative.

Screening Summary. Due to the difficulty of implementation, uncertainty in meeting PRAOs, and potential excessive cost, ex-situ soil washing will not be retained. Other treatment options provide greater effectiveness. Also, thermal treatment is EPA's presumptive remedy for treatment of VOC contaminated soil.

4.3.7.3.4 EX-SITU CHEMICAL EXTRACTION

Chemical extraction is a process in which contaminants are dissolved when contaminated material and a chemical extractant are mixed. The extracted solution is then separated and further treated if necessary. Chemical extraction is considered an innovative technology and would require pilot studies for the LSGPS to determine if PRAOs could be met. Treated soil could be backfilled into excavation areas or used as common fill.

Effectiveness. Chemical extraction of soil contaminated with chlorinated VOCs may be effective as a remediation option for the LSGPS; pilot studies would be required to determine effectiveness. The chemical extraction process may leave traces of the chemical extractant in the treated solids; the toxicity of the remaining solution needs to be considered.

Implementability. Chemical extraction is expected to be difficult to implement at the LSGPS due to the need for pilot studies and the complexity of treatment facilities.

Cost. Cost of implementing chemical extraction to remediate contaminated soil is expected to be moderate to high due to the need for pilot studies and the complexity of treatment facilities.

Screening Summary. Due to the difficulty of implementation, uncertainty in meeting PRAOs, and potential excessive cost, chemical extraction of contaminants from soil will not be retained. Other treatment options provide greater effectiveness. Also, thermal treatment is EPA's presumptive remedy for treatment of VOC contaminated soil.

4.3.7.3.5 EX-SITU THERMAL DESORPTION

Ex-situ thermal desorption is a physical separation process in which contaminants are heated to volatilize water and organic contaminants. This can occur either on- or off-site. Vapors are then removed from the system using a carrier gas or through pressure venting, treated if necessary, and off-gassed to the atmosphere. VOCs at the LSGPS would be expected to be effectively treated using low temperature thermal desorption in which wastes are heated to between 200 to 600 °F. Excavated soil would be processed through the thermal desorption unit and treated until PRAOs were achieved. Unless heated to the higher end of the temperature range, organic components in the soil are not damaged. This enables treated soil to retain the ability to support future biological activity. Treated soil could be backfilled into excavation areas or used as common fill.

Effectiveness. Thermal desorption is an effective process in removing and/or destroying VOCs in soil and is a presumptive treatment technology for soil (EPA 1993).

Implementability. Mobile thermal desorption units are commercially available. There appears to be space available for staging the facilities at the site. Air emission requirements should not be difficult to attain. Thermal desorption is easy to implement.

Cost. Costs associated with thermal desorption are considered to be moderate to high due to treatment costs. Treatment costs are directly related to the volume of soil to be treated.

Screening Summary. Thermal desorption will be retained in conjunction with excavation, transportation, and disposal options.

4.3.7.3.6 EX-SITU INCINERATION

Ex-situ incineration is similar to thermal desorption but involves the use of a combustion chamber or kiln operating at temperatures of 1,600 to 2,200 ^{o}F to destroy organic constituents in contaminated materials. Excavated soil would be processed through the incinerator and treated to meet PRAOs. Off gases and combustion residuals may require additional treatment. If treated on-site, soil could be backfilled into excavation areas or used as common fill.

Effectiveness. Incineration is an effective process in removing and/or destroying VOCs in soil.

Implementability. There are no known incineration facilities in close proximity to the LSGPS area; however, mobile incineration units are commercially available. The nearest known off-site, RCRA-licensed incineration facility is located in Utah. On-site incineration may be difficult to implement due to air emissions concerns; off-site incineration is easily implemented.

Cost. Costs associated with incineration are considered to be high due to treatment costs (both on- and off-site) and transportation costs (for off-site treatment only).

Screening Summary. Incineration will not be considered further since thermal desorption treatment provides similar effectiveness at lower cost.

4.3.7.3.7 EX-SITU DEHALOGENATION

Ex-situ dehalogenation is achieved when reagents are added to soil contaminated with chlorinated VOCs. Contaminated materials are screened, processed using a crusher and pug mill, mixed with reagents and then heated in a reactor. The process consists of the replacement of the halogens or the decomposition and partial volatilization of the contaminated material. Treated soil could be backfilled into excavation areas or used as common fill.

Effectiveness. Dehalogenation of soil contaminated with chlorinated VOCs is expected to be effective as a remediation option for the LSGPS. This option is expected to be able to reduce contaminants in soil to meet PRAOs for the LSGPS; however, pilot studies would be necessary to confirm this.

Implementability. Dehalogenation of contaminated soil is expected to be difficult to implement at the LSGPS due to the need for pilot studies and the complexity of the treatment facilities.

Cost. Cost of using dehalogenation to remediate contaminated soil is expected to be high due to treatment costs and the cost of pilot studies.

Screening Summary. Due to the difficulty of implementation and potential excessive cost, dehalogenation of excavated contaminated soil will not be retained. Other treatment options provide greater effectiveness. Also, thermal treatment is EPA's presumptive remedy for treatment of VOC contaminated soil.

4.3.7.3.8 EX-SITU CHEMICAL OXIDATION

Ex-situ chemical oxidation involves the mixing of excavated soil with a chemical oxidant such as hydrogen peroxide, sodium permanganate, or potassium permanganate. Chemical oxidation of VOCs produces hydrochloric acid and carbon dioxide. Treated soil could be backfilled into excavation areas or used as common fill.

Effectiveness. Chemical oxidation is effective in removing chlorinated VOCs. A pilot study would be necessary to determine if soil PRAOs could be met.

Implementability. Chemical oxidation of excavated soil is considered to be moderately difficult to implement at the LSGPS due to the expected complexity of the treatment system. However, the components of the technology are readily available.

Cost. Cost is directly affected by the volume of soil and the soil chemical oxygen demand. The cost of implementing chemical oxidation at the LSGPS is moderate.

Screening Summary. Chemical oxidation will not be retained as a stand-alone alternative, since other treatment options provide equal or better effectiveness at similar or lower cost.

4.3.7.4 Off-Site Disposal

Off-site disposal options for contaminated soil from the LSGPS include a solid waste landfill (for nonhazardous wastes), and a hazardous waste landfill.

Off-site disposal involves placing excavated contaminated material in an engineered, licensed containment facility located outside the LSGPS boundary. Nonhazardous wastes could possibly be disposed of in an off-site permitted solid waste landfill in compliance with applicable laws. It is expected that some materials incidental to remedial actions will be disposed of in this manner.

Materials that are deemed to be hazardous waste would require disposal in a RCRA-permitted treatment, storage, and disposal facility. These facilities are also known as RCRA Subtitle C facilities. Excavation and disposal at an off-site RCRA hazardous waste landfill is considered to be very costly because of the high costs for transportation and disposal. The closest RCRA hazardous waste landfill locations are in Idaho, Oregon, and Utah.

Effectiveness. Off-site disposal is highly effective as waste is isolated in an engineered and licensed facility.

Implementability. Disposal at an off-site hazardous waste landfill is easily implementable; however, it is not known at this time what portion of contaminated soil, if any, could be disposed of at a solid waste landfill.

Cost. Transportation and disposal costs associated with solid waste landfill are expected to be low to moderate. Transportation and disposal costs for a hazardous waste treatment, storage, and disposal are considered moderate to high. Costs are directly related to the volume of waste disposed.

Screening Summary. Off-site disposal will not be retained as a stand-alone alternative, but may be used in conjunction with other options to form alternatives. Disposal at a solid waste landfill will be retained for non-hazardous materials.

4.3.7.5 On-Site Disposal

On-site disposal options for contaminated soil from the LSGPS include disposal of treated or untreated soil. Permanent, on-site disposal is used as a source control measure to reduce or eliminate exposure to, and mobility of, contaminated soil. Contaminated soil would be excavated and consolidated into a single, usually smaller area. Containment source control measures can be used to divert surface water from the contaminated medium and to minimize infiltration (and subsequent formation of leachate) of surface water/precipitation into the underlying contaminated medium. Infiltration can be reduced or prevented by physical barriers or by increasing evapotranspiration processes. The physical capping or covering of wastes during containment reduces or eliminates the potential health risk that may be associated with exposure (direct contact or airborne releases of particulates) to the contaminated media. Permanent, on-site disposal may involve installing physical barriers beneath as well as above the waste. This added barrier may be needed to provide additional protection of groundwater from potential leachate contamination.

The design configuration of an on-site repository for VOC contaminated soil from the LSGPS would likely involve a lined and capped repository cell with leachate collection. If necessary, the repository would be designed to meet RCRA Subtitle C requirements. Factors to consider in design include physical condition of the contaminated media, leachability, hydrogeology, precipitation, depth to groundwater, current groundwater quality, area groundwater use, and applicable groundwater standards. Desired land use following cap construction should also be considered in cap design.

Treated soil may be backfilled into excavation area or use of treated soil as common fill. Soil treated to PRAOs will no longer pose unacceptable risks to human health or the environment. Some treatment options may alter the geotechnical properties of the soil making it unacceptable for some structural applications. Geotechnical testing may be necessary prior to backfilling treated soil for certain end uses.

Effectiveness. On-site disposal is an effective means of disposing of untreated and treated soil; however, PRAOs would not be met for disposal of untreated soil. The long-term effectiveness and permanence of an engineered repository for untreated soil is dependent upon proper maintenance. Multilayered caps are susceptible to ponding of surface water, erosion, settlement, and disruption of the cover integrity by vehicles, deep-rooting vegetation, and burrowing animals. In addition, institutional controls would be required to prevent land uses incompatible with the reclaimed site. Specifically, land uses that would compromise the repository cap should be precluded.

Implementability. Disposal of treated or untreated soil at the LSGPS is considered technically implementable. No problems are foreseen that would hinder on-site disposal or backfilling of treated soil. Sufficient open space for a repository appears to be available in the vicinity of the Brenntag source area. The construction of a lined repository with a multilayered cap is considered a conventional construction practice; materials and construction methods are readily available. Also, design methods and requirements are well documented and understood.

Cost. Disposal costs associated with backfilling of treated soil are considered low. Costs associated with construction and maintenance of waste repository are expected to be moderate.

Screening Summary. On-site disposal will be retained for treated soil. On-site disposal of untreated soil will not be retained as a stand-alone alternative since other more effective and permanent soil treatment options can meet PRAOs at similar costs.

4.4 SUMMARY OF TECHNOLOGY AND PROCESS OPTION SCREENING

Table 4-3 summarizes the general response actions, technologies, and process options that were identified and screened for remediation at the LSGPS. The table also summarizes the results of the screening of each process option based on effectiveness, implementability, and cost. The table identifies each option as being retained or not retained.

5.0 DETAILED DESCRIPTION OF SELECTED TECHNOLOGY OPTIONS

In this section, retained technologies and process options, presented in Table 5-1, are further screened and developed. Supporting options will be re-introduced during the development of alternatives in Section 6.0. Groundwater and soil technology options are selected for use in remedial alternatives and developed in detailed conceptual designs. These technology options are assembled into site-wide remedial alternatives and further screened in detail against the NCP criteria in Section 6.0.

5.1 SELECTION OF REMEDIAL TECHNOLOGY OPTIONS

Based on the results from the technology and process option screening performed in Section 4.0, this section provides rationale for selecting specific technologies that are considered the best options for achieving PRAOs at the LSGPS. Technology options that are expected to be included in all alternatives (except No Further Action) were grouped as Common Elements. Technologies were developed for each source area (Brenntag and Beall) for the two principal contaminated media in those areas: groundwater and contaminated soil. In addition, groundwater technologies were developed for the Beall source area plume leading edge and for site-wide groundwater remediation. Descriptions of these technologies are presented in this section. Final configuration of remedial alternatives will be determined during remedial design.

As summarized in Section 2.0, no soil or groundwater COC concentrations measured at the Beall source area indicate the release or presence of NAPL. Contaminated soil at the Beall source area appears to be the result of releases of dilute TCE. Source material at the Brenntag source area includes contaminated soil that appears to be the result of NAPL releases at the surface. High concentrations of PCE in groundwater at the Brenntag source area, above 1 percent solubility levels, indicate that residual NAPL may be present in the saturated zone. However, no mobile NAPL has been found in groundwater samples at the LSGPS and no other indications of recoverable liquid NAPL were found during the RI or other investigations. Therefore, technologies targeting the recovery or treatment of free-phase liquids have not been retained.

5.1.1 Common Elements

All remedial alternatives, except No Further Action, have common elements. These common elements are described here and not repeated in the detailed descriptions of alternatives (Section 6.0). These elements include long-term monitoring, 5-year reviews, and institutional controls. The following assumptions are provided for the common elements. Costs associated with these common elements are provided in Appendix H.

1. Long-term monitoring. Monitoring would include sampling of the existing monitoring well network that presently includes 81 wells. In addition, 12 surface water stations would be sampled. Monitoring is assumed to be conducted on a semi-annual basis for the first 5 years and annually thereafter, for the duration of the remedial action. For the purposes of cost estimates in the FS, DEQ assumed 30 years for the extent of the long-term sampling for those remedial actions that do not meet ARARs in the long term.

2. CERCLA 5-year reviews. These reviews would be conducted every five years for 30 years and would include document review, site interviews, a site inspection, risk evaluation, and a summary report.

3. Institutional controls. Section 4.3.2 details the examples given below of possible institutional controls that may be established for the LSGPS. Specific institutional controls necessary at the LSGPS will be identified after the preferred alternative has been selected.

    a. Land Use Controls. No land use controls are identified at this time.

    b. Groundwater Use Restrictions. It is assumed that a controlled groundwater area will be established for the LSGPS.

    c. Community information and education programs. It is assumed that federal, state, and local health officials and others will provide annual community education and awareness updates. Other educational programs may be necessary depending on the preferred alternative selected.

    d. Site Administrative Procedures. Monitoring and, if necessary, contingency components for immediate protection of human health for area residents and workers include any or all of the following:

        i. Semi-annual groundwater monitoring of ten (10) residential wells for ten years.
        ii. Semi-annual groundwater monitoring of twelve (12) business wells for ten years.
        iii. Connection of an individual residence to the available public water supply.
        iv. Connection of one mobile home park with 12 units (house considered above) to the available public water supply.
        v. Connection of an individual business to the available public water supply.
        vi. Provision of granular activated carbon/UV wellhead treatment systems for a single residence including annual monitoring and granular activated carbon replacement for 20 years.
        vii. Provision of granular activated carbon/UV wellhead treatment system for a single commercial establishment including annual monitoring and granular activated carbon replacement for 20 years.
        viii. Extension of the public water supply down Klenck and around Island Park Road/Cerise Road.

5.1.2 Groundwater Technologies

This section provides a description of selected groundwater remediation technologies, reasons for consideration at the LSGPS, and general descriptions of their applications at the LSGPS. Five technologies have been considered to address remediation of groundwater at and downgradient of the identified source areas and in site-wide groundwater. These groundwater treatment technologies are:

- Monitored natural attenuation;
- Pump and treat (hydraulic barrier);
- Permeable reactive barrier;
- In-situ enhanced bioremediation; and
- Air sparging and SVE.

5.1.2.1 Monitored Natural Attenuation

Monitored natural attenuation is not considered an effective treatment technology for source areas and associated groundwater (especially at the Brenntag source area) due to high contaminant concentrations in these areas and the lack of evidence that monitored natural attenuation could meet PRAOs by itself. However, monitored natural attenuation is considered potentially effective at maintaining PRAOs in groundwater after source areas and associated downgradient groundwater have been treated with active remediation methods. In addition, monitored natural attenuation is considered potentially effective in portions of site-wide groundwater where contaminant concentrations are considered low to moderate (within 10 times the MCL).

At the Beall source area, the leading edge of the plume (see Figure 4-1) is expected to migrate over time (Appendix E) and could cause groundwater to exceed MCLs in downgradient areas. A PRAO has been established to prevent groundwater degradation that could occur in this area as the plume migrates (see Section 4.2). Monitored natural attenuation is not considered effective, as evidenced by the presence of the plume in this area. Therefore, monitored natural attenuation is selected as a stand-alone technology for site-wide groundwater only.

5.1.2.2 Pump and Treat (Hydraulic Barrier)

Pump and treat has been the most widely selected groundwater treatment technology at hazardous waste sites (EPA 2001). EPA guidance (EPA 1996b) and an analysis of groundwater modeling (Appendix E) indicate that pump and treat can be an effective technology for hydraulic containment at the LSGPS; however, this technology is expected to have high operation and maintenance costs. Therefore, pump and treat will only be considered to prevent migration of the plume downgradient of the Beall source area in conjunction with other groundwater remedial technologies.

5.1.2.3 Permeable Reactive Barrier

The permeable reactive barrier technology has been selected for the LSGPS because this technology has been successfully implemented at other, similar sites and it is a commonly selected in-situ groundwater treatment technology (EPA 2001) for sites without recoverable NAPL like the LSGPS. A permeable reactive barrier is principally considered a method to contain and treat source area groundwater at the LSGPS; this technology is not considered cost effective for addressing low level contamination present in site-wide groundwater (Appendix F). Under this option, contaminated groundwater emanating from the Brenntag and Beall source areas would be contained and treated using zero-valent iron barriers constructed perpendicular to the groundwater flow direction. After passing through the permeable reactive barrier, the downgradient groundwater is expected to naturally attenuate. However, groundwater upgradient of the treatment system would not be affected. Other organic contaminants, such as petroleum or methanol that may be present in groundwater are not expected to negatively impact the effectiveness of the permeable reactive barrier. Additional technologies may be applied to upgradient source areas and downgradient plume areas to enhance the overall remediation strategy to achieve PRAOs in a shorter timeframe or achieve PRAOs throughout the source area.

5.1.2.4 In-Situ Enhanced Bioremediation

In-situ bioremediation has been selected for the LSGPS because this technology has been successfully implemented at other, similar sites and is one of the most commonly selected in-situ groundwater treatment technologies (EPA 2001) for sites without recoverable NAPL like the LSGPS. This technology could be applied at the LSGPS source areas, the leading edge of the plume emanating from the Beall source area, or site-wide groundwater (Appendix G).

This technology consists of enhanced anaerobic bioremediation followed by enhanced aerobic bioremediation. Enhanced anaerobic bioremediation at the Brenntag and Beall source areas would involve the addition of nutrients to promote biodegradation of highly chlorinated VOCs. At the Beall source area, a second treatment area would be designed at the leading edge of the plume to prevent further COC migration in this area. The conceptual design assumes that HRC-X (a concentrated form of hydrogen releasing compound) and lactate would be added during the first years of remediation, although other nutrients may be chosen during the remedial design. Following the initiation of this phase, aerobic bioremediation would begin by the addition of oxygen-releasing compounds (ORCs) to promote biodegradation of the less chlorinated VOCs. Other organic contaminants, such as petroleum or methanol that may be present in groundwater particularly at the Brenntag source area may be helpful in providing additional carbon substrate for enhanced bioremediation.

Continued application of enhanced anaerobic and aerobic bioremediation in the source areas may be required over the long term. The design assumptions for this option would need to be confirmed prior to remedial action if this option were selected.

5.1.2.5 Air Sparging and Soil Vapor Extraction

Air sparging/SVE has been selected for the LSGPS because this technology has been successfully implemented at other, similar sites and it is one of the most commonly selected in-situ groundwater treatment technologies (EPA 2001) for sites without recoverable NAPL like the LSGPS. Air sparging/SVE is principally considered a method to treat source area groundwater at the LSGPS; this technology is not considered cost effective for addressing low level contamination present in site-wide groundwater. This technology could be applied at the LSGPS source areas or the leading edge of the plume emanating from the Beall source area.

This option at the Brenntag and Beall source areas would involve construction of an air sparge and SVE treatment barrier immediately downgradient of the source areas. At the Beall source area, a second treatment barrier would be constructed at the leading edge of the plume to prevent further COC migration in this area. Air would be injected through vertical sparge wells completed to bedrock along a treatment zone perpendicular to groundwater flow and spanning the width of the groundwater plume. The air would volatilize VOCs in the saturated zone and carry contaminants up to the vadose zone. Ozone would be injected along with air to provide direct oxidation of VOCs. In areas where suspected NAPL or other organic contaminants, such as petroleum or methanol, may be present, additional ozone may be required because these conditions create a high chemical-oxidant demand.

Horizontal SVE wells located immediately below ground surface would extract the contaminated vapors. Depending upon the concentration of VOCs in the SVE discharge, thermal oxidation, catalytic oxidation, or carbon adsorption would be used for vapor treatment; however, carbon adsorption is most appropriate for the low vapor concentrations expected at the LSGPS. After passing through the air sparge/SVE system, the downgradient groundwater is expected to naturally attenuate. However, groundwater upgradient of the treatment system would not be affected. Additional technologies may be applied to upgradient source areas and downgradient plume areas to enhance the overall remediation strategy to achieve PRAOs in a shorter timeframe or achieve PRAOs throughout the source area.

5.1.3 Soil Technologies

This section provides a description of selected soil remediation technologies, reasons for selection at the LSGPS, and general descriptions of their applications at the LSGPS. No soil contamination indicating source areas has been identified outside of the two main source areas. Site-wide soil remediation is not identified as a PRAO. Therefore, soil remediation technologies will focus on the two source areas. Three technologies have been assembled to address remediation of contaminated soil at identified source areas. These soil treatment technologies are:

- Soil vapor extraction;
- Excavation and thermal desorption; and
- In-situ chemical oxidation.

5.1.3.1 Soil Vapor Extraction

SVE has been selected primarily because it is one of EPA's presumptive remedies for VOCs in soil (EPA 1993) and is appropriate at the LSGPS. This option at the Brenntag and Beall source areas would involve construction of SVE treatment systems within the areas of contaminated soil identified on Figures 4-2 and 4-3. Vertical and/or horizontal SVE wells installed in the vadose zone would extract VOCs from contaminated soil. Depending upon the concentration of VOCs in the SVE discharge, thermal oxidation, catalytic oxidation, or carbon adsorption would be used for vapor treatment. Pilot studies conducted at the Brenntag property (Appendix B) have generated little specific design parameters for SVE; therefore, additional design tests would be needed prior to remedial action.

5.1.3.2 Excavation and Thermal Treatment

Excavation and thermal treatment has been selected primarily because it is one of EPA's presumptive remedies for VOCs in soil (EPA 1993) and is appropriate at the LSGPS. This option consists of excavation of contaminated soil, on-site treatment of soil using thermal desorption, and on-site disposal of treated soil. This option at the Brenntag and Beall source areas would involve excavation of soil remediation areas identified on Figures 4-2 and 4-3. Excavated soil would then be processed through a portable thermal desorption unit, where soil would be heated to volatilize VOCs. Depending upon the concentration of VOCs in the treatment discharge, thermal oxidation, catalytic oxidation, or carbon adsorption would be used for vapor treatment.

5.1.3.3 In-Situ Chemical Oxidation

In-situ chemical oxidation has been selected to provide a method for remediation of the saturated zone within the source areas where high concentrations of residual groundwater contamination may exist and where residual contaminated soil may be present. Under this option, saturated zone groundwater and soil contamination associated with the Brenntag and Beall source areas would be treated using injected chemical oxidants. This option is expected to be employed to address recalcitrant saturated zone sources at the Brenntag source area that may not be adequately remediated with other options. In-situ chemical oxidation could be considered as a stand-alone treatment technology at the Beall source area due to the lack of active biodegradation and the apparent lack of NAPL sources in the saturated zone. The oxidants applied in in-situ chemical oxidation are typically hydrogen peroxide, permanganate, ozone, and more recently sodium persulfate. The preferred oxidant would be sodium permanganate or potassium permanganate. Hydrogen peroxide was not considered due to safety handling issues and low pH requirements to obtain a Fenton reaction. Persulfate oxidation is still in the testing phase at other sites and was not considered. Ozone air sparging is considered in the groundwater alternatives. In areas where suspected NAPL or other organic contaminants, such as petroleum or methanol, may be present, additional oxidant may be required because these conditions create a high chemical-oxidant demand.

5.2 BRENNTAG SOURCE AREA GROUNDWATER OPTIONS

This section presents the conceptual design of groundwater remedial options for the Brenntag source area. Costs for these options are provided in Appendix H.

5.2.1 Permeable Reactive Barrier

This alternative at the Brenntag source area would include the installation of a permeable reactive barrier downgradient of the source area, as presented on Figure 5-1. The location of the barrier was selected to be downgradient of identified NAPL-contaminated source areas and excavated material are not expected to contain NAPL-contaminated soil; however, groundwater in this area may contain total VOC concentrations of up to 6,000 µg/L. The wall would be constructed across the entire width of the groundwater plume in this area, estimated at 325 feet in width. The barrier would be installed to bedrock (approximately 30 feet bgs) with zero-valent iron emplaced throughout the saturated thickness (25 feet). A flow-through thickness of 3.8 feet has been estimated, resulting in a required mass of iron of 2,316 tons. The design parameters of the permeable reactive barrier were developed with EnviroMetal Technologies, Inc. (Appendix F). The barrier would be installed by continuous trenching or biopolymer slurry (see Section 4.3.6.7 for technology descriptions). Contaminated groundwater passing through the permeable reactive barrier would be treated to reduce VOC concentrations to meet PRAOs.

Groundwater and system performance monitoring would be conducted using a network of 37 wells and analysis for natural attenuation parameters and VOCs. The 37 monitoring wells are existing wells MW002, MW003, MW004, MW005, MW006, MW007, MW008, MW009, MW010, MW011, MW100, MW101, MW102, MW103, MW104, MW105, MW116, MW117, MW121, MW122, MW124, MW125, MW126, MW127, and MW128 and 12 new 2-inch diameter monitoring wells (see Figure 5-1). Additional monitoring wells are available at the Brenntag source area and downgradient plume. The selection or addition of wells may be adjusted for comprehensive alternative development or during remedial design.

5.2.2 Air Sparging and Soil Vapor Extraction

Under this alternative, an air sparging and SVE barrier would be constructed immediately downgradient of the Brenntag source area. The conceptual design of this system is shown on Figure 5-2. The design of the air sparge system is based on pilot studies conducted at the Brenntag source area (Appendix B). The results of the pilot study are preliminary and would need to be confirmed prior to remedial action if this alternative were selected. Final configuration of remedial alternatives will be determined during remedial design.

Fifteen 2-inch-diameter sparge wells would be constructed to form a 325-feet-long boundary treatment zone. Each well would be completed to bedrock and spaced approximately 22 feet apart. The length and depth of the treatment zone are based on the dimensions of the PCE plume in this area. Wells would be spaced 11 feet apart, based on the minimum effectiveness radius determined during pilot studies (Appendix B). Minimum sparge-well air-flow rate would be 5 standard cubic feet per minute (scfm) based on pilot study work. However, flow rates at and below 5 scfm may be less efficient; therefore the system would be constructed to deliver up to 20 scfm in order to maximize cumulative mass removal (Battelle 2002). System flow rate would total from 75 to 300 scfm. Ozone concentrations in air would be maintained at about 1,200 parts per million based on pilot study results (Appendix B).

Horizontal SVE wells would be installed in two gravel trenches constructed parallel to and on either side of the sparge well treatment zone. Each gravel trench would be 325 feet long, 2 feet wide, and be constructed from ground surface to the water table (approximately 10 feet deep). The SVE wells would be installed while the trenches are being excavated. The total SVE air-flow rate would be twice the sparge air-flow rate, based on design guidance (Naval Facilities Engineering Command 2001). Each SVE trench flow rate would be 75 to 300 scfm, for a total combined flow rate of 150 to 600 scfm. SVE vapor discharge would be treated with granular activated carbon adsorbers.

Groundwater and system performance monitoring would be conducted using a network of 35 wells to be analyzed for natural attenuation parameters and VOCs. The 35 monitoring wells include existing wells MW002, MW003, MW004, MW005, MW006, MW007, MW008, MW009, MW010, MW011, MW100, MW101, MW102, MW103, MW104, MW105, MW116, MW117, MW121, MW122, MW124, MW125, MW126, MW127, and MW128 and 10 new 2-inch-diameter monitoring wells (see Figure 5-2). Additional monitoring wells are available at the Brenntag source area and downgradient plume. The selection or addition of wells may be adjusted for comprehensive alternative development or during remedial design.

5.2.3 In-Situ Enhanced Bioremediation

An enhanced bioremediation system at the Brenntag source area would use a lactate recirculation treatment system in the source area and a series of injection wells configured in a treatment zone across the plume width, downgradient of the source area (Figure 5-3). The recirculation system is considered more cost effective than a barrier system in the source area. The recirculation treatment system would consist of five 2-inch-diameter extraction wells and three 2-inch-diameter injection wells. Groundwater would be extracted, supplemented with lactate, and reinjected to promote anaerobic degradation. Nutrient delivery would be accomplished by pumping and recirculating lactate-amended groundwater until lactate was fully distributed. The total flow rate of the recirculation system is assumed to be 55 gallons per minute (gpm) based on groundwater modeling (Appendix E).

A treatment zone would be installed downgradient of the Brenntag source area to provide treatment of this portion of the groundwater plume, based on vendor recommendations (Appendix G). The treatment zone would consist of five rows of injection wells, each 200 feet long. Well spacing within each row would be 10 feet, and the rows would be spaced 10 feet apart. The treatment zone would be installed immediately upgradient of MW122. Injection wells would be installed as 2-inch-diameter wells to allow multiple applications of HRC-X over time. A total of 100 injection wells would be required.

During the initial phase of remediation, which is estimated to last 3 years or more, HRC-X would be injected at the treatment zone and lactate would be injected in the recirculation system to promote anaerobic degradation. Nutrient delivery would be accomplished by pumping lactate or injecting HRC-X amendments to fully distribute them across the aquifer thickness. After nutrient delivery is completed, injection and recirculation would be halted and the groundwater monitored for degradation parameters and VOCs. Batch delivery of lactate and HRC-X to the aquifer would be repeated as necessary, approximately every 6 months with the recirculation system and every 3 years for the barrier system, to degrade PCE, TCE, and cis-1,2-DCE until PRAOs are achieved throughout the plume. In the second phase of this alternative, which is estimated to last 3 years or more, ORC would be introduced using the same injection well networks to promote aerobic degradation of VC until PRAOs are achieved throughout the plume. Repeated applications of lactate and ORC in the source area may be required over the long term to continue to meet PRAOs in the source area.

Groundwater and system performance monitoring would be conducted using a network of 31 wells to be analyzed for natural attenuation parameters and VOCs. The 31 monitoring wells are existing wells

MW002, MW003, MW004, MW005, MW006, MW007, MW008, MW009, MW010, MW011, MW100, MW101, MW102, MW103, MW104, MW105, MW116, MW117, MW121, MW122, MW124, MW125, MW126, MW127, and MW128 and six new 2-inch diameter monitoring wells (see Figure 5-3). Additional monitoring wells are available at the Brenntag source area and downgradient plume. The selection of specific wells may be adjusted for comprehensive alternative development or during remedial design.

5.3 BRENNTAG SOURCE AREA SOIL OPTIONS

This section presents the conceptual design of soil remedial options for the Brenntag source area. Costs for these options are provided in Appendix H. Effectiveness of soil remediation options would be monitored using groundwater data from existing wells MW002, MW003, MW004, MW005, MW006, MW007, MW008, MW009, MW010, MW011, MW100, MW101, MW102, MW103, MW104, MW105, MW116, MW117, MW121, MW122, MW124, MW125, MW126, MW127, and MW128 (see Figure 5-4). Direct soil confirmation sampling will also be conducted and is discussed in Section 6.0.

5.3.1 Soil Vapor Extraction

Under this alternative, vertical SVE wells would be installed within the identified soil remediation areas at the Brenntag source area. The conceptual design of this system is shown on Figure 5-5. Each well would be constructed from ground surface to the water table (approximately 10 feet deep). Based on guidelines presented by Keller (2003) for fine sand formations, each SVE well is assumed to have a 16-foot radius of influence at 9 inches of mercury vacuum and a flow rate of 4 scfm per foot of vent screen. The air flow rate for each well would be 40 scfm, assuming 10 feet of screen length. Wells would be spaced to provide 100 percent overlap so that wells could alternatively be used as passive air inlets. Based on the treatment area shown on Figure 5-5 (7,454 square feet) and adjusting well locations to ensure full coverage of soil remediation areas, a total of 22 2-inch-diameter SVE wells would be installed. Assuming that half of the wells would be used as passive air inlets at any one time, the total combined flow rate for the system would be 440 scfm. SVE vapor discharge would be treated with granular activated carbon adsorbers. Optimal well spacing, screened interval placement, and flow rate selection for the final remedial design would be determined through pilot studies and additional design tests and modeling.

5.3.2 Excavation and Thermal Treatment

Under this alternative, soil would be excavated within the identified remediation areas at the Brenntag source area. The estimated extent of soil with contaminant levels above remediation goals is shown on Figure 5-6. Soil would be excavated from ground surface to the bottom of the fine-grain silty sand unit, an estimated average of 14 feet bgs. The total volume of contaminated soil to be excavated is estimated at 3,865 cubic yards. In the southeastern portion of the Brenntag facility, one area of soil contamination is beneath a portion of a tank storage area. It is assumed that contaminated soil in this area would be removed after affected facilities were temporarily relocated and foundations partially removed. Sheet piling is assumed to be used for slope stabilization during excavation. Soil desorption equipment would be temporarily located within the immediate vicinity of the soil removal areas. Excavation areas are assumed to be backfilled with treated soil.

5.3.3 In-Situ Chemical Oxidation

This alternative at the Brenntag source area would include the installation of multiple injection wells throughout the source area to inject the chemical oxidant solution (sodium permanganate). The conceptual design includes six injection wells and is presented on Figure 5-7. The source area will likely require multiple injection phases, particularly in areas where suspected NAPL or other organic contaminants, such as petroleum or methanol, may be present, because these conditions create a high chemical-oxidant demand. Injection spacing would also need to be increased in areas of high concentrations due to faster contaminant reaction rates, which lead to more limited transport distances from the injection site. Pressurized injection may also be employed to obtain better lateral transport using higher oxidant concentrations, resulting in fewer injection points.

NAPL-contaminated soil and high groundwater concentrations of chlorinated VOCs would be quickly oxidized to carbon dioxide, manganese oxide, potassium or sodium, chloride, and free hydrogen. Manganese oxide has the potential to cause reduced permeability and may cause plugging in injection wells.

5.4 BEALL SOURCE AREA GROUNDWATER OPTIONS

This section presents the conceptual design of groundwater remedial options for the Beall source area. Costs for these options are provided in Appendix H.

5.4.1 Permeable Reactive Barrier

This alternative at the Beall source area would include the installation of a permeable reactive barrier downgradient of the source area as presented on Figure 5-8. The location of the permeable reactive barrier was selected to be downgradient of identified soil contamination areas; however, groundwater in this area may contain total VOC concentrations of up to 1,000 µg/L and may require special considerations during construction. The barrier would be constructed across the entire width of the groundwater plume in this area, estimated at 350 feet in width. The permeable reactive barrier would be installed to bedrock (approximately 68 feet bgs) with zero-valent iron emplaced throughout the saturated thickness (28 feet). A flow-through thickness of 0.7 feet has been estimated, resulting in a required mass of iron of 515 tons. The design parameters of the permeable reactive barrier were developed with EnviroMetal Technologies, Inc. (Appendix F). The permeable reactive barrier would be installed by biopolymer slurry. Contaminated groundwater passing through the permeable reactive barrier would be treated to reduce VOC concentrations to PRAOs.

Groundwater and system performance monitoring would be conducted using a network of 21 wells to be analyzed for natural attenuation parameters and VOCs. The 21 monitoring wells are existing wells MW012, MW200, MW201, MW202, MW203, MW204, MW205, MW210, MW211, MW212, MW213, and MW219 and nine new 2-inch diameter monitoring wells (see Figure 5-8). Additional monitoring wells are available at the Beall source area and downgradient plume. The selection or addition of wells may be adjusted for comprehensive alternative development or during remedial design.

5.4.2 Air Sparging and Soil Vapor Extraction

Under this alternative, an air sparging and SVE treatment barrier would be constructed immediately downgradient of the Beall source area. The conceptual design of this system is shown on Figure 5-9. The system would consist of twelve 2-inch diameter sparge wells constructed to form a 250-feet-long boundary treatment zone. Each well would be completed to bedrock, and wells would be spaced approximately 22 feet apart. The length and depth of the treatment zone is based on the dimensions of the TCE plume in this area. Well spacing is based on the minimum effectiveness radius determined during pilot studies at the Brenntag source area (Appendix B). Brenntag pilot study data is considered applicable to the Beall area because aquifer matrix and water table thickness are similar at both sites. Minimum sparge-well air-flow rate would be 5 scfm based on the Brenntag pilot study work. However, flow rates at and below 5 scfm may be less efficient; therefore, the system would be constructed to deliver up to 20 scfm per well in order to maximize cumulative mass removal (Battelle 2002). System flow rate would total from 60 to 240 scfm. Ozone concentrations in air would be maintained at about 1,200 parts per million based on pilot study results (Appendix B).

Vertical 2-inch diameter SVE wells would be installed in two rows constructed parallel to and on either side of the sparge well treatment zone. SVE wells would be constructed from ground surface to the water table (approximately 45 feet deep). SVE wells would be spaced 22 feet apart, for a total of 24 wells. The total SVE air-flow rate would be twice the sparge air-flow rate, based on design guidance (Naval Facilities Engineering Command 2001). SVE well flow-rate would be 5 to 20 scfm, for a total combined flow rate of 120 to 480 scfm for the system. SVE vapor discharge would be treated with granular activated carbon adsorbers.

Groundwater and system performance monitoring would be conducted using a network of 19 wells to be analyzed for natural attenuation parameters and VOCs. The 19 monitoring wells are existing wells MW012, MW200, MW201, MW202, MW203, MW204, MW205, MW210, MW211, MW212, MW213, and MW219 and seven additional 2-inch diameter monitoring well (see Figure 5-9). Additional monitoring wells are available at the Beall source area and downgradient plume. The selection or addition of wells may be adjusted for comprehensive alternative development or during remedial design.

5.4.3 In-Situ Enhanced Bioremediation

An enhanced bioremediation system implemented at the Beall source area would use a lactate recirculation treatment system in the source area (Figure 5-10). The recirculation system is considered more cost effective than a barrier system in the source area. The groundwater gradients in the main Beall source area (west of the upper Lockwood irrigation ditch) are low, and induced gradients provided by a recirculation system would be more effective at nutrient distribution than a system (like the treatment zone) that would rely upon natural gradients.

The recirculation treatment system would consist of three 2-inch diameter-extraction wells and two 2-inch-diameter injection wells. Groundwater would be extracted, supplemented with lactate, and reinjected to promote anaerobic degradation. Nutrient delivery would be accomplished by pumping and recirculating lactate-amended groundwater until lactate was fully distributed. The total flow rate of the recirculation system is assumed to be 15 gpm based on groundwater modeling (Appendix E).

During the initial phase of remediation, which is estimated to last 6 years or more, lactate would be injected in the recirculation system to promote anaerobic degradation. Nutrient delivery would be accomplished by pumping lactate amendments to fully distribute them across the aquifer thickness. After nutrient delivery was completed, injection and recirculation would be halted and the groundwater monitored for degradation parameters and VOCs. Batch delivery of lactate to the aquifer would be repeated as necessary, approximately every 6 months, to degrade contaminants PCE, TCE, and cis-1,2-DCE until PRAOs are achieved throughout the plume. In the second phase of this alternative, which is estimated to last 6 years or more, ORC would be introduced using the same injection well networks to promote aerobic degradation of VC until PRAOs are achieved throughout the plume.

Groundwater and system performance monitoring would be conducted using a network of 12 wells to be analyzed for natural attenuation parameters and VOCs. The 12 monitoring wells are existing wells MW012, MW200, MW201, MW202, MW203, MW204, MW205, MW210, MW211, MW212, MW213, and MW219 (see Figure 5-10). No additional monitoring wells are proposed. Additional monitoring wells are available at the Beall source area and downgradient plume. The selection or addition of wells may be adjusted for comprehensive alternative development or during remedial design.

5.5 BEALL SOURCE AREA PLUME LEADING EDGE OPTIONS

This section presents the conceptual design of groundwater remedial options for the leading edge of the plume emanating from the Beall source area. At the Beall source area, the leading edge of the plume is expected to migrate over time and could cause groundwater to exceed MCLs in downgradient areas. A PRAO has been established to prevent groundwater degradation that could occur in this area as the plume migrates. Costs for these options are provided in Appendix H.

5.5.1 Hydraulic Barrier

This alternative at the Beall source area plume leading edge would include construction of a hydraulic barrier at the downgradient edge of the plume, as presented on Figure 5-11. The hydraulic barrier installed at the leading edge of the plume would consist of three 2-inch diameter extraction wells, granular activated carbon treatment, and would discharge to two downgradient injection wells. The hydraulic barrier would be used to extract, treat and reinject groundwater at a rate of 15 gpm to prevent contaminated groundwater from migrating further in this area. Modeling that supports this assessment is presented in Appendix E. Contaminated groundwater would be intercepted and treated at the hydraulic barrier to contain the leading edge of the plume and prevent further migration.

Groundwater and system performance monitoring would be conducted using a network of 7 wells to be analyzed for natural attenuation parameters and VOCs. The 7 monitoring wells include existing wells MW023, MW085, MW300, MW301 and MW302 and two new 2-inch diameter monitoring wells (see Figure 5-11). Additional monitoring wells are available at the Beall source area downgradient plume. The selection or addition of wells may be adjusted for comprehensive alternative development or during remedial design.

5.5.2 Air Sparging and Soil Vapor Extraction

Under this alternative, an air sparging and SVE treatment barrier would be constructed at the leading edge of the plume emanating from the Beall source area. The conceptual design of this system is shown on Figure 5-12. The system would consist of twelve 2-inch diameter sparge wells constructed to form a 250-feet-long boundary treatment zone. Each well would be completed to bedrock, and wells would be spaced approximately 22 feet apart. The length and depth of the treatment zones are based on the dimensions of the TCE plume in this area. Well spacing is based on the minimum effectiveness radius determined during pilot studies at the Brenntag source area (Appendix B). Brenntag pilot study data is considered applicable to the leading edge of the plume in this area because aquifer matrix and water table thickness are similar at both sites. Minimum sparge-well air-flow rate would be 5 scfm based on the Brenntag pilot study work. However, flow rates at and below 5 scfm may be less efficient; therefore, the system would be constructed to deliver up to 20 scfm per well in order to maximize cumulative mass removal (Battelle 2002). Each system flow rate would total from 60 to 240 scfm. Ozone concentrations in air would be maintained at about 1,200 parts per million based on pilot study results (Appendix B).

Vertical 2-inch diameter SVE wells would be installed in two rows constructed parallel to and on either side of the sparge well treatment zone. SVE wells would be constructed from ground surface to the water table (approximately 45 feet deep). SVE wells would be spaced 22 feet apart, for a total of 24 wells. The total SVE air-flow rate would be twice the sparge air-flow rate, based on design guidance (Naval Facilities Engineering Command 2001). SVE well flow-rate would be 5 to 20 scfm, for a total combined flow rate of 120 to 480 scfm for the system. SVE vapor discharge would be treated with granular activated carbon adsorbers.

Groundwater and system performance monitoring would be conducted using a network of 14 wells to be analyzed for natural attenuation parameters and VOCs. The 14 monitoring wells include existing wells MW023, MW085, MW300, MW301 and MW302 and nine new 2-inch diameter monitoring wells (see Figure 5-12). Additional monitoring wells are available at the Beall source area and downgradient plume. The selection or addition of wells may be adjusted for comprehensive alternative development or during remedial design.

5.5.3 In-Situ Enhanced Bioremediation

The enhanced bioremediation system would use a series of injection wells configured in a treatment zone across the plume width at the leading edge of the plume emanating from the Beall source area (Figure 5-13). Based on preliminary recommendations from the technology vendor Regenesis (Appendix G), a treatment zone would be installed at the downgradient edge of the plume and would consist of four rows of injection wells; well spacing within each row would be 10 feet, and the rows would be spaced 5 feet apart. The treatment zone would be installed in the vicinity of monitoring well MW300 (200 feet long) to provide treatment of the downgradient edge of the plume to inhibit further migration of the plume leading edge. A total of 80 injection wells would be installed in the treatment zone.

During the initial phase of remediation, which is estimated to last 6 years or more, HRC-X would be injected at the treatment zone to promote anaerobic degradation. Nutrient delivery would be accomplished by placing HRC-X across the entire aquifer thickness. After nutrient delivery was completed, injection would be halted and the groundwater monitored for degradation parameters and VOCs. Batch delivery HRC-X to the aquifer would be repeated as necessary, approximately every 3 years for the treatment zone system, to degrade PCE, TCE, cis-1,2-DCE until PRAOs are achieved throughout the plume. In the second phase of this alternative, which is estimated to last 6 years or more, ORC would be introduced using the same injection well networks to promote aerobic degradation of VC until PRAOs are achieved throughout the plume.

Groundwater and system performance monitoring would be conducted using a network of eight wells to be analyzed for natural attenuation parameters and VOCs. The eight monitoring wells include existing wells MW023, MW085, MW300, MW301 and MW302 and three new 2-inch diameter monitoring wells (see Figure 5-13). Additional monitoring wells are available at the Beall source area and downgradient plume. The selection or addition of wells may be adjusted for comprehensive alternative development or during remedial design.

5.6 BEALL SOURCE AREA SOIL OPTIONS

This section presents the conceptual design of soil remedial options for the Beall source area. Costs for these options are provided in Appendix H. Effectiveness of soil remediation options would be monitored using groundwater data from existing wells MW012, MW023, MW085, MW200, MW201, MW202, MW203, MW204, MW205, MW210, MW211, MW212, MW213, MW219, MW300, MW301 and MW302 (see Figure 5-14). Direct soil confirmation sampling will also be included and is discussed in Section 6.0.

5.6.1 Soil Vapor Extraction

Under this alternative, vertical SVE wells would be installed within the identified soil remediation areas at the Beall source area. The conceptual design of this system is shown on Figure 5-15. Each well would be constructed from ground surface to the water table (approximately 45 feet deep). Based on guidelines presented by Keller (2003) for fine sand formations, each SVE well is assumed to have a 16-foot radius of influence at 9 inches of mercury vacuum and a flow rate of 4 scfm per foot of vent screen. The air flow rate for each well is estimated at 160 scfm, assuming 40 feet of screen length. Wells would be spaced to provide 100 percent overlap so that wells could alternatively be used as passive air inlets. Based on the treatment area shown on Figure 5-13 (9,862 square feet) and adjusting well locations to ensure full coverage of soil remediation areas, a total of 39 4-inch-diameter SVE wells would be installed. Assuming that half of the wells (19) would be used as passive air inlets at any one time, the total combined flow rate of the system would be 3,200 scfm. SVE vapor discharge would be treated with granular activated carbon adsorbers. Optimal well spacing, screened interval placement, and flow rate selection for the remedial design would be determined through pilot studies and additional design tests and modeling.

5.6.2 Excavation and Thermal Treatment

Under this alternative, soil would be excavated within the identified remediation areas at the Beall source area. The estimated extent of soil with contaminant levels above remediation goals is shown on Figure 5-16. Soil contamination above remediation goals has been found from ground surface to the bottom of the fine-grain silty sand unit, an estimated average of 45 feet bgs. The total volume of contaminated soil in this area is estimated at 16,437 cubic yards. In the eastern side of the excavation area, soil contamination is present beneath a portion of the former steam clean bay, including associated drain piping and oil-water separator. These facilities would be removed during remedial activities. Sheet piling would be installed during excavation for slope stabilization. Soil desorption equipment would be temporarily located within the immediate vicinity of the soil removal area. Excavation areas would be backfilled with treated soil.

5.6.3 In-Situ Chemical Oxidation

This alternative at the Beall source area would include the installation of multiple injection wells in the source area to inject the chemical oxidant solution (sodium permanganate). The conceptual design includes two injection wells and is presented on Figure 5-17. Injection spacing may need to be increased in areas of high concentrations due to faster contaminant reaction rates, which lead to more limited transport distances from the injection site. Pressurized injection of permanganate oxidant may also be employed to obtain better lateral transport using higher oxidant concentrations, and would decrease the number of injection points and the number of oxidant injections required to attain PRAOs. Soil concentrations and high groundwater concentrations of chlorinated VOCs would be quickly oxidized to carbon dioxide, manganese oxide, potassium or sodium, chloride, and free hydrogen. Manganese oxide has the potential to cause reduced permeability and may cause plugging in injection wells.

5.7 SITE-WIDE GROUNDWATER OPTIONS

This section presents the conceptual design of groundwater remedial options for the site-wide groundwater. Costs for these options are provided in Appendix H.

5.7.1 Monitored Natural Attenuation

Monitored natural attenuation of site-wide groundwater would involve monitoring over time for VOCs and natural attenuation parameters to confirm contaminant reduction to PRAOs. Groundwater monitoring would be conducted using a network of 39 wells. This well network generally includes existing monitoring wells located outside the source areas. The 39 monitoring wells are existing wells MW001, MW015, MW016, MW019, MW020, MW029, MW106, MW107, MW108, MW109, MW110, MW111, MW112, MW113, MW114, MW115, MW118, MW119, MW120, MW123, MW206, MW207, MW208, MW209, MW214, MW215, MW216, MW217, MW218, MW303, MW304, MW305, MW306, MW307, MW308, MW309, MW310, MW311, and MW312 (see Figure 5-18). The selection of specific wells may be adjusted for comprehensive alternative development or during remedial design.

5.7.2 In-Situ Enhanced Bioremediation

An enhanced bioremediation system for site-wide groundwater would use a series of injection wells configured in select areas where PRAOs/MCLs were exceeded as shown on Figure 5-19. The locations of MCL exceedences in site-wide groundwater vary with time. In April 2003 (see Appendix A) MCLs were exceeded for COCs in groundwater at five monitoring wells outside the principal groundwater remediation areas associated with the Brenntag and Beall source areas. The conceptual design for this system assumes barrier treatment zones would be installed at three areas within the site-wide groundwater area to provide treatment of portions of the site-wide groundwater plume. Each treatment zone would consist of two rows of injection wells, each 200 feet long, based on vendor recommendations for source areas (Appendix G). Well spacing within each row would be 20 feet, and the rows would be spaced 10 feet apart. The barrier locations would be selected during remedial design. Injection wells would be installed as 2-inch-diameter wells to allow multiple applications of HRC-X over time. A total of 60 injection wells would be required.

During the initial phase of remediation, HRC-X would be injected at the barrier treatment zone to promote anaerobic degradation. Nutrient delivery would be accomplished by injecting HRC-X amendments to fully distribute them across the aquifer thickness. After nutrient delivery was completed, injection would be halted and the groundwater monitored for degradation parameters and VOCs. Batch delivery of lactate and HRC-X to the aquifer would be repeated as necessary to degrade PCE, TCE, and cis-1,2-DCE until PRAOs are achieved throughout the plume. In the second phase of this alternative ORCs would be introduced using the same injection well networks to promote aerobic degradation of VC until PRAOs are achieved throughout the plume.

Groundwater monitoring would involve monitoring over time for VOCs and natural attenuation parameters to confirm contaminant reduction to PRAOs. Groundwater monitoring would be conducted using a network of 39 wells. This well network generally includes existing monitoring wells located outside the source areas. The 39 monitoring wells are existing wells MW001, MW015, MW016, MW019, MW020, MW029, MW106, MW107, MW108, MW109, MW110, MW111, MW112, MW113, MW114, MW115, MW118, MW119, MW120, MW123, MW206, MW207, MW208, MW209, MW214, MW215, MW216, MW217, MW218, MW303, MW304, MW305, MW306, MW307, MW308, MW309, MW310, MW311, and MW312 (see Figure 5-19). No additional monitoring wells are proposed. The selection of specific wells may be adjusted for comprehensive alternative development or during remedial design.

5.8 CONCLUSIONS

Remedial technologies and process options considered applicable to VOC contamination at the LSGPS were developed, evaluated and screened in Section 4.0. Options that were retained as key remedial options were identified in Table 5-1 and developed in detail in Section 5.0. These key options will be combined into comprehensive remedial alternatives in Section 6.0 and evaluated in detail against the NCP criteria.

6.0 DETAILED ANALYSIS OF ALTERNATIVES

This section assembles and evaluates selected remedial alternatives based on nine criteria as required by the NCP in 40 CFR 300.430(e) (EPA 1990). The nine criteria are listed and described below.

Overall Protection of Human Health and the Environment. This criterion assesses whether each alternative provides adequate protection of human health and the environment. The results of the ecological risk assessment for the LSGPS indicated the site did not pose an unacceptable risk to ecological receptors. Based on these findings, no action is required to address ecological risk at the LSGPS. The overall assessment of protection draws on the evaluations of long-term effectiveness and permanence, short-term effectiveness, and compliance with ARARs. Protectiveness focuses on how risks associated with the LSGPS are reduced or eliminated by each alternative. Risk reductions are associated with how effectively an alternative meets the PRAOs. This criterion is considered a threshold requirement and must be met by the selected alternative.

Compliance with ARARs. This criterion is used to evaluate whether each alternative will meet all identified federal and state ARARs, or whether justification exists for waiving one or more ARAR. The detailed analysis will describe how each alternative will meet these requirements. This criterion is also a threshold that must be met by the selected alternative unless an ARAR is waived. ARARs for LSGPS are identified in Appendix C. Section 3.0 provides an outline of the ARARs identified for the LSGPS.

Long-Term Effectiveness and Permanence. Each alternative is evaluated in terms of risk remaining at the LSGPS after PRAOs have been met. The primary focus of this evaluation is the extent and effectiveness of controls used to manage the risk posed by treatment of residual or untreated wastes. The following criteria are considered:

- Adequacy of mitigative controls
- Reliability of mitigative controls
- Magnitude of residual risk

Reduction of Toxicity, Mobility, or Volume Through Treatment. This evaluation criterion addresses the statutory preference for treatment options that permanently and significantly reduce toxicity, mobility, or volume of the contaminants. The following criteria are considered when evaluating treatment of the principal threats:

- Treatment process used and materials treated to destroy toxic contaminants
- Reduction in contaminant mobility
- Total volumes of contaminated media treated
- Degree of reduction of toxic contaminants

Short-Term Effectiveness. This evaluation criterion addresses the effects of the alternative during the construction and implementation phase until PRAOs are met. Under this criterion, alternatives are evaluated with respect to their effects on human health and the environment during remedial action implementation. The following factors are considered:

- Exposure of the community during implementation
- Exposure of workers during construction
- Environmental impacts
- Time required to achieve PRAOs

Implementability. This criterion addresses the technical and administrative feasibility of implementing an alternative and the availability of various services and materials required for its implementation. The following factors are considered:

- Ability to construct, operate, and maintain the technology
- Reliability of the technology
- Monitoring considerations
- Availability of services, equipment, materials, and specialists
- Administrative feasibility including ability to obtain approvals from regulatory agencies

Cost. The cost estimate for each alternative is based on estimates of capital and O&M costs. Costs are developed following EPA guidelines for cost estimates during the FS (EPA 2000). The types of costs that are assessed include the following:

- Capital costs, including both direct and indirect costs
- Annual O&M costs, including long-term effectiveness monitoring cost

- Periodic cost, including preparation of the 5-year review
- Net present worth of capital, O&M costs, and periodic costs

Direct costs include the purchase of equipment, labor, and materials necessary to install the alternative. Indirect costs include those for engineering, financial, and other services, such as testing and monitoring. Annual O&M costs for each alternative include maintenance materials, labor, and auxiliary materials, as well as operating costs.

The present worth of each alternative provides the basis for the cost comparison. The present worth cost represents the amount of money that, if invested in the initial year of the remedial action at a given rate, would provide the funds required to make future payments to cover all costs associated with the remedial action over its planned life. The cost estimates of the remedial alternatives are based on estimates provided through Remedial Action Cost Engineering and Requirements (RACER 2003).

The present worth analysis is performed on all remedial alternatives using a 7 percent discount (interest) rate over a period of 30 years. Inflation and depreciation are not considered in preparing the present worth costs. Appendix H contains spreadsheets showing each component of the present worth costs.

State (Support Agency) Acceptance. This criterion evaluates the technical and administrative issues and concerns the state (or the support agency in the case of State-lead sites) may have regarding the alternative. DEQ is the lead agency for the technical evaluation of the LSGPS. Therefore, DEQ will be soliciting EPA's acceptance for the preferred alternative as provided in 40 CFR 300.515(e)(1). The assessment of EPA's concerns regarding each remedial alternative may not be completed until comments on the RI/FS are received. Therefore, this criterion is not addressed further in this FS. EPA's concerns that will be assessed include the following:

- EPA's position and key concerns related to the preferred alternative and other proposed alternatives
- EPA's comments on ARARs

Community Acceptance. This assessment involves identifying community support for, reservations about, or opposition to various components of the alternatives. The assessment of the community acceptance regarding each remedial alternative will be addressed in the Record of Decision once comments on the Proposed Plan have been received. Therefore, this criterion is not addressed further in this FS.

6.1 ASSEMBLY OF REMEDIAL ALTERNATIVES

Based on the results from the technology and process option screening, eight comprehensive remedial alternatives, including No Further Action, have been assembled for detailed and comparative analysis with respect to the nine NCP criteria. These eight alternatives have been assembled from the remedial options carried forward from alternative screening in Section 4 and described in detail in Section 5. Table 6-1 presents the eight site-wide remedial alternatives and the selected remedial options for each. The NCP identifies an objective that a range of cleanup options be developed. Therefore, the treatment and containment combinations have been assembled to provide a range of effectiveness, timeframes to meet PRAOs, and costs.

6.2 ALTERNATIVE 1

Alternative 1 consists of No Further Action. The No Further Action alternative is required by the NCP. The No Further Action alternative provides a baseline against which other alternatives are compared. Under this alternative, no action would be taken to alter current conditions at the LSGPS, the Brenntag source area, or the Beall source area. However, CERCLA 5-year reviews would be conducted. No construction, operation, or maintenance of remedial measures would be required. Under the No Further Action alternative, groundwater contamination at the LSGPS is assumed to remain in its current condition.

Overall Protection of Human Health and the Environment

The No Further Action alternative does not eliminate, reduce, or control exposure to contaminated groundwater. Risk assessments completed for the LSGPS have determined that unacceptable risks to human health exist. The No Further Action alternative does not attain the PRAOs and is not protective of human health.

Compliance with ARARs

Chemical-specific ARARs have been identified for groundwater and surface water at the LSGPS. Under the No Further Action alternative, these chemical-specific ARARs would continue to be exceeded in many areas of the site, including areas considered for groundwater remediation (see Figure 4-1). No location- or action-specific ARARs exist for the No Further Action alternative because, as part of the alternative, no actions would be taken to address the contamination at the site.

Long-Term Effectiveness and Permanence

Existing residual groundwater contamination at the LSGPS poses unacceptable human health risks under current and likely future land use scenarios. Under the No Further Action alternative, these risks would remain unacceptable over the long term for expected land uses. Additional unacceptable risks would occur if incompatible land uses and unanticipated groundwater use as a drinking water supply were allowed. No institutional controls exist; such as well construction permitting and construction restrictions, that would assure protection of human health over the long term.

Reduction in Toxicity, Mobility, and Volume of Contaminants Through Treatment

The No Further Action alternative would not result in a reduction in toxicity, mobility, or volume of contaminants through the use of treatment options. No contaminant treatment is proposed as part of the alternative.

Short-Term Effectiveness

The No Further Action alternative would not result in additional short-term risks to the community, remediation workers, or environment above baseline conditions because no actions would be conducted. However, PRAOs would not be met in soil or groundwater under this alternative.

Implementability

The No Further Action alternative is readily implemented because no actions would need to be taken.

Cost

The total present worth cost for implementing Alternative 1 at the LSGPS is $ 90,600 (see Appendix H).

6.3 ALTERNATIVE 2

Alternative 2 includes the following remedial options:

- Common Elements (institutional controls, long-term monitoring, 5-year reviews, and continued risk mitigation measures);

This alternative is the least aggressive approach to site remediation and provides protection of human health through institutional controls and risk mitigation measures only. Table 6-2 provides a summary of proposed groundwater monitoring to be conducted under Alternative 2 (see Figure 2-1 for monitoring locations). Detailed descriptions of Alternative 2 components are provided in Section 5.

Overall Protection of Human Health and the Environment

Alternative 2 would protect human health and the environment at the LSGPS through institutional controls and risk mitigation measures. No active groundwater, surface water or soil containment or treatment would occur.

Institutional controls would be employed to restrict use of groundwater that would result in adverse risk to human health. Risk mitigation measures would be implemented as necessary to treat groundwater serving residences or businesses or provide connections to the public water supply system. Risks to site workers and the public would be adequately controlled during implementation of risk mitigation measures and long-term monitoring through site-specific health and safety plans.

Compliance with ARARs

Alternative 2 is expected to meet all federal, state, and local ARARs except chemical-specific ARARs for groundwater and surface water. Groundwater and surface water contaminant concentrations in portions of the LSGPS would be expected to remain above PRAOs and regulatory limits over the long term. EPA and the State of Montana do not have contaminant-specific soil quality standards. Contaminated groundwater collected during implementation of risk mitigation measures and long-term monitoring would be treated and disposed of on-site.

Long-Term Effectiveness and Permanence

Institutional controls and risk mitigation measures could provide adequate protection of human health if properly implemented and maintained. However, they rely upon continuing management to maintain their effectiveness.

Existing residual groundwater contamination at the LSGPS poses unacceptable human health risks under current and likely future land use scenarios. Under Alternative 2, residual risk would remain above levels of concern in portions of site groundwater and surface water over the long term.

Reduction of Toxicity, Mobility, or Volume of Contaminants Through Treatment

Institutional controls and risk mitigation measures provide no reduction in the toxicity, mobility or volume of contaminants.

Short-Term Effectiveness

Exposure of remediation workers, the surrounding community and the local environment to contaminants during implementation of institutional controls and risk mitigation measures would be minimal.

Contaminated groundwater collected during implementation of risk mitigation measures and long-term monitoring would be treated and disposed of on-site.

PRAOs would not be met in soil, groundwater or surface water in the foreseeable future.

Implementability

Alternative 2 is technically and administratively implementable at the LSGPS.

Institutional controls have been implemented at other, similar sites, and are commonly used. Federal, state, and local agencies have administrative authority to implement institutional controls. Equipment, materials, and services necessary for risk mitigation measures and long-term monitoring are available.

Cost

The total present worth cost for implementing Alternative 2 at the LSGPS is $ 698,200 (see Appendix H).

6.4 ALTERNATIVE 3

Alternative 3 includes the following remedial options:

- Common Elements (institutional controls, long-term monitoring, 5-year reviews, and continued risk mitigation measures);
- Excavation and thermal treatment of contaminated soil at both the Brenntag and Beall source areas; and
- Monitored natural attenuation of groundwater.

The approach to site remediation under Alternative 3 includes active treatment of soil sources and monitored natural attenuation for site-wide groundwater while relying upon institutional controls and risk mitigation measures for protection of human health and the environment over the long term. Table 6-2 provides a summary of proposed groundwater and surface water monitoring to be conducted under Alternative 3 (see Figure 2-1 for monitoring locations). Table 6-3 provides a summary of the conceptual design assumptions for Alternative 3. Detailed descriptions of Alternative 3 components along with figures showing conceptual design layouts are provided in Section 5.

Overall Protection of Human Health and the Environment

Alternative 3 would protect human health and the environment at the LSGPS through a combination of institutional controls, risk mitigation measures, soil removal and treatment, and monitored natural attenuation.

Institutional controls would be employed to restrict use of groundwater that would result in adverse risk to human health. Risk mitigation measures would be implemented as necessary to treat groundwater serving residences or businesses or provide connections to the public water supply system. Risks to workers and the public would be adequately controlled during implementation of risk mitigation measures, long-term monitoring, and soil excavation and treatment through site-specific health and safety plans.

Under Alternative 3, vadose soil considered a source to groundwater contamination would be excavated and thermally treated to remove VOCs. Excavation and thermal treatment of soil would significantly reduce migration of contaminants from vadose soil to groundwater.

No active groundwater containment or treatment would occur and monitored natural attenuation would be relied upon for reduction of VOCs throughout the LSGPS over time. However, monitored natural attenuation would not be expected to reduce groundwater contaminant levels significantly and groundwater COC concentrations would remain above PRAOs for the foreseeable future.

Compliance with ARARs

Alternative 3 is expected to meet all federal, state, and local ARARs except chemical-specific ARARs for groundwater and surface water. Groundwater and surface water contaminant concentrations in portions of the LSGPS would be expected to remain above PRAOs and regulatory limits over the long term. EPA and the State of Montana do not have contaminant-specific soil quality standards.

Prior to thermal treatment, contaminated soil would be stored in staging piles in accordance with remediation waste requirements. Thermal desorption emissions are expected to contain elevated total VOC concentrations that will be treated with carbon adsorption units to reduce the total organic compound emissions consistent with air quality regulations. The spent carbon units may be recycled or regenerated by the manufacturer or managed and disposed of based on solid and hazardous waste requirements.

Contaminated groundwater collected during implementation of risk mitigation measures and long-term monitoring would be treated and disposed of on-site.

Long-Term Effectiveness and Permanence

Institutional controls and risk mitigation measures could provide adequate protection of human health if properly implemented and maintained. However, they rely upon continuous management to maintain their effectiveness.

Excavation is considered a reliable option for removing contaminated vadose soil in both source areas, including contaminated soil at the water table. Thermal desorption has been demonstrated to be effective at numerous sites for soil treatment and is an EPA presumptive remedy for sites with VOC contamination in soil (EPA 1996b). The thermal desorption unit adequately and reliably removes VOCs from the excavated vadose zone soil through volatilization. Regular exhaust-gas vapor monitoring of VOCs and confirmation sampling of treated soil would be conducted to confirm treatment effectiveness. Residual risk in soil (migration of contaminants to groundwater) would remain below levels of concern over the long term.

Monitored natural attenuation alone is not considered an adequate or reliable method to reduce contaminant concentrations in groundwater in all portions of the site. Residual risk would remain above levels of concern in portions of groundwater and surface water over the long term.

Reduction of Toxicity, Mobility, or Volume of Contaminants Through Treatment

Institutional controls and risk mitigation measures provide no reduction in the toxicity, mobility or volume of contaminants.

Thermal desorption uses physical processes to remove contaminants from excavated soil at the Brenntag and Beall source areas and reduce concentrations to meet PRAOs in source area soil. Thermal desorption would reduce the toxicity, mobility and volume of contaminants in excavated soil.

In portions of the LSGPS where natural attenuation is expected to be active, monitored natural attenuation would provide a small and slow reduction in the toxicity and volume of contaminants in groundwater by transforming them into less harmful substances through biological and chemical processes. However, during the biological degradation process, PCE, TCE, and cis-1,2-DCE would be transformed into the more toxic VC before it is degraded into less toxic ethene. It is possible that VC concentrations and associated risk in portions of groundwater would increase for a period of time. Monitored natural attenuation does not reduce the mobility of the contaminants in groundwater.

Short-Term Effectiveness

Exposure of remediation workers, the surrounding community and the local environment to contaminants during implementation of institutional controls, risk mitigation measures, soil excavation and thermal treatment, and monitored natural attenuation would be minimal.

No difficulties are foreseen with managing contaminated soil, water, and vapor produced during implementation of risk mitigation measures, soil excavation and treatment, and long-term monitoring. During construction and operations, soil containing VOCs would be excavated and temporarily stored in above-ground staging piles and may produce some low concentration VOC vapor emissions prior to treatment. The thermal desorption treatment unit would emit concentrated VOC vapor emissions that would be treated to acceptable levels using carbon adsorption units. The spent carbon units may be recycled or regenerated by the manufacturer or managed and disposed of based on solid and hazardous waste requirements. Contaminated groundwater collected during implementation of risk mitigation measures and long-term monitoring would be treated and discharged on-site.

The time to reach PRAOs in soil is estimated to be 1 year based on the volume and typical treatment throughputs for portable thermal treatment units.

PRAOs would not be met in groundwater and surface water in the foreseeable future.

Implementability

Alternative 3 is technically and administratively implementable at the LSGPS.

Institutional controls have been implemented at other, similar sites, and are commonly used. Federal, state, and local agencies have administrative authority to implement institutional controls. Equipment, materials, and services necessary for risk mitigation measures and long-term monitoring are available.

Thermal desorption has been successfully conducted at other, similar sites. Thermal treatment units and the equipment and services to excavate soil are commercially available. Excavation of soil beneath facility foundations and equipment would be difficult and would require removal of the affected facilities. Soil excavation is easy to implement in areas away from facility foundations. Excavation at the Beall source area to depths of approximately 45 feet would be difficult.

Monitored natural attenuation is easy to implement as a site-wide monitoring well network is already in place.

Cost

The total present worth cost for implementing Alternative 3 at the LSGPS is $ 7,046,700 (see Appendix H).

6.5 ALTERNATIVE 4

Alternative 4 includes the following remedial options:

- Common Elements (institutional controls, long-term monitoring, 5-year reviews, and continued risk mitigation measures);
- Treatment of groundwater with enhanced bioremediation at both the Brenntag and Beall source areas;
- Treatment of groundwater with enhanced bioremediation at the Beall source area plume leading edge; and
- Treatment of site-wide groundwater with enhanced bioremediation followed by monitored natural attenuation.

The approach to site remediation under Alternative 4 includes active treatment of contaminated groundwater while relying upon institutional controls and risk mitigation measures for protection of human health and the environment over the long term. Alternative 4 does not provide for source soil remediation. Table 6-2 provides a summary of proposed groundwater and surface water monitoring to be conducted under Alternative 4 (see Figure 2-1 for monitoring locations). Table 6-4 provides a summary of the conceptual design assumptions for Alternative 4. Detailed descriptions of Alternative 4 components along with figures showing conceptual design layouts are provided in Section 5.

Overall Protection of Human Health and the Environment

Alternative 4 would protect human health and the environment at the LSGPS through a combination of institutional controls, risk mitigation measures, in-situ groundwater treatment, and monitored natural attenuation.

Institutional controls would be employed to restrict use of groundwater that would result in adverse risk to human health. Risk mitigation measures would be implemented as necessary to treat groundwater serving residences or businesses or provide connections to the public water supply system. Risks to workers and the public would be adequately controlled during implementation of risk mitigation measures, in-situ groundwater treatment activities, and long-term monitoring through site-specific health and safety plans.

Enhanced bioremediation treatment of groundwater would significantly reduce concentrations of contaminants in groundwater and would be expected to achieve PRAOs in groundwater outside source areas.

Monitored natural attenuation would be implemented to maintain or further reduce VOC concentrations in groundwater after enhanced bioremediation reduced COC concentrations to PRAOs. However, vadose soil sources at both the Brenntag and Beall source areas would not be treated or contained and would continue to be sources of groundwater contamination over time.

Groundwater COC concentrations within source areas would be expected to remain above PRAOs over the long term or rebound above PRAOs due to continued migration of contaminants from these sources. Continued anaerobic and aerobic treatment within the source areas is expected to be required over the long term.

Compliance with ARARs

Alternative 4 is expected to meet all federal, state, and local ARARs except chemical-specific ARARs for groundwater. Groundwater contaminant concentrations in source areas of the LSGPS would be expected to remain above PRAOs and regulatory limits over the long term. Chemical-specific ARARs for surface water are expected to be met over the long term. EPA and the State of Montana do not have contaminant-specific soil quality standards.

Installation of monitoring, extraction and injection wells will produce soil and liquid waste that will be managed and disposed of based on solid and hazardous waste requirements. Soil would be treated on-site or transported off-site and disposed of in accordance with solid and hazardous waste disposal regulations. Contaminated groundwater collected during the construction of risk mitigation measures and long-term monitoring would be treated and disposed of on-site.

Long-Term Effectiveness and Permanence

Institutional controls and risk mitigation measures could provide adequate protection of human health if properly implemented and maintained. However, they rely upon continuous management to maintain their effectiveness.

Enhanced bioremediation has been demonstrated to be effective and reliable at numerous sites for groundwater treatment and is expected to be effective at the LSGPS outside of source areas. Enhanced bioremediation would significantly degrade VOCs in source areas but groundwater concentrations are expected to rebound due to continued migration of VOCs from vadose soil sources in both source areas and due to the suspected presence of VOCs in saturated zone soil in the Brenntag source area. Residual risk in soil (migration of contaminants to groundwater) would remain above levels of concern over the long term. The presence of petroleum hydrocarbons and toluene in the Brenntag source area are not expected to negatively impact the effectiveness of this alternative.

Monitored natural attenuation would act to maintain or continue to reduce VOC concentrations in groundwater after PRAOs were met through enhanced bioremediation treatment.

Residual risk in surface water would be below levels of concern but would remain above levels of concern in groundwater within the source areas over the long term. Enhanced bioremediation treatment would be required over the long term to address continued migration of contaminants from the source areas into groundwater.

Reduction of Toxicity, Mobility, or Volume of Contaminants Through Treatment

Institutional controls and risk mitigation measures provide no reduction in the toxicity, mobility or volume of contaminants.

Enhanced bioremediation uses biological processes to degrade contaminants in groundwater to less harmful ones. Enhanced bioremediation would reduce the toxicity and volume of contaminants in groundwater but not their mobility.

After PRAOs are met in portions of groundwater, monitored natural attenuation would provide a small and slow reduction in the toxicity and volume of contaminants in groundwater by transforming them into less harmful substances through biological and chemical processes. However, during the enhanced bioremediation and monitored natural attenuation biological degradation processes, PCE, TCE, and cis-1,2-DCE would be transformed into the more toxic VC during reductive dechlorination prior to aerobic degradation to the less toxic ethene. It is possible that VC concentrations and associated risks would increase for a period of time in portions of groundwater. VC buildup in the aquifer would be monitored and VC would be degraded with enhanced aerobic processes to ensure that concentrations did not create an unacceptable risk. Monitored natural attenuation does not reduce the mobility of the contaminants in groundwater.

Short-Term Effectiveness

Exposure of remediation workers, the surrounding community and the local environment to contaminants during implementation of institutional controls, risk mitigation measures, enhanced bioremediation, and monitored natural attenuation would be minimal.

No difficulties are foreseen with managing the small quantities of contaminated soil and water produced during well construction, operations, implementation of risk mitigation measures, and long-term monitoring. Soil would be treated on-site or transported off-site and disposed of in accordance with solid and hazardous waste disposal regulations. Contaminated groundwater would be treated and discharged on-site. During construction and operations, groundwater from the in-situ treatment system would be pumped through above-ground circulation and enhanced bioremediation systems; however, systems would generally be enclosed and remediation worker exposure is expected to be limited.

The time to reach PRAOs in groundwater and surface water outside of source areas is estimated to be 9 years based on three, 3-year enhanced bioremediation treatment cycles; however, there is some uncertainty in the timeframe to reach PRAOs due to continued migration of contaminants from the source areas. PRAOs are not expected to be met in source area groundwater within the foreseeable future due to continued migration of contaminants from contaminated vadose and saturated zone soil; therefore, it would be necessary to continue source area enhanced bioremediation treatment indefinitely. PRAOs would not be met in contaminated soil because no active treatment would be conducted.

Implementability

Alternative 4 is technically and administratively implementable at the LSGPS.

Institutional controls have been implemented at other, similar sites, and are commonly used. Federal, state, and local agencies have administrative authority to implement institutional controls. Equipment, materials, and services necessary for risk mitigation measures and long-term monitoring are available.

Enhanced bioremediation has been successfully conducted at other, similar sites. The equipment and services to install and operate the treatment injection system and to sample groundwater monitoring wells are commercially available. The treatment components and groundwater monitoring are expected to have only a minor effect on activities at the LSGPS. Additional design tests and modeling would be necessary to determine optimal well placement, nutrient injection rates, and flow rates.

Monitored natural attenuation is easy to implement as a site-wide monitoring well network is already in place.

Cost

The total present worth cost for implementing Alternative 4 at the LSGPS is $ 9,905,600 (see Appendix H).

6.6 ALTERNATIVE 5

Alternative 5 includes the following remedial options:

- Common Elements (institutional controls, long-term monitoring, 5-year reviews, and continued risk mitigation measures);
- Air sparging and soil vapor extraction to treat contaminated groundwater at both the Brenntag and Beall source areas;

- Containment and treatment of groundwater with air sparging and soil vapor extraction at the Beall source area plume leading edge;
- Soil vapor extraction to treat contaminated soil at both the Brenntag and Beall source areas; and
- Treatment of site-wide groundwater with monitored natural attenuation.

The approach to site remediation under Alternative 5 includes active in-situ treatment of contaminated groundwater and soil using air sparging and SVE in combination with institutional controls and risk mitigation measures for protection of human health and the environment over the long term. Table 6-2 provides a summary of proposed groundwater and surface water monitoring to be conducted under Alternative 5 (see Figure 2-1 for monitoring locations). Table 6-5 provides a summary of the conceptual design assumptions for Alternative 5. Detailed descriptions of Alternative 5 components along with figures showing conceptual design layouts are provided in Section 5.

Overall Protection of Human Health and the Environment

Alternative 5 would protect human health and the environment at the LSGPS through a combination of institutional controls, risk mitigation measures, in-situ groundwater treatment, in-situ soil treatment, and monitored natural attenuation.

Institutional controls would be employed to restrict use of groundwater that would result in adverse risk to human health. Risk mitigation measures would be implemented as necessary to treat groundwater serving residences or businesses or provide connections to the public water supply system. Risks to workers and the public would be adequately controlled during implementation of risk mitigation measures, in-situ soil and groundwater treatment activities, and long-term monitoring through site-specific health and safety plans.

Monitored natural attenuation would be relied upon to maintain or further reduce VOC concentrations after in-situ groundwater and soil treatments were implemented. Assuming effective treatment of groundwater by the air sparge/SVE systems, PRAOs would be expected to be reached in a about 10 years in groundwater downgradient of the Brenntag source area and in about 24 years in groundwater downgradient of the Beall source area (see Appendix E).

Groundwater treatment at the source areas and the Beall source area plume leading edge with air sparging and soil vapor extraction would significantly reduce concentrations of contaminants in groundwater. It is assumed that this treatment would achieve PRAOs in surface water and in groundwater at and downgradient of the treatment systems. However, pilot studies were inconclusive whether or not air sparge and soil vapor extraction treatment alone could achieve PRAOs in the Beall source area and additional pilot work would be necessary to address this uncertainty.

SVE treatment of vadose soil considered a source to groundwater contamination would remove VOCs and significantly reduce migration of contaminants from vadose soil to groundwater. PRAOs in vadose soil are expected to be met in the Beall source area. There is some uncertainty whether PRAOs could be met within the Brenntag source area due to high concentrations of VOCs in vadose zone soil. Pilot studies would be necessary prior to design.

PRAOs are expected to be achieved within the Beall source area in both groundwater and soil. Due to uncertainties with the effectiveness of SVE soil treatment in the Brenntag source area, soil COC concentrations within this source area are expected to remain above PRAOs. Consequently groundwater COC concentrations are expected to remain above PRAOs over the long term in the Brenntag source area due to continued migration of contaminants from soil sources.

Compliance with ARARs

Alternative 5 is expected to meet all federal, state, and local ARARs except chemical-specific ARARs for groundwater. Groundwater contaminant concentrations in the Brenntag source area would be expected to remain above PRAOs and regulatory limits over the long term. Chemical-specific ARARs for surface water are expected to be met over the long term. EPA and the State of Montana do not have contaminant-specific soil quality standards.

Installation of monitoring, extraction, and injection wells will produce soil and liquid waste that will be managed and disposed of based on solid and hazardous waste requirements. Soil would be treated on-site or transported off-site and disposed of in accordance with solid and hazardous waste disposal regulations. Contaminated water collected during the construction of risk mitigation measures and long-term monitoring would be treated and disposed of on-site.

SVE emissions are expected to contain elevated total VOC concentrations. The systems would be vented to carbon absorption units that reduce the total organic compound emissions to comply with air quality regulations. The spent carbon adsorption units could be recycled or regenerated by the manufacturer, or disposed of in accordance with solid and hazardous waste disposal regulations.

Long-Term Effectiveness and Permanence

Institutional controls and risk mitigation measures could provide adequate protection of human health if properly implemented and maintained. However, they rely upon continuous management to maintain their effectiveness.

Air sparging has been demonstrated at numerous sites with treatment efficiency rates up to 100 percent (EPA 1997; Federal Remediation Technology Roundtable 2003). VOCs are removed from the groundwater through volatilization or destroyed through direct oxidation (with ozone), and vapor-phase VOCs are then removed from the subsurface by the soil vapor extraction system. Treatment effectiveness is limited in a heterogeneous subsurface environment. Treatment radius may also be reduced at depth, particularly in the area immediately above bedrock where sparge well treatment radius is narrowest. Installation of a gravel-filled treatment trench with a horizontal sparge well placed immediately above bedrock should be considered to improve treatment at depth. Regular groundwater monitoring of VOCs would be conducted to confirm treatment effectiveness.

SVE has been demonstrated to be effective at numerous sites and is EPA's preferred presumptive remedy for sites with VOC contamination in soil (EPA 1996b). The SVE system removes VOCs from the vadose zone soil through volatilization. The SVE system would not be effective at removing VOCs from contaminated soil in the saturated zone and has reduced effectiveness at the water table. This could prove problematic at the Brenntag source area where high concentrations of VOCs are present at the water table and residual risk (migration of contaminants to groundwater) would remain above levels of concern over the long term. Treatment effectiveness may also be limited by the heterogeneous subsurface environment and presence of low-permeability, fine-grain silt and clay. Although SVE is expected to achieve PRAOs in Beall vadose soil, these limitations create some uncertainty as to the timeframe required to meet soil PRAOs. Regular SVE vapor monitoring of VOCs and subsurface soil sampling would be conducted to evaluate treatment effectiveness. Residual risk in soil (migration of contaminants to groundwater) at the Beall source area would be reduced below levels of concern over the long term.

There is some additional uncertainty as to the overall effectiveness of this alternative at the Brenntag source area because preliminary air sparge/SVE pilot study results were inconclusive as to whether or not treatment could achieve PRAOs in groundwater; additional pilot study work is recommended prior to full-scale construction. In addition, due to uncertainties with saturated zone sources and the expected limited effectiveness of SVE to treat contaminated soil near the water table at the Brenntag source area, some continued release of VOCs to groundwater is expected over the long term. Groundwater entering the air sparge treatment zone would continue to contain elevated concentrations of VOCs. Therefore, operation of the air sparge/SVE system and institutional controls would be required for an indefinite time to ensure protectiveness because residual groundwater risk in this area may remain above levels of concern over the long term. The presence of petroleum hydrocarbons and toluene in the Brenntag source area are not expected to negatively impact the effectiveness of this alternative.

Monitored natural attenuation would act to maintain or continue to reduce VOC concentrations in groundwater after PRAOs were met through air sparging/SVE.

Residual risk in groundwater would be reduced below levels of concern at the Beall source area but would remain above levels of concern within the Brenntag source areas over the long term. Residual risk in surface water would be reduced below levels of concern throughout the LSGPS over the long term. Air sparge/SVE groundwater treatment would be required over the long term in the Brenntag source area to address expected continued migration of contaminants from the source areas into groundwater.

Reduction of Toxicity, Mobility, or Volume of Contaminants Through Treatment

Institutional controls and risk mitigation measures provide no reduction in the toxicity, mobility or volume of contaminants.

Air sparging and SVE use physical and chemical (ozone oxidation) processes to destroy and remove contaminants from soil and groundwater at the LSGPS. These processes reduce the volume and toxicity of contaminants in soil and groundwater. SVE vapors collected in carbon would require further treatment or disposal. The mobility of contaminants in groundwater may change because the air sparge system is expected to create some temporary groundwater mounding during initial startup and if operated in a pulsed mode. The duration and magnitude of groundwater mounding is unknown, but some short-term changes to groundwater flow direction are likely.

After PRAOs were met in portions of groundwater, monitored natural attenuation would provide a small and slow reduction in the toxicity and volume of contaminants in groundwater by transforming them into less harmful substances through biological and chemical processes. However, during the biological degradation process, PCE, TCE, and cis-1,2-DCE would be transformed into the more toxic VC during reductive dechlorination prior to aerobic degradation to the less toxic ethene. It is possible that VC concentrations and associated risk in portions of groundwater would increase for a period of time. Monitored natural attenuation does not reduce the mobility of the contaminants in groundwater.

Short-Term Effectiveness

Exposure of remediation workers, the surrounding community and the local environment to contaminants during implementation of institutional controls, risk mitigation measures, air sparging, SVE, monitored natural attenuation, and long-term monitoring would be minimal.

No difficulties are foreseen with managing the small quantities of contaminated soil, water, and vapor produced during construction, operations, implementation of risk mitigation measures, and long-term monitoring. Soil would be treated on-site or transported off-site and disposed of in accordance with solid and hazardous waste disposal regulations. Contaminated groundwater would be treated and discharged on-site. During construction and operations, remediation worker exposure is expected to be limited because groundwater containing VOCs would remain underground and VOC vapor emissions would be treated to acceptable levels using carbon adsorption units.

PRAOs would be met in about 10 years in the groundwater and surface water downgradient of the Brenntag source area and in about 24 years in the groundwater downgradient of the Beall source area (see Appendix E). SVE treatment of Brenntag source area soil would continue for about 10 years; however, PRAOs are not expected to be met in all areas. PRAOs are not expected to be achieved in the Brenntag source area groundwater; therefore it would be necessary to continue air sparge/SVE groundwater treatment indefinitely. PRAOs would be met in about 5 years in Beall source area soil and in an estimated 10 years in Beall source area groundwater. However the timeframe to reach groundwater PRAOs in the Beall source area has some uncertainty due to the limitations of SVE vadose soil treatment in this area. It would be necessary to operate the air sparge/SVE treatment system at the Beall source area plume leading edge for about 24 years until upgradient groundwater COC concentrations reached PRAO.

Implementability

Alternative 5 is technically and administratively implementable at the LSGPS.

Institutional controls have been implemented at other, similar sites, and are commonly used. Federal, state, and local agencies have administrative authority to implement institutional controls. Equipment, materials, and services necessary for risk mitigation measures and long-term monitoring are available.

Air sparging and SVE have been successfully conducted at other, similar sites. Preliminary pilot studies implemented at the Brenntag source area showed short-term reduction in VOC concentrations in groundwater. However, long-term and full-scale effects have not been determined. The equipment and services to install and operate the treatment systems and to sample groundwater monitoring wells are commercially available. The treatment components and groundwater monitoring are expected to have only a minor effect on activities at the LSGPS. Additional design tests and modeling would be necessary to determine optimal air sparge/SVE well placement and flow rates. Air sparging is considered easy to implement at both the Brenntag and Beall source areas. SVE is considered moderately difficult to construct due to proximity to operating facilities and foundations and expected difficulties with installing trenches and wells in these locations. Air sparging and SVE systems are uncomplicated and easy to operate.

Monitored natural attenuation is easy to implement as a site-wide monitoring well network is already in place.

Cost

The total present worth cost for implementing Alternative 5 at the LSGPS is $13,466,500 (see Appendix H).

6.7 ALTERNATIVE 6

Alternative 6 includes the following remedial options:

- Common Elements (institutional controls, long-term monitoring, 5-year reviews, and continued risk mitigation measures);
- Containment and treatment of contaminated groundwater with a permeable reactive barrier at the Brenntag source area;
- Treatment of contaminated groundwater with enhanced bioremediation at both the Brenntag and Beall source areas;

- Treatment of contaminated groundwater with enhanced bioremediation at the Beall source area plume leading edge;
- Excavation and thermal treatment of contaminated vadose soil at the Brenntag source area;
- Treatment of contaminated vadose soil with soil vapor extraction at the Beall source area;
- Treatment of saturated zone contaminated soil with chemical oxidation at the Brenntag source area; and
- Treatment of site-wide groundwater with enhanced bioremediation followed by monitored natural attenuation.

The approach to site remediation under Alternative 6 includes a combination of groundwater and soil treatments that would achieve PRAOs in all media and not rely upon institutional controls and risk mitigation measures for protection of human health and the environment over the long term. Table 6-2 provides a summary of proposed groundwater and surface water monitoring to be conducted under Alternative 6 (see Figure 2-1 for monitoring locations). Table 6-6 provides a summary of the conceptual design assumptions for Alternative 6. Detailed descriptions of Alternative 6 components along with figures showing conceptual design layouts are provided in Section 5.

Overall Protection of Human Health and the Environment

Alternative 6 would protect human health and the environment at the LSGPS through a combination of institutional controls, risk mitigation measures, in-situ groundwater treatment, in-situ soil treatment, soil removal and treatment, and monitored natural attenuation.

Institutional controls would be employed to restrict use of groundwater that would result in adverse risk to human health. Risk mitigation measures would be implemented as necessary to treat groundwater serving residences or businesses or provide connections to the public water supply system. Risks to workers and the public would be adequately controlled during implementation of risk mitigation measures, in-situ soil and groundwater treatment activities, soil removal and treatment, and long-term monitoring through site-specific health and safety plans.

Excavation and thermal treatment of vadose soil at the Brenntag source area and SVE treatment of vadose soil at the Beall source area would significantly reduce migration of contaminants from vadose soil to groundwater and meet soil PRAOs. In addition, in-situ chemical oxidation of VOCs in saturated soil at the Brenntag source area would degrade VOC contamination rapidly; however, due to the high concentrations of VOCs multiple phases of injection would likely be required to achieve PRAOs in source area groundwater.

A permeable reactive barrier at the Brenntag source area would contain and treat contaminated groundwater and effectively prevent downgradient migration of contaminants in groundwater from the source area. It is assumed that this treatment would achieve PRAOs in surface water and in groundwater at and downgradient of the treatment systems.

Enhanced bioremediation treatment of groundwater would significantly reduce concentrations of contaminants in groundwater and, in combination with other remedial options, would be expected to achieve PRAOs in groundwater throughout the site, including source areas. The Brenntag source area may require longer treatment time due to higher concentrations of sources.

Monitored natural attenuation would be implemented to maintain or further reduce VOC concentrations in groundwater after enhanced bioremediation, in combination with other remedial options, reduced COC concentrations to PRAOs.

Compliance with ARARs

Alternative 6 is expected to meet all federal, state, and local ARARs including chemical-specific ARARs for groundwater and surface water over the long term. Groundwater contaminant concentrations within and downgradient of source areas of the LSGPS would be expected to achieve PRAOs and regulatory limits over the long term. EPA and the State of Montana do not have contaminant-specific soil quality standards.

Installation of monitoring, extraction and injection wells, and the permeable reactive barrier will produce soil and liquid waste that will be managed and disposed of based on solid and hazardous waste requirements. Soil would be treated on-site or transported off-site and disposed of in accordance with solid and hazardous waste disposal regulations. Prior to thermal treatment, contaminated soil would be stored in staging piles in accordance with remediation waste requirements. Contaminated groundwater collected during the construction of risk mitigation measures and long-term monitoring would be treated and disposed of on-site.

SVE and thermal desorption emissions are expected to contain elevated total VOC concentrations that will be treated with carbon absorption units to reduce the total VOC emissions to comply with air quality regulations. The spent carbon units may be recycled or regenerated by the manufacturer, or managed and disposed of in accordance with solid and hazardous waste disposal regulations.

Long-Term Effectiveness and Permanence

Institutional controls and risk mitigation measures could provide adequate protection of human health if properly implemented and maintained. However, they rely upon continuous management to maintain their effectiveness.

The use of a permeable reactive barrier will reduce the concentrations of PCE, TCE, cis-1,2-DCE, and VC in groundwater flowing through the permeable reactive barrier to levels below PRAOs. Continued maintenance of the permeable reactive barrier would be required until PRAOs are met in groundwater throughout the Brenntag source area.

SVE has been demonstrated to be effective at numerous sites and is EPA's preferred presumptive remedy for sites with VOC contamination in soil (EPA 1996b). The SVE system removes VOCs from the vadose zone soil through volatilization. The SVE system would not be effective at removing VOCs from contaminated soil in the saturated zone and has reduced effectiveness at the water table. Treatment effectiveness may also be limited by the heterogeneous subsurface environment and presence of low-permeability, fine-grain silt and clay. Although SVE is expected to achieve PRAOs in Beall vadose soil, these limitations create some uncertainty as to the timeframe required to meet soil PRAOs. Regular SVE vapor monitoring of VOCs and subsurface soil sampling would be conducted to confirm treatment effectiveness. Residual risk in soil (migration of contaminants to groundwater) at the Beall source area would be reduced below levels of concern over the long term.

Excavation is considered a reliable option for removing contaminated vadose soil in the Brenntag source area, including contaminated soil at the water table. Thermal desorption has been demonstrated to be effective at numerous sites for soil treatment and is an EPA presumptive remedy for sites with VOC contamination in soil (EPA 1996b). The thermal desorption unit adequately and reliably removes VOCs from the excavated vadose zone soil through volatilization. Regular exhaust-gas vapor monitoring of VOCs and confirmation sampling of treated soil would be conducted to confirm treatment effectiveness.

Residual risk in soil (migration of contaminants to groundwater) would remain below levels of concern over the long term.

In-situ chemical oxidation has been shown to be an effective treatment of VOC contaminated soil and groundwater. In-situ chemical oxidation would be effective at destroying VOCs in the saturated zone at the Brenntag source area. As with SVE, treatment effectiveness may also be limited by the heterogeneous subsurface environment and presence of low-permeability, fine-grain silt and clay. The presence of large masses of other organic compounds, such as petroleum, has been detected in the Brenntag source area and may cause high oxidant consumption and increased time and cost to reach PRAOs. Effectiveness would be verified through groundwater monitoring in the source area and locations that showed continuous elevated levels of VOCs or a rebound in VOC concentrations would require additional treatments.

Enhanced bioremediation has been demonstrated to be effective and reliable at numerous sites for groundwater treatment and is expected to be effective at the LSGPS under this alternative. Enhanced bioremediation would significantly degrade VOCs in source areas and groundwater concentrations are expected to achieve PRAOs because vadose and saturated zone soil would be successfully treated with excavation and thermal treatment, SVE, and in-situ chemical oxidation. The presence of petroleum hydrocarbons and toluene in the Brenntag source area are not expected to negatively impact the effectiveness of this alternative.

Monitored natural attenuation would act to maintain or continue to reduce VOC concentrations in groundwater after PRAOs were met through enhanced bioremediation treatment, in combination with other remedial options.

Residual risk in groundwater and surface water would be reduced below levels of concern in all areas of the LSGPS over the long term.

Reduction of Toxicity, Mobility, or Volume of Contaminants Through Treatment

Institutional controls and risk mitigation measures provide no reduction in the toxicity, mobility or volume of contaminants.

Alternative 6 uses a permeable reactive barrier to destroy contaminants in groundwater downgradient of the Brenntag source area and reduce concentrations to PRAOs. This alternative reduces the toxicity, mobility, and volume of dissolved-phase contamination.

Thermal desorption uses physical processes to remove contaminants from excavated soil at the Brenntag and Beall source areas and reduce concentrations to meet PRAOs. Thermal desorption would reduce the toxicity, mobility and volume of contaminants in excavated soil.

In-situ chemical oxidation uses chemical processes to destroy VOCs in the saturated zone. In-situ oxidation would reduce the toxicity and volume of contaminants in the source areas.

SVE uses primarily physical processes to remove contaminants from soil and reduce concentrations to meet PRAOs. SVE under this alternative reduces the volume and toxicity of contaminants in soil. SVE vapors collected in carbon adsorption units would require further treatment or disposal.

Enhanced bioremediation uses biological processes to degrade contaminants in groundwater to less harmful ones. Enhanced bioremediation would reduce the toxicity and volume of contaminants in groundwater but not their mobility.

After PRAOs were met in portions of groundwater, monitored natural attenuation would provide a small and slow reduction in the toxicity and volume of contaminants in groundwater by transforming them into less harmful substances through biological and chemical processes. However, during the enhanced bioremediation and monitored natural attenuation biological degradation processes, PCE, TCE, and cis-1,2-DCE would be transformed into the more toxic VC during reductive dechlorination prior to aerobic degradation to the less toxic ethene. It is possible that VC concentrations and associated risks would increase for a period of time in portions of groundwater. VC buildup in the aquifer would be monitored and VC would be degraded with enhanced aerobic processes to ensure that concentrations did not create an unacceptable risk. Monitored natural attenuation does not reduce the mobility of the contaminants in groundwater.

Short-Term Effectiveness

Exposure of remediation workers, the surrounding community and the local environment to contaminants would be minimal during implementation of institutional controls, risk mitigation measures, permeable reactive barrier installation, enhanced bioremediation, SVE, soil excavation and thermal treatment, and monitored natural attenuation.

No difficulties are foreseen with managing the small quantities of contaminated soil, water, and vapor produced during SVE, permeable reactive barrier, and in-situ bioremediation construction and operations, implementation of risk mitigation measures, and long-term monitoring. Soil would be treated on-site or transported off-site and disposed of in accordance with solid and hazardous waste disposal regulations. VOC vapor emissions would be treated to acceptable levels using carbon adsorption units. Contaminated groundwater would be treated and discharged on-site. During construction and operations, groundwater from the in-situ treatment system would be pumped through above-ground circulation and enhanced bioremediation systems; however, systems would generally be enclosed and remediation worker exposure is expected to be limited.

No difficulties are foreseen with managing contaminated soil and vapor produced during soil excavation and treatment. During construction and operations, soil containing VOCs would be excavated and temporarily stored in above-ground staging piles and may produce some low concentration VOC vapor emissions prior to treatment. The thermal desorption treatment unit would emit concentrated VOC vapor emissions that would be treated to acceptable levels using carbon adsorption units. The spent carbon units may be recycled or regenerated by the manufacturer or managed and disposed of based on solid and hazardous waste requirements. The time to reach PRAOs in soil is estimated to be one year based on the volume and typical treatment throughputs for portable thermal treatment units.

The excavation necessary to install the permeable reactive barrier will produce soil containing VOCs. Controls would be implemented to protect remediation workers and to prevent excess exposure to contaminated soil during its removal, transport, treatment, and disposal. The use of continuous trenching and backfilling will eliminate the need for dewatering, and will reduce the amount of water from the plume being brought to the surface. Since the system is below ground and requires little maintenance, remediation workers may be exposed to groundwater only when sampling.

In-situ chemical oxidation effectively oxidizes all organic matter that it encounters. The oxidation reactions are relatively fast and effective for dissolved-phase contaminants. Destruction of NAPL-contaminated soil will likely require multiple injections and longer times to completely destroy all contaminants. VOCs present in large masses of other organic compounds will require longer treatment times and may continue to contribute dissolved contaminants until treatment is completed. Once the source of dissolved VOCs is completely oxidized, downgradient PCE, TCE, cis-1,2-DCE, and VC concentrations will begin to decline. In-situ chemical oxidation will reduce the timeframe required to meet groundwater PRAOs in the Brenntag source area.

The time to reach PRAOs in groundwater within the Beall source area and groundwater and surface water outside of both the Beall and Brenntag source areas is estimated to be 9 years based on three, 3-year enhanced bioremediation treatment cycles. PRAOs would be met in contaminated vadose soil within 5 years in the Beall source area with SVE treatment and within one year in the Brenntag source area using excavation and thermal treatment. The timeframe to reach groundwater PRAOs in the Beall source area has some uncertainty due to the limitations of SVE vadose soil treatment in this area. Based on the aggressive combination of source area soil and groundwater treatments, PRAOs are expected to be met in the Brenntag source area groundwater; however, the time to reach PRAOs is difficult to predict.

Implementability

Alternative 6 is technically and administratively implementable at the LSGPS.

Institutional controls have been implemented at other, similar sites, and are commonly used. Federal, state, and local agencies have administrative authority to implement institutional controls. Equipment, materials, and services necessary for risk mitigation measures and long-term monitoring are available.

Permeable reactive barriers have been successfully installed and maintained at other, similar sites. More than 80 permeable reactive barriers have been installed around the world. Several vendors specialize in continuous trenching and production of zero-valent iron. Continuous trenching techniques are commonly used for installation of permeable reactive barriers and other systems, such as drainage trenches and pipe installation. Installation by injection and biopolymer slurry is less common and would require specialized equipment and contractor expertise. Permeable reactive barrier construction at the Brenntag source area is expected to be moderately difficult due to the length and depth of the trench.

The permeable reactive barrier construction is not expected to have significant short-term impacts to the activities at the Brenntag property because the location of the barrier is away from active work areas. Continued groundwater monitoring is expected to have only a minor effect on activities at the LSGPS. Additional design tests and modeling would be necessary to determine optimal permeable reactive barrier placement and design.

Thermal desorption has been successfully conducted at other, similar sites. Thermal treatment units and the equipment and services to excavate soil are commercially available. Excavation of soil beneath facility foundations and equipment would be difficult and would require removal of the affected facilities. Soil excavation is easy to implement in areas away from facility foundations. Excavation at the Brenntag source area to depths of approximately 14 feet would not be difficult.

In-situ chemical oxidation has been successfully conducted at other, similar sites. Several vendors specialize in design and installation of in-situ chemical oxidation injection systems. Equipment and materials used for installation and operation of in-situ chemical oxidation systems are readily available. In-situ chemical oxidation construction, operation, process monitoring, and groundwater monitoring are expected to have only a minor effect on activities at the LSGPS. The injection system will only be used periodically and will require little maintenance. Workers may be exposed to oxidants during the mixing and injection process and will be exposed to groundwater only when sampling. Oxidants require special precautions when shipping, storing and handling and these requirements would be specified in site-specific health and safety plans.

Enhanced bioremediation has been successfully conducted at other, similar sites. The equipment and services to install and operate the treatment injection system and to sample groundwater monitoring wells are commercially available. The treatment components and groundwater monitoring are expected to have only a minor effect on activities at the LSGPS. Additional design tests and modeling would be necessary to determine optimal well placement, nutrient injection rates, and flow rates.

SVE has been successfully conducted at other, similar sites. Preliminary pilot studies implemented at the Brenntag source area showed short-term reduction in VOC concentrations in groundwater. However, long term and full scale effects have not been determined. The equipment and services to install and operate the treatment systems and to sample groundwater monitoring wells are commercially available. Additional design tests and modeling would be necessary to determine optimal SVE well placement and flow rates. SVE is considered moderately difficult to construct due to proximity to operating facilities and foundations and expected difficulties with installing trenches and wells in these locations. SVE systems are uncomplicated and easy to operate.

Monitored natural attenuation is easy to implement as a site-wide monitoring well network is already in place.

Cost

The total present worth cost for implementing Alternative 6 at the LSGPS is $14,453,800 (see Appendix H).

6.8 ALTERNATIVE 7

Alternative 7 includes the following remedial options:

- Common Elements (institutional controls, long-term monitoring, 5-year reviews, and continued risk mitigation measures);
- Containment and treatment of contaminated groundwater with permeable reactive barriers at both the Brenntag and Beall source areas;
- Containment of the Beall source area plume leading edge with a hydraulic barrier;
- Treatment of contaminated vadose soil by soil vapor extraction at both the Brenntag and Beall source areas;
- Treatment of saturated zone contaminated soil with in-situ chemical oxidation at both the Brenntag and Beall source areas; and
- Treatment of site-wide groundwater with monitored natural attenuation.

The approach to site remediation under Alternative 7 includes a combination of in-situ groundwater and soil treatments and hydraulic containment that would achieve PRAOs in all media and not rely upon institutional controls and risk mitigation measures for protection of human health and the environment over the long term. Table 6-2 provides a summary of proposed groundwater and surface water monitoring to be conducted under Alternative 7 (see Figure 2-1 for monitoring locations). Table 6-7 provides a summary of the conceptual design assumptions for Alternative 7. Detailed descriptions of Alternative 7 components along with figures showing conceptual design layouts are provided in Section 5.

Overall Protection of Human Health and the Environment

Alternative 7 would protect human health and the environment at the LSGPS through a combination of institutional controls, risk mitigation measures, in-situ groundwater treatment, in-situ soil treatment, hydraulic containment, and monitored natural attenuation.

Institutional controls would be employed to restrict use of groundwater that would result in adverse risk to human health. Risk mitigation measures would be implemented as necessary to treat groundwater serving residences or businesses or provide connections to the public water supply system. Risks to workers and the public would be adequately controlled during implementation of risk mitigation measures, in-situ soil and groundwater treatment activities, and long-term monitoring through site-specific health and safety plans.

Permeable reactive barriers at the Brenntag and Beall source areas would contain and treat contaminated groundwater and effectively prevent downgradient migration of contaminants in groundwater from the source areas. It is assumed that this treatment would achieve PRAOs in surface water and in groundwater at and downgradient of the treatment systems.

Soil vapor extraction treatment of vadose soil at both the Brenntag and Beall source areas would significantly reduce migration of contaminants from vadose soil to groundwater. In both the Beall and Brenntag source areas, SVE would be combined with in-situ oxidation in saturated soil and vadose soil to achieve PRAOs in source area soil and groundwater. In-situ oxidation degrades VOC contamination rapidly; however, multiple phases of injection would likely be required particularly in the Brenntag source area where high concentrations of VOCs are found. A hydraulic barrier at the Beall source area plume leading edge would prevent further migration of contaminated groundwater in this area. Monitored natural attenuation would be implemented to maintain or further reduce VOC concentrations to PRAOs in groundwater after permeable reactive barriers, in combination with other remedial options, have reduced groundwater VOC concentrations.

Compliance with ARARs

Alternative 7 is expected to meet all federal, state, and local ARARs including chemical-specific ARARs for groundwater and surface water over the long term. Groundwater contaminant concentrations within and downgradient of source areas of the LSGPS would be expected to meet PRAOs and regulatory limits over the long term. EPA and the State of Montana do not have contaminant-specific soil quality standards.

Installation of monitoring wells, extraction and injection wells and the permeable reactive barriers will produce soil and liquid waste that will be managed and disposed of based on solid and hazardous waste requirements. Soil would be treated on-site or transported off-site and disposed of in accordance with solid and hazardous waste disposal regulations. Contaminated groundwater collected during the construction of risk mitigation measures and long-term monitoring would be treated and disposed of on-site.

Groundwater extracted at the hydraulic barrier would be treated in carbon adsorption units to chemical-specific ARARs prior to reinjection to the aquifer.

SVE emissions are expected to contain elevated total VOC concentrations that will be treated with carbon absorption units to reduce the total VOC emissions to comply with air quality regulations. The spent carbon units may be recycled or regenerated by the manufacturer, or managed and disposed of in accordance with solid and hazardous waste disposal regulations.

Long-Term Effectiveness and Permanence

Institutional controls and risk mitigation measures could provide adequate protection of human health if properly implemented and maintained. However, they rely upon continuous management to maintain their effectiveness.

The use of permeable reactive barriers will reduce the concentrations of PCE, TCE, cis-1,2-DCE, and VC in groundwater flowing through the permeable reactive barriers to levels below PRAOs. Continued maintenance of the permeable reactive barriers would be required until PRAOs are met in groundwater throughout the Brenntag and Beall source area.

SVE has been demonstrated to be effective at numerous sites and is EPA's preferred presumptive remedy for sites with VOC contamination in soil (EPA 1996b). The SVE system removes VOCs from the vadose zone soil through volatilization. The SVE system would not be effective at removing VOCs from contaminated soil in the saturated zone and has reduced effectiveness at the water table. This could prove problematic at the Brenntag source area where high concentrations of COCs are present at the water table and SVE alone is not expected to achieve soil PRAOs. Treatment effectiveness may also be limited by the heterogeneous subsurface environment and presence of low-permeability, fine-grain silt and clay. Although SVE is expected to achieve PRAOs in Beall vadose soil, these limitations create some uncertainty as to the timeframe required to meet soil PRAOs. Regular SVE vapor monitoring of VOCs and subsurface soil sampling would be conducted to confirm treatment effectiveness.

In-situ chemical oxidation has been shown to be an effective treatment of VOC contaminated soil and groundwater. In-situ chemical oxidation would be effective at destroying VOCs in the saturated zone at both source areas, including high concentrations of VOCs present at the water table in the Brenntag source area. In addition, in-situ oxidation would be used to treat vadose soil in the Brenntag source area to achieve PRAOs in soil. As with SVE, treatment effectiveness may also be limited by the heterogeneous subsurface environment and presence of low-permeability, fine-grain silt and clay. The presence of large masses of other organic compounds, such as petroleum, has been detected in the Brenntag source area and may cause high oxidant consumption and increased time and cost to reach PRAOs. Effectiveness would be verified through groundwater monitoring in the source areas and locations that showed continuous elevated levels of VOCs or a rebound in VOC concentrations would require additional treatments.

Groundwater pump and treat is an effective method for containing contaminated groundwater by forming a hydraulic barrier. This hydraulic barrier would need to be maintained until natural attenuation reduced contaminant levels between the permeable reactive barrier and the hydraulic barrier to PRAOs.

Monitored natural attenuation would act to maintain or continue to reduce VOC concentrations in groundwater after PRAOs were met through permeable reactive barrier treatment in combination with other remedial options.

Residual risk in groundwater and surface water would be reduced below levels of concern in all areas of the LSGPS over the long term.

Reduction of Toxicity, Mobility, or Volume of Contaminants Through Treatment

Institutional controls provide no reduction in the toxicity, mobility or volume of contaminants.

Alternative 7 uses permeable reactive barriers to destroy contaminants in groundwater downgradient of the Brenntag and Beall source areas and reduce concentrations to PRAOs. This alternative reduces the toxicity, mobility, and volume of dissolved-phase contamination.

SVE uses primarily physical processes to remove contaminants from soil and reduce concentrations to meet PRAOs. SVE under this alternative reduces the volume and toxicity of contaminants in soil. SVE vapors collected in carbon adsorption units would require further treatment or disposal.

The hydraulic barrier located at the Beall source area plume leading edge would provide a significant reduction of mobility of contaminants and some reduction in volume. Hydraulic containment would effectively prevent contaminants in groundwater from migrating further downgradient. Contaminants removed through pumping would be collected in carbon adsorption units, which would require further treatment or disposal.

In-situ chemical oxidation uses chemical processes to destroy VOCs in the saturated and vadose zones. In-situ oxidation would reduce the toxicity and volume of contaminants in the source areas.

After PRAOs were met in portions of groundwater, monitored natural attenuation would provide a small and slow reduction in the toxicity and volume of contaminants in groundwater by transforming them into less harmful substances through biological and chemical processes. However, during the biological degradation processes, PCE, TCE, and cis-1,2-DCE would be transformed into the more toxic VC during reductive dechlorination prior to aerobic degradation to the less toxic ethene. It is possible that VC concentrations and associated risks would increase for a period of time in portions of groundwater.

Short-Term Effectiveness

Exposure of remediation workers, the surrounding community and the local environment to contaminants would be minimal during implementation of institutional controls, risk mitigation measures, permeable reactive barrier installation, SVE, in-situ chemical oxidation, and monitored natural attenuation.

No difficulties are foreseen with managing the small quantities of contaminated soil, water, and vapor produced during SVE and hydraulic barrier construction and operations, implementation of risk mitigation measures, and long-term monitoring. Soil would be treated on-site or transported off-site and disposed of in accordance with solid and hazardous waste disposal regulations. VOC vapor emissions would be treated to acceptable levels using carbon adsorption units. Contaminated groundwater would be treated and discharged on-site.

The excavation necessary to install the permeable reactive barriers will produce soil containing VOCs. Controls would be implemented to protect remediation workers and to prevent excess exposure to contaminated soil during its removal, transport, and disposal. The use of continuous trenching and backfilling will eliminate the need for dewatering, and will reduce the amount of water from the plume being brought to the surface. Since the system is below ground and requires little maintenance, remediation workers may be exposed to groundwater only when sampling.

In-situ chemical oxidation effectively oxidizes all organic matter that it encounters. The oxidation reactions are relatively fast and effective for dissolved-phase contaminants. Destruction of NAPL-contaminated soil will likely require multiple injections and longer times to completely destroy all contaminants. VOCs present in large masses of other organic compounds will require longer treatment times and may continue to contribute dissolved contaminants until treatment is completed. Once the source of dissolved VOCs is completely oxidized, downgradient PCE, TCE, cis-1,2-DCE, and VC concentrations will begin to decline. In-situ chemical oxidation will reduce the timeframe required to meet groundwater PRAOs in the Brenntag and Beall source areas.

PRAOs would be met in about 10 years in the groundwater downgradient of the Brenntag source area and in about 24 years in the groundwater downgradient of the Beall source area (see Appendix E). SVE treatment of Brenntag source area soil, in combination with in-situ chemical oxidation, would be expected to achieve soil PRAOs in about 5 years. PRAOs would be met in about 10 years in Beall source area groundwater. Based on the aggressive combination of source area soil and groundwater treatments, PRAOs are expected to be met in the Brenntag source area groundwater; however, the time to reach PRAOs is difficult to predict.

Implementability

Alternative 7 is technically and administratively implementable at the LSGPS.

Institutional controls have been implemented at other, similar sites, and are commonly used. Federal, state, and local agencies have administrative authority to implement institutional controls. Equipment, materials, and services necessary for mitigation measures and long-term monitoring are available.

Permeable reactive barrier installations have been successfully conducted at other, similar sites. More than 80 permeable reactive barriers have been installed around the world. Several vendors specialize in continuous trenching and production of zero-valent iron. Continuous trenching techniques are commonly used for installation of permeable reactive barriers and other systems, such as drainage trenches and pipe installation. Installation by injection and biopolymer slurry is less common and would require specialized equipment and contractor expertise. Permeable reactive barrier construction at the Brenntag source area is expected to be moderately difficult due to the length and depth of the trench. The permeable reactive barrier installation may be difficult at the Beall property due to the greater depth of construction.

The permeable reactive barrier construction is not expected to have significant short-term impacts to the activities at the Brenntag and Beall properties because trench locations are away from active work areas. Continued groundwater monitoring is expected to have only a minor effect on activities at the LSGPS. Additional design tests and modeling would be necessary to determine optimal permeable reactive barrier placement and design.

In-situ chemical oxidation has been successfully conducted at other, similar sites. Several vendors specialize in design and installation of in-situ chemical oxidation injection systems. Equipment and materials used for installation and operation of in-situ chemical oxidation systems are readily available. In-situ chemical oxidation construction, operation, process monitoring, and groundwater monitoring are expected to have only a minor effect on activities at the LSGPS. The injection system will only be used periodically and will require little maintenance. Workers may be exposed to oxidants during the mixing and injection process and will be exposed to groundwater only when sampling. Oxidants require special precautions when shipping, storing and handling and these requirements would be specified in site-specific health and safety plans.

SVE has been successfully conducted at other, similar sites. Preliminary pilot studies implemented at the Brenntag source area showed short-term reduction in VOC concentrations in groundwater. However, long-term and full-scale effects have not been determined. The equipment and services to install and operate the treatment system and to sample groundwater monitoring wells are commercially available. Additional design tests and modeling would be necessary to determine optimal SVE well placement and flow rates.

Construction and operation of the hydraulic barrier are considered easy. Pump and treat is a common, well established technology that has been implemented successfully at numerous other similar sites.

Monitored natural attenuation is easy to implement as a site-wide monitoring well network is already in place.

Cost

The total present worth cost for implementing Alternative 7 at the LSGPS is $16,576,800 (see Appendix H).

6.9 ALTERNATIVE 8

Alternative 8 includes the following remedial options:

- Common Elements (institutional controls, long-term monitoring, 5-year reviews, and continued risk mitigation measures);
- Containment and treatment of contaminated groundwater with permeable reactive barriers at both the Brenntag and Beall source areas;
- Containment and treatment of contaminated groundwater with air sparging and soil vapor extraction at the Beall source area plume leading edge;
- Treatment of contaminated groundwater with enhanced bioremediation at both the Brenntag and Beall source areas;
- Excavation and thermal treatment of contaminated vadose soil at both the Brenntag and Beall source areas;
- Treatment of saturated zone contaminated soil with chemical oxidation at both the Brenntag and Beall source areas; and
- Treatment of site-wide groundwater with enhanced bioremediation followed by monitored natural attenuation.

The approach to site remediation under Alternative 8 includes an aggressive combination of available groundwater and soil treatment options that would achieve PRAOs in all media in the shortest timeframe and not rely upon institutional controls and risk mitigation measures for protection of human health and the environment over the long term. Table 6-2 provides a summary of proposed groundwater and surface water monitoring to be conducted under Alternative 8 (see Figure 2-1 for monitoring locations). Table 6-8 provides a summary of the conceptual design assumptions for Alternative 8. Detailed descriptions of Alternative 8 components along with figures showing conceptual design layouts are provided in Section 5.

Overall Protection of Human Health and the Environment

Alternative 8 would protect human health and the environment at the LSGPS through a combination of institutional controls, risk mitigation measures, in-situ groundwater treatment, soil removal and treatment, in-situ soil treatment, and monitored natural attenuation.

Institutional controls would be employed to restrict use of groundwater that would result in adverse risk to human health. Risk mitigation measures would be implemented as necessary to treat groundwater serving residences or businesses or provide connections to the public water supply system. Risks to workers and the public would be adequately controlled during implementation of risk mitigation measures, in-situ soil and groundwater treatment activities, soil removal and treatment, and long-term monitoring through site-specific health and safety plans.

Excavation and thermal treatment of vadose soil at the Brenntag and Beall source areas would significantly reduce or eliminate migration of contaminants from vadose soil to groundwater and meet soil PRAOs. In addition, in-situ chemical oxidation of VOCs in saturated soil at the Brenntag and Beall source areas would degrade VOC contamination rapidly; however, multiple phases of injection would likely be required to achieve PRAOs in the Beall source area groundwater.

Permeable reactive barriers at the Brenntag and Beall source areas would contain and treat contaminated groundwater and effectively prevent downgradient migration of contaminants in groundwater from the source areas. It is assumed that this treatment would achieve PRAOs in surface water and in groundwater at and downgradient of the reactive barriers.

Groundwater treatment at the Beall source area plume leading edge with air sparging and soil vapor extraction would significantly reduce concentrations of contaminants in groundwater and prevent further migration of contaminated groundwater in this area.

Enhanced bioremediation treatment of source area and site-wide groundwater would significantly reduce concentrations of contaminants in groundwater and, in combination with other remedial options, would be expected to achieve PRAOs in source area and site-wide groundwater. The Brenntag source area may require longer treatment due to higher concentrations of sources.

Monitored natural attenuation would be implemented to maintain or further reduce VOC concentrations in groundwater after enhanced bioremediation, in combination with other remedial options, reduced groundwater COC concentrations to PRAOs.

Compliance with ARARs

Alternative 8 is expected to meet all federal, state, and local ARARs including chemical-specific ARARs for groundwater and surface water over the long term. Groundwater contaminant concentrations within and downgradient of source areas of the LSGPS would be expected to achieve PRAOs and regulatory limits over the long term. EPA and the State of Montana do not have contaminant-specific soil quality standards.

Installation of monitoring, extraction and injection wells, and permeable reactive barriers will produce soil and liquid waste that will be managed and disposed of based on solid and hazardous waste requirements. Soil would be treated on-site or transported off-site and disposed of in accordance with solid and hazardous waste disposal regulations. Prior to thermal treatment, contaminated soil would be stored in staging piles in accordance with remediation waste requirements. Contaminated groundwater collected during the construction of risk mitigation measures and long-term monitoring would be treated and disposed of on-site.

SVE and thermal desorption emissions are expected to contain elevated total VOC concentrations that will be treated with carbon absorption units to reduce the total VOC emissions to comply with air quality regulations. The spent carbon units may be recycled or regenerated by the manufacturer, or managed and disposed of in accordance with solid and hazardous waste disposal regulations.

Long-Term Effectiveness and Permanence

Institutional controls and risk mitigation measures could provide adequate protection of human health if properly implemented and maintained. However, they rely upon continuous management to maintain their effectiveness.

The use of permeable reactive barriers will reduce the concentrations of PCE, TCE, cis-1,2-DCE, and VC in groundwater flowing through the permeable reactive barriers to levels below PRAOs. Continued maintenance of the permeable reactive barriers would be required until PRAOs are met in groundwater in the Brenntag and Beall source area.

Air sparging has been demonstrated at numerous sites with treatment efficiency rates up to 100 percent (EPA 1997; Federal Remediation Technology Roundtable 2003). VOCs are removed from the groundwater through volatilization or destroyed through direct oxidation (with ozone), and vapor-phase VOCs are then removed from the subsurface by the soil vapor extraction system. Treatment effectiveness is limited in a heterogeneous subsurface environment. Treatment radius may also be reduced at depth, particularly in the area immediately above bedrock where sparge well treatment radius is narrowest. Installation of a gravel-filled treatment trench with a horizontal sparge well placed immediately above bedrock should be considered to improve treatment at depth. Regular groundwater monitoring of VOCs would be conducted to confirm treatment effectiveness.

In-situ chemical oxidation has been shown to be an effective treatment of VOC contaminated soil and groundwater. In-situ chemical oxidation would be effective at destroying VOCs in the saturated zone at both source areas. As with SVE, treatment effectiveness may also be limited by the heterogeneous subsurface environment and presence of low-permeability, fine-grain silt and clay. The presence of large masses of other organic compounds, such as petroleum, has been detected in the Brenntag source area and may cause excessive oxidant consumption and increased time and cost to reach PRAOs. Effectiveness would be verified through groundwater monitoring in the source areas and areas that showed continuous elevated levels of VOCs or where VOC concentrations rebounded would require additional treatments.

Enhanced bioremediation has been demonstrated to be effective and reliable at numerous sites for groundwater treatment and is expected to be effective at the LSGPS under this alternative. Enhanced bioremediation would significantly degrade VOCs in source areas and groundwater concentrations are expected to achieve PRAOs because vadose and saturated zone soil would be successfully treated with excavation and thermal treatment and in-situ chemical oxidation. The presence of petroleum hydrocarbons and toluene in the Brenntag source area are not expected to negatively impact the effectiveness of this alternative.

Monitored natural attenuation would act to maintain or continue to reduce VOC concentrations in groundwater after PRAOs were met through enhanced bioremediation treatment, in combination with other remedial options.

Residual risk in groundwater and surface water would be reduced below levels of concern in all areas of the LSGPS over the long term.

Reduction of Toxicity, Mobility, or Volume of Contaminants Through Treatment

Institutional controls and risk mitigation measures provide no reduction in the toxicity, mobility or volume of contaminants.

Alternative 8 uses a permeable reactive barrier to destroy contaminants in groundwater at and downgradient of the Brenntag and Beall source areas and reduces concentrations to PRAOs. This alternative reduces the toxicity, mobility, and volume of dissolved-phase contamination.

Air sparging and SVE use physical and chemical (ozone oxidation) processes to destroy and remove contaminants from soil and groundwater at the LSGPS. These processes reduce the volume and toxicity of contaminants in soil and groundwater. SVE vapors collected in carbon would require further treatment or disposal. The mobility of contaminants in groundwater may change because the air sparge system is expected to create some temporary groundwater mounding during initial startup and if operated in a pulsed mode. The duration and magnitude of groundwater mounding is unknown, but some short-term changes to groundwater flow direction are likely.

Thermal desorption uses physical processes to remove contaminants from soil at the Brenntag and Beall source areas and reduce concentrations to meet PRAOs. Thermal desorption would reduce the toxicity, mobility and volume of contaminants in soil.

In-situ chemical oxidation uses chemical processes to destroy VOCs in the saturated zone. In-situ oxidation would reduce the toxicity and volume of contaminants in the source areas.

Enhanced bioremediation uses biological processes to degrade contaminants in groundwater to less harmful ones. Enhanced bioremediation would reduce the toxicity and volume of contaminants in groundwater but not their mobility.

After PRAOs were met in portions of groundwater, monitored natural attenuation would provide a small and slow reduction in the toxicity and volume of contaminants in groundwater by transforming them into less harmful substances through biological and chemical processes. However, during the enhanced bioremediation and monitored natural attenuation biological degradation processes, PCE, TCE, and cis-1,2-DCE would be transformed into the more toxic VC during reductive dechlorination prior to aerobic degradation to the less toxic ethene. It is possible that VC concentrations and associated risks would increase for a period of time in portions of groundwater. VC buildup in the aquifer would be monitored and VC would be degraded with enhanced aerobic processes to ensure that concentrations did not create an unacceptable risk. Monitored natural attenuation does not reduce the mobility of the contaminants in groundwater.

Short-Term Effectiveness

Exposure of remediation workers, the surrounding community and the local environment to contaminants would be minimal during implementation of institutional controls, risk mitigation measures, permeable reactive barrier installation, enhanced bioremediation, air sparge/SVE, soil excavation and thermal treatment, in-situ chemical oxidation, and monitored natural attenuation.

No difficulties are foreseen with managing the small quantities of contaminated soil, water, and vapor produced during air sparge/SVE and in-situ bioremediation construction and operations, implementation of risk mitigation measures, and long-term monitoring. Soil would be treated on-site or transported off-site and disposed of in accordance with solid and hazardous waste disposal regulations. VOC vapor emissions would be treated to acceptable levels using carbon adsorption units. Contaminated groundwater would be treated and discharged on-site. During construction and operations, groundwater from the in-situ treatment system would be pumped through above-ground circulation and enhanced bioremediation systems; however, systems would generally be enclosed and worker exposure is expected to be limited.

No difficulties are foreseen with managing contaminated soil and vapor produced during soil excavation and treatment. During construction and operations, soil containing VOCs would be excavated and temporarily stored in above-ground staging piles and may produce some low concentration VOC vapor emissions prior to treatment. The thermal desorption treatment unit would emit concentrated VOC vapor emissions that would be treated to acceptable levels using carbon adsorption units. The spent carbon units may be recycled or regenerated by the manufacturer or managed and disposed of based on solid and hazardous waste requirements. The time to reach PRAOs in soil is estimated to be 1 year based on the volume and typical treatment throughputs for portable thermal treatment units.

The excavation necessary to install the permeable reactive barrier will produce soil containing VOCs. Controls would be implemented to protect remediation workers and to prevent excess exposure to contaminated soil during its removal, transport, and disposal. The use of continuous trenching and backfilling will eliminate the need for dewatering, and will reduce the amount of water from the plume being brought to the surface. Since the system is below ground and requires little maintenance, remediation workers may be exposed to groundwater only when sampling.

In-situ chemical oxidation effectively oxidizes all organic matter that it encounters. The oxidation reactions are relatively fast and effective for dissolved-phase contaminants. Destruction of NAPL-contaminated soil will likely require multiple injections and longer times to completely destroy all contaminants. VOCs present in large masses of other organic compounds will require longer treatment times and may continue to contribute dissolved contaminants until treatment is completed. Once the source of dissolved VOCs is completely oxidized, downgradient PCE, TCE, cis-1,2-DCE, and VC concentrations will begin to decline. In-situ chemical oxidation will reduce the timeframe required to meet groundwater PRAOs in the Brenntag source area.

The time to reach PRAOs in groundwater within the Beall source area and groundwater and surface water outside of both the Beall and Brenntag source areas is estimated to be 9 years based on three, 3-year enhanced bioremediation treatment cycles. PRAOs would be met in contaminated soil within one year in the Beall and Brenntag source areas using excavation and thermal treatment. The timeframe to reach groundwater PRAOs in the Beall source area is estimated to be about 5 years. Based on the aggressive combination of source area soil and groundwater treatments, PRAOs are expected to be met in the Brenntag source area groundwater; however, the time to reach PRAOs is difficult to predict.

Implementability

Alternative 8 is technically and administratively implementable at the LSGPS.

Institutional controls have been implemented at other, similar sites, and are commonly used. Federal, state, and local agencies have administrative authority to implement institutional controls. Equipment, materials, and services necessary for risk mitigation measures and long-term monitoring are available.

Permeable reactive barrier installations have been successfully conducted at other, similar sites. More than 80 permeable reactive barriers have been installed around the world. Several vendors specialize in continuous trenching and production of zero-valent iron. Continuous trenching techniques are commonly used for installation of permeable reactive barriers and other systems, such as drainage trenches and pipe installation. Installation by injection and biopolymer slurry is less common and would require specialized equipment and contractor expertise. Permeable reactive barrier construction at the Brenntag source area is expected to be moderately difficult due to the length and depth of the trench. The permeable reactive barrier installation may be difficult at the Beall property due to the greater depth of construction.

The permeable reactive barrier construction is not expected to have significant short-term impacts to the activities at the Brenntag property because the location of the trench is away from active work areas. Continued groundwater monitoring is expected to have only a minor effect on activities at the LSGPS. Additional design tests and modeling would be necessary to determine optimal permeable reactive barrier placement and design.

Thermal desorption has been successfully conducted at other, similar sites. Thermal treatment units and the equipment and services to excavate soil are commercially available. Excavation of soil beneath facility foundations and equipment would be difficult and would require removal of the affected facilities. Excavation at the Brenntag source area to depths of approximately 14 feet would not be difficult. Excavation at the Beall source area to depths of approximately 45 feet would be difficult. Soil excavation is easy to implement in areas away from facility foundations.

In-situ chemical oxidation has been successfully conducted at other, similar sites. Several vendors specialize in design and installation of in-situ chemical oxidation injection systems. Equipment and materials used for installation and operation of in-situ chemical oxidation systems are readily available. In-situ chemical oxidation construction, operation, process monitoring, and groundwater monitoring are expected to have only a minor effect on activities at the LSGPS. The injection system will only be used periodically and will require little maintenance. Workers may be exposed to oxidants during the mixing and injection process and will be exposed to groundwater only when sampling. Oxidants require special precautions when shipping, storing and handling and these requirements would be specified in site-specific health and safety plans.

Air sparging and SVE have been successfully conducted at other, similar sites. Preliminary pilot studies implemented at the Brenntag source area showed short-term reduction in VOC concentrations in groundwater. However, long term and full scale effects have not been determined. The equipment and services to install and operate the treatment system and to sample groundwater monitoring wells are commercially available. The treatment components and groundwater monitoring are expected to have only a minor effect on activities at the LSGPS. Additional design tests and modeling would be necessary to determine optimal air sparge/SVE well placement and flow rates. Construction of the air sparging and SVE system at the Beall source area plume leading edge is considered easy since no interferences with facilities are anticipated.

Enhanced bioremediation has been successfully conducted at other, similar sites. The equipment and services to install and operate the treatment injection system and to sample groundwater monitoring wells are commercially available. The treatment components and groundwater monitoring are expected to have only a minor effect on activities at the LSGPS. Additional design tests and modeling would be necessary to determine optimal well placement, nutrient injection rates, and flow rates.

Monitored natural attenuation is easy to implement as a site-wide monitoring well network is already in place.

Cost

The total present worth cost for implementing Alternative 8 at the LSGPS is $ 20,372,500 (see Appendix H).

6.10 SUMMARY

In this section, eight comprehensive remedial alternatives were assembled and evaluated based on nine criteria as required by the NCP in 40 CFR 300.430(e) (EPA 1990). These eight alternatives include a variety of treatment and containment combinations that have been assembled to provide a range of effectiveness, timeframes to meet PRAOs, and costs to meet the NCP objective that a range of cleanup options be developed. Conceptual designs and costs were presented for each of the alternatives. Detailed descriptions of the components along with figures showing conceptual design layouts were provided in Section 5.

In the next section, the eight comprehensive alternatives will be summarized and compared. DEQ and EPA will use the results of the detailed and comparative analysis in the remedy selection process.

7.0 COMPARATIVE ANALYSIS OF ALTERNATIVES

The following analysis compares the eight remedial alternatives against each of the evaluation criteria. A summary of the comparison of alternatives is provided in Table 7-1.

7.1 OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT

Alternative 1 is not protective of human health and the environment. Alternatives 2 and 3 are considered protective of human health and the environment but are not expected to achieve groundwater or surface water PRAOs for all portions of the site. Protectiveness under Alternative 2 is provided by limiting exposure to residual contaminants through institutional controls. Protectiveness under Alternative 3 is provided by a combination of institutional controls and soil removal and treatment. Alternatives 4 and 5 are protective of human health and the environment but are not expected to achieve groundwater PRAOs for all portions of the site. Protectiveness under Alternatives 4 and 5 is achieved through a combination of reducing contaminant concentrations in groundwater and limiting exposure to residual contaminants through institutional controls. Institutional controls will be relied upon under Alternatives 2, 3, 4, and 5 over the long term to be protective.

Alternatives 6, 7, and 8 are protective of human health and the environment and are expected to achieve groundwater and surface water PRAOs throughout the site. Protectiveness is achieved through a combination of removing or treating soil sources of contamination, reducing contaminant concentrations in groundwater to meet PRAOs, and limiting exposure to residual contaminants through institutional controls. Groundwater protection is improved under Alternatives 6, 7, and 8 compared to Alternatives 2, 3, 4 and 5 because additional contaminated soil is removed or treated.

No additional human exposure to contaminants occurs under Alternative 1 because intrusive action or sampling is not conducted. The potential for human exposure to contaminants exists under all of the other alternatives because some contaminated groundwater and/or soil is handled or aboveground treatment is required. Alternative 2 requires only limited monitoring and handling of contaminated groundwater is minimal. Alternatives 3, 6, and 8 require removal of contaminated soil and human exposure could occur during excavation and handling. Although Alternatives 4, 6, 7, and 8 require aboveground handling and/or treatment of contaminated groundwater, direct contact with contaminants occurs only during the relatively short periods of time when active remediation (nutrient and oxygen enhancement) or granular activated carbon change-out is occurring.

Vapor releases under Alternatives 3, 5, 6, 7, and 8 would have the greatest potential impact to human health and the environment due to air discharges during treatment. However, minimal impact on the surrounding communities and ecosystems would be expected if vapor discharge were treated with an effective treatment technology such as granular activated carbon.

7.2 COMPLIANCE WITH ARARS

All alternatives are expected to meet all location-specific and action-specific ARARs. Alternative 1 would not achieve chemical-specific ARARs since contaminants in groundwater and surface water current exceed regulatory standards. Alternatives 2 and 3 are not expected to meet chemical-specific ARARs for groundwater and surface water. Alternatives 4 and 5 are not expected to meet chemical-specific ARARs for groundwater. Alternatives 6, 7, and 8 are expected to meet all chemical-specific ARARs.

7.3 LONG-TERM EFFECTIVENESS AND PERMANENCE

Alternative 1 provides no reduction in contaminant levels or risk.

Institutional controls and risk mitigation measures under Alternatives 2 through 8 could provide adequate protection of human health if properly implemented and maintained. However, they rely upon continuous management to maintain their effectiveness.

Monitored natural attenuation under all alternatives is not considered an adequate or reliable control method to reduce contaminant concentrations in groundwater in all portions of the site. Enhanced bioremediation under Alternatives 4, 6, and 8 is considered a reliable method for reducing contaminant concentrations in groundwater; however it is not considered adequate for addressing residual sources within the vadose or saturated zones. Permeable reactive barriers and air sparging/SVE under Alternatives 5, 6, 7, and 8 are considered effective technologies for treating and/or containing contaminated groundwater if designed and constructed properly. Permeable reactive barriers under Alternatives 5, 6, and 7 are considered more effective than air sparging/SVE and under Alternative 4 at controlling release of groundwater contaminants from the source areas. The effectiveness of Alternative 4 is diminished due to soil heterogeneity and the difficulty to sparge effectively near the bedrock interface. The hydraulic barrier considered under Alternative 7 is considered a reliable mechanism for controlling the migration of contaminated groundwater at the Beall source area plume leading edge.

Excavation and thermal treatment of soil under Alternatives 3, 6, and 8 meet soil PRAOs and are considered the most effective and reliable soil treatment option. SVE under Alternative 4, 6, and 7 provides significant mass removal of contaminants, is expected to achieve soil PRAOs in the Beall source area, but may not meet soil PRAOs in the Brenntag source area. SVE in combination with in-situ chemical oxidation in the Brenntag source area under Alternative 7 is expected to meet soil PRAOs. In-situ chemical oxidation is considered a reliable option for addressing areas of saturated zone soil contamination under Alternatives 5, 6, and 7.

Some residual risk above levels of concern (including migration from soil to groundwater soil screening levels) remains in contaminated soil, groundwater, and/or surface water under Alternatives 2, 3, 4, and 5 and these alternatives rely upon institutional controls over the long term for protection. Residual risk under Alternatives 6, 7, and 8 is reduced below levels of concern over the long term.

7.4 REDUCTION OF TOXICITY, MOBILITY, OR VOLUME OF CONTAMINANTS

No reduction in toxicity, mobility, or volume of contaminants occurs under Alternatives 1 and 2.

Alternatives 4 through 8 reduce the toxicity and volume of contaminants at the LSGPS through treatment of contaminated groundwater. Under these alternatives over 136 million gallons of contaminated groundwater would be treated. These alternatives permanently destroy the contaminants within the groundwater aquifer or remove contaminants from the groundwater. Alternatives 4, 6, and 8 use enhanced bioremediation to destroy contaminants using biological degradation. In addition, Alternatives 6, 7, and 8 degrade contaminants by permanently destroying contaminants through zero-valent iron treatment. Alternative 7 includes a hydraulic barrier downgradient of the Beall source area that removes contaminants from the aquifer and collects the contaminants in granular activated carbon units. Alternatives 5 and 8 destroy contaminants in place using ozone and remove contaminants from the groundwater using air sparging and SVE and collect the contaminants in granular activated carbon units.

Alternatives 3, 5, 6, 7, and 8 reduce the toxicity and volume of contaminants found in soil. Under Alternatives 3 and 8, contaminants are removed from approximately 20,302 cubic yards of excavated soil by thermal treatment and either destroyed in exhaust treatment systems or collected in granular activated carbon units. Under Alternative 6, approximately 3,865 cubic yards of soil are thermally treated. Contaminants are destroyed in-situ with chemical oxidation under Alternatives 6, 7 and 8. Contaminants removed from soil with SVE under Alternatives 5, 6, and 7 are collected in granular activated carbon treatment systems and either destroyed during carbon regeneration or incineration or disposed of off site. Alternatives 6, 7 and 8 would remediate contaminated soil at and below the water table that Alternative 5 cannot remediate due to the limitations of SVE. In addition, the effectiveness of Alternative 5 is diminished due to soil heterogeneity. Alternatives 6, 7 and 8 are considered the most effective alternatives to address areas with high concentrations of contaminants in groundwater and saturated soil.

Alternatives 6, 7, and 8 reduce the mobility of contaminants with permeable reactive barriers. Contaminant mobility in groundwater is further reduced by Alternative 7 downgradient of the Beall source area through hydraulic containment, provided by a pump and treat system. Under Alternatives 5 and 8, contaminant mobility in groundwater may be adversely affected by potential mounding caused by air sparging; however adverse effects could likely be minimized by system design and operations. Alternative 4 provides no reduction in contaminant mobility. Soil removal and thermal treatment under Alternatives 3, 6, and 8 greatly reduces the mobility of contaminants migrating from vadose soil to groundwater.

7.5 SHORT-TERM EFFECTIVENESS

Alternative 1 creates no short-term impacts to human health or the environment because no action is performed. Alternatives 2 through 8 have short-term impacts to remediation workers, the public, and the environment during implementation. Alternatives 2 through 8 implement risk mitigation measures and monitoring that will have minimal impacts to the community, remediation workers, and the environment. Alternatives 4, 5, 6, 7, and 8 have installed aboveground treatment components that may create minor visual and auditory nuisances. The potential for remediation workers to have direct contact with contaminants in groundwater occurs when the groundwater remediation systems are operating. Thermal treatment facilities required under Alternatives 3, 6 and 8 would function only temporarily. Excavation activities under Alternative 3, 6 and 8 would require disruption and removal of some facilities to be effective. Environmental drilling to install monitoring wells and/or extraction and injection wells would occur under Alternatives 4 through 8. Environmental drilling and excavation may produce contaminated soil cuttings and liquids that present some risk to remediation workers at the site. Groundwater monitoring will have minimal impact on workers responsible for periodic sampling. No off-site water discharges occur under any of the alternatives.

PRAOs are not achieved in all or portions of soil under Alternatives 1, 2, 4, and 5. PRAOs are not achieved in all or portions of groundwater under Alternatives 1, 2, 3, 4, and 5. PRAOs are not achieved in surface water under Alternatives 1, 2, and 3. Alternatives 6, 7, and 8 achieve PRAOs in groundwater, surface water and soil.

Soil excavation and thermal treatment achieves PRAOs within one year under Alternatives 3, 6, and 8. SVE achieves soil PRAOs at the Beall source area within about 5 years under Alternatives 5, 6, and 7. SVE in combination with in-situ chemical oxidation achieves soil PRAOs at the Brenntag source area within about 5 years under Alternative 7. PRAOs are achieved in groundwater and surface water in about 9 years under Alternatives 6 and 8 and in between 10 and 24 years under Alternative 7. However, the timeframe to meet groundwater PRAOs in the Brenntag source area is difficult to predict due to the presence of high concentrations of source material in this area. PRAOs are expected to be reached in groundwater downgradient of source areas in a shorter timeframe than within each source area. Alternative 8 is expected to achieve PRAOs in the shortest timeframe due to the combination of remedial options implemented under this alternative.

7.6 IMPLEMENTABILITY

Alternative 1, No Further Action, is the easiest alternative to implement. Alternative 2 is also easy to construct and operate as it only involves risk mitigation measures and long-term monitoring.

Soil excavation and SVE construction under Alternatives 3, 6, and 8 would be moderately difficult in areas where operating facilities exist and require special techniques or facility relocation. Thermal treatment and SVE systems are considered easy to operate since the equipment is not complicated, although strict air discharge limits would need to be met. In-situ chemical oxidation is considered easy to construct and operate under Alternatives 6, 7, and 8 since the chemicals and injection methods are well known and commonly available.

Permeable reactive barriers would be moderately difficult to construct at the Brenntag source area under Alternatives 6, 7, and 8 because of the length and depth of trenching required and difficult to construct in the Beall source area under Alternatives 7 and 8 due to the greater trenching depths required. However, permeable reactive barriers have been successfully installed at other similar sites and expected construction difficulties are not considered insurmountable. Permeable reactive barriers are expected to be easy to operate since there is no operating equipment. Air sparge/SVE groundwater treatment components under Alternatives 4, 7, and 8 and in-situ enhanced bioremediation components under

Alternatives 4, 6, and 8 are uncomplicated and commonly available systems and are considered easy to construct and operate.

Thermal treatment of excavated soil is considered the most reliable soil treatment option compared to either in-situ SVE or in-situ chemical oxidation. In-situ SVE and in-situ chemical oxidation are both limited by the heterogeneous subsurface environment and presence of low-permeability, fine-grain silt and clay. Permeable reactive barrier treatment, air sparge/SVE and in-situ bioremediation are all considered moderately reliable technologies. Site-specific pilot or design studies are considered necessary for each in order to maximize effectiveness.

Services, equipment, and materials are considered available for all alternatives and all alternatives are considered administratively feasible.

Finally, all alternatives except for No Further Action require routine monitoring and sampling including 5-year CERCLA reviews. Alternatives 4 through 8 require periodic operations and maintenance for the life of the treatment, including system monitoring and sampling, replacing parts and pumps, cleaning components, and replacing the granular activated carbon.

7.7 COST

Table 7-1 provides a summary of the costs of implementing remedial alternatives at the LSGPS. Alternative 8 is the most expensive alternative followed in descending order by Alternatives 7, 6, 5, 4, 3, 2, and 1. Appendix H summarizes cost details for each remedial alternative.

8.0 REMEDY SELECTION AND REMEDIAL ACTION PROCESS

The FS has identified a number of potential remedial alternatives to clean up COCs that have been released into soil and groundwater at the LSGPS. These alternatives have been evaluated against criteria established by the NCP. After approval of the RI and FS reports by DEQ and EPA, the Agencies will release a summary of their preferred remedial approach in a document called the Proposed Plan. At that time, the Agencies will conduct public meetings to present information about the LSGPS, the findings of the RI/FS, and the Agencies' proposed remedial actions. The public is encouraged to review all information contained in the LSGPS Administrative Record, including the RI/FS and Proposed Plan. The public will have the opportunity to provide comments on the Proposed Plan. The Agencies will address and respond to comments in a responsiveness summary. The Agencies will then decide upon a final remedy and will document their decision in a Record of Decision based on all information contained in the Administrative Record and comments and information received during the public comment period for the Proposed Plan.

After the Record of Decision is finalized, the Agencies will proceed with actions necessary to design and implement the remedy. Remedial design and remedial action may be implemented by the Agencies or potentially responsible parties. Any work conducted by potentially responsible parties will be under the direct oversight of the Agencies.

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APPENDIX A

April 2003 Monitoring Results

APPENDIX B

Pilot Study Results

APPENDIX C

Identification and Description of ARARs for Feasibility Analysis of Alternatives

APPENDIX D

Vadose Soil Modeling

APPENDIX E

Groundwater Modeling

APPENDIX F

Permeable Reactive Barrier Vendor Evaluations

APPENDIX G

Enhanced Bioremediation Vendor Evaluations

APPENDIX H

Cost Estimates

FIGURES

TABLES