Golder Associates Inc.

1951 Old Cuthbert Road, Suite 301
Cherry Hill, NJ 08034
Tel: (856) 616-8166
Fax: (856) 616-1874

FEASIBILITY STUDY
FOR OPERABLE UNIT 2
NEASE CHEMICAL COMPANY
SALEM, OHIO

Prepared for:

RÜTGERS Organics Corporation
201 Struble Road
State College, Pennsylvania 16801

Prepared by:

Golder Associates Inc.
1951 Old Cuthbert Road, Suite 301
Cherry Hill, New Jersey 08054

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February 2005

Project No.: 933-6154

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1951 Old Cuthbert Road, Suite 301
Cherry Hill, NJ 08034
Telephone (856) 616-8166
Fax (856) 616-1874
www.golder.com

May 11, 2005

Project No.: 933-6154

Ms. Mary P. Logan
USEPA Region V (SR-6J)
77 West Jackson Boulevard
Chicago, IL 60604

RE: NEASE CHEMICAL SITE, SALEM, OHIO
FEASIBILITY STUDY - OPERABLE UNIT 2

Dear Ms. Logan:

As stated in USEPA's letter dated April 21, 2005, USEPA and Ohio EPA have reviewed and approved the *Feasibility Study for Operable Unit 2, Nease Chemical Company, Salem, Ohio,* dated February 2005. USEPA's letter also provided a list of comments which identified some minor revisions to the Feasibility Study and directed that the identified portions of the Feasibility Study be revised. On behalf of RÜTGERS Organic Corporation (ROC), Golder Associates has revised the portions of Feasibility Study identified in USEPA's comments. As such, three copies of the insertion package are enclosed and should be used to replace the respective portions of the February 2005 Feasibility Study:

- Revised Table of Contents and Text;
- New Table 2-5;
- Revised Tables 5-1, 6-1, and 6-2E;
- Revised Cover Sheet for Appendix A; and,
- New Figure III-1 for Appendix A.

Three copies of the insertion package have also been provided to Ohio EPA.

All of USEPA's Specific (Language/Text) Revisions or Clarifications listed in Item B of the Agency Comments and Errata provided in USEPA's April 21, 2005 letter have been addressed in the enclosed insert package. In addition, please note that Golder Associates has removed one duplicative paragraph found in the February 2005 Feasibility Study. The last paragraph in Section 2.7.2 in the February 2005 Feasibility Study discussed the Crane-Deming seep. This same information was discussed in the following Section 2.7.3. Therefore the duplicative paragraph in Section 2.7.2 was removed.

USEPA's April 21, 2005 letter, as well as the Additional Issues listed in Item A in the Agency Comments and Errata highlighted a few issues for consideration. While we believe these issues are relevant to future project activities, the Feasibility Study has not been revised to address them. Primarily, these issues discuss determining the soil cover thickness and assessment of the southern shallow groundwater. We agree with USEPA that these issues are best resolved during the Pre-Design Investigation and Detailed Design phases of the project.

If you should have any questions regarding the enclosed Feasibility Study insertion package, please do not hesitate to contact Dr. Rainer Domalski at ROC (814/238-5200) or the undersigned (856/616-8166). We look forward to working with the Agencies in moving this project forward.

Very truly yours,

GOLDER ASSOCIATES INC.

Randolph S. White, P.E.
Principal

for P. Stephen Finn, C. Eng.
Principal

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Enclosures

cc:	Sheila Abraham,	OEPA
	Tim Christman,	OEPA
	Rainer Domalski,	ROC

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ACRONYMS

AOC	Administrative Order by Consent
ARAR	Applicable or Relevant and Appropriate Requirements
BTEX	Benzene, Toluene, Ethylbenzene, and Xylenes
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
COC	Contaminant of Concern
COPCs	Chemicals of Potential Concern
CPT	Cone Penetrometer Test
CSM	Conceptual Site Model
CTE	Central Tendency Exposure
DCA	Dichloroethane
DCE	Dichloroethene
DNAPL	Dense Non-Aqueous Phase Liquid
EA	Endangerment Assessment
EPA	Environmental Protection Agency
FS	Feasibility Study
ft. MSL	Feet Above Mean Sea Level
gpm	Gallons Per Minute
GRA	General Response Actions
HCl	Hydrogen Chloride
HDPE	High Density Polyethylene
HHRA	Human Health Risk Assessment
HI	Health Index
LCS	Leachate Collection System
LOAEL	Lowest Observed Adverse Effect Level
LTRA	Long-Term Removal Actions
MCL	Maximum Contaminant Level
MFLBC	Middle Fork Little Beaver Creek
MKS	Middle Kittaning Sandstone
MNA	Monitored Natural Attenuation
NAPL	Non-Aqueous Phase Liquid
NCP	National Contingency Plan
NOAEL	No Observed Adverse Effect Level
NPDES	National Pollutant Discharge Elimination System
NZVI	Nanoscale Zero-Valent Iron
O&M	Operation and Maintenance
OAC	Ohio Administrative Code
ORC	Ohio Revised Code
ORP	Oxidation-Reduction Potential
OU	Operable Unit
PAH	Polycyclic Aromatic Hydrocarbons
PCB	Polychlorinated Biphenyls
PCE	Perchloroethene or Tetrachloroethene
PDI	Pre-Design Investigation
PPM	Parts Per Million
PRB	Permeable Reactive Barrier
PRG	Preliminary Remediation Goal

RAO	Remedial Action Objective
RCRA	Resource Conservation and Recovery Act
RI	Remedial Investigation
RME	Reasonable Maximum Exposure
ROC	RÜTGERS Organics Corporation
SERA	Screening Ecological Risk Assessment
sf	Square Feet
SSL	Soil Screening Level
SVE	Soil Vapor Extraction
SVOC	Semi-volatile Organic Compound
TBC	To Be Considered
TCA	Trichloroethane
TCE	Trichloroethene
TeCA	Tetrachloroethane
UIC	Underground Injection Control
USEPA	United States Environmental Protection Agency
UST	Underground Storage Tank
VAP	Voluntary Action Program
VOC	Volatile Organic Compound
VPAC	Vapor Phase Activated Carbon
WWTP	Waste Water Treatment Plant
ZVI	Zero-Valent Iron

Guide to Data Qualifiers:

Some analytical results are presented with a letter following the concentration value. These are data qualifiers assigned to the result by the analytical laboratory or by a data validator. The following are some common data qualifiers that are be used in this text - note that sometimes qualifiers are combined to create new meanings.

J	Quantitation is approximate due to limitations identified during data validation
U	indicates that a compound was not detected above its detection limit
N	The analysis indicates the presence of an analyte for which there is presumptive evidence to make a tentative identification
R	Unreliable result - analyte may not be present in this sample

1.0 INTRODUCTION

1.1 Overview

This Feasibility Study (FS) Report has been prepared by Golder Associates Inc. (Golder Associates), on behalf of RÜTGERS Organics Corporation (ROC) for the Nease Chemical Site, Salem, Ohio (Site). The location of the Site is shown on Figure 1-1. The FS Report has been prepared in accordance with United States Environmental Protection Agency (USEPA) Guidance for Conducting Remedial Investigations and Feasibility Studies (RI/FS) under CERCLA (USEPA, October 1988). Administratively, the FS Report is submitted in accordance with the requirements of the January 1988 Administrative Order by Consent (AOC).

The FS builds upon the results of the Remedial Investigation (RI) for the Site, conducted principally by ERM-Midwest, Inc. The RI Report was approved by USEPA and the Ohio Environmental Protection Agency (Ohio EPA; both referred to herein as the Agencies) on June 19, 1996. The final Endangerment Assessment (EA), which also forms part of the RI, was submitted to the Agencies in April 2004, and includes the Human Health Risk Assessment (HHRA) and the Ecological Risk Assessment. The Agencies issued final approval of the EA on August 30, 2004.

The overall objective of this FS is to provide the technical basis for selection of a remedy for Operable Unit 2 (OU-2) that will be protective of human health and the environment and consistent with the National Contingency Plan (NCP). OU-2 is defined by USEPA as the permanent remedy for potential source areas and groundwater. OU-1 encompasses the Long-Term Removal Actions (LTRA) that were the subject of a separate Administrative Order by Consent that was entered in 1993. OU-1 actions included a shallow groundwater extraction and treatment system and sediment migration controls that have been operational since 1995. OU-3 includes Feeder Creek and Middle Fork Little Beaver Creek (MFLBC) sediments and will be addressed subsequent to OU-2.

Specific objectives of this FS are to:

- Develop and present a sound Conceptual Site Model (CSM), including the geologic, hydrogeologic and physical site setting, and the nature, extent, fate and transport of chemical impacts within that setting;

- Identify Remedial Action Objectives (RAOs) for media that have been identified as impacted with chemical constituents of potential concern (COPCs);

- Develop general response actions and identify, screen, and select remedial technologies and process options that addresses the RAOs;

- Assemble the retained technologies into a list of potential OU-2 remedial action alternatives; and

- Screen, and conduct a detailed analysis of the retained OU-2 remedial action alternatives, and provide a comparative analysis of these alternatives.

The CSM, RAOs, and the identification and screening of remedial technologies/process options were presented by Golder Associates, on behalf of ROC, to the Agencies during a meeting held on March 18, 2003. As agreed to during the March 18, 2003 meeting, ROC subsequently conducted an additional round of groundwater monitoring in accordance with a work scope pre-approved by the Agencies. The new groundwater data was assessed, Agency comments on the information presented during the March 18, 2003 meeting were addressed, and the identification and screening of OU-2 remedial action alternatives was presented to the Agencies during a second meeting held on October 15, 2003. Based on agency comments provided during the October 15, 2003 meeting, Golder Associates, on behalf of ROC, prepared a letter report which clarified a number of the issues presented and discussed and summarized the RAO's, technology screening and remedial alternatives screening results. This letter report also presented the results of the additional round of groundwater monitoring. The letter report was submitted to the Agencies on October 31, 2003.

The Agencies provided written comments on the letter report and the OU-2 remedial action alternative screening results on March 16, 2004 (USEPA) and May 6, 2004 (Ohio EPA). ROC and Golder Associates discussed the Agency comments with USEPA during a teleconference on May 20, 2004 and confirmed the results of these discussions in a letter to the Agencies dated May 26, 2004. It was agreed that ROC would proceed with the FS utilizing the retained technologies and OU-2 remedial action alternatives as presented in the October 31, 2003 letter report and, in a letter dated June 9, 2004, USEPA directed the submittal of the OU-2 FS.

Following the submittal of the September 2004 Draft FS, a meeting was held with the Agencies on November 4 and 5, 2004 to discuss their comments prior to providing written comments to ROC. The Agencies written comments on the Draft FS were subsequently provided to ROC on

November 22, 2004. Following ROCs review of the comments, another meeting was held on January 12 and 13, 2005 to discuss ROCs proposed responses to the comments and how the FS would be revised to address the comments.

1.2 FS Report Format

The remainder of the FS Report is organized as follows:

- Section 2 provides the CSM, including a characterization of the Site-specific geology, hydrogeology, and physical conditions. The CSM also describes the nature and extent of chemical impacts in soil, former pond fill/sludge and groundwater;

- Section 3 presents the RAOs for OU-2, which are subsequently used to develop and evaluate OU-2-specific remedial technologies and alternatives. This section also summarizes potential risks associated with predicted exposures to COPC in site media, as defined in the EA, as well as a discussion of applicable or relevant and appropriate requirements (ARARs) and other “To Be Considered” (TBC) standards ;

- Section 4 presents the identification and screening of remedial technologies that address each of the RAO’s;

- Section 5 presents the identification and screening of OU-2 remedial alternatives;

- Section 6 provides a detailed evaluation of each of the retained OU-2 remedial alternatives in accordance with the NCP evaluation criteria;

- Section 7 provides a comparative analysis of the retained OU-2 remedial alternatives; and,

- Section 8 provides a list of references used during the preparation of this FS.

2.0 CONCEPTUAL SITE MODEL

2.1 General Site Description

Figure 1-1 shows the location of the Site, the surrounding land use and a layout of the major on-facility and off-facility features. The former Nease Chemical Site included a manufacturing area south of the Conrail Railroad tracks and wastewater ponds on both sides of the Conrail Railroad tracks. Historically Crane-Deming owned adjacent property between the Conrail Railroad tracks and Allen Road. Although ROC has owned this property, including the production building, since 1998, Crane-Deming continues to operate a pump manufacturing facility on the property. The on-property area includes the on-facility and off-facility areas shown on Figure 1-1. The Site also includes the Middle Fork Little Beaver Creek (MFLBC) which, along with Feeder Creek, is being addressed as a separate operable unit (OU-3).

2.1.1 On-Facility Area

Only one building remains in the central portion of the former manufacturing facility which currently houses the treatment system for groundwater extracted from LCS-1 (see Section 2.2 below). Other remnant features of the former manufacturing activities are the former wastewater neutralization ponds shown on Figure 1-1.

2.1.2 Off-Facility Area

The off-facility portion of the ROC property includes the Crane-Deming operations to the north and east. Crane-Deming now leases a portion of the property from ROC, which it formerly owned.

2.1.3 Surrounding Land Use

Residential properties are located adjacent to the property along State Route 14. Other industrial/commercial facilities are located east and northeast of the property along Allen Road. The ROC property and area to the east and northeast are zoned for industrial purposes.

2.1.4 Topography

The land elevation in the central portion of the on-facility area is approximately 1,200 feet above mean sea level (ft MSL). From this area, the land slopes gently southwestward to State Route 14, and northeastward to the Conrail Railroad tracks at about an elevation 1,180 ft MSL. Across the Conrail Railroad tracks the land slopes steeply further to the northeast where it flattens in the area surrounding the Crane-Deming building and the Feeder Creek drainage system at an elevation of approximately 1,160 ft MSL. Comparisons with historic topographic maps indicate that the steep slope northeast of the Conrail Railroad tracks, particularly in the vicinity of the off-facility seep, is a result of cutting into the natural hillside that occurred in association with construction of the Crane-Deming building.

2.1.5 Site Hydrology

Surface water drains from the property along the Feeder Creek System, and the Route 14 drainage ditch. For ease of discussion, the on-property surface water drainage patterns are divided into two portions: drainage ways north of the Conrail Railroad tracks, and drainage ways south of the Conrail Railroad tracks, as shown on Figure 3-2 in Appendix A[1]. The Crane-Deming Marsh, which is identified in Figure 3-2, is discussed in Section 2.7.3 of this report as the Off-Facility Seep.

Surface Water Drainage from On-Facility Area South of Conrail Railroad Tracks

Exclusion Area A: Surface water flows from the area designated as Exclusion Area A into a sediment control structure. The water continues to flow from the sediment control structure into the Conrail Railroad track drainage. This drainage flows along the Conrail Railroad tracks and into the former Pond 2 culvert, a 24-inch pipe that flows beneath the Conrail Railroad tracks.

Former Pond 1. Former Pond 1 retains water from precipitation and surface run-off at all times during the year. Under the Removal AOC, water is pumped from former Pond 1 and treated at the on-property water treatment plant prior to discharge to the Golf Course Tributary of the MFLBC (approximately 1,500 feet south-east of the property).

Former Pond 2. Former Pond 2 was backfilled in the 1970s and no longer retains water. Surface water run-off from the former Pond 2 area is channeled through a sediment control structure or barrier into a small drainage way that flows to the southeast along the fenceline separating the southern portion of the on-facility area from the Conrail Railroad tracks. This drainage way

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[1] Certain figures from the RI and the EA are referenced and included in Appendix A.

enters the former Pond 2 culvert, and flows under the Conrail Railroad tracks onto the off-facility portion of the ROC property.

<u>Former Plant Front Lawn:</u> Surface water drains from the former plant front lawn south into a drainage ditch that runs along Route 14. The Route 14 drainage ditch also collects runoff from the road and other off-property areas and flows intermittently to the southeast into the Golf Course tributary at the intersection of Allen Road and Route 14. The Route 14 drainage ditch includes sections of open ditch and covered culverts.

<u>Marshy Area Near Exclusion Area B:</u> A marshy area is located near Exclusion Area B. This area appears to be a reflection of the retainage of surface water during most of the year. Surface water flows north from this area into a drainageway that exits the property southeast of former Pond 7. This drainage enters the former Pond 2 culvert and then drains into the Feeder Creek System.

<u>Former Pond 7</u>. Former Pond 7 no longer exists as a pond and does not retain surface water. Surface water run-off from former Pond 7 exits from the northwest and southeast ends of the former pond area (Figure 3-2 in Appendix A). Drainage from the southeast end flows into the former Pond 2 culvert, eventually draining into the Feeder Creek System. Drainage from the northwest end is directed into a small drainageway that flows into a culvert that crosses beneath the Conrail Railroad tracks and enters the Feeder Creek system between former Ponds 3 and 4.

<u>North Marsh:</u> The North Marsh area, a historically unused portion of the on-facility area, has two distinct exits: north and south. The southern exit flows under the Conrail Railroad tracks via the former Pond 7 culvert (Figure 3-2 in Appendix A), and enters the Feeder Creek drainage system on the northern portion of the on-facility area near former Pond 4.

The northern flow from the North Marsh area exits the on-facility area at the northern most point of the property. The drainage flows under the Conrail Railroad tracks via a culvert and flows east and enters a natural drainage ravine which flows into a small unnamed creek present on the Slanker property. This unnamed creek flows east, eventually flowing into the MFLBC north of the intersection of Beechwood and Allen Roads (Figure 3-2 in Appendix A).

Surface Water Drainage From Off-Facility Area North of Conrail Railroad Tracks

<u>Former Pond 3</u>. Former Pond 3 no longer exists as a pond and does not retain surface water. Surface water drainage exits through a discharge point in the southeastern portion of former Pond 3. Surface water from former Pond 3 joins with surface water drainage from former Pond 2 culvert (Figure 3-2 in Appendix A), and flows into the Feeder Creek drainage system. Substantial vegetative growth is presently established over former Pond 3.

<u>Former Pond 4</u>. Former Pond 4 no longer exists as a pond and does not retain surface water. Run-off from former Pond 4 area is collected by a small tributary to the Feeder Creek System (Figure 3-2 in Appendix A). Similar to former Pond 3, substantial vegetative growth is presently established over former Pond 4.

<u>Railroad Marsh</u>. The Railroad Marsh area to the west of former Pond 4 is the source of surface water that flows near former Pond 4. Water exits the Railroad Marsh area and flows beneath a natural gas pipeline through a small culvert and continues past former Pond 4. Run-off from the former Pond 4 area is collected by this drainage and is directed into the Feeder Creek System (Figure 3-2 in Appendix A).

Previous remedial measures were conducted at the property as part of the Removal AOC and included the construction of sediment control structures on drainageways that exit on the property. These measures serve to mitigate the migration of sediments off-property, while allowing surface water drainage to continue.

2.2 Previous Remedial Actions Completed

ROC has already completed various interim remedial actions including Removal Actions in 1983, 1991, and on-going Operation and Maintenance (O&M) activities. Each of which is described in more detail below. Figure 2-1 illustrates where these previous remedial actions were implemented.

Interim Action, 1983

In the Fall of 1983, ROC implemented[2] various steps including the removal of drums and associated affected soils from Exclusion Area A, removal of soil from Exclusion Area B, and

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[2] ROC completed this action voluntarily and not under the Agencies' oversight.

installation of soil erosion controls at the property. Five-thousand four hundred cubic yards of soil were removed from Exclusion Area A, and 684 cubic yards of soil were removed from Exclusion Area B. In addition, ROC excavated 2,790 cubic yards of soils from former Pond 1 and 630 cubic yards from a freshwater ditch parallel to the south side of the main railroad line. All of the excavated soil was disposed of at a permitted, off-Site hazardous waste disposal facility.

Fiber drums and some steel drums in poor condition found in Exclusion Area A were disposed of with the affected soil. A total of 115 intact drums were removed separately. Several of these drums were found to be empty and were disposed of with the soil. A total of 101 drums were overpacked, stored in the warehouse, opened, and sampled. These drums were removed from the on-facility area and disposed of at a permitted hazardous waste facility. Following the removal of soil and drums from Exclusion Area A, a metal detector survey and exploratory backhoe pits found no additional buried drums.

In response to concerns relating to the potential for sediments leaving the property and to prevent or minimize soil erosion, a number of steps were taken, which included: seeding of former Pond 2 to establish a grass ground cover; installation of geotextile fabric barriers across drainage swales and fresh water ditches; installation of rock dams; and installation of hay-bale barriers around the Exclusion Areas.

Interim Action, 1991

In late 1991, ROC began instituting remedial actions at the property to reduce potential off-property transport of contaminants prior to implementing any permanent remedies deemed necessary in the future. These measures were conducted following the implementation of the soil borings investigations performed as part of the RI investigations, and as such, have modified surface soil conditions in localized areas (e.g., former Ponds 1 and 2 and Exclusion Area A). Briefly, these cleanup measures included the construction of berms at the locations of former Pond 2 and Exclusion Area A and associated sediment control/outlet structures. It is understood that the “core” material of these berms was derived from soils existing on-property. For example, the core for the Exclusion Area A berm was constructed from soil derived from Exclusion Area A. It is also understood that the cover/topsoil layers for these berms were constructed from upgradient and/or imported “clean” soils and not from any areas believed to have been impacted by previous activities on the property. These areas were seeded as part of the final construction procedures and since that time a vegetative cover has developed.

Surface Water and Sediment Control

To isolate potential source areas from the effects of erosion, a number of surface water diversion and sediment control measures were constructed across the property (ROC, 1996). These were:

- Berm construction to create sediment control storage for Exclusion Area A, and former Ponds 1 and 2;
- Outlet control structures to cause ponding for sediment control in former Ponds 2 and 7, and Exclusion Area A; and,
- Diversions to route run-off from the west around the on-facility area.

The sediment control outlet structures have multiple features to trap and remove sediment (ROC, 1990). These features are silt fences, stone ballast berms, aggregate berms, filter fabrics, and perforated corrugated metal pipes. In addition, surface drainage channels were constructed to capture and divert unimpacted surface water runoff draining onto the property from the west away from the on-facility sources. In this way, sediment control measures handle a reduced quantity of run-off. All surface drainage channels were designed to accommodate any flows resulting from a 25-year, 24-hour storm event.

Shallow Groundwater Control and Treatment

To reduce the potential discharge of shallow groundwater to the ground surface, a collection trench and aggregate drain downgradient from Exclusion Area A and former Ponds 1 and 2 (LCS-1), and a collection drain and recovery well immediately downgradient and adjacent to former Pond 2 (LCS-2) were constructed. Prior to commissioning the on-facility treatment plant, this water was pumped on an intermittent daily basis to an on-facility storage tank for off-Site treatment and disposal. Under measures implemented as part of the Removal AOC, collected shallow groundwater from LCS-1 is presently pumped to the treatment plant (modified), which is located in the existing on-facility warehouse for treatment. Shallow groundwater collected from LCS-2 continues to be transported off-Site for treatment and disposal.

Ongoing Operation and Maintenance

ROC is currently operating and maintaining LCS-1 and LCS-2. Periodic sampling is conducted of the air, vapors, and effluent associated with the groundwater treatment plant. Treatment plant upgrades and maintenance have occurred throughout the last several years, and ROC currently has ongoing efforts to design and construct further treatment plant improvements. Periodic maintenance, including access controls, surface water drainage system, and general maintenance and inspection is completed at the property.

2.3 Potential Source Areas

2.3.1 Exclusion Area A

Exclusion Area A was identified as an area covering approximately 1.3 acres in the central portion of the former manufacturing area where chemicals and wastes were handled, as shown on Figure 1-1. As part of the previous remedial actions (see Section 2.2) approximately 5,500 cubic yards of impacted soils were removed from this area and disposed of off-site.

A summary of the analytical results (volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), and Mirex) from soil samples collected from test pit Nos. TP-16, TP-17, and TP-19, which were installed in Exclusion Area A during the RI (i.e., following the soil removal program), is presented below:

Samples collected from 0 to 0.5 ft bgs:

- Total VOCs: 0.008 mg/kg to 0.016 mg/kg
- Total SVOCs: 0.43 mg/kg to 1.083 mg/kg
- Mirex: 1.82 mg/kg to 6.29 mg/kg

Samples collected from 0.5 to 3.5 ft bgs:

- Total VOCs: 0.002 mg/kg to 0.322 mg/kg
- Total SVOCs: not detected to 9.39 mg/kg
- Mirex: 0.959 mg/kg to 7.610 mg/kg

Samples collected from 3.5 to 6.5 ft bgs:

- Total VOCs: 0.093 mg/kg to 3.641 mg/kg
- Total SVOCs: not detected to 37.958 mg/kg
- Mirex: 0.0357 mg/kg to 32.8 mg/kg

Exclusion Area A is underlain by between 20 to 30 feet of low permeability silty clay glacial till which minimizes the downward migration of any remnant chemical impacts in this area.

Remnant chemical impacts have impacted shallow overburden groundwater which flows northeasterly and toward the Conrail Railroad tracks. Shallow groundwater from this area is collected by LCS-1 (see Section 2-2).

2.3.2 Exclusion Area B

Exclusion Area B covers a small area, approximately 0.25 acres and was historically an area with limited vegetation. As part of the previous remedial actions, approximately 700 cubic yards of impacted soil were removed and disposed of off-site. A summary of the analytical results from soil samples collected from test pits Nos. TP-09 and TP-23 which were installed in Exclusion Area B during the RI (i.e., following the soil removal program) is presented below:

Samples collected from <u>0 to 0.5 ft bgs:</u>

- Total VOCs: 0.012 mg/kg to 0.083 mg/kg
- Total SVOCs: 0.263 mg/kg to 1.7 mg/kg
- Mirex: 0.068 mg/kg to 17.8 mg/kg

Samples collected from <u>0.5 to 3.5 ft bgs:</u>

- Total VOCs: 0.354 mg/kg to 6.56 mg/kg
- Total SVOCs: not detected to 0.38 mg/kg
- Mirex: not detected to 0.103 mg/kg

Samples collected from 3.5 <u>to 6.5 ft bgs:</u>

- Total VOCs: 8.49 mg/kg to 18.787 mg/kg
- Total SVOCs: 0.45 mg/kg to 1.639 mg/kg
- Mirex: 0.003 mg/kg to 0.026 mg/kg

2.3.3 Former Wastewater Neutralization Ponds

Historical Use

Combined, former Ponds 1 and 2 cover approximately 1.5 acres, and are located adjacent to each other in the on-facility portion of the property (see Figure 1-1). Former Pond 1 is the smallest of the five former neutralization ponds, and is the only former pond that still retains water throughout the year. Former Ponds 1 and 2 are believed to have served as the first of a series of impoundments used to neutralize wastewater during the Nease Chemicals active manufacturing. It is believed that wastewater was first discharged to former Pond 1, neutralized, and then conveyed to former Pond 2. After a period of settlement, neutralized wastes were pumped from former Pond 2, neutralized further if necessary, and then pumped to former Ponds 3, 4, or 7 for final settlement of solids. Due to their close proximity and similar use, former Ponds 1 and 2 are addressed as a single area.

Former Ponds 1 and 2

Physical Conditions

Former Ponds 1 and 2 were decommissioned by Nease Chemical in 1975 pursuant to a 1973 Consent Judgment entered into by Nease Chemical and Ohio EPA. During decommissioning, liquids from former Ponds 1 and 2 were drained, further neutralized, and discharged to the Salem municipal Wastewater Treatment Plant (WWTP). Former Ponds 1 and 2 were then covered with agricultural lime and filled with soils borrowed from other on-facility areas (ROC, 1996). A small amount of water remained in former Pond 2 after being drained and lime was applied to the remaining pool of water in the former pond. According to the SMC-Martin Phase I Report dated September 1984 (SMC-Martin, 1984c), material was excavated from former Pond 1 and properly disposed of off-Site as part of interim remedial measures conducted on-facility in late 1983. Following the excavation, the former pond was not backfilled and as a result stormwater accumulates in former Pond 1. Surface water from Pond 1 was sampled in 1993. The analytical results are provided in Table 2-5.

Groundwater is encountered 3 to 8 feet below ground surface in former Ponds 1 and 2. A portion of the shallow groundwater downgradient of former Pond 2 is collected by LCS-2 and then transported and disposed of off-site.

As shown on the generalized cross-section presented on Figure 2-3, and based on soil borings completed as part of the RI (see Figure 2-2 and Figure 2-3 for locations), brown silty clay fill materials overly native gray to brown silty clay till deposits in former Ponds 1 and 2. Sludge (largely calcium sulfate) is present below and within the fill and above the gray to brown silty clay horizon in former Pond 1. Former Pond 2 is similar to former Pond 1, where brown silty clay with gravel fill material (4 to 7 feet thick) is encountered overlying and within the sludge material (2 to 7 feet thick). The sludge in turn overlies the native gray to brown silty clay till deposits (5 to 7 feet thick), which in turn rests upon the bedrock, the Washingtonville Shale, which is gray in color. While sludge may have accumulated in former Ponds 1 and 2 in a uniform manner, it appears that the sludge has been disturbed during decommissioning or the implementation of the interim remedial actions. As a result, the sludge thickness in former Ponds 1 and 2 is variable. In summary, the materials within the former Ponds 1 and 2 are a heterogeneous mixture of clayey to gravel fill and wastewater neutralization sludge. In addition, based on the boring logs, there does not appear to be a continuous sludge layer within former Ponds 1 and 2.

Data from 1985 pond borings (SMC, 1986), RI soil borings and cone penetrometer tests (CPTs) (Golder Associates, 1996) indicate that native grey to brown silty clay till forms the majority of the subbase of former Ponds 1 and 2, ranging in thickness from 2 to 7 feet, and was encountered in all the borings installed within the former ponds. Sandier materials are observed in the eastern portion of former Pond 1 and the western part of former Pond 2 immediately above the bedrock surface. The Washingtonville Shale lies about 16 to 22 feet below the ground surface at the former Ponds 1 and 2.

The hydraulic conductivity of the fill and sludge material is on the order of $1x10^{-6}$ cm/s and the permeability of the till is on the order of $1x10^{-7}$ to $1x10^{-8}$ cm/s. During the 1990 investigation, there was sufficient strength to support a truck-mounted drill rig in the former Pond 2 area.

Chemical Conditions

Based on soil borings collected during the RI, the total detected VOC levels in former Ponds 1 and 2 fill/sludge material ranged from 0.041 mg/kg to 3,342 mg/kg, and in underlying till deposits ranged from 0.074 mg/kg to 53,519 mg/kg. Tetrachloroethene (PCE) is the primary VOC in the till deposits and fill, ranging up to 38,000 mg/kg. Benzene and 1,1,2,2-tetrachloroethane (1,1,2,2-TeCA) were also found at levels less than, but within one order of magnitude of the PCE concentration.

Total detected SVOC levels in former Ponds 1 and 2 fill materials ranged from 0.084 mg/kg to 10,924 mg/kg and in underlying till ranged from 5.9 mg/kg to 4,965 mg/kg. Diphenyl sulfone and 1,2-dichlorobenzene were the primary SVOCs identified in both till and fill in terms of concentrations, with average identified concentrations generally ranging from one to four orders of magnitude higher than other SVOCs detected.

Pesticides identified in former Ponds 1 and 2 samples, other than mirex, were limited to methoxychlor, dieldrin, and endosulfan sulfate. The latter two compounds were found in only one sample each. Methoxychlor ranged from 0.83J mg/kg to 46.4 mg/kg in fill and from 0.58 mg/kg to 270 mg/kg in till deposit samples. Mirex in former Ponds 1 and 2 was identified in fill at levels ranging from 1.21 mg/kg to 938 mg/kg, and in native soil at levels ranging from 0.08 mg/kg to 554 mg/kg.

Higher OVA/HNU readings were generally observed at depth in former Ponds 1 and 2. Higher concentrations of VOCs and SVOCs were generally detected at depth, in particular between 9 and 15 feet below ground surface, and in places below the sludge and within the native till deposits. Elevated constituent levels were detected as deep as 20 feet in borings SB-20 and SB-21. In former Pond 2 oil sheens were observed in soil borings SB-20 and SB-21 portions of the native soils below the fill/sludge. Higher and more frequently elevated OVA/HNU readings (1000+/500+) were also observed within the till deposits at depth.

Based upon the data collected in the RI, the subsequent Eastern Plume/DNAPL Investigation (Golder Associates, 1998) and the 2003 groundwater sampling event, DNAPL has been historically observed in the following wells: S-12, S-18, HP-04, D-12, T-2, and RW-1. These wells are screened in the overburden and bedrock and are all located within or immediately downgradient from former Ponds 1 and 2. Monitoring wells S-12, D-12 and S-18 were included in the 2003 sampling event, but DNAPL was observed only in well S-18. Notably, the 2003 groundwater investigation did not focus on determining the presence of DNAPL in monitoring wells. Former Ponds 1 and 2 is the likely primary source of DNAPL impacts in the Washingtonville Shale, as a result of the presence of much thinner till deposits and sandy materials that underlie former Pond 2.

Historic DNAPL detections in well D-12, which is screened in the Middle Kittaning Sandstone (MKS) immediately adjacent to the eastern perimeter of former Pond 2, may be the result of vertical migration into the upper portion of the MKS or improper well construction techniques. In addition, there was a former production well (T-2) near former Pond 2, which has since been decommissioned, that could have contributed to the presence of DNAPL as a result of its long screen. All of the other potential groundwater impact source areas (i.e., former Ponds 3, 4 and 7, and Exclusion Areas A and B) are underlain by much thicker clayey tills that would effectively limit the downward migration of chemical impacts. Consequently, it appears that DNAPL is restricted to the immediate vicinity of former Ponds 1 and 2 and this is further suggested by the rapid decline in dissolved phase concentrations downgradient of this area. Given the geological conditions, it is anticipated that most of the DNAPL is trapped within the pore spaces/fractures of the bedrock, and/or physically adsorbed into the subsurface matrix. As discussed further in

Section 2.4.2, the underclay associated with the Washingtonville Shale would also tend to limit the vertical distribution of DNAPL. Section 2.7.1 provides a further description of the presence and distribution of DNAPL in the subsurface.

Table 2-1 presents a summary of important chemical and physical characteristics for former Ponds 1 and 2 as well as for former Ponds 3, 4, and 7. Notably, the organic mass measured below the fill/sludge, the magnitude of OVA readings, and thickness of fill/sludge in former Ponds 1 and 2 are several orders of magnitude higher than found in former Ponds 3, 4, and 7. Conversely, the thickness of the underlying clayey till below former Ponds 3, 4 and 7 is considerably greater and/or more uniform than that found below former Ponds 1 and 2.

As a result, former Ponds 1 and 2 are believed to be the primary source of groundwater impacts at the site. This conclusion is further supported by the analytical data from PZ-6B-U that is screened in the upper portion of the MKS downgradient of former Ponds 1 and 2, as summarized below.

<u>Monitoring Well PZ-6B-U (1996):</u>

- VOCs: 19 chemicals detected including chlorinated ethenes and ethanes, acetone, BTEX compounds (benzene, toluene, ethylbenzene, and xylenes), chlorobenzene, chloroform, methylene chloride, carbon disulfide, 1,2-dichloropropane, and styrene. The total VOC concentration was 289,704 ug/l (not including dichlorobenzenes, which, in 1996, were reported as SVOCs);
- SVOCs: Hexachloroethane (10 J ug/l), 2,4-dichlorophenol (57 ug/l), 2,4,6-trichlorophenol (17 J ug/l), 1,4-dichlorobenzene (81 ug/l), benzyl alcohol (25 ug/l), 1,2-dichlorobenzene (120,000 ug/l), benzoic acid (140 ug/l), 1,2,4-trichlorobenzene (2 J ug/l), naphthalene (4 J ug/l), and hexachlorobutadiene (8 J ug/l); and,
- Mirex: Detection of 0.459 ug/l.

<u>Monitoring Well PZ-6B-U (2003):</u>

- VOCs: 26 chemicals detected including chlorinated ethenes and ethanes, acetone, BTEX compounds, chlorinated benzene compounds, chloroform, methylene chloride, carbon disulfide, 1,2-Dichloropropane, styrene, naphthalene, and hexachlorobutadiene. The total VOC concentration was 165,065 ug/l;
- SVOCs: Hexachloroethane (4 J ug/l), 2,4-dichlorophenol (45 ug/l), 2,4,6-Trichlorophenol (8 J ug/l), and diphenyl sulfone (360 JN ug/l); and,
- Mirex: Estimated detection of 0.0462 J ug/l.

Former Ponds 3, 4, and 7 do not appear to present an important source of groundwater impacts, as discussed further in the following sections.

Former Pond 3

Physical Conditions

Former Pond 3 covers approximately 2.9 acres and is believed to have been utilized as a solids settling basin for neutralized wastewater that had been treated in former Pond 2. The pond was decommissioned in 1975, however the exposed neutralization sludge in the pond was reportedly not covered due to its low bearing strength at the time. Volunteer vegetation has now become well established as shown on the photographs taken in Spring/Summer 2004 presented on Figure 2-4. As discussed below, the sludges are expected to have consolidated over the past 30 years resulting in increases to the bearing strength. In 1990 there was sufficient strength to support a truck-mounted drill rig with the assistance of pontoons and plywood.

As shown on the generalized cross-section presented on Figure 2-5 (see Figure 2-2 for soil boring locations), neutralization sludge materials within the former pond area range in thickness from 1 to 4 feet. A thick layer (7 to 11 feet) of gray silty clay till deposits, with small, isolated and discontinuous sand seams underlies the sludge layer. A gray/brown sand and gravel material underlies the native silty clay on the western and eastern edges of the former pond. Washingtonville Shale is present below the native soils.

Groundwater is encountered approximately 2 to 5 feet below ground surface based on the 1996 Eastern Plume Investigation. The hydraulic conductivity of the neutralization sludge material is on the order of 10^{-8} cm/s and the hydraulic conductivity of the native silty brown clay is on the order of 10^{-7} to 10^{-8} cm/s.

Chemical Conditions

Based on soil boring samples collected during the RI, the total detected VOC levels in former Pond 3 sludge ranged from 0.006 mg/kg to 0.406 mg/kg. Total detected VOC levels in former Pond 3 native soils ranged from non-detect to 17 mg/kg. PCE is the primary VOC identified in both former Pond 3 sludge and soil. Benzene, trichlorethene (TCE), and 1,2-dichloroethane (1,2-DCA) were also identified at concentrations greater than 0.1 mg/kg in soil.

Only two SVOCs were identified in former Pond 3 sludge samples: n-Nitrosodiphenylamine and diphenyl sulfone. Total SVOC levels identified in sludge ranged from non-detect to 0.15 mg/kg. Four SVOCs were identified in former Pond 3 soil samples: nitrosodiphenylamine, diphenyl sulfone, phenol, and benzoic acid. Total SVOC levels identified in soil samples ranged from 0.15 mg/kg to 12.2 mg/kg.

The only pesticide, other than mirex, identified in former Pond 3 sludge and soil samples was methoxychlor, which was detected in one sludge sample at an estimated concentration of 0.4 mg/kg and in two soil samples at estimated concentrations of 0.036 mg/kg and 0.061 mg/kg. Mirex was detected in all the sludge samples at concentrations ranging from 0.104 mg/kg to 4.15 mg/kg and at lower estimated concentrations, ranging from 0.001 mg/kg to 0.011 mg/kg, in the soil samples.

Former Pond 3 does not appear to be an important source of groundwater impacts since the thick continuous silty clay layer beneath the fill/sludge effectively mitigates the potential downward migration of chemicals found in the sludge. This conclusion is further supported by analytical data from groundwater samples collected from overburden monitoring well S-3 which is located downgradient of former Pond 3 as summarized below:

Monitoring Well S-3 (1992-1993)

- VOCs: No VOCs (of the four analyzed) were detected;
- SVOCs: Except for phenol at an estimated concentration of 2 to 4 ug/l, all SVOCs (of the eight analyzed) were not detected; and,
- Mirex: Not detected to an estimated concentration of 0.0026 ug/l

Monitoring Well S-3 (2003)

- VOCs: Except for acetone at 5 ug/l, all VOCs were not detected;
- SVOCs: Insufficient sample volume due to low yield; and,
- Mirex: Not detected

Another monitoring well that has been indicated for describing the conditions beneath former Pond 3 is S-2, which is located on the eastern edge of the former pond. However, wells S-12, D-12, and T-2, all of which have elevated chemical concentrations, are all located immediately upgradient of this well in the former Ponds 1 and 2 source area. Therefore, the chemical impacts found at S-2 are likely attributable to Former Ponds 1 and 2, suggesting that well S-2 should not be used to determine whether former Pond 3 is a source to groundwater. However, while S-2 should not be used to indicate former Pond 3 as a source area, well S-2 has relatively low concentrations of chemicals (as compared with wells along the centerline of the former Ponds 1 and 2 plume), which is further evidence that former Pond 3 is not a significant source to groundwater. Total VOCs detected in S-2 in 2003 were 83 ug/l compared with S-12 which had a total VOC concentration of 49,831 ug/l (see Figure 2-14).

In addition as summarized in Table 2-1, former Pond 3 contains a relatively small amount of organic chemical mass (900 lb) as compared to former Ponds 1 and 2 (560,000 lb) and only 2 lb of organic chemical mass was found below the base of the former pond as compared to 385,000 lb in former Ponds 1 and 2.

Former Pond 4

Physical Conditions

Former Pond 4 covers approximately 1.3 acres and is believed to have been utilized as solids settling basin for neutralized wastewater that had been treated in former Ponds 1 and 2. The pond was decommissioned in 1975 and since the pond held only a minimal amount of sludge, Nease Chemical was able to cover the pond with soil borrowed from other locations on the property. Volunteer vegetation has since stabilized the soil cover, as shown on the photographs in Figure 2-4.

Figure 2-6 presents a generalized cross-section of former Pond 4. Based on the available data and soil borings collected during the RI (see Figure 2-2 for soil boring locations), there is a 2 to 6 foot thick soil cover consisting of brown to gray silty clay fill in most locations within the former footprint of former Pond 4. However, sludge material was encountered on the surface of the former pond at boring location SB-34. This sludge may be the result of materials mixed into the soil cover during placement or indicates an area where the soil cover was not placed. Below the fill soil cover, sludge ranges in thickness from 1 to 9 feet, and overlies brown to gray silty clay till deposits with isolated and discontinuous lenses of sandier material. The till deposits range in thickness from 6 feet to 9 feet in the southern and western portions of the former pond, with as much as 39 feet of native clays and silts in the deepest area of former Pond 4 along the eastern edge of the former pond (ROC, 1996). Groundwater is encountered approximately 3 to 7 feet below ground surface. In 1990, the former pond soil cover provided sufficient bearing strength to support a truck-mounted drill rig.

The hydraulic conductivity reported for the fill and sludge is not consistent with values seen in other former ponds, and ranges from 10^{-4} cm/s to 10^{-5} cm/s. The native silty clay till underlying the former pond has a hydraulic conductivity on the order of 10^{-7} cm/s to 10^{-8} cm/s.

Chemical Conditions

Based on RI soil borings, the total detected VOC levels in former Pond 4 fill and sludge ranged from non-detect to 8.77 mg/kg. Total detected VOC levels in former Pond 4 till ranged from non-detect to 98 mg/kg. Acetone was the primary VOC identified in both former Pond 4 fill and till samples, with PCE and benzene also present in former Pond 4 till at lower levels.

Three SVOCs were identified in former Pond 4 fill samples: diphenyl sulfone, benzoic acid, and 1,2-dichlorobenzene. Total SVOC levels identified in former Pond 4 fill ranged from 0.22 mg/kg to 29.65 mg/kg. Total SVOCs concentrations identified in former Pond 4 till deposits ranged from 0.22 mg/kg to 21.754 mg/kg. The four primary SVOCs identified in former Pond 4 were diphenyl sulfone, benzoic acid, 1,2-dichlorobenzene, and bis(2-ethylhexyl)phthalate.

Except for mirex, no pesticides were identified in former Pond 4 fill or till deposit samples. Mirex was identified in four fill samples at concentrations ranging from approximately 0.006 mg/kg to 0.417 mg/kg and photomirex was identified at concentrations of approximately 0.002 mg/kg to 0.005 mg/kg in two fill samples. Mirex was identified in till deposits at levels ranging from approximately 0.005 mg/kg to 0.034 mg/kg.

Similar to former Pond 3, former Pond 4 does not appear to be an important source of groundwater impacts given the small amount of sludge, and the thick continuous layer of silty clay beneath the former pond which effectively mitigates the downward migration of chemical impacts. This conclusion is further support by analytical data from groundwater samples collected from downgradient overburden monitoring wells S-1 and L-VF2 as summarized below:

Monitoring Well S-1 (1992-1993)

- VOCs: Except for estimated concentrations of total 1,2-dichloroethene (1,2-DCE) (2 ug/l) and TCE (4 ug/l) no other VOCs were detected (notably, these VOCs were not detected in 2003);
- SVOCs: Except for phenol at estimated concentration of 1 to 2 ug/l, all other SVOCs were not detected; and,
- Mirex: Not detected.

Monitoring Well S-1 (2003)

- VOCs: Except for acetone at 12 ug/l, all VOCs were not detected;
- SVOCs: All SVOCs were not detected; and,
- Mirex: Not detected.

Monitoring Well L-VF2 (1992-1993)

- VOCs: All VOCs were not detected;
- SVOCs: Except for 6 out of 10, SVOCs analyzed were detected at estimated concentrations between 1 and 7 ug/l, all other SVOCs were not detected; and,
- Mirex: Not detected.

In addition, as summarized on Table 2-1, former Pond 4 contains a relatively small amount of organic chemical mass (725 lb) as compared to former Ponds 1 and 2 (560,000 lbs) and only 6 lb of organic chemical mass was found below the base of the former pond as compared to 385,000 lb found below the base of former Ponds 1 and 2.

Former Pond 7

Physical Conditions

Former Pond 7 covers about 0.8 acres and is believed to have been used in a similar manner to former Ponds 3 and 4 as a solid settling basin for neutralized waste that had been treated in former Ponds 1 and 2. The pond was decommissioned in December 1975 by draining the pond and placement of lime. Nease Chemical was unable to cover and fill former Pond 7 due to the low bearing strength of the sludge. Currently, volunteer vegetation has been established on the surface of the former pond as shown on Figure 2-4. Immediately south of former Pond 7, is an area designated as former Pond 7 Soil/Sludge Storage Area, since it is believed that Nease Chemical used this area to temporarily store sludge dredged from former Pond 7. For the purposes of this Feasibility Study, the former Pond 7 Soil/Sludge Storage Area, is included in the analysis of former Pond 7 presented herein.

Figure 2-7 presents a generalized cross-section of former Pond 7 (see Figure 2-2 for soil boring locations). Based on soil borings completed during the RI, sludge is encountered at ground surface and ranges in thickness from 2.5 feet to 9 feet. The sludge is underlain by a thick layer of brown-gray silty clay till deposits ranging in thickness between 4 and 8 feet and interbedded with thin, isolated, discontinuous sand seams ranging in thickness from 1 inch to 5 inches. The area was generally unstable in 1990 and a drill rig could not access the former pond. It is likely that the sludge has further consolidated since that time providing a higher bearing strength.

Groundwater occurs at approximately 2 to 5 feet below ground surface. The hydraulic conductivity of the sludge and underlying till deposits is on the order of 1x10^{-7} cm/s to 1x10^{-8} cm/s.

Chemical Conditions

Based on soil borings collected during the RI, chemical concentrations detected in former Pond 7 samples are substantially lower than those in former Ponds 1 and 2 but somewhat higher than levels found in former Ponds 3 and 4. Total detected VOC concentrations in former Pond 7 sludge and fill ranged from 0.027 mg/kg to 163.4 mg/kg, and exhibit an apparent increasing trend with depth within the sludge. Benzene has the highest concentration (74 mg/kg) in former Pond 7 sludge. Twelve other VOCs were detected at levels in excess of 1 mg/kg. Total detected VOC levels in the till deposits beneath former Pond 7 ranged from non-detect to 2.262 mg/kg. VOC levels exhibited an apparent decreasing trend in silty clay till deposits with depth. The primary VOC detected in soil samples from former Pond 7 was acetone.

Total SVOC concentrations identified in former Pond 7 sludge ranged from 0.13 mg/kg to 1,200 mg/kg. Diphenyl sulfone was the primary SVOC identified, with a minimum concentration of 0.130 mg/kg and a maximum concentration of approximately 1,200 mg/kg, which is two to four orders of magnitude higher than the average concentrations of other identified SVOCs in sludge. Total SVOCs in former Pond 7 native soils ranged from 0.828 mg/kg to 136 mg/kg, with benzoic acid and diphyenyl sulfone being the primary SVOCs identified. Several other SVOCs were identified in former Pond 7 soil at levels two to five orders of magnitude lower than those observed for the above SVOCs.

The only pesticide detected, except for mirex, was methoxychlor, which was found in two former Pond 7 sludge samples at concentrations of approximately 22 mg/kg and 4.9 mg/kg. Methoxychlor was also detected in till samples at concentrations of approximately 0.041 mg/kg to 0.059 mg/kg. Mirex was identified in former Pond 7 sludge at levels ranging from approximately 0.010 mg/kg to 5.38 mg/kg and in former Pond 7 native silty clay till underlying the sludge at levels ranging from non-detect to approximately 0.014 mg/kg.

Table 2-1 provides a summary of important physical and chemical characteristics associated with former Pond 7. Based on these data, former Pond 7 does not appear to be an important source of groundwater impacts since the thick continuous silty clay layer beneath the sludge effectively mitigates the potential downward migration of chemical impacts in the sludge. In addition, while the estimated organic chemical mass found in former Pond 7 is greater than what was found in former Ponds 3 and 4. Former Pond 7 contains substantially less organic chemical mass (9,919 lb) than found in former Ponds 1 and 2 (560,000 lb). Importantly, only 7 lb of organic chemical mass was found in the silty clay till deposits below the former pond whereas 385,000 lb of mass was found at the base of former Ponds 1 and 2.

2.3.4 Landfilled Area Beneath Crane-Deming Building

A small landfilled area was reported to exist beneath the footprint of the Crane-Deming facility. Little is known regarding the history of the landfill area except that:

- It was not constructed by or used by Nease Chemical; and,
- It is expected to contain primarily construction and demolition debris.

This area lies entirely within the MKS plume downgradient of former Ponds 1 and 2 and thus any impacts to groundwater it may have (or did have) are difficult to distinguish from the MKS plume. There are no chemical signatures in groundwater wells downgradient from the landfilled area that are different from those detected in the MKS plume source area. Thus, no further assessment of this area is needed to evaluate effective remedial alternatives in this FS.

2.4 Site Geology

The geology at the Site can be generally described as consisting of glacial till overburden deposits of the Kent Moraine lying above various sedimentary bedrock units consisting of, in descending order, the Washingtonville Shale (and associated coal seam and underclay) and the MKS. Deeper bedrock units beneath the Site include the Columbiana Shale, Putnam Hill Shale/Vanport Limestone, various coal seams and sandstones. The Putnam Hill Shale/Vanport Limestone, Clarion Coal, and Tionesta Sandstone units were investigated during RI activities and the three rounds of groundwater sampling (1992, 1993 and 1995). Based on the results of these investigations, these deeper bedrock units appear to be hydraulically isolated from the Washingtonville Shale and MKS by the intervening Columbiana Shale that appears to be acting as an aquitard, and thus have not been the focus of further remedial investigation. A description of the glacial till overburden and MKS units, highlighting aspects relative to potential chemical migration, is provided below.

2.4.1 Overburden

The Site is located within the limits of the Kent Moraine, which is characteristically a “fine-grained” glacial drift. At the Site this glacial till predominantly has a silty clay character with very little gravel and is interspersed with locally discrete zones of sandier material. While some of these sand zones at first appeared to be correlatable, large amounts of CPT data (Golder Associates, 1996) has demonstrated that the sands are laterally discontinuous, and therefore do not provide laterally continuous pathways available for contaminant migration or recovery. The sandy material zones were found to generally grade into the surrounding mass of the glacial till. Hydraulic testing of these sandy zones has verified their discrete, discontinuous character, as groundwater yields were significantly limited. As a result, these isolated and discontinuous sandy seams do not appreciably increase the overall permeability of the silty clay till overburden.

Although the glacial till overlying bedrock is sandier in the southwestern portion of the on-facility area in the vicinity of the property entrance and to a lesser degree in the southeastern portion of the property, throughout the majority of the property the sands are less prevalent and the overburden is comprised mostly of silts and clays. Particularly, in the northern portion of the property, near former Pond 7, the CPTs did not intercept sands and the till is dominated by silts and clays of substantial thickness which, as described above, would effectively mitigate the downward migration of any chemical impacts.

In the area of former Pond 3, RI borings showed that at all locations sampled, a relatively thin sludge layer (1 to 4 foot thickness) is underlain by till deposits consisting of silty clay interbedded with discontinuous sand seams with the silty clays ranging in thickness from 7 feet to 11 feet. In the area of former Pond 4, soil borings indicate the former pond is generally underlain by a dry, clay horizon, ranging in thickness from 6 feet to 9 feet in the southern and western portions of the pond, with as much as 39 feet of till deposits in the deepest area of former Pond 4 along the eastern edge of the former pond.

In former Ponds 1 and 2 area, data from 1985 pond borings (SMC, 1986), RI soil borings and CPTs indicate that a clay till forms the majority of the subbase, ranging in thickness from 2 to 7 feet and resting directly on the Washingtonville Shale. Where present, this clayey horizon likely serves to retard vertically downward migration of DNAPLs into bedrock. However, these data also indicate that there are sandier materials locally present lying directly atop the Washingtonville shale that could serve to pass DNAPLs to the transitional groundwater system.

In Exclusion Area A and former production area, CPT data indicate that the majority of these areas are underlain by a predominately silt-clay till that ranges in thickness between 20 feet and 35 feet, with occasional discontinuous sandier horizons. It is important to note that these discrete sandy horizons appear to be hydraulically isolated from the sands that occur in and around former Ponds 1 and 2 area. This is of particular importance in identifying potential sources associated with the observed impacts at wells PZ-3S and B-S (i.e., it is difficult, if not impossible to correlate the chemical impacts in upper sands at B-S and PZ-3S with chemical impacts emanating from former Ponds 1 and 2 source area). See Figure 2-8 for well locations.

In summary, the geology of the overburden till deposits indicates that former Ponds 1 and 2 have the greater potential to be the primary source of groundwater impacts/DNAPL impacts within the upper bedrock units (i.e., Washingtonville Shale and MKS), however, as discussed previously, improper well construction techniques could be the cause of DNAPL observations in the MKS. This conclusion is based on the presence of a much thinner, occasionally sandy till deposits and isolated sandier zones that underlay former Ponds 1 and 2. All the other potential groundwater impacts/DNAPL sources (i.e. former Ponds 3, 4 and 7, Exclusion Area A and Exclusion Area B) contain substantially smaller amounts of sludge, much lower chemical concentrations and are underlain by much thicker silty clay tills that would effectively mitigate downward migration.

2.4.2 Bedrock

The bedrock surface is highest in the western portion of the Site. Over the majority of the Site area, the bedrock surface slopes steeply away from the Site in an east/northeast direction towards the MFLBC. In the extreme southern portion of the Site, the bedrock surface slopes steeply to the south/southeast.

The Washingtonville Shale and associated coal seam and underclay are the uppermost bedrock unit below the Site. This unit is present over the majority of the Site area at thicknesses ranging up to approximately 35 feet (monitoring well ILB). The upper portion of the Washingtonville Shale unit is weathered, highly fractured and thinly bedded, and exhibits a dip of approximately

2.5 feet in 100 feet, towards the south. The deeper portions of the shale are less fractured and exhibit properties of more competent rock.

At or near the base of the Washingtonville Shale lies the Middle Kittanning Coal. This unit is continuous beneath the Washingtonville Shale and underlies most of the ROC Site area. Directly beneath the coal lies an underclay that has a thickness of 1 to 2 feet; however, there are discrete locations where the underclay is not encountered. The more competent portions of the Washingtonville Shale, the Middle Kittanning Coal and the underclay, where present, together with the overburden glacial till clays beneath former Pond 2, act as a physical barrier reducing the potential downward migration of chemical impacts, including DNAPL where present.

Based on borehole data (ROC, 1996), the Washingtonville Shale appears to have been eroded east of the Conrail right-of-way where the MKS unit is the uppermost bedrock unit underlying the glacial overburden. The erosional contact between the Washingtonville Shale and the MKS appears to be in the vicinity of the Crane-Deming building.

No outcrops of bedrock are present anywhere in the Site area, although bedrock is present within a few feet of the ground surface in the area east of the Conrail right-of-way near monitoring well S-13 where the overburden was historically excavated for the construction of the Crane-Deming building. Beneath the location of former Pond 2, the bedrock surface (Washingtonville Shale) is generally flat and lies about 20 feet bgs.

The MKS consists of a fine to medium grained and cross-bedded sandstone with stringers of coal deposited within the sandstone unit. The general regional dip is to the east-northeast. The MKS is characterized by fractures comprised of bedding plane partings with vertical joints more sparsely encountered. Downhole video logging (Golder, 1997) revealed both of these types of fractures in well RW-1, which was drilled down through the entire depth of the MKS. The thickness of the MKS at the Site ranges from 21 feet at monitoring well D-9 to a maximum of 53 feet at monitoring well cluster C. The MKS unit is truncated in the vicinity of Allen Road by the erosional valley side wall of the MFLBC buried valley. The bedding planes of the MKS thus follow the curved erosional sidewall of the buried valley in a northwesterly direction from monitoring well D-7 (adjacent to Allen Road) in an arcuate subcrop between well S-1 and eventually north to cluster L. See Figure 2-8 for monitoring well locations.

2.5 Site Hydrogeology

The following provides a summary of the salient features of the conceptual hydrogeologic model. It should be noted that the conceptual model presented below is a synthesis of numerous Site investigations performed over several years of investigations. The results of these investigations are reported in detail in the Final RI (ROC, 1996), the Removal Action Work Plan Addendum (Golder Associates, 1995a), Status Report on Implementation of Tasks, RAWPA (Golder Associates, 1995b), the 1996 IRM Seep Investigation and Fabric Barrier Work Plan (Golder Associates, 1996), and the Eastern Plume DNAPL Report (Golder Associates, 1997). These reports and work plans provide the results from borehole drilling, slug tests, pumping tests, and cone penetrometer tests that are instrumental in developing the conceptual hydrogeologic model.

In broad terms, the hydrogeologic units in the Site area consist of the following:

- Overburden (inclusive of fill, silty/clay glacial till with discrete, discontinuous sand zones);
- Transition bedrock aquitard (Washingtonville Shale and associated coal seam and underclay); and,
- The MKS bedrock aquifer.

The overburden (glacial till), including the discrete, discontinuous sand zones, has an overall low net permeability and yields relatively low volumes of water (Golder Associates, 1995b). As an example, as discussed in Section 2.5.3, a pumping test conducted in the overburden showed little effect on adjacent wells and that groundwater yields were essentially comprised of borehole storage. The glacial till dominates the overburden units (see cross-sections A-A’ through E-E’ of Golder Associates, 1996b, and included in Appendix A) and the variably thick mantle of overburden overlies the surface of the Washingtonville Shale and associated coal seam and underclay that is broadly defined as the “transition zone aquitard”. This transition zone aquitard provides a low permeability unit that limits the potential downward migration of DNAPL. DNAPL migration through this aquitard may also occur as a result improper monitoring well construction of bedrock wells, down dip from former Ponds 1 and 2. The MKS underlies the transition zone to the west of the Conrail right-of-way, but is the uppermost bedrock unit east of the Conrail right-of-way where the Washingtonville Shale is absent.

2.5.1 Groundwater Flow Direction/Horizontal Hydraulic Gradients

Overburden

Groundwater within overburden at the Site is clearly separated into two flow regimes: one primary regime in which groundwater flows east/northeast toward MFLBC, and a second, less significant regime in the southern portion of the Site (south of the treatment building), where groundwater flow within the overburden is towards the south/southeast. The groundwater contours are locally influenced by variations in land surface topography, the topography of the bedrock surface, and surface water drainageways. The divide between the east/northeast flow and the south/southeast flow directions is consistent with the change in bedrock and land surface topography in the southern portion of the on-facility area near the treatment plant building, and is responsible for the presence of a groundwater divide in this part of the Site.

Horizontal hydraulic gradients in the east/northeast flow regime are steep, as shown on Figure 2-9, coincident with the steep topographic contours immediately downgradient of the former Pond 2 area and the Conrail right-of-way (approximately 0.04 ft/ft). This area of the Site is also the area where the phreatic surface is nearest to the ground surface. In fact, the off-facility seep adjacent to the Crane-Deming building is believed to be at least partially due to a result of the outcropping of the phreatic surface as shown on Figure 2-10. In the south/southeast flow regime, horizontal hydraulic gradients are also steep (approximately 0.06 ft/ft) immediately south of the on-facility area where the surface topography is steep. These gradients, reflective of topographic control, emphasize the divide between the two overburden flow regimes.

Bedrock and Bedrock/MFLBC Regime

Groundwater flow within the MKS is similar in flow direction to the overburden system, although not nearly as strongly influenced by local variations in land surface and bedrock topography or surface water drainageways. There is a slight separation of bedrock groundwater flow directions in the southern portion of the on-facility area where groundwater flows to the southeast (similar to the divide in overburden flow directions). However; the predominant bedrock flow direction of groundwater within the MKS is eastward (see Figure 2-11). Flow within the MKS occurs primarily through the bedding plane partings. Flow can also occur across beddings planes when encountering a vertical joint.

As shown on Figure 2-12, a key feature in understanding the chemical impacts observed in the overburden contained within the MFLBC river valley is the direct connection between the MKS and the overburden. Overburden has filled an eroded glacial valley where the upper bedrock unit (Washingtonville Shale) that underlies most of the ROC property has been removed (herein referred to as the buried bedrock valley or MFLBC valley). Within the buried bedrock valley overburden, a hydrologic pathway from the MKS beneath the Site to the lower horizons of the overburden exists and accounts for the groundwater impacts observed within the buried bedrock valley overburden.

This connection between the MKS and the MFLBC valley overburden constitutes a major feature in the hydraulic groundwater pathway from the property. Figure 2-13 presents a hydrogeologic cross-section (see Figure 2-8 for cross-section location) and illustrates the equipotential contours of groundwater in this region showing the upward movement of groundwater from the MKS into the buried bedrock valley overburden. Two major changes occur in this area. First, dilution occurs as groundwater from the MKS beneath the Site mixes with native groundwater that originates from the south and east in the buried bedrock valley (see Figures 2-11 and 2-12). The dilution may be evaluated semi-quantitatively by the relative magnitudes of the groundwater specific discharges, q=Ki, where K and i are the hydraulic conductivity and gradient, respectively. Groundwater specific discharges were estimated for the MKS and the MFLBC overburden flows from the south, the east, and from deeper in the bedrock valley below the lower contact of the MKS. The following table estimates q using Figure 2-11 and data from the 1997 investigation (Golder, 1998).

	K (cm/sec)	i (ft/ft)	q (ft/day)
MKS flow	$6.7\text{x}10^{-4}$	0.005	0.009
Overburden flow in MFLBC			
-from the south	$1.4\text{x}10^{-4}$	0.063	0.026
-from the east	$1.4\text{x}10^{-4}$	0.063	0.026
-upward flow in the valley	$1.4\text{x}0^{-4}$	0.12	0.051

The calculations indicate that the specific discharges from other areas are all greater than the specific discharge of MKS groundwater from the property. A total dilution factor can not be accurately determined due to the uncertainty in the areas over which each of the discharges occur. However, the area over which the MKS flow from the property occurs is approximately equal to the area over which the flow from the east occurs, and therefore the flows from the other sources increase the dilution, which is likely to be approximately an order of magnitude greater than the

MKS flow from the property. Furthermore, dilution increases along the buried valley north of the site at a higher rate, as mixing with clean water Occurs from the east as well as from the west and from below.

On entering the bedrock valley, the groundwater flow changes direction from an easterly path to a northerly path, parallel to and driven by the flow in the MFLBC buried valley. This hydraulic system, which is typical of buried bedrock river valleys, means that groundwater impacts originating from the site will not migrate beyond the MFLBC to the east, but will be diluted with native groundwater and continue flowing to the north and discharging to the MFLBC at diluted and attenuated concentrations. The D, E, F, J, and K wells nests are positioned within the buried bedrock valley to monitor the discharge of the groundwater from the Site as it mixes with the water in the buried valley. Chemical impacts in these wells are discussed in Section 2.7.1.

2.5.2 Vertical Hydraulic Gradients

In general, there appears to be a transition from downward hydraulic gradients (ranging from about -0.002 ft/ft to -0.5 ft/ft) between the overburden and MKS units in the western portion of the property (including the area around former Ponds 1 and 2) to upward hydraulic gradients east of the property (ranging from about 0.007 ft/ft to 0.43 ft/ft). The upward gradients are particularly prominent near Allen Road, and within cluster wells installed in the buried bedrock valley of the MFLBC; one example of which is the artesian well S-19. At the central portion of the property (within the general location of the Feeder Creek and areas west and north of the Crane-Deming Plant) the vertical hydraulic gradients are relatively flat. It is in this generally flat area that the Washingtonville Shale “transition zone aquitard” pinches out and the MKS is in direct contact with the overburden soils.

In the southern portion of the property, vertical gradients are downward between discrete sand horizons of the overburden (ranging from about -0.44 ft/ft to -0.74 ft/ft numbers. At PZ-3, groundwater impacts are confined to just the upper sands (PZ-3M is non-detect), and it appears that the intervening silty clay till is acting as an aquitard mitigating deeper groundwater impacts.

2.5.3 Hydraulic Properties of Overburden

Based on slug tests performed at the Site, hydraulic conductivities for the overburden unit are controlled by the lithologic character of the glacial till. The clay and silt fractions in the glacial till predominate in the overburden unit as a whole, although loose, laterally discontinuous, and poorly consolidated sandy zones (sand lenses or sand units as defined in the RI) are commingled within the glacial till. Although the sand horizons have an average hydraulic conductivity of about 10^{-4} cm/sec, the silty clay portion which surrounds the sandy horizons in the glacial till displays hydraulic conductivities of about 10^{-7} cm/sec, thus isolating the discrete sand seams within an aquitard, yielding little groundwater. This hydraulically tight behavior has been documented in pumping tests showing the lack of hydraulic connection, and response to pumping between closely spaced piezometers and monitoring wells (Golder Associates, 1995b). The step drawdown test further showed that groundwater pumped during the test was essentially from borehole storage, with marginal increases in well yield as drawdown approached local sandy or silty-sand horizons. Furthermore, these tests also showed that the sandy horizons were isolated from each other by the silty clay matrix which surrounds the sandy horizons, because during the pumping of well S-7, adjacent wells did not respond. The isolation of the sand horizons within the silty clay matrix is also documented in trench logs (Golder Associates, 1995b).

2.5.4 Groundwater Flow Velocity

Based on RI data, calculated groundwater flow velocities within the overburden range from about 3 ft/yr to 120 ft/yr, based on a hydraulic conductivity range of 0.8×10^{-4} cm/s to 5.5×10^{-4} cm/s and a hydraulic gradient range of 0.008 to 0.047 ft/ft (Golder Associates, 1995a). These velocities are calculated for the more transmissive sandy layers in the Ponds 1 and 2 areas only, and while these sandy layers exist within the overburden till, as discussed in Section 2.5.3, they are discontinuous and isolated within the low permeability silty clay, and they ultimately have little material influence on the groundwater yield of the silty clay till unit.

Groundwater velocity is variable within the MKS, typical of fractured bedrock systems. Porosity varies throughout the MKS as a result of the various depositional processes of the sandstone (RI, RNC 1996), and effective porosity can be substantially different then the total porosity. An effective porosity 0.02 is appropriate for the upper, fine-grained bedded unit, which is supported in the literature, e.g., Domenico and Schwartz (1990) gives a range of effective porosity for sandstone of 0.005-0.10. An overall estimate of total porosity is estimated to be approximately 0.20. Based on an average hydraulic conductivity of 6.7×10^{-4} cm/s (RI reference), a hydraulic gradient from west of the facility to the MFLBC area, of 0.02 ft/ft, and porosity of 20%, the groundwater flow velocity is about 70 feet per year (ft/yr) (Golder, 1997). For the upper, fine-grained unit, a revised estimate incorporating an effective porosity of 0.02, and a hydraulic gradient of 0.0047 ft/ft, representative of the area between Ponds 1 and 2 and the MKS/MFLBC bedrock valley contact area, results in a groundwater velocity of 160 ft/yr. These ranges approximate a water travel time within the MKS, from beneath the property to the lower horizons of the buried valley fill overburden east of Allen Road, on the order of 10-20 years. This calculation does not include the time required for groundwater to move vertically downward from the overburden to the MKS.

2.6 Soil Chemistry

Extensive soil data has been collected from test pits and soil borings during the RI, as shown on Figures III-5 and III-6 in Appendix A of the EA. A summary of the key information follows below. Data collected within the former neutralization ponds is discussed separately in Section 2-3.

- The primary area of impacted soils is limited to the on-facility portion of the Site bounded by the Conrail Railroad tracks to the north, and by State Route 14 to the south. The only area of elevated levels located north of the Conrail Railroad tracks was associated with the Feeder Creek immediately south of former Pond 3 and is not addressed by OU-2.

- The highest soil concentrations (outside of the former neutralization ponds) were identified in Exclusion Area A, Exclusion Area B, and the Former Production Area, especially northwest of former Ponds 1 and 2 (Test Pit TP-13).

- VOC present in these areas appear to increase with depth. Total VOCs ranges by depth interval are as follows:

    - 0 to 0.5 feet – non-detect to 1.4 mg/kg
    - 0.5 to 3.5 feet – non-detect to 6.5 mg/kg
    - 3.5 to 6.5 feet – non-detect to 18.7 mg/kg

  The primary VOCs detected were PCE, 1,1,2,2-TeCA, TCE and benzene.

- SVOC concentrations also increase with depth:

    - 0 to 0.5 feet – non-detect to 7.6 mg/kg
    - 0.5 to 3.5 feet – non-detect to 10.9 mg/kg
    - 3.5 to 6.5 feet – non-detect to 37 mg/kg

  The primary SVOCs detected were diphenyl sulfone, hexachlorobenzene and 1,2-dichlorobenzene.

- Mirex was detected in on-facility samples and some off-facility samples in shallow (0 to 0.5 feet) soil. Mirex detected below 0.5 feet is primarily limited to Exclusion Area A, Exclusion Area B, and the Former Production Area, especially northwest of former Ponds 1 and 2 (Test Pit TP-13). In general, mirex levels in soil decrease with depth:

    - 0 to 0.5 feet – non-detect to 2,080 mg/kg
    - 0.5 to 3.5 feet – non-detect to 126 mg/kg
    - 3.5 to 6.5 feet – non-detect to 32.8 mg/kg

- There were some detections of a few VOCs and SVOCs in the low part per billion range in three test pit locations north of the Conrail Railroad tracks (TP30 and TP31 located just west of the Crane-Deming Building and in the general vicinity of the Crane-Deming Seep, and SB35 just north of the eastern side of the Crane-Deming Building and west of Allen Road).

- Surface soil data from samples taken along the State Route 14 ditch indicate the presence of several chemicals: Anthracene, Benzo(a)pyrene, Benzo(g,h,i)perylene, Benzo(k)flouranthene, dibenzo(a,h,i)anthracene, Fluranthene, Indeno(1,2,3-cd)pyrene, Phenanthrene, Pyrene, Mirex, Arsenic, Cadmuim, Chromium, Iron, Lead, Manganese, Mercury, Silver, and Zinc which potentially could be site related or a result of asphalt runoff and automobile emissions. In general, concentrations of metals are consistent with literature background.

    See Plate 7 in Appendix A for general soil impact distribution.

In summary, the main impacted soil areas are within the former main plant area which includes Exclusion Area A and Exclusion Area B. Off-facility areas with minor impacts are within the property now owned by ROC.

Risk-driving chemicals in soils were evaluated in the Human Health Assessment. The main risk-driving chemicals in surface soils (0 to 0.5 feet below ground surface) include mirex, manganese, iron, arsenic, benzo(a)pyrene, chromium, and hexachlorobenzene. Of these, the metals (manganese, iron, arsenic, and chromium) are consistent with published literature background levels. Risk driving chemicals in subsurface soils (deeper than 0.5 feet) include benzene, mirex, PCE, 1,1,2,2-TeCA, chlorobenzene, vinyl chloride, 1,2-DCA, carbon tetrachloride, hexachlorobenzene, TCE, hexachlorobutadiene, and hexachloroethane.

2.7 Groundwater Chemistry

Figures 2-14 through 2-28 show concentrations of total VOCs, total SVOCs, and select VOCs or SVOCs in the overburden and bedrock units, (comprised of the Washingtonville Shale, the Upper Kittaning Coal Seam and the MKS). Contours were interpreted on many of these figures using the most recent groundwater data (June 2003). Based on the results of the recent and historic investigations there exists one predominant area of groundwater impact at the Site. This area originates in the vicinity of former Ponds 1 and 2 and occurs in both the overburden and bedrock. The groundwater quality impacts and their potential sources are discussed separately below.

2.7.1 East/Northeast Flowing Groundwater Regime

The following provides a general discussion of the distribution of groundwater chemical impacts in the overburden, bedrock and Crane-Deming seep (or off-facility seep). A more detailed description of the historical trends and fate and transport pathways is presented in Section 2.8.

Overburden (Eastern Shallow Groundwater)

Overburden groundwater impacts from VOCs and SVOCs are shown on Figures 2-14 and 2-15 respectively. The low permeability of the overburden (discussed in previous sections) appears to have restricted lateral migration of groundwater impacts such that they are generally confined to the vicinity of former Ponds 1 and 2. The eastern extent of overburden impacts is also limited due to the thickness of the overburden decreases immediately east of the on-facility area where the bedrock surface nears and/or outcrops (Section 2.4.2) at the ground surface such that constituents in the overburden groundwater discharge at a seep west of the Crane-Deming building (off-facility seep). The limited eastern elongation of groundwater constituents in the overburden is likely due to the low permeability of the overburden and subsequent low groundwater flow rate as well as natural attenuation mechanisms such as volatilization, adsorption, and biodegradation within the saturated and vadose zones.

Overburden (Southern Shallow Groundwater)

Other groundwater quality impacts have been identified in small, discrete areas in the extreme southern portion of the on-facility area and are restricted mainly to the near surface overburden. These areas are likely separate and unrelated to the eastern or MKS plume and are referred to as the “southern area of groundwater impacts.” The groundwater divide (discussed in Section 2.5.1 and shown on Figure 2-9) separates the southern groundwater from the east/northeastern flowing groundwater. Also, chemical data indicates that a decreasing gradient in concentration exists between the Ponds 1 and 2 areas and the southern area. For example, the 1995 data showed that well S-6 measured greater than 26,000 ug/L of total VOCs, while well S-8, located farther to the south and east, contained only 6,139 ug/L. The extent of these southern area overburden groundwater impacts is shown on Figures 2-14 and 2-15. A further discussion of the southern shallow groundwater impacts is presented in Section 2.7.2.

MKS Plume

The extent of VOCs in the MKS (Figure 2-16) is bounded by the recent and historic non-detects in the D, E, F, J, and K well nests adjacent to the MFLBC. Groundwater flow analysis (Section 2.5.1) showed that the plume turns to the north, approximately co-linear with the MFLBC, as it mixes with the native flow in the buried bedrock valley of the MFLBC. The extent of VOC impacts has not expanded since 1995-1996 as shown by the comparable plot for 1995-1996[3] (Figure 2-17). In fact, substantial concentration reductions have occurred from 1995-1996 to 2003 throughout the plume, including wells near Allen Road such as D-7 (1,218 to 256 ug/L), D-8 (5,358 to 3,057 ug/L), and S-17 (4,590 to 2,771 ug/L). The extent of SVOCs in bedrock, primarily in the MKS, is shown on Figure 2-18, and is similar in shape and extent to VOC impacts.

The constituents which comprise the MKS plume include, in large part, the chlorinated ethene class of compounds, PCE, TCE, and the daughter products of biodegradation cis-1,2-dichloroethene (cis-DCE), vinyl chloride and ethene. The MKS plume also includes 1,1,2,2-TeCA, 1,2-DCA, benzene, toluene, ethylbenzene and xylenes (BTEX), chlorobenzene and 1,2-dichlorobenzene. These compounds comprise 99.75% by mass of the total VOCs and SVOCs in PZ-6B-U, the most contaminated well in the MKS, which lies closely downgradient of former Ponds 1 and 2. Figures 2-19 and 2-20 present concentration contours for PCE and TCE, respectively. It is noted that the RI soil boring chemistry indicated that PCE soil concentrations are, in general, an order of magnitude greater than TCE concentrations. The figures indicate that these compounds are present in high concentrations in the former Ponds 1 and 2 area (PZ-6B-U=112,000 ug/L combined concentration), but are reduced nearly 5 orders of magnitude in the downgradient area (G-UBA=4 ug/L combined concentration).

Figures 2-21 through 2-23 indicate concentrations of the “daughter” compounds cis-DCE, vinyl chloride and ethane, respectively. These compounds are present throughout the former Ponds 1 and 2 area and constitute the majority of the downgradient chlorinated ethenes plume indicating that substantial reductive dechlorination is occurring under natural conditions. The extent of these daughter products is consistent with the total VOCs extent, in which the D, F, E, J and K well nests provide non-detect delineation. In wells G-UBA and S-19, vinyl chloride is substantially elevated, and further evaluation of chemical distribution within the buried bedrock valley is appropriate. Well S-16, an overburden well in the buried valley, can provide additional delineation for this portion of the plume. S-16 is characterized by predominantly chlorinated ethene daughter products, with elevated concentrations of cis-DCE (171 ug/L) and vinyl chloride (107 ug/L) in 1995 and low concentrations of all other compounds (29 ug/L all other VOCs and not detected for all SVOCs).

To further evaluate the chemical distribution in the MFLBC buried bedrock valley, an investigation to include a new monitoring location north of G-UBA/S-19, east of Allen Road and west of the MFLBC will be performed during the pre-design investigation (PDI).

Figure 2-24 shows that the compound 1,1,2,2-TeCA is present only in former Ponds 1 and 2 area, at a concentrations as high as 9,800 ug/L, and is not detected downgradient of well D-15. The primary daughter products of biodegradation of 1,1,2,2-TeCA, include cis-DCE, trans-1,2-dichloroethene (trans-DCE), vinyl chloride and ethene (House, 2002) which are present in downgradient areas. 1,2-DCA is also present in the former Ponds 1 and 2 area at a level of 2,200 ug/L at PZ-6B-U, but decreases to 60 ug/L at GUBA further downgradient area, as shown on Figure 2-25. 1,2-DCA may biotically degrade, ultimately to ethene (House, 2002). In Figure 2-26, total BTEX is presented, and shows that in the former Ponds 1 and 2 area, concentrations are as high as 12,857 ug/L, but decline two orders of magnitude to 160 ug/L in the downgradient area. The compound 1,2-dichlorobenzene, as shown on Figure 2-27, is present in the source area at a concentration of 19,000 ug/L and declines to 820 ug/L in the downgradient area. Chlorobenzene concentrations above Federal maximum contaminant levels (MCLs) are confined to the southern overburden (B-S, PZ-3S, and PZ-7), and the former Ponds 1 and 2 area (S-12, D-12, and PZ-6B-U), and a plume figure is not included in this report.

Section 2.8 discusses the contaminant trends in the context of natural attenuation, and includes modeling for the purposes of estimating degradation half-lives of the major contaminants.

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[3] Note, PZ designated wells were sampled in December 1996 and all other wells were sampled in December 1995

Vertical Delineation

There have been no to only limited chemical impacts in the formations below the MKS. Recent and historic sampling indicates non-detected results and low level detections only. In well D-13, located on facility, except for three low SVOC detections between 1J and 14 ug/L and low pesticide detections (4,4-DDT=0.0028 J, Dieldrin=0.0039 J, Mirex=0.0344, Photomirex=0.000504 JN [ug/l]) in 1992-1993, no other VOC or SVOC were detected. Deep wells sampled in 2003 and the associated sampling results included D-14 (acetone at 8J ug/l, a typical laboratory contaminant, 8 J), D-LBA (all not detected), and D-9 (all not detected). The units below the MKS are therefore characterized by very low VOC and SVOC impacts (which may include typical laboratory contaminants), and part per trillion level pesticide detections, which may be due to sampling and/or laboratory inconsistencies. In addition, groundwater from these lower units will flow upward in the vicinity of the buried bedrock valley.

Pesticides in Groundwater

Mirex is highly sorptive and has an extremely low solubility (approximately 1 ug/L - IPCS, 1984), and its primary method of transport is via particulate matter. Where present in the MKS plume, concentrations are very low with declining trends. Figure 2-28 presents mirex results from 2003 (photomirex and kepone were not detected in any wells) along with the previous sampling result, and the trend (increasing or declining), between the two sampling events. Mirex was detected in eight wells in 2003, three of which were in off-facility wells, and all of these off-facility detections were estimated values below the method reporting limit. Since 1995-1996, mirex has generally declined in concentration in these off-facility wells. In PZ-6B-U, mirex decreased from 0.459 ug/L in 1996 to 0.0462 J ug/L in 2003, and in PZ-6B-L, mirex increased slightly from <0.002 ug/L in 1996 to 0.0286 J ug/L in 2003. In S-17, mirex decreased from 0.085 ug/ L in 1995 to 0.0475 J ug/L in 2003. Of the eight on-property detections, four are likely associated with particulate matter as indicated by turbidity measurements during sampling, including the three locations where mirex concentrations increased (S-2, S-11 and D-12)[4]. Mirex is generally decreasing[5] at a relatively rapid rate in groundwater, and its physical properties preclude its future migration potential as a significant groundwater chemical.

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[4] Turbidity measurements are included in Appendix C.

[5] The decrease in mirex concentrations may also be attributable to improved sampling technique, although certain wells continue to generate suspended solids when sampled.

DNAPL

Dense non-aqueous phase liquid (DNAPL) has historically been observed in on-property monitoring wells since the early to mid-1990's[6] (see Section 2.3.3, former Ponds 1 and 2). Specifically, DNAPL has been observed in monitoring wells S-12, S-18, TP-04, D-12 and former wells T-2 and RW-1. Figure 2-8 shows the location of these wells. The common feature of all of these wells is that they are located within, or immediately adjacent to, former Ponds 1 and 2.

When evaluating groundwater chemistry at a site containing DNAPL, a common rule of thumb is to compare chemical concentrations to 1% of their solubility in water. However, it is important to realize that chemical concentrations exceeding 1% solubility do not necessarily indicate the presence of DNAPL at a given well location. For example, chemical concentrations in monitoring wells PZ-6B-U and PZ-6B-L exceed 1% solubility which is likely due to an upgradient source (i.e., former Ponds 1 and 2) and not DNAPL at that location.

While some horizontal migration of DNAPL along bedding plans of the Washingtonville shale may have occurred, DNAPL is expected to be limited to the vicinity of former Ponds 1 and 2. In addition, some vertical migration of DNAPL may have occurred through fractures in the Washingtonville Shale and the MKS. However, vertical migration is expected to be limited due to the presence of the underclay within the Washingtonville Shale. The low chemical concentrations detected in deep bedrock wells in the vicinity of former Ponds 1 and 2 do not indicate that meaningful quantities of DNAPL have migrated vertically.

It is important to note that in order for DNAPL migration to occur it must have a driving force or an active source. Since chemical discharges to former Ponds 1 and 2 ceased approximately 30 years ago, it is likely that there is little, if any, remaining DNAPL driving force. Therefore, while free DNAPL may exist, it is likely to be isolated with little mobility potential.

The DNAPL currently observed does not exist in discrete, homogeneous pools. Rather, it sporadically occurs within overburden and bedrock at the base of and immediately adjacent to former Ponds 1 and 2. Given its heterogeneous distribution, it is not possible to make any meaningful estimates of the volume of DNAPL in the subsurface. To date, no systematic DNAPL recovery has been conducted. As discussed in Section 5.3 of this FS, a focused

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[6] The July 2003 groundwater monitoring did not focus on the assessment of DNAPL.

investigation of the presence of DNAPL in existing monitoring wells and new monitoring wells will be conducted during the PDI.

The primary source of DNAPL is not known (there are no known specific DNAPL discharge events), but it is expected that DNAPL chemicals were contained in the wastewater released to former Ponds 1 and 2.

In summary, DNAPL sporadically exists in the vicinity of former Ponds 1 and 2 both within the ponds and within overburden and bedrock surrounding the ponds and its migration potential is limited. While concentrations of DNAPL chemicals have been detected at greater than 1% of their solubility in monitoring wells downgradient from former Ponds 1 and 2, these data are more likely reflective of DNAPL impacts to groundwater in the immediate vicinity of former Ponds 1 and 2, rather than the presence of DNAPL in those downgradient monitoring wells. The exact understanding of the heterogeneous DNAPL distribution is not possible or critical for the development of an effective groundwater remediation strategy.

2.7.2 Discrete Impacts in Southern Portion of the On-Facility Area

As discussed in Section 2.7.1, a separate and less prominent groundwater flow regime exists in the extreme southern portion of the on-facility area. Within the overburden, VOCs and SVOCs have been detected in the vicinity of wells PZ-3S/B-S and PZ-7, which occur south of the groundwater flow divide between the east/northeastern and southeasterly flow regimes. Historical data indicates that the southern groundwater is likely isolated from the Ponds 1 and 2 area. For example, while monitoring well S-6 contained elevated concentrations of VOCs (54,000-78,000 ug/L in the RI), monitoring well S-8, located between S-6 and the southern area as shown on Figure 2-8, contained two orders of magnitude lower concentrations (820-1,235 ug/L). The southern shallow groundwater will be further evaluated during the PDI. Figures 2-14 and 2-15 illustrate the concentrations of total VOCs and total SVOCs, respectively, in these two areas.

These impacts are generally confined to the shallow sandy seams within the silty clay till of the overburden, as shown on the hydrogeologic cross-section presented on Figure 2-29 (see Figure 2-8 for cross-section locations). The sandy seams are discontinuous and further chemical migration is limited by the silty clay till. Elevated impacts seen in PZ-7 are not present in PZ-4S/M/B. Also, elevated impacts observed in PZ-3S and B-S are not present in PZ-3M/B or in A-S/A-UBA, further emphasizing the localized nature of the impacts. The exact source of groundwater impacts in these two areas is unknown. However, while soil gas studies were not conclusive, it is possible that the source(s) is a small remnant of historic operations that left discrete amounts of source material in the near surface overburden. DNAPL has not been observed in any of the boreholes advanced in this area.

The southeastern extent of these impacts off-property is physically limited by the drop in surface elevation. The residences downgradient to the southeast are closest to well nests A and PZ-4, which are relatively impacted. However, a residence to the south of the property is downgradient of well PZ-7. Residential wells are generally screened within bedrock and residential well sampling has resulted in no detections of site-related contaminants.

2.7.3 Off-Facility Seep

Since July 1994, ROC has reported to the Agencies the presence of a non-flowing seep (off-facility seep) in the vicinity of the Crane-Deming Building as shown on Figure 1-1. The off-facility seep is believed to have been created during the construction of the Crane-Deming building from cuts made into the previous land surface which exposed shallow groundwater in that area. Observations have indicated that discharge of water at the surface has been intermittent and is primarily a reflection of a water table elevation approximately coincident with the water elevation of the off-facility seep itself. The accumulation of precipitation is also expected to at least partially account for the saturated conditions. Monitoring of this seep indicates that the “system” is essentially static and water (groundwater and precipitation) that accumulates in this area is impounded in this slight topographic depression. Analysis of two rounds of groundwater sampling has shown that the near surface groundwater in the area has total VOC impacts ranging from approximately 2,122 ug/l at SP-1 to 25,667 ug/l at SP-3 (both values from May 1997 sampling results).

Minor impacts to surficial soils in the vicinity of the seepage area are believed to be a result of shallow groundwater seepage at the surface. Two surface soil samples (<6 inches bgs) were collected in the vicinity of the Crane-Deming seepage area at test pits TP-30 and TP-31. VOCs were not detected in the samples and total SVOC detections ranged from 0.174 mg/kg at TP-30 to 0.262 mg/kg at TP-31. Mirex ranged from 0.013 mg/kg at TP-31 to 0.10 mg/kg at TP-30. Vegetation within the seepage area is stressed either from shallow groundwater impacts for from anaerobic conditions resulting from high biological oxygen demand loading in the seepage area. This area is not a source of groundwater impacts, conversely the off-facility seep is a result of groundwater discharging to the near surface.

The off-facility seep area will be evaluated further during the PDI to assess the nature and extent of shallow groundwater and surficial soil impacts needed to design the remedial action in this area.

2.8 Natural Attenuation Evaluation

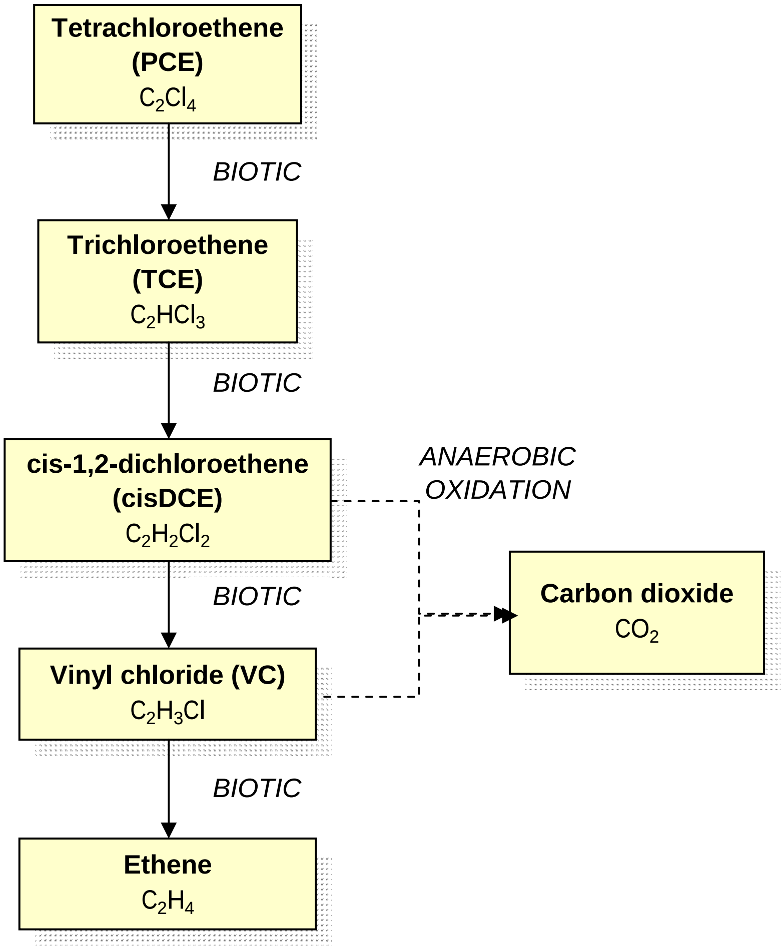
2.8.1 Degradation Chemistry

Aliphatic chlorinated compounds are subject to biodegradation by native bacteria under anaerobic (oxygen depleted) and aerobic conditions. These processes include reductive dechlorination, aerobic oxidation, anaerobic oxidation, and aerobic cometabolism. The most ubiquitous degradation process observed at sites impacted by chlorinated organic chemicals is anaerobic reductive dechlorination, in which molecular hydrogen reacts to replace chlorine atoms on a chlorinated ethene molecule, facilitated by bacteria which gain energy from the process. The degradation rates that can occur are meaningful for purposes of evaluating remedies for site restoration.

Chlorinated Compound Biodegradation Mechanism

There are five compounds in the “family” of chlorinated ethenes that are primarily included in the reductive dechlorination sequence. Tetra- or perchloroethene (PCE) and trichloroethene (TCE) are “parent” compounds that have been released to the environment due to their use in manufacturing processes. “Daughter” products are formed from the biodegradation of these compounds in the sequence shown below (e.g., Chapelle, 2001).

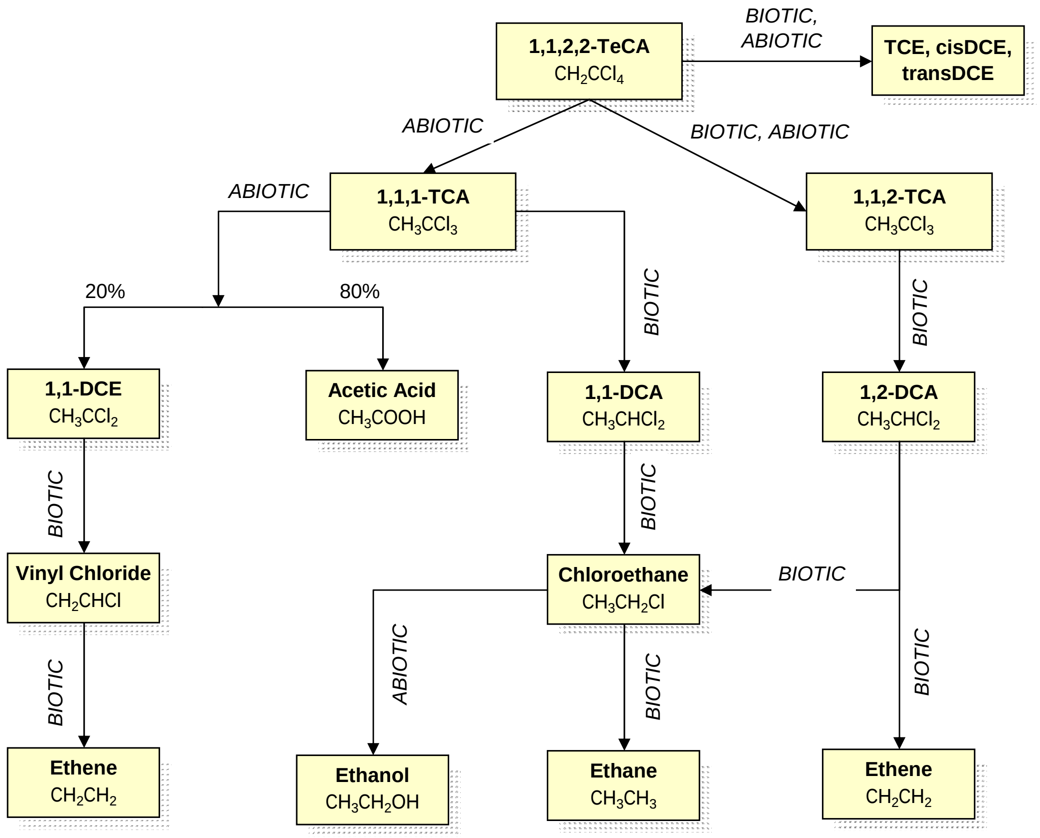
REDUCTIVE PATHWAY FOR THE TRANSFORMATIONS OF CHLORINATED ETHENES



Each compound contains one more hydrogen and one less chlorine atom than the previous compound in the chain, such that the final link in the chain, ethene (molecular formula C2H4), which is non-toxic, contains no chlorine.

The chlorinated ethanes, including 1,1,2,2-TeCA, 1,1,1-trichloroethane (1,1,1-TCA) and 1,2-DCA, can also degrade in the environment by both abiotic and biotic (i.e. biologically mediated) mechanisms as shown below (Vogel et al., 1987; Lorah, 2003; House, 2002):

REDUCTIVE PATHWAYS FOR THE TRANSFORMATIONS OF CHLORINATED ETHANES



The relative biotic and abiotic degradation rates are dependent on site conditions. The abiotic mechanism (specifically hydrolysis) that degrades 1,1,1-TCA results in production of acetic acid (80%) and 1,1-dichloroethene (20%) and published half-lives are on the order of 1 year (Montgomery, 2000; Schwarzenbach et al, 1993; Howard et al, 1991). 1,1-dichloroethene (1,1-DCE) degrades biotically to vinyl chloride, which may be oxidized or further degrade to ethene, depending upon the conditions. The biotic degradation pathway produces 1,1-dichloroethane (1,1-DCA), which breaks down biotically to chloroethane and subsequently ethane. Both the biotic and abiotic pathways can occur simultaneously.

Aromatic Compound Biodegradation Mechanisms

The biodegradation of petroleum hydrocarbons, including BTEX compounds, occurs through their use by microorganisms as primary substrates (sources of carbon and energy). During the metabolism process, electrons are transferred from the hydrocarbon to facilitate the release of energy. The hydrocarbon is therefore termed an “electron donor”. The process also requires an “electron acceptor” for the transferred electrons, as well as nutrients such as nitrate or phosphate. Typical electron acceptors are oxygen, nitrate, iron III, sulfate, and carbon dioxide, which are utilized preferentially in that order. Under some circumstances, manganese IV or chlorinated solvents may also be utilized as electron acceptors. The degradation of petroleum hydrocarbons occurs most effectively under aerobic (oxygen reducing) conditions, and reaction efficiency reduces significantly down the scale of electron acceptors.

The biodegradation of petroleum hydrocarbons also effectively occurs under anaerobic (particularly sulfate reducing and methanogenic) conditions (Chapelle, 2001), and is now becoming recognized that in terms of total mass removal, the more prevalent anaerobic degradation processes result in substantial mass removal. The degradation process is limited by the supply of electron acceptors, but since these are generally present in abundance in the natural environment, the biodegradation of BTEX hydrocarbons under anaerobic conditions typically proceeds to complete degradation to non-toxic by-products. Howard, et al., 1991 provide anaerobic half-lives for BTEX chemicals (e.g., benzene) of 112 to 730 days.

Chlorobenzenes

Chlorinated benzene compounds degrade similarly to chlorinated ethene compounds in groundwater systems. Anaerobic reductive dechlorination of chlorobenzenes is a potential pathway of degradation at the Site. In recent years, there have been a number of documented cases where anaerobic reductive dechlorination of chlorobenzenes (especially hexa- and penta-chlorobenzenes) has been observed. A microorganism known as *Dehalacoccoides* strain CBDB1 has been identified as utilizing chlorobenzenes for energy, and is capable of reductively dechlorinating all tetrachlorobenzenes, 1,2,3-trichlorobenzene, and 1,2,4-trichlorobenzene. (Adrian, 2000). According to one study, nitrifying conditions in groundwater can inhibit reductive dechlorination (Chapelle, 2001). Evidence has been documented regarding reductive dechlorination of chlorobenzenes under aerobic conditions (USEPA, 1998; Chapelle, 2001).

2.8.2 Historical Data Trends

Significant decreases in groundwater chemical impacts have occurred since at least 1992. Figures 2-30 to 2-32 present concentration trends in overburden well S-12 (located immediately adjacent to former Ponds 1 and 2), bedrock well PZ-6B-U (located closely downgradient of former Ponds

1 and 2), and bedrock well G-UBA (located in downgradient portion of the MKS plume), respectively. In S-12 (a source area well in the overburden that contained the highest chemical concentrations in the July 2003 sampling), decreases in total VOCs have occurred since 1992 as shown in Figure 2-30. Since 1995 the parent chlorinated aliphatic compounds PCE and 1,1,2,2-TeCA and the BTEX compound benzene, decreased 28% to 52%. The concentration of TCE, which may either be a parent compound or a daughter product of PCE and 1,1,2,2-TeCA to a lesser extent, increased slightly, and compounds present only as daughter products of biodegradation, cis-DCE, trans-DCE, and VINYL CHLORIDE, increased. The concentration of 1,2-DCA, which is typically a parent, but may be a daughter product, decrease 47%. These data trends indicate that reductive dechlorination is occurring, and that TCE and the other daughter compounds are being produced from the decay of parent compounds, resulting in levels of TCE that are approximately stable (it is being produced while also being degraded) while the subsequent daughter products increase in concentration. Eventually, the daughter products will also decrease in concentration as microbial processes accelerate[7]. The presence and amount of trans-DCE indicates that biodegradation of 1,1,2,2-TeCA is occurring, as this compound (trans-DCE) is normally only a small fraction of the concentration of cis-DCE, when degraded from PCE and/or TCE only. Benzoic acid is an intermediate breakdown product of certain BTEX compounds (Prenafeta-Boldú, et.al, 2002). Total VOCs decreased 69% from 1995, indicating a substantial decrease in chemical mass. Much of the decrease is attributable to the decrease in benzoic acid from 100,000 ug/L to 120 ug/L and the decrease in total VOCs and SVOCs excluding benzoic acid is over 14,000 ug/L, or 22%.

PZ-6B-U is a shallow bedrock well that contained the highest chemical concentrations in bedrock during the July 2003 monitoring event (see Figure 2-31). The parent chlorinated aliphatic compounds PCE, TCE, 1,1,2,2-TeCA, and 1,2-DCA and the BTEX compounds benzene and toluene, decreased 46% to 63% from 1995. The daughter products of biodegradation, 1,2-DCE[8] and VINYL CHLORIDE, also decreased in parallel with the decrease in parent compounds. Total VOCs and SVOCs decreased from approximately 302,000 ug/L to 178,000 ug/L indicating a substantial decrease in chemical mass. Other parent compounds either increased: chlorobenzene (420 ug/L to 600 ug/L) and 1,2-dichlorobenzene (12,000 ug/L to 19,000 ug/L),

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[7] Microbial processes can be accelerated through the technology called enhanced biodegradation where the limiting factors of the microbial process are identified (such as nutrient shortage) and then provided in sufficient volume to stimulate the biodegradation process (such as nutrient injection).

[8] In the 1996 data set, analysis was done for only total 1,2-DCE, the cis- and trans- isomers were not separated.

decreased: toluene (2,900 ug/l to 1,800 ug/L), or were below MCLs: xylene, ethylbenzene and chloroform.

Well G-UBA is an MKS well in the vicinity of the MFLBC bedrock valley, and has shown decreasing to stable overall trends since 1992 as shown on Figure 2-32. Increases have occurred of the breakdown product of biodegradation vinyl chloride and of 1,2-dichlorobenzene. The concentration of 1,2-DCB was relatively low in comparison with its MCL of 600 ug/L.

The molar ratio of daughter to parent compounds increases sharply with distance from the source (Table 2-2) providing further evidence of degradation. The wells shown, PZ-6B-U, PZ-6B-L, D-15, D-8 and G-UBA are all located in the MKS within the extent of the primary chemical plume. Although they are screened at somewhat different elevations, the trend of increasing daughter products to parent compounds is valid, regardless of whether a well is within the “heart” or centerline of the chemical plume. The data indicate that degradation products are increasing in relation to parent compounds with distance from the source, and this is occurring whether along a centerline or in a more fringe location.

The significance of the spatial trends in the concentration data were further explored through analytical modeling of the groundwater plume, using the USEPA BIOCHLOR model for chlorinated ethenes, and the equivalent formulation for other compounds published by Domenico and Schwartz (1990). The following sections describe the results of these analyses, and complete details are provided in Appendix B.

2.8.3 Modeling of Biodegradation along the Primary Flow Path

Chlorinated Ethene Modeling

The biodegradation of PCE and TCE was modeled using the USEPA fate and transport model BIOCHLOR (USEPA, 2000). BIOCHLOR simulates natural attenuation of chlorinated solvents in groundwater using one-dimensional advection, three-dimensional dispersion, adsorption, and biotransformation via reductive dechlorination (the dominant degradation process at most chlorinated solvent sites). The model requires the user to input site-specific source area dimensions and concentrations, hydrogeologic parameters, and chemical-specific adsorption parameters[9]. The measured downgradient concentrations are then “fitted” to the model output by

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[9] Input data are specified in Attachment B, based upon the site-specific data collected in the RI and published literature.

varying the half-lives of the contaminants. In this way, the effects of biodegradation, as distinct from other abiotic attenuation processes such as dispersion, can be assessed. A porous media approximation for modeling of contaminant plume in the MKS is assumed. On a macro scale, (i.e., on a plume scale), contaminant transport in fractured rock can be approximated using porous media models (National Research Council, 1996). The structure of the MKS, including bedding plane partings and sparse vertical joints, is consistent with an approximation to a porous media model on a macro scale. It is also evident from the consistent, regular potentiometric level data of the MKS that extreme heterogeneity is not present at a macro scale.

The groundwater hydraulic parameters chosen are discussed in Section 2.5.4. A vertical dispersivity value was incorporated to include the effect of vertical dispersion consistent with the conceptual source model in which chemicals are introduced to the upper portions of the bedrock and spread vertically downgradient along the groundwater flow path. This is a conservative assumption for the prediction of biodegradation rates; however, the sensitivity of the downgradient concentrations is low for values of vertical dispersivity lower than 0.001. In the absence of site-specific data, the fraction of organic carbon is estimated within a typical range to be 0.0005 (USEPA, 2000). A source depth of 20 feet was estimated given that the vertical interval spanned by PZ-6B-U [32 to 37 feet below ground surface, (ft bgs)] is substantially more impacted than by either PZ-6B-M (total PCE, TCE, cisDCE, and vinyl chloride of 659 ug/L; Golder Associates, 1997) or PZ-6B-L. The top of the MKS is present in the PZ-6B location at 22 bgs, while well PZ-6B-M is screened approximately 30 feet lower from 51 ft to 56 ft bgs, and thus a 20 foot vertical interval was estimated as the most impacted interval. In addition, non-detected compounds are assigned a value of half their detection limit.

The modeling was conducted using the 2003 data for bedrock monitoring wells PZ-6B-U, D-15, D-8, G-UBA, and the D-VF2/D-VF3 well nest, which represent concentrations potentially along the centerline of the plume from the source area towards the MFLBC, at distances of 200 ft, 770, 900, and 1140 ft. The simulation output (Appendix B) shows the final fit to the site data. Well PZ-6B-U (screened from 32-37 ft bgs) concentrations were matched at the source (Distance = 0 ft), while the concentration curve for each compound was matched to the data at well G-UBA. The model over predicts the concentrations at well D-15, and to a lesser extent, at D-8, suggesting that degradation rates may be faster in these areas, or that wells D-8 and D-15 are located somewhat off the centerline or below the plume. Because the groundwater flow turns to the north at the MKS/overburden contact location (Figure 2-13), D-8 is likely located off of the centerline, in the “trailing” portion of the plume. The total VOCs data (Figure 2-16) also indicates that G-UBA is located in the plume centerline while D-8 is slightly to the south, and therefore the degradation curves have been fitted to G-UBA and not to D-8.

The downgradient portion of the plume, as indicated by the D-VF2/D-VF3 well nest, is located within the unconsolidated MFLBC buried valley, in which hydrogeologic conditions are different, as discussed in the Site Conceptual Model. Substantial dilution is occurring in this regime, which is not specifically modeled by Biochlor, since the model assumes uniform hydrogeologic conditions. Therefore, the non-detected values in D-VF2/D-VF3 are presented as reference points, but not used for fitting the degradation curves.

The model results indicate that biodegradation plays a significant role in the reduction and elimination of contaminants along the groundwater flow path. The half-lives derived from the model[10] (Table 2-3) further confirm the occurrence of complete[11] natural biodegradation of the chlorinated ethenes, based upon comparison to published values in Howard et al. (1991).

An additional modeling scenario was considered, upon request from Ohio EPA, in which the source term would be represented by deep MKS well PZ-6B-L (screened from 1,108-1,113 feet mean seal level) instead of the more impacted PZ-6B-U, as some of the MKS monitoring wells are screened deeper than PZ-6B-U. It is noted that although the most realistic model to construct is one in which the maximum concentrations along a connected flow path are included, the source term in this scenario was represented by PZ-6B-L rather than the more impacted PZ-6B-U. The setup results in an unrealistic set of data, e.g., a downgradient well, D-15 contained a higher concentration of 1,2-dichlorobenzene (1000 ug/L) than the source well (420 ug/L in PZ-6B-L). Other chemicals reflected an unrealistic setup in that concentration levels were similar to, or higher, than the source concentrations, resulting in unrealistically low or negative degradation rates and generally unrealistic relationships.

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[10] The formulation of the biodegradation and retardation terms in BIOCHLOR differs from those in Domenico and Schwartz (1990) and in most of the published literature (e.g. Howard (1991)) in that the half-life terms are reduced by a factor equal to the retardation. In order to provide consistency between formulations, the BIOCHLOR half-life terms are presented without the retardation factor modification.

[11] It is significant that complete biodegradation is occurring resulting in the non-toxic end-product ethene.

2.8.4 Modeling of Other VOCs

To evaluate the degradation of other VOC compounds, the equivalent advection-dispersion-degradation model formulation of Domenico and Schwartz (1990) was employed, which consists of a steady state flow model with a time-dependent transport model[12]. The same physical input parameters were utilized as for BIOCHLOR and once again the biodegradation rates were adjusted to fit the downgradient site data, using well G-UBA. Appendix B contains model output graphs (both BIOCHLOR and Domenico and Schwartz) for all the compounds listed in Table 2-3. In the 2-D-Domenico and Schwartz model output graph, the upper curves are the model formulation *without* the biodegradation term; the lower curves contains the biodegradation term. Once again, it is evident that the concentration-distance data indicates significant evidence of natural biodegradation, and the resulting half-lives (Table 2-3) are consistent with the published values in Howard et al. (1991).

2.8.5 Geochemical Indicators

Biodegradation processes that transform organic compounds also utilize or produce certain inorganic constituents, and comparison of these “geochemical indicators” to background concentrations provides useful additional insight into the processes occurring in an organic chemical plume. Reductive dechlorination is the most important process for the natural biodegradation of the more highly chlorinated organic chemicals, and occurs under mildly reducing anaerobic conditions (reduction of electron acceptors nitrate and ferric iron). Complete reductive dechlorination of the less chlorinated solvents (cis-DCE, vinyl chloride) to ethene occurs under anaerobic sulfate-reducing and methanogenic conditions. The measured site data (Table 2-4) reveal that the bedrock conditions are anaerobic (oxygen concentrations = 0.0 mg/L) and oxidation-reduction potential (ORP) values range from -73 to -270 mV, indicating levels that are in the optimal range for complete reductive dechlorination to ethene (Weidemeier et al., 1997; USEPA, 1998). Background ORP levels in the bedrock are 21 to 53 mV, indicating that the strongly reducing conditions are coincident with the natural biodegradation processes within the plume. The reducing conditions are characterized by, at a minimum, nitrate and iron reduction. Sulfate data is variable, and may not be a significant electron acceptor at the site. Methane data indicate an increase in methane along the flow path (80 ug/L in PZ-6B-U, and 300 ug/L and 740 ug/L in G-UBA and D-8, respectively).

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[12] Note that a typographical error appears in Domenico and Schwartz (1990), equation (17-22), the final term contains α_z, rather than α_x.

The elevated chloride concentrations within the plume (ranging from 8 to 155 mg/L) with the highest concentrations centered about the source area (e.g., PZ-6B-U contains 111 mg/L of chloride) provide further confirmation that dechlorination is occurring (background chloride is <1 mg/L). Geochemical data measured during sampling is provided in Appendix C.

In summary, several complementary lines of evidence, in accordance with USEPA guidelines, are present indicating that natural biodegradation of all key groundwater contaminants is occurring at the site at robust rates. As a result, the plume is contained (or stable) and is being naturally restored at the present time. These conclusions are important to the evaluation of remedial alternatives discussed later in this FS, since it is appropriate to give preference to approaches that are synergistic, rather than antagonistic, to the currently favorable natural conditions.

3.0 DEVELOPMENT OF REMEDIAL ACTION OBJECTIVES

3.1 Endangerment Assessment Results

3.1.1 Potential Human Health Risks

The Final Endangerment Assessment for the Nease Chemical Site (Endangerment Assessment or EA; Environ, 2004) considered the current and future use scenarios described below. It should be noted that only the potential exposures associated with media included in OU-2 are discussed herein. The OU-2 media include on-facility and off-facility groundwater and soil, including surface soil within the State Route 14 drainage ditch. Feeder Creek and MFLBC media (surface water, sediments, fish, beef, and milk) are included in OU-3.

Current Use Scenario - On-Facility Locations

- Current on-facility trespasser exposures to Chemicals of Potential Concern (COPCs) in the air and soil were evaluated for several pathways. These include incidental ingestion of soils, dermal contact with soil, inhalation of wind blown soil dust, and inhalation of outdoor air.

Current Use Scenario - Off-Facility Locations

- Current off-facility industrial worker exposures to COPCs in air, soil, and groundwater were evaluated for several pathways. These include incidental ingestion of soils, dermal contact with soil, inhalation of air above the off-facility seep (west of the Crane-Deming building), and inhalation of indoor air.

- Current off-facility residential exposures to COPCs in soil and groundwater were evaluated for several pathways. These include incidental ingestion of soils including dermal contact with soil, inhalation of wind-blown soil dust, inhalation of outdoor air, inhalation of indoor air, ingestion of sediments, dermal contact with sediments, ingestion of game, and ingestion of home-grown vegetables.

Future Use Scenario – On-Facility Locations

- Future on-facility trespasser exposures to COPCs are the same as those under the current scenario.

- Future on-facility industrial worker exposures to COPCs in air, soil, and groundwater were evaluated for several pathways. These include ingestion of groundwater, dermal contact with groundwater while showering, inhalation of indoor air while showering, incidental ingestion of soils, dermal contact with soil, and inhalation of indoor air.

- Future on-facility construction worker exposures to COPCs in air, surface soils, and subsurface soil (up to 20 feet below ground surface) were evaluated for four pathways. These include incidental ingestion of soils, dermal contact with soil, inhalation of soil dust due to construction activities, and inhalation of organic vapors due to construction activities.

- Future on-facility residential exposures[13] to COPCs in air, groundwater, and soils were evaluated for several pathways. These include ingestion of groundwater, dermal contact with groundwater while showering, inhalation of indoor air while showering, incidental ingestion of soils, dermal contact with soil, inhalation of windblown soil dust, inhalation of indoor air, inhalation of outdoor air, and ingestion of homegrown vegetables.

Future Use Scenario – Off-Facility Locations

- Future off-facility worker exposures to COPCs in air, soil, and groundwater were evaluated for several pathways. These include ingestion of groundwater, dermal contact with groundwater while showering, inhalation of indoor air while showering, incidental ingestion of soils, dermal contact with soils, inhalation of air above the groundwater seep, and inhalation of indoor air.

- Future off-facility residential exposures to COPCs in air, groundwater, soils and sediments were evaluated for several pathways. These include ingestion of groundwater, dermal contact with groundwater while showering, inhalation of indoor air while showering, incidental ingestion of soils, dermal contact with soil, inhalation of wind-blown soil dust, inhalation of outdoor air, inhalation of indoor air, ingestion of and dermal contact with surface soil[14] in the State Route 14 drainage ditch, ingestion of game, and ingestion of home-grown vegetables.

Summary of Health Risks

The EA presented two risk calculations based on Reasonable Maximum Exposures (RMEs) and Central Tendency Exposures (CTEs). The RME represents the most conservative "high end" exposures as defined by USEPA, "exposure above about the 90th percentile of the populated distribution" (USEPA 1995b). The RME is further defined as the highest possible exposure that is reasonably expected to occur and, as such, incorporates several conservative default exposure assumptions. The CTE risk calculations generally reflect the central estimates of exposure or dose, and may be based on either the arithmetic mean exposure or the median exposure. USEPA's acceptable risk range is 1E-04 to 1E-06[15] for potential carcinogenic risks and a hazard index equal to or less than one for potential non-carcinogenic risks.

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[13] As noted previously, the site is zoned for industrial purposes and future residential exposures can be precluded by Institutional Controls

[14] The EA referred to surface soil in drainage ditches as sediments

[15] In the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) (40 CFR Part 300), USEPA states that" "For known or suspected carcinogens, acceptable exposure levels are generally concentration levels that represent an excess upper bound lifetime cancer risk to an individual between 10^{-4} and 10^{-6} using information on the relationship between dose and response."

The following paragraphs and Table 3-1 provide a summary of the risk evaluation for each of the receptors and exposure scenarios listed above for the current and hypothetical future use scenarios associated with OU-2.

Current Use Scenarios – On-Facility and Off-Facility Locations

None of the current exposure scenarios resulted in risks that exceed USEPA's acceptable range.

Future Use Scenarios – On-Facility Locations

Trespassers

Potential risks to an on-facility trespasser result primarily from the presence of mirex and manganese in surface soil. As noted in the Endangerment Assessment, the levels of manganese measured in soil are consistent with literature background levels. As shown in Table 3-1, the calculated potential carcinogenic risk and non-carcinogenic risks for the on-facility trespasser are within the USEPA's acceptable range.

Industrial Worker

Potential risks to future on-facility industrial workers, as discussed in Chapter VIII, Section C1b of the Endangerment Assessment, result primarily from exposure to volatile organic chemicals in groundwater (primarily PCE, benzene, and 1,1,2,2-TeCA) and, to a lesser extent, mirex. The exposure scenario assumed that on-facility groundwater would be used for drinking and bathing. As shown in Table 3-1, the potential carcinogenic risks from groundwater exposures are greater than 1E-04 for both the RME and CTE calculations. Additionally, the potential HIs from groundwater exposures for both the RME and the CTE calculations exceed unity. Among the other pathways, indoor air exposure results in potential risks that exceed USEPA's acceptable range due to 1,1,2,2-TeCA, benzene, and PCE volatilizing from groundwater. Exposures to surface soil do not result in calculated carcinogenic or non-carcinogenic risks exceeding USEPA's acceptable range.

Construction Worker

Potentially unacceptable non-carcinogenic risks to the future on-facility construction worker are primarily associated with inhalation of construction dust containing manganese, vapor inhalation due to 1,2-DCA, 1,1,2,2-TeCA, benzene, chlorobenzene, PCE, and mirex in subsurface soil, and ingestion of soil due to mirex and iron. As indicated in the EA, levels of manganese and iron detected in on-facility samples are comparable to literature background levels. As shown in Table 3-1, the calculated potential carcinogenic risks are within USEPA's acceptable range.

Resident

Potential carcinogenic and non-carcinogenic risks exceeding USEPA's acceptable range for the future on-facility resident primarily result from direct contact with soils, inhalation of indoor air, and ingestion and inhalation of vapors from groundwater. The primary chemicals contributing to the risk from indoor air exposures are PCE, TCE, and benzene. The primary chemicals contributing to the risk from groundwater exposures are PCE, 1,1,2,2-TeCA, and mirex. Ingestion of soil results in risks exceeding USEPA's acceptable range primarily due to arsenic and mirex. The levels of arsenic measured in soils are consistent with literature background levels.

Off-Facility Locations

Industrial Worker

Potential carcinogenic and non-carcinogenic risks exceed USEPA's acceptable range for the future off-facility industrial workers as a result from exposure to volatile organic chemicals (primarily vinyl chloride, 1,1,2,2-TeCA, PCE, 1,2-DCE, and benzene) in groundwater via ingestion, dermal contact, and vapor inhalation during showering. No other exposures result in potential carcinogenic or non-carcinogenic risks above USEPA's acceptable range.

Resident

Calculated potential carcinogenic and non-carcinogenic risks exceeding USEPA's acceptable range are primarily due to ingestion of groundwater (arsenic, iron and manganese). However, it is important to note that the levels of arsenic, iron, and manganese that contribute to these potential risks are consistent with literature levels. None of the other pathways resulted in risks (carcinogenic and non-carcinogenic) exceeding USEPA's acceptable range.

Wastewater Treatment Plant Sludge Cells

As stated in the EA, limited characterization of mirex concentrations in the historical sludge beds and associated areas at the City of Salem Waste Water Treatment Plant was conducted as part of the RI. While the limited characterization indicates that no unacceptable risks are presented by these sludges under reasonable exposure scenarios, the potential for higher concentrations of mirex to be present in these materials is unknown. Assuming mirex-impacted materials exist, and they remain at depth, then no human receptors would be exposed to these materials and no risks would be anticipated.

Nonetheless, since there is no mechanism currently in place to ensure that intrusive activities in this area will not occur (thereby creating potential exposure pathways), the following will be considered during the PDI and detailed design:

- ROC and other parties engaged in future remedial activities will work with the City of Salem to ensure that the WWTP area is appropriately controlled, such that no exposures occur in the event of future intrusive activities occur at the WWTP and its environs.
- If control of exposures to these sludges cannot be guaranteed, then a more thorough characterization of these areas will be necessary in order to quantify the risks to future receptors resulting from potential exposures to mirex in these materials. This characterization could include additional information on disposal practices at the WWTP or further sampling and analysis of the former sludge bed areas.

3.1.2 Screening Ecological Risk Assessment (SERA)

The following discussion addresses potential ecological risks presented in the EA associated with OU-2 media (fill/sludge in the former ponds, soil and surface soil in Route 14 drainage ditch)[16]. The RA considered chemicals that were detected during RI (Final RI Report; RNC, 1996) and in the supplemental studies conducted in the State Route 14 drainage ditch (Golder Associates, Inc. 1996b). It is important to recognize that the data used in the RA is eight to thirteen years old and therefore may not reflect the current conditions as natural attenuation processes may have altered the historically measured concentrations. In addition to potential natural changes, surface soil has been physically disturbed in some areas as a result of interim remedial measures at the property as described in Section 2.2. Consequently, the current surface soil chemical concentrations and resulting risk estimates may require reassessment during the PDI.

Risks to six upper trophic wildlife receptors (four mammals and two birds) were calculated based on an area-wide assessment using the mean chemical concentration in the various media. This assessment conservatively assumed that each receptor acquire their entire diet from the on-

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[16] Feeder Creek is not part of OU-2 and will be addressed separately.

property area[17]. Hazard quotients (i.e., the chemical concentration in the medium compared to the corresponding toxicological benchmark) greater than one were calculated, indicating the potential for risk (adverse ecological effect). Exceedances of a hazard quotient of one were calculated for all receptors exposed to mirex. Other chemicals resulted in hazard quotients at or about one based on the lowest observed adverse effect level (LOAEL) analysis.

Potential risks to lower trophic level biota were assessed on a sample location by sample location basis comparing the measured concentration of a given chemical to the toxicologic benchmark for that media. The ecological assessment for OU-2 media concluded that although a number of chemicals were detected in surface soil, the risks are very low to negligible for most chemicals. Mirex however, was detected at the highest frequency and concentration although there are no toxicological benchmarks for these chemicals and receptors. Therefore, the mirex-related risks to soil dwelling lower trophic level biota were not predicted.

The highest occurrences and concentrations of mirex are in the on-facility test pit surface soil samples. The off-facility soils provide minimal risk given their relatively low concentrations. The State Route 14 samples are from drainage ditch surface soil that runs along the highway and is therefore exposed to asphalt runoff and automobile emissions and a number of constituents were observed[18]. However, its habitat for semi-aquatic species is marginal in comparison to other areas (e.g., Feeder Creek) due to its maintained mowed vegetation conditions and infrequent flow only during storm events.

3.1.3 Summary of Potential Site Risks

The Final Endangerment Assessment considered several current and future use scenarios and receptors. The following presents a summary of the potential risks associated with these scenarios for OU-2 groundwater, soil and drainage ditch surface soil. Table 3-1 provides a summary of potential site risks.

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[17] This assumption very likely results in an overestimation of exposure and risk for the hawk, fox and raccoon. The 75 acre on property area is considerably smaller than typical home ranges for these receptors. In addition, the on-property habitat is not prime habitat for these wider ranging species and thus these species would spend only a portion of their time on the property.

[18] These chemicals include several polyaromatic hydrocarbons (PAHs) such as anthracene, benzo(a)pyrene, benzo(g,h,i)perylene, benzo(k)fluranthene, dibenzo(a,h,i)anthracene, fluranthene, indeno(1,2,3-cd)pyrene, phenanthrene, and pyrene, along with mirex, arsenic, cadmuim, chromium, iron, lead, manganese, mercury, silver, and zinc.

- None of the current use scenario exposure pathways resulted in potential risks exceeding USEPA's acceptable risk range;

- None of the calculated potential risks for the future trespasser exceed USEPA's acceptable risk range;

- Exposures to groundwater (primarily VOCs) is responsible for the majority of the unacceptable potential risk calculated for the hypothetical future resident and industrial worker;

- Unacceptable risks to the construction worker are also due to exposures from the inhalation of construction dust and vapors and incidental ingestion of soil[19];

- None of the calculated potential risks for industrial worker exposure to surface soil exceed USEPA's acceptable risk range;

- Concentrations of arsenic, manganese, and iron, which are major contributors to some of the calculated potential risks, are consistent with literature background; and,

- Hazard quotients exceeding one were calculated for several upper trophic wildlife receptors as a result of exposure to mirex in surface soil including surface soil in the Route 14 drainage ditch. However, it was conservatively assumed that these receptors acquire their entire diet from the on-property area. While in reality the home range of these receptors is substantially larger than the on-property area of the site. Receptors with small home ranges, such as the shrew, vole, and marsh wren have hazard quotients above the hazard index of 1.

3.2 ARARs and TBCs

Section 121(d) of CERCLA requires that remedial actions at CERCLA sites comply with legally applicable or relevant and appropriate cleanup standards, standards of control, and other substantive environmental protection requirements, criteria or limitations promulgated under Federal or State law, which are collectively referred to as "ARARs", unless such ARARs are waived under CERCLA § 121(d)(4). "Applicable" requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria or limitations promulgated under Federal or State law that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site. "Relevant and appropriate" requirements are those requirements that, while not legally "applicable", address problems or situations sufficiently similar to those encountered at the site that their use is well suited to the particular site. Only those State standards[20] that are

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[19] Note that exposures to pond sludges have not been included in the construction worker assessment.

[20] The Ohio EPA provided a generic list of potential ARARs which is included in Appendix H of this FS.

promulgated, are identified by the State in a timely manner, and are more stringent than Federal requirements may be applicable or relevant and appropriate. ARARs may relate to the substances addressed by the remedial action (chemical-specific), to the location of the site (location-specific), or the manner in which the remedial action is implemented (action-specific).

In addition to applicable or relevant and appropriate requirements, the lead agency may, as appropriate, identify other advisories, criteria, or guidance to be considered for a particular release. The "TBC" category consists of advisories, criteria, or guidance that were developed by USEPA, other federal agencies or states/territories that may be useful in developing CERCLA remedies.

The following discussion focuses on chemical-specific ARARs and “TBC” information for the Site which are considered when establishing Preliminary Remediation Goals (PRGs). Location-specific and action-specific ARARs and TBCs are discussed in Section 6 in the detailed evaluation of each OU-2 alternative.

Chemical-Specific ARARs and TBCs

Chemical-specific ARARs and TBCs represent health or risk-based concentration limits in various environmental media for specific chemicals. State standards are considered ARARs only where they are promulgated in adopted regulations and are more stringent than the Federal ARAR-equivalent. As such, where equivalent Federal and State ARARs exist, only the Federal ARARs are cited. The following chemical-specific ARARS and TBCs have been identified for the OU-2 media:

Federal Chemical Specific ARARs or TBCS

- National Primary Drinking Water Standards (40 CFR Part 141) establish primary MCLs for public water systems measured at the tap based on protection of health and consideration of technical and economic feasibility. The Federal MCLs are considered PRGs for the groundwater restoration objective and are listed on Table 3-2 for the COPC identified in the EA.

- USEPA Soil Screening Levels (SSLs) (USEPA 1996a) are unpromulgated and as such are not ARAR but are classified as TBC. As stated in the USEPA Soil Screening Guidance: User’s Guide (USEPA, July 1996) the “SSLs are not national cleanup standards. SSLs alone do not trigger the need for a response action or define ‘unacceptable’ levels of contaminants in soil.”

State Chemical Specific ARARs

- Ohio Primary Drinking Water Standards (OAC 3745-81) establish primary MCLs for public water systems. The Ohio MCLs are considered PRGs for the groundwater restoration objective and are listed on Table 3-2 for the COC identified in the EA.

- Ohio has promulgated generic direct contact soil standards (OAC 3745-300-08) as part of their Voluntary Action Program (VAP). These generic standards are listed as either risk derived or are based on saturation. Since a site-specific risk assessment was conducted, these generic direct contact numbers are not considered PRGs and the results of the EA are used to establish remedial objectives. In addition, Ohio has other nonpromulgated soil cleanup guidance (Ohio EPA, 2002) for the VAP which are not ARAR.

3.3 Preliminary Remediation Goals

PRGs are developed from the results of the risk assessment and from chemical specific ARARs discussed above. The PRGs consist of numerical targets for the COPCs (identified in the EA) in specific media and are intended to guide the development and evaluation of remedial alternatives. PRGs have been established for OU-2 groundwater and surface soil including surface soil in the Route 14 drainage ditch as discussed below. Although this FS focuses on OU-2 remedial goals, at the conclusion of the remedial process for the Site, Site-wide remedial goals will be achieved such that future receptors are protected.

3.3.1 PRGs for Groundwater

The USEPA MCLs or the Ohio MCLs (where more stringent than the USEPA MCLs) listed in Table 3-2 and are considered PRGs for OU-2 groundwater. It is recognized that MCLs are provided for individual constituents and may not take into account the cumulative risks posed by mixtures of constituents. Completion of groundwater remedial action at the site will require an evaluation of the cumulative residual risk to determine if appropriate final cleanup levels have been reached.

3.3.2 PRGs for Soil

Since there are no promulgated soil remediation standards, the PRGs for OU-2 soils have been developed based on the results of the EA. In particular, PRGs for surface soil (including surface soil in the Route 14 drainage ditch) have been based on potential ecological exposures to mirex, since ecological receptors are the most sensitive and since predicted current and future industrial worker and trespasser exposures to surface soil do not result in risks outside of USEPA's acceptable risk range. The following presents the approach used to develop a PRG for mirex in surface soil (including drainage ditch surface soil).

The PRG for mirex was determined by back calculating a soil concentration that would result in a hazard quotient of one based on food chain modeling. Food chain modeling methods are described in detail in Chapter X of the EA. Additionally, hazard quotients and associated uncertainties are also discussed in Chapter X of the EA. For some wide-ranging receptors, specifically the raccoon, red fox, and the red-tailed hawk, the receptor's home range plays an important role in the calculation of hazard quotients. Calculations that do not include consideration of home range assume that the receptor obtains their entire diet from the on-property area and that all of the diet contains the COPC. Both of these assumptions are unrealistic particularly since the overall goal is protection of ecological receptor populations, rather than individuals. The home range for the raccoon and red fox is approximately 504 ha (1245 acres) and for the red-tailed hawk is approximately 876 ha (2,165 acres) based on the Ohio EPA Ecological Risk Assessment Guidance Document dated February 2003 (Ohio EPA, 2003).

The PRG calculations address the home ranges of each receptor in the following ways: 1) they include the percentage of the receptor's home range that is comprised of surface soil potentially containing mirex within the on and off-facility areas; and 2) they include floodplain soil potentially containing mirex within the receptor's home range. Surface soil containing mirex is essentially limited to the on-facility area, which covers approximately 43 acres[21], and approximately 1.5 acres of the on-facility area is currently covered with pavement or buildings which effectively eliminate the ecological pathway. The remaining on-facility area available to ecological receptors is therefore approximately 41.5 acres, which represents 3.3 % of the home range for the raccoon and red fox and 1.9% of the home range of the red-tailed hawk. It is important to note that the percentages of the home range will be further reduced as substantial portions of the on-facility area will be covered with clean materials as part of the remedial action. No adjustments to the dietary composition for home range were made for less wide-ranging receptors such as the meadow vole, short-tailed shrew, and march wren.

To account for possible ingestion of floodplain soil within the wider ranging receptors,' home ranges specifically the raccoon, red fox, and red-tailed hawk, the floodplain area of the MFLBC

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[21] Mirex was not detected in surface soils (<6 inches bgs) in the vicinity of the Crane-Deming building.

within the home range of each receptor was determined, as shown on Figure 3-1. The total area of floodplain located within the home range of the raccoon and red fox is approximately 24.5 acres, which represents approximately 2% of their home range. The red-tailed hawk has a home range that could include 52.5 acres of floodplain soil, which is approximately 2.5% of the home range. The mirex concentration detected in floodplain soils within the home range was used in the food chain modeling. Data from RI samples SS95-08A-01 through SS95-08A-3 were used to calculate the concentration for the raccoon and red fox and resulted in an average (arithmetic mean) floodplain soil concentration of 59.3 ug/kg[22]. For the red-tailed hawk the same data points as well as RI samples SS95-08B-01 through SS95-08B-03 were used, resulting in an average concentration of 35.4 ug/kg. Using these concentrations and the corresponding areas, a back calculation of the on-facility soil concentration that would result in a hazard quotient of one was performed as presented in Appendix D.

Table 3-3 below shows the on-facility soil concentrations resulting in a hazard quotient of one based on the No Observed Adverse Effect Level (NOAEL) and the LOAEL for each receptor including consideration of home range, as described in the above paragraph. Based upon this analysis, ROC believes a mirex PRG in the range of 930 ug/kg to 3,700 ug/kg for on-facility surface soil is considered to be appropriate at this Site for all receptors, including short and wide home range receptors, given the conservationess of the calculations particularly since the selected remedial action will include additional cover. This level assures no material effect on all the identified receptors. Further refinement of this goal may be appropriate as part of the PDI, for example, to consider portions of the on-facility area that will be covered (i.e., not available for ecological exposures) by the selected remedy.

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[22] For non detect results, one half the detection limit was used in calculating the average concentration.

Table 3-3
ON-FACILITY SOIL CONCENTRATION (UG/KG) RESULTING IN A HAZARD QUOTIENT OF ONE

Chemical	Meadow Vole (100%)	Short-tailed shrew (100%)	Raccoon (3.3%)[1]	Red Fox (3.3%)	March Wren (100%)	Red-tailed hawk (1.9%)
NOEAL BASED	2,935	186	2,600	1,220	2,150	270,000
LOEAL BASED	14,675	930	13,000	3,700	10,750	1,350,000

[1] Raccoon habitat can vary greatly in size. The Ohio EPA Ecological Risk Assessment Guidance does not specify a home range for raccoons, so the value reflected in Table 3-3 is an extrapolation based on the home range of the red fox. The extrapolation is consistent with Chapter 10 of the Endangerment Assessment (Environ 2004), which discusses raccoon home ranges of "several 100 hectares". For comparison purposes, a conservative home range of 156 hectare (385 acres) was also evaluated (based on Stuewer 1943 as cited in USEPA's "Wildlife Exposure Handbook" (December 1993)). This home range would result in a NOEAL based soil concentration of 790 ug/kg and a LOEAL based soil concentration of 3,950 ug/kg. Given the uncertainties of raccoon habitat size, this comparison supports the recommended PRG.

3.4 Established Remedial Action Objectives

Based on the CSM presented in Section 2.0, the results of the EA presented in Section 3.1, and the PRGs presented in Section 3.3, the following RAOs have been established for OU-2

RAO 1 - Mitigate[23] Future Releases From and Potential Exposures to COPC Contained Within Former Ponds 1 and 2.

This objective includes two major components as follows:

- Mitigate future releases of chemicals contained in former Ponds 1 and 2 fill/sludge to shallow overburden and MKS groundwater; and,
- Mitigate direct contact and inhalation exposures to chemicals contained within fill/sludge in former Ponds 1 and 2.

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[23] For the purposes of this section "Mitigate" and "Mitigation" refer to remediation to Site-specific standards to achieve acceptable risk goals. These standards and goals will be further defined in future Site-related documents.

RAO 2 - Mitigate Future Exposures to COPC Contained Within Former Ponds 3, 4, and 7 Fill/Sludge

The primary component of this objective is to mitigate ecological exposures to mirex in surficial materials within former Ponds 3, 4, and 7. In addition, while former Ponds 3, 4, and 7 are currently stabilized by soil covers and/or vegetation, a component of this RAO includes providing further stabilization, where needed, to mitigate potential future erosion. An objective for reducing infiltration into former Ponds 3, 4, and 7 is not included in this RAO due to the lower chemical mass (particularly at depth), the substantial thickness of low permeability till underlying the former ponds, and the lack of impacts to shallow groundwater downgradient of former Ponds 3, 4, and 7 as described in the Section 2.3.3 of the CSM. However, further assessment of groundwater impacts downgradient from former Ponds 4 and 7 will be conducted during the PDI to assess whether these ponds are a source of groundwater impact (see Section 5.3). The scope of the PDI activities to address this issue will be developed in conjunction with the Agencies.

RAO 3 - Mitigate Shallow Groundwater Discharges

There are two components of this RAO that address shallow groundwater, as follows:

- Mitigate potential eastern shallow groundwater impacts; and,
- Mitigate localized shallow groundwater impacts close to southern property boundary.

RAO 4 - MKS Groundwater Receptor Protection/Restoration

The overall long-term objective for MKS groundwater is restoration to MCLs. Where MCLs do not meet Site risk goals, calculated cumulatively alternate groundwater cleanup objectives will be defined in future Site-related documents. There are no current uses of groundwater (on- or off-property) and RAO-5 below addresses potential on-property uses.

RAO 5 – Protect On-Property Residential and Groundwater Receptors

This objective is intended to ensure that residents do not come into contact with impacted soil or groundwater. The mechanism to achieve this objective will be placement of institutional controls in the form of deed restrictions that will eliminate complete exposure pathways to impacted soil or groundwater by prohibiting residential use of the property and potable use of groundwater until the residential and groundwater remedial goals are achieved.

RAO 6 - Mitigate Future Worker and Ecological Exposures to Soil

The EA identifies potentially unacceptable risks associated with exposure to COPC in soils for the industrial worker and construction worker scenarios. These risks were associated with exposure pathways related to indoor air, incidental ingestion and dermal contact with soil, inhalation of construction vapors and construction dust. As discussed above, potential adverse ecological impacts from exposures to mirex in surface soil (including surface soil in the Route 14 drainage ditch) also requires mitigation.

4.0 DEVELOPMENT AND SCREENING OF TECHNOLOGIES

4.1 General Response Actions

General Response Actions (GRAs) were identified that address the RAOs presented in Section 3.0 by either reducing the concentration of chemical impacts or reducing the likelihood of exposures to impacted media. The following GRAs were identified for the Site:

- No action;
- Institutional controls;
- Containment;
- Removal/collection;
- In-situ treatment;
- Ex-situ treatment; and,
- Disposal/discharge.

Remedial technologies and process options associated with each of the GRAs were subsequently identified and screened as discussed below.

4.2 Screening of Technologies and Process Options

This section presents the remedial technologies (and related process options) that would potentially achieve the RAOs. The screening of the remedial technologies was based on the following criteria:

- Effectiveness: This criterion evaluates the ability of a technology to achieve the RAOs, and provide long-term protectiveness of human health and the environment. Potential short-term impacts to human health and the environment, and the reliability of the technology are also important components of this screening criterion;

- Implementability: This criterion addresses the technical and administrative feasibility of implementing the technology as well as the availability of required services and materials; and,

- Cost: This criterion utilizes engineering judgment to develop relative estimated costs of each technology for a given RAO. The cost estimates are qualitative (low, moderate, high) at this technology screening stage in the FS.

The following provides a description of the technologies and process options considered for each RAO and summarizes the results of the technology screening.

4.2.1 Screening of Technologies / Process Options for RAO-1 (Former Ponds 1 and 2)

Table 4-1 lists the GRAs, technologies and process options considered to address RAO-1 (former Ponds 1 and 2). A summary of results of the screening level evaluation is also presented on Table 4-1.

4.2.1.1 Containment: Capping, Vertical Barriers, Horizontal Barriers

Description

A physical containment system would be constructed surrounding chemically impacted fill/sludge within former Ponds 1 and 2. The containment system would consist of the following components.

- A low permeability cap (potentially including clay or geosynthetics) would be installed over former Ponds 1 and 2 to minimize the infiltration of precipitation. The cap would extend beyond the limits of the vertical barrier component of the containment system described below;
- Vertical barriers (potentially consisting of high density polyethylene (HDPE) panels, soil/bentonite slurry wall, or grout curtain) would be installed to minimize the flow of groundwater into and out of chemically impacted materials within former Ponds 1 and 2; and,
- A horizontal barrier would be constructed beneath former Ponds 1 and 2. Cement or bentonite grout would be injected within the fractures of the Washington Shale to form a low permeability layer and thus minimize the downward migration of chemical impacts.

Figure 4-1 shows a conceptual diagram of the former Ponds 1 and 2 containment system.

Effectiveness: High to Moderate

The capping and vertical barrier components of this technology are expected to be highly effective for minimizing the infiltration of precipitation and lateral migration of groundwater, respectively. The horizontal barrier to downward chemical migration is expected to be only moderately effective given the uncertainty of being able to construct a uniform and continuous low permeability barrier within the fractured shale matrix below the ponds.

Implementability: Easy to Moderate

Similarly, the implementability of constructing the low permeability cap and vertical barriers within the surrounding soil is considered easy as the equipment, methods, and materials are readily available. While the equipment, methods, and materials for constructing the horizontal barrier are also readily available, the implementability of constructing a uniform and continuous horizontal barrier within the shale beneath the former ponds is considered to be moderately difficult to implement due to the difficult accessibility for drilling equipment in the interior of the former ponds particularly former Pond 1 and the difficulties with verifying a continuous barrier.

Cost: Low

The relative cost of this technology is expected to be low compared to the other technologies identified for RAO-1.

Status: Retain

This technology has been retained due to its potential high to moderate level of effectiveness, moderate implementability, and lower cost. While the horizontal barrier constructed within the fractured shale beneath the former ponds may not provide full control of the downward migration of chemical impacts, the entire containment system is expected to provide substantial containment of the chemical impacts and so is worthy of additional consideration.

It is important to note that chemical/DNAPL impacts are expected to have migrated outside of the former Ponds 1 and 2 and may be relatively inaccessible within the fractured matrix of the shale and MKS outside of the former pond. There are no known technologies that would be highly effective in addressing the sporadic and heterogeneous distribution of DNAPL within the bedrock beneath former Ponds 1 and 2.

4.2.1.2 In-Situ Soil Mixing/Stripping, Stabilization and Solidification

Description

This technology requires the use of a crane or large backhoe/excavator mounted soil mixing, air/reagent injection and vapor collection equipment. Vapor phase treatment equipment is also required to handle extracted vapors. Figures 4-2 and 4-3 provide schematic diagrams of typical in-situ soil mixing/air stripping, and stabilization/solidification equipment and processes.

Air stripping via soil mixing with air injection will be performed using large augers or paddles covered by a shroud. During mixing, the augers or paddles are moved up and down several times within the soil column while air is injected through the auger or paddles into the fill. The continued mixing facilitates the soil air stripping process by exposing large surface areas of soil to the injected air. The duration of mixing may range from approximately 0.5 to 2 hours depending on the results of a treatability study which is normally required to be performed to design the process. To enhance collection of the generated vapors, a negative pressure will be maintained within the shroud to capture volatile chemicals released during mixing. Recovered VOCs will be treated using appropriate above ground treatment technologies such as vapor phase activated carbon (VPAC) or a catalytic oxidizer. The specific treatment method will need to meet emission standards and will be determined during detailed design.

After completion of the soil mixing/stripping phase, reagents such as Portland cement, bentonite, organophillic clay, kiln dust, and/or lime can be used as the stabilization/solidification agent and applied to the fill/sludge at a rate determined by a treatability study. These reagents will be introduced in slurry form and mixed using augers or paddles to achieve a uniformly stabilized and solidified matrix with low chemical leaching potential. Chemicals not removed and recovered during the soil mixing/stripping phase will be encapsulated within the low permeability stabilized and solidified matrix. Mixing will be carried out on an overlapping grid pattern to ensure effective treatment of the entire fill/sludge area, as shown on Figure 4-4.

Figure 4-5 shows a conceptual diagram of the former Ponds 1 and 2 in-situ stripping, stabilization, and solidification system. This technology is able to achieve the following:

- Reduction of the volatile chemical mass via soil mixing/air stripping and treatment of the extracted vapors;
- Reduction of the leachability of the remaining low volatility chemicals on a microscale via soil mixing with appropriate reagents to achieve stabilization/solidification; and,
- Reduction of the mobility of the remaining low volatility chemicals via soil mixing with appropriate reagents to achieve stabilization/solidification resulting in a low permeability solidified matrix.

The detailed performance specifications for this technology will be developed during a treatability study conducted during the PDI. The primary objectives of the treatability study are to evaluate the following:

- Variables to optimize volatile chemical mass reduction (e.g., mixing time);

- Stabilization/solidification formulations that will provide the desired physical properties (e.g., strength); and,
- Reduction of chemical leachability achieved by various formulations (i.e., synthetic precipitation leaching procedure analysis).

Stabilization/solidification formulations anticipated to be evaluated during the treatability study may include mixtures of Portland cement, organiphillic clay, hydrated lime, cement kiln dust, etc. The treatability study will be used to select soil mixing/air stripping variables and stabilization/solidification formulations that provide optimal performance. The treatability study results will also be used to establish performance standards for volatile chemical mass reduction, chemical leachability, and bearing strength.

Following completion of the in-situ soil mixing/air stripping and stabilization/solidification treatment of the former Ponds 1 and 2 materials, a cover will be constructed over the treated area to mitigate future direct contact exposures. The cover would consist of either a soil barrier cover as described in Section 4.2.6.1 and Appendix E or a geosynthetic membrane cover as discussed in Section 4.2.3.7. Following cover construction, the treatment area will be maintained as open green space and residential or commercial/industrial use of the area will be prohibited by institutional controls.

Effectiveness: High

Golder Associates has evaluated and conducted treatability testing of this technology at a site having very comparable conditions, e.g., high VOC and SVOC concentrations (greater than 25,000 mg/kg) along with elevated polychlorinated biphenyl (PCB) concentrations contained in sludge (SCP Carlstadt Superfund Site, New Jersey). Volatile organic chemicals were reduced by approximately 95% and the leachability of the remaining heavier chemicals was reduced by more than 95%. USEPA Region II selected this technology in the Record of Decision for the site. The effectiveness of this technology applied to the former Ponds 1 and 2 fill/sludge is expected to be similarly high.

Implementability: Moderate

Due to the specialized equipment and process knowledge required, this technology is expected to have moderate implementability.

Cost: Moderate to High

This technology utilizes large equipment, treatment reagents, and requires above ground vapor phase collection and treatment. As a result, the cost of this technology relative to other technologies is expected to be moderate to high.

Status: Retain

Given its potential high effectiveness, moderate implementability at a moderate to high cost, this technology is retained for further evaluation.

4.2.1.3 In-Situ Treatment Using Chemical Oxidation

Description

Chemical oxidants (e.g., hydrogen peroxide, Fenton's reagent, ozone and permanganate) would be injected into the subsurface materials within former Ponds 1 and 2. These chemicals can be used to destroy contaminants by converting them to innocuous compounds commonly found in nature. A commonly used chemical oxidant is Fenton's Reagent, which involves the application of hydrogen peroxide with an iron catalyst. When this application is done, a hydroxyl radical is formed, which is a strong oxidizing agent and is capable of oxidizing many complex organic compounds. Any residual hydrogen peroxide decomposes to water and oxygen and remaining iron particles ultimately settle out in the subsurface.

Delivery methods can vary. The oxidant can be injected through a well or injector head directly into the subsurface or mixed with a catalyst and injected. Sometimes the oxidant is combined with an extract from the site and then injected and recirculated. In order to use hydrogen peroxide, it may be necessary to use stabilizers because of the compound's volatility. Chemical oxidation has been used to treat VOCs including dichloroethenes, TCE, PCE, and BTEX as well as semi-volatile organic chemicals (SVOCs) including pesticides, polycyclic aromatic hydrocarbons (PAHs), and polychlorinated biphenyls (PCBs). The intended end products of reaction are carbon dioxide, water, and inorganic chloride. Chemical oxidation has not been found effective for some chlorinated ethanes (e.g., 1,1,2,2-TeCA and 1,1-DCA). Natural organic matter, iron, manganese, methane, acetate, carbonates and bicarbonates will consume the oxidant and thus higher dosages are required. The potential for gas generation is present also with this technology. USEPA has advised caution before approving the use of hydrogen peroxide for in situ chemical oxidation of flammable compounds such as for gasoline remediation. A project conducted at an underground storage tank (UST) project in Cherry Point, North Carolina resulted in buckling of an asphalt parking lot and a subsequent fire and explosion (ITRC, 2001).

Effectiveness: Low

Given their non-selective nature, oxidants have the potential to effectively treat the various types of organic chemicals contained within former Ponds 1 and 2 fill/sludge. However, in order for this technology to be effective, the chemical oxidant must make direct contact with the chemical it is required to treat. The low permeability of the sludge contained within former Ponds 1 and 2, the heterogeneity of materials and the contrasts between higher permeability (fill) and lower permeability (sludge) materials would not allow for uniform delivery of the chemical oxidants throughout the fill/sludge matrix and thus direct contact of the oxidants with the chemical impacts is expected to be only sporadic. Repeated injections will be required for the heavily impacted former Ponds 1 and 2 fill/sludge in order to provide sufficient quantities of oxidizing chemicals. This combination of limiting factors is expected to result in this technology not being able to effectively treat the chemical impacts within the former Ponds 1 and 2 materials. This anticipated low effectiveness was independently verified through discussions with a vendor of in-situ chemical oxidation technology who did not recommend its application to a fill/sludge matrix of the type found in former Ponds 1 and 2.

Implementability: Difficult

In general, the equipment, services, and materials for chemical oxidation are readily available. However, the uniform delivery of the oxidants will be very difficult to implement.

Cost: High

The Site conditions would require a tight spacing of delivery points and use of large amounts of chemical oxidants over a long period of time. Thus, the cost of this technology relative to other technologies is expected to be high.

Status: Eliminated

Given the anticipated limited effectiveness and difficult implementability, this technology has been eliminated from further consideration for the former Ponds 1, and 2 fill/sludge.

4.2.1.4 In-Situ Treatment Using Thermal Desorption

Description

In-situ thermal desorption of the fill/sludge within former Ponds 1 and 2 would be achieved via installation of thermal wells, consisting of a perforated outer steel casing and an interior heating element, in a closely spaced triangular pattern throughout the area. A heat resistant silica blanket would be placed over the area forming a seal to minimize losses of VOCs and steam, as well as to reduce intrusion of atmospheric air. The wells and an approximately 6-inch wide concentric halo around the wells would be heated to approximately 1,400°F to 1900°F. (Note: the desired temperature and well spacing is a design consideration and may vary.) Heat propagating throughout the area would first vaporize moisture, and then increase sludge/fill temperatures to approximately 450°F. Increasing the temperature of the sludge/fill would also increase its pneumatic permeability and help penetrate the permeability contrasts within the fill/sludge. A modest vacuum (approximately 3 to 5 inches water) would be applied to each well in the system to remove the generated vapors/steam. The increased temperature will vaporize most of the organic chemicals that will then be drawn through the high temperature wells. Most of the organic chemical treatment occurs within the high temperature thermal wells and the halo around the wells. Extracted vapors would be treated utilizing an above ground treatment train, potentially consisting of an indirect fired thermal oxidizer at ground surface followed by a heat exchanger and a VPAC system. Once treatment of the subsurface materials is complete, a soil barrier (1-foot thick, minimum) will be constructed over the surface of the former Ponds 1 and 2. This soil barrier cover will be similar to that described in Section 4.2.6.1 proposed for surface soils. Figures 4-6 and 4-7 shows a conceptual diagram of this technology.

The performance specifications for this technology will be developed during a treatability study conducted during the PDI. This study would evaluate treatment temperature, well spacing, vapor treatment, and chemical effects on equipment. Other field trials may be needed to fully assess the effectiveness of this technology in the site-specific conditions.

Effectiveness: Moderate

This technology has the potential of being able to remove and treat a wide variety of organic chemicals, including pesticides. However, treatability studies and possibly field trials would be needed.

This technology has the potential for penetrating the permeability contrasts within the fill/sludge and thus would add to its potential effectiveness. There are, however, a number of potential limitations which include, but are not limited to, differential subsidence of the fill/sludge, treatment of fill/soil below the groundwater table, generation of hydrochloric acid and resulting effects on system durability and treatment requirements which may reduce this technology's effectiveness. Therefore, this technology is considered to have moderate effectiveness.

Implementability: Moderate to Difficult

This is a specialized technology and the equipment, methods, and materials are not readily available. In addition, the installation of the heater wells in the interior of the former Ponds 1 and 2 area may be very difficult due to soft ground conditions, and liquefaction of the heated fill/sludge may produce differential subsidence of equipment. Thus, this technology is considered moderate to difficult to implement.

Cost: High

The cost of this technology relative to the other technologies considered for RAO-1 is high.

Status: Retain

Even though there are substantial effectiveness and implementability concerns, this technology has been retained for further evaluation in the detailed analyses given its potential ability to penetrate the permeability contrasts and effectively treat a wide range of organic chemicals.

4.2.1.5 In-Situ Treatment Using Conventional or Enhanced SVE

Description

Soil vapor extraction (SVE) is a conventional and well understood technology that generally consists of the installation of multiple closely spaced extraction wells with an ex-situ vacuum source drawing soil vapor from the subsurface. The extracted soil vapor, containing volatile organic chemicals, is treated in an above ground vapor phase treatment system prior to being released to the atmosphere. Heat enhancement can be used to facilitate the volatilization of some of the lower volatility organic chemicals.

Effectiveness: Low

The effectiveness of this technology is limited by the low permeability of sludge and permeability contrasts (heterogeneity of sludge/fill) in the subsurface, low extraction rates, and the potential for short-circuiting of soil vapors through more permeable material. These limitations will result in poor performance for treating chemical impacts contained within lower permeability materials. Also, the presence of groundwater in the subsurface is expected to substantially reduce the effectiveness of this technology and a dewatering system would be installed as a mitigative measure, but removing water from the matrix pore space within the sludge will be difficult. Furthermore, the effectiveness for removing low volatility organic chemicals, even with heat enhancement, is expected to be low.

Implementability: Moderate to Difficult

While the equipment, methods, and materials are conventional, Site conditions (low bearing strength particularly in former Pond 1) will make installation of SVE wells difficult and the subsurface heterogeneity, permeability and phase contrasts and the saturated conditions will also make it difficult to achieve a uniform removal of soil vapors throughout the subsurface. Therefore, implementation of this technology is considered to be moderate to difficult.

Cost: Moderate

Given the need to address groundwater, to possibly add heat to address low volatility compounds and to install and operate closely spaced extraction wells over a long period, the anticipated cost of this technology is expected to be moderate.

Status: Eliminated

Given the anticipated low effectiveness and difficult implementability, this technology has been eliminated from further consideration.

4.2.1.6 Removal by Excavation Within Enclosure and Off-Site Transportation and Disposal

Description

Excavation of fill/sludge would be conducted using standard mechanical means. However, due to the anticipated excessive release of VOCs during excavation and the required material handling steps this technology would likely need to be undertaken within an enclosure to control impacts to adjacent areas. There are approximately 45,000 cubic yards of impacted material within the former Ponds 1 and 2 footprint, including sludge, native soil fill, and underlying impacted soil extending to depths of more than 20 feet. High concentrations of VOC and SVOC constituents are present, with organic vapor readings of 1,000 parts per million (ppm) being recorded during the RI. Groundwater occurs within a few feet of the ground surface and given the saturated nature of the sludge/fill, considerable dewatering efforts will be required, further increasing material handling steps, the time to implement the technology, and subsequent VOC releases.

Effectiveness and Implementability: Low and Difficult

The effectiveness of the excavation technology was rated low based upon overwhelming short-term effectiveness concerns. Following excavation of soil/sludge, there will still be substantial quantities of chemical impacts within the bedrock that could not be removed via excavation and so there are additional long-term effectiveness concerns. The risks posed to the public in the surrounding community and elsewhere, and to workers during remedy implementation (over a minimum of two years) are considered to be unacceptably high. Implementing this technology in a manner that would mitigate these risks is not expected to be feasible. The specific short-term effectiveness and implementability concerns associated with this technology are summarized below.

Excavation Issues

Due to the high concentrations of VOCs found in former Ponds 1 and 2, VOC emissions would need to be strictly controlled to protect the adjacent residential receptors, construction workers, and nearby industrial workers. Due to the potential impacts to the adjacent areas, the excavation and material handling activities would need to be undertaken within an enclosed control structure. The resulting emissions from the enclosure would require treatment prior to being discharged to the atmosphere. Specifically, the difficulties associated with excavation and material handling within an enclosure are described below:

- Large and likely multiple enclosures would be required to contain emissions from the excavation and material handling steps; construction and maintenance of such enclosures would be extremely complex, especially in very close proximity to a railroad.

- The rate of ventilation (and corresponding treatment) would need to be properly sized to prevent buildup of VOC vapors, and prevent buildup of explosive gas mixtures. USEPA has shown that the required ventilation rates can be very high to provide the necessary level of protection (USEPA, 1992).

- Additional VOC, carbon monoxide, and particulates would be emitted by heavy equipment (diesel/gas engine exhaust) operating within the enclosure which would exacerbate health and safety risks.

- The potential for damage, leakage or rupture of the enclosure and decreased efficiency or failure of emission control equipment that would lead to releases of VOCs and odors to the atmosphere (and attendant unacceptable health risks) is significant.

- Health and safety considerations for workers within enclosures include the following:

    - USEPA has documented that there is generally a 20°F increase in temperature within an enclosure compared to outdoor ambient temperatures (USEPA, 1992). The higher temperatures are cause for concern in terms of elevated VOC emissions, humidity and heat exhaustion for workers, especially when using Level B PPE (which would be required in this case).
    - Physical hazards associated with material handling, separation and other manual activities conducted by workers within an enclosure are a particular concern as a result of reduced visibility (level B protection, reduced light, and smoke from heavy equipment exhaust), slippery conditions, reduced worker mobility in Level B, heat stress, and expected congested conditions within the enclosure.

- High humidity can cause reduced emission control effectiveness if vapor phase GAC is used for treatment of ventilation air.

- There would be limited available space within the enclosure(s) to perform the necessary excavation and material handling activities causing congested work conditions, reduced efficiency, reduced visibility, and increased safety hazards.

Material Handling Issues

The handling of excavated material and backfill will prove difficult and result in prolonged exposure of open material faces even with the use of temporary covers. The following specific difficulties can be anticipated:

- Due to the large size of the required excavation and instability of the former pond materials, a “step out” approach would be required. The maximum reach distance required, including a 5-foot buffer zone, is approximately 110 feet. A typical large excavator has a reach length of 50 to 70 feet. A specialty large excavator, if available, could have a maximum reach length between 80 to 90 feet. Therefore, not all material could be excavated from exterior of the former ponds without using a “step out” approach. This approach would consist of excavating a portion of former Ponds 1 and 2 then backfilling with clean fill so as to create a working platform for equipment to excavate the next portion of former Ponds 1 and 2. Such processes are usually accompanied by difficulty in separating clean fill and contaminated fill throughout the process.

- Impacted liquids will need to be removed from excavations, separated, stored, treated, and/or disposed of off-site. Saturated excavated materials will need to be drained of free liquids prior to further material separation / stockpiling / handling; a process which may take days to weeks. These conditions will slow and complicate the excavation process, and present additional safety hazards for workers.

Off-Site Transportation and Disposal Issues

The off-Site transportation of approximately 45,000 cubic yards of impacted soil/sludge and an undetermined amount of impacted water from dewatering will be required. It is estimated that greater than 2,000 truck round trips will be required over a large distance. Community disturbances, highway accident risks, and VOC emissions along the transport routes are expected to be considerable. In addition, there are limited facilities available that can accept this material and none are close to the Site. These facilities typically have limited storage capacity and therefore the rate at which material can be shipped will be limited, thus increasing the overall time to complete the excavation and the period over which subsequent VOC releases can occur. Treatment of emissions will likely be required during any waiting periods. The risk of a release of material to the environment en route to the disposal facility or in loading or unloading operations is substantial. Such an uncontrolled release could occur anywhere along the route to the disposal facility and this represents a substantial and unavoidable risk with this technology.

Costs: Very High

The cost of this technology relative to all other technologies for RAO-1 is expected to be very high.

Status: Eliminated

The short-term effectiveness concerns and difficult implementation issues are considered unacceptable for the excavation and off-site disposal technology. Furthermore, the long-term effectiveness of this technology is not expected to offer any material improvement over the other technologies that can be implemented at much less risk to workers and the public.

4.2.2 Screening of Technologies / Process Options for RAO-2 (Former Ponds 3, 4, and 7)

The primary objective of RAO-2 is to mitigate potential ecological exposures to mirex in surface fill/sludge contained within former Ponds 3, 4, and 7. As described in Section 3.4 (RAOs), because former Ponds 3, 4, and 7 do not appear to be major sources of groundwater impacts reducing the infiltration of precipitation into the former ponds has not been identified as an objective. Notably, PDI activities (as described in Section 5.3), will be performed to evaluate the potential of the former ponds to function as sources of groundwater impacts.

The following presents a description and screening level evaluation of the technologies/process options identified to address RAO-2. Table 4-2 lists the GRAs and technologies/process options, summarizes the screening level evaluation and indicates whether the technology was retained for further consideration.

4.2.2.1 Containment Using a Soil Barrier Cover and/or Existing Cover Enhancements

Description

Because the physical conditions of the current cover, the bearing strength of the contents, and the susceptibility to erosion differs for each of the former Ponds 3, 4, and 7, this technology is applied differently to each of the former ponds. Even though the cover designs could differ on each of the former ponds due to engineering considerations, the overall objective of the cover on each former pond is the same, i.e., the mitigation of potential direct contact pathways for ecological receptors. Portions of the existing cover on each of the former ponds may be sufficient to provide this protection.

For example, former Pond 4 is already covered with a substantial soil cover and well established vegetation with adequate bearing strength to accommodate standard construction equipment (see Section 2.3.3). The soil barrier cover placed on former Pond 4 would therefore only be used to enhance the existing cover in areas where it is thin. Limited portions of the former Pond 4 side slopes are located adjacent to Feeder Creek, and thus may requiring armoring to prevent potential erosion by surface water.

The existing soil covers over former Ponds 3 and 7 are believed to be less extensive with former Pond 7 expected to have the least amount of existing soil cover. A new soil cover may need to be placed over substantial areas in these former ponds. It is also believed that the surface bearing strength of former Ponds 3 and 7 is less than that of former Pond 4. Therefore, the covers required for former Ponds 3 and 7 may need to be constructed of light weight materials and/or the former pond materials may need to be stabilized beforehand. More side slope armoring may potentially be required for former Pond 3 as it is surrounded on three sides by Feeder Creek and is thus may be more susceptible to periodic erosion. No side slope armoring is anticipated for former Pond 7. The extent of armoring (if any is needed) will be determined during detailed design.

In general, the soil barrier covers will consist of a minimum of 1-foot of clean earthen materials placed over a synthetic marker/physical barrier. The 1-foot soil layer will be capable of supporting vegetation or will be augmented as necessary, with a topsoil component. Where a new cover is installed or where the thickness of the existing cover is enhanced, a synthetic marker barrier will be placed on the existing ground surface for an added protection barrier and for delineation of materials during future maintenance. An investigation of the existing cover in each of the former ponds will be conducted during the PDI to assess the following:

- Existing cover thickness;
- Existing cover soil type;
- Bearing strength;
- Chemical impacts to surface soil; and,
- Slope stability and susceptibility to erosion.

The type and extent of the cover required to mitigate potential future ecological exposure pathways will be determined for each former pond based on the PDI and additional engineering analysis. The soil barrier cover will be coupled with institutional controls to prohibit any future residential or industrial/commercial uses of the former ponds (other than “green space”) and prohibit future disturbance of the barrier covers. An inspection and maintenance program will be conducted to ensure the soil barrier covers will continue to function effectively in the future and that only compatible future use is made of these areas.

Effectiveness: High

The effectiveness of soil barrier covers to mitigate direct contact exposures are well proven. Appendix E presents an engineering analysis of the 1-foot (minimum) soil barrier cover and demonstrates the long-term effectiveness of this technology. Thus, this technology is deemed to be highly effective.

Implementability: Easy to Moderate

The construction equipment, materials and methods are straightforward, however, constructability issues associated with working in soft ground conditions are expected to be moderately challenging. Therefore, this technology is expected to have an easy to moderate implementability.

Cost: Low

The cost of soil barrier covers is anticipated to be low to moderate compared to the other technologies. The cost will depend on the final extent and engineering design of the covers as determined during the PDI and detailed design.

Status: Retained

Due to its high effectiveness and easy implementability, this technology is retained for further consideration.

4.2.2.2 Soil Modifications to Improve Bearing Strength

Description

As discussed in Section 2.3.3, the bearing strength of the surface materials in former Ponds 3 and 7 are anticipated to be lower than in former Pond 4. Prior to installing a soil barrier cover or enhancing portions of the existing cover, it may be necessary to improve the bearing strength of the surficial materials in these former ponds. The specific engineering method utilized to improve the bearing strength sufficient to construct a cover is a design issue and may include adding fill taken from other portions of the Site, in-situ stabilization (mixing of reagents such as cement, lime, or kiln dust into the surficial fill/sludge), and/or reinforcement with geosynthetic materials (such as a geogrid). As described in Section 4.2.2.1, an investigation of geotechnical properties of the existing pond cover materials will be conducted during the PDI. Depending on the PDI results and the engineering evaluation and design, increasing the bearing strength may only be needed in certain portions of the former ponds.

Effectiveness: High

This technology may not entirely achieve RAO-2 on its own but may be needed to implement other technologies. This technology is anticipated to be highly effective in this supporting role.

Implementability: Easy to Moderate

The construction equipment, materials and methods are conventional and generally straightforward, however, constructability issues with working in soft soils are expected to be moderately challenging. Therefore, this technology is expected to have an easy to moderate implementability.

Cost: Low to Moderate

Depending on what design and methods are used and to what extent the former ponds require bearing strength improvement (which will be determined during the PDI and detailed design), the cost of this technology is expected to be low to moderate.

Status: Retained

This technology is retained as a supporting technology for other RAO-2 technologies.

4.2.2.3 In-Situ Treatment Using Conventional SVE

Description

Conventional SVE is a standard and well-known technology and is described in Section 4.2.1.5.

Effectiveness: Low

SVE has a low to moderate effectiveness in low permeability materials and a low effectiveness in very soft plastic fill/sludge such as those observed in former Pond 7. SVE is not expected to be effective for treating surface soil or where there are permeability contrasts (i.e., fill and sludge) in the subsurface (i.e., former Ponds 3, 4, and 7). In addition, SVE will not be effective for treating mirex (a low volatility/mobility organic compound), which drives the direct contact exposure concerns at former Ponds 3, 4, and 7. Therefore, the overall effectiveness of the SVE technology is anticipated to be low for this application (i.e., mitigating direct contact exposures to surface fill/sludge).

Implementability: Difficult

In general, the SVE technology is easily implemented as the equipment, methods and materials are conventional and easily obtainable. However, SVE wells will be difficult to install and operate in the soft ground conditions expected. Therefore, this technology will be difficult to implement.

Cost: Moderate

The cost of this technology with modifications to address the soft ground conditions and low permeable materials is expected to be moderate.

Status: Eliminated

Because of its very limited effectiveness and difficult implementability, this technology has been eliminated from further consideration.

4.2.3 Screening of Technologies / Process Options for RAO-3 (Eastern and Southern Shallow Groundwater)

The primary objective of RAO-3 is to mitigate potential shallow groundwater impacts. As discussed in Section 2.7.3, shallow groundwater from on-property sources discharges to a surface seep to the west of the southern portion of the Crane-Deming building (off-facility seep). An additional component of this objective is to remediate a small isolated area of groundwater impacts on the southeast side of the property. PDI activities will evaluate if impacted groundwater has migrated off-property from the southeast side of the property.

The following presents a description and screening level evaluation of the technologies/process options identified to address RAO-3. Table 4-3 lists the response actions and technologies/ process options, summarizes the screening level evaluation and indicates whether the technology was retained for further consideration.

4.2.3.1 On-Facility Collection and Treatment Via Continued Operation of LCS-1 and LCS-2

Description

Shallow groundwater control systems LCS-1 and LCS-2 (located on Figure 2-1) have been in operation since 1994. Since inception, over 16.6 million gallons have been collected from LCS-1 and over 1.1 million gallons from LCS-2 (data through July 2004). On average, LCS-1 and LCS-2 have collected 3.4 gallons per minute (gpm) and 0.23 gpm, respectively. The highest monthly averages recorded were approximately 6-8 gpm and 1 gpm, respectively. However, it is believed surface water runoff is not excluded from the collection system, and it is likely that a portion of the collected waters in LCS-1 is due to surface water inflow. Figure 4-8 presents LCS-1 collection flows and precipitation (from station Salem Center 2E) showing a qualitative correlation between precipitation and flow[24]. Historically, there have been exceptions to the correlation likely due to LCS-1 operational variability. The data also indicate a "base flow" in LCS-1 of approximately 1,500-2,000 gallons per day (May 1994 to July 1994), or 1-1.4 gallons per minute (gpm) during periods of low precipitation, indicative of the portion of flow due to groundwater base flow capture[25]. LCS-1 water is directed to the on-site treatment facility while LCS-2 water is disposed of off-site due to the high metals content, particularly iron. LCS-1 collects water downgradient of Exclusion Area "A", while LCS-2 intercepts water downgradient of former Ponds 1 and 2. Complete interception of shallow groundwater is not achieved particularly downgradient of former Ponds 1 and 2. Further evaluation and modifications to LCS-1 would be completed to minimize surface water inflow.

Effectiveness: Moderate

This system is moderately effective. LCS-1 is able to capture a greater amount of shallow groundwater than is LCS-2 due to its greater depth and length. However, not all of the impacted shallow groundwater in either area is collected by the respective system, limiting their effectiveness.

Implementability: Easy

This system is currently in operation and is therefore easy to implement.

Cost: High

While there would be little additional investment needed for capital costs for this remedy, the operating costs associated with pumping and treating the collected shallow groundwater are high due to O&M of the treatment plant and due to off-site transportation and disposal of LCS-2 water.

Status: Retained

This technology has been retained for further consideration.

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[24] This correlation, and the associated discussion of LCS-1 flow rate, including "base flow" rate, is presented as an indication that surface water inflow may be a substantial contributor to the overall flow.

[25] Notably, the flow rate for LCS-1 and for the potential shallow groundwater recovery trench (see Section 4.2.3.2) will be assessed during the PDI.

4.2.3.2 Off-Facility Collection Via Shallow Trench and Treatment In a New or Modified Treatment Plant

Description

A new shallow groundwater collection trench would be constructed to the east of the Conrail Railroad tracks as shown on Figure 4-9. The trench would be designed so that it would intercept shallow (overburden) groundwater originating from the vicinity of former Ponds 1 and 2, the primary source of shallow groundwater impacts. The shallow groundwater collection trench would also extend downgradient from Exclusion Areas A and B and thus will address potential shallow groundwater impacts from these areas. In addition, as discussed in Section 4.2.4, potential MKS groundwater impacts from Exclusion Areas A and B will also be mitigated by the MKS source area groundwater remediation technologies.

The trench would be approximately 600 feet in length, approximately 2 feet in width, extending across the full extent of overburden impacts and keyed into the upper fractured portion of the Washingtonville shale, where present. The depth to bedrock along the proposed trench location ranges from 9-12 feet, and the saturated thickness ranges from 4-9 feet. The ultimate placement of the material removed will be determined during design. Data collected during the PDI will allow a site-specific assessment of potential consolidation into one or more of the former ponds.

An estimated shallow groundwater extraction rate from the collection trench is 3 gallons per minute (gpm). This rate is estimated based on a combination of analyses. Estimating the flux from hydrogeologic parameters (Golder, 1997), including using the maximum hydraulic conductivity of the permeable zones only in the overburden (5.5×10^{-4} cm/sec) in the Ponds 1 and 2 area, and an average hydraulic gradient (0.047 ft/ft), yields a specific discharge of 29 ft/yr. Assuming a projected trench length of 600 feet normal to the groundwater flow direction, with a saturated depth of 10 feet, an interception rate of 2.3 gpm is predicted. The potential trench flow may also be estimated by extrapolating from the performance of LCS-2. On average, LCS-2 captures 0.23 gpm (Section 4.2.3.1). Extrapolating from the dimensions and saturated thickness of LCS-2 yields a predicted trench flow of 3.9 gpm. An average of these estimates yields a value of 3 gpm as a preliminary conservative design flow rate.

Details of the trench construction, type of backfill, use of collection piping in trench, number and placement of pumps, etc. would be determined during detailed design. It is currently envisioned that the trench would be backfilled with a coarse gravel, and sump pumps would be installed along the length of the trench to transport collected water to the treatment facility. The collected shallow groundwater would be pumped to the existing plant through piping installed within the existing culvert that runs below the Conrail railroad tracks. Alternatively, a new treatment system may be constructed at the Crane-Deming building.

The anticipated increase in flow to the treatment facility may require modifications to the existing treatment plant. Some expansion of the treatment facility may also be required to address increased chemical loading of metals, particularly iron, and VOCs. Required plant upgrades would include additional equalization tank capacity, increased usage of liquid and vapor phase carbon. Fouling from increased iron concentrations would necessitate treatment and removal that may include an aerator, treatment chemicals, mixers, clarifier and sand filter, filter pump, and sludge handling systems. Improvements to enhance the removal of VOCs and SVOCs would possibly include adding a low profile air stripper and increasing the size of the carbon units to reduce the changeout frequency. Concentrations of other metals appear to be lower than the current discharge limits. The specific modifications to the existing treatment plant or the design of a new treatment plant would be determined during detailed design.

The shallow groundwater collection trench discussed above will address shallow groundwater impacts primarily from the former Ponds 1 and 2 area as well as potentially from Exclusion Areas A and B. In addition, the shallow groundwater collection trench will also address shallow groundwater in the off-facility seep area. As discussed in Section 5.3, further assessment of the off-facility seep area will be conducted during the PDI to assess the nature and extent of shallow groundwater and surficial soil impacts. This PDI data will be used to assist the design of the collection trench configuration, to determine the ultimate placement of materials removed from the collection trench, and to assess the extent to which surface soil in this area needs to be addressed.

Effectiveness: High

This technology will effectively collect a greater volume of shallow groundwater than is currently being collected and will effectively mitigate impacted shallow groundwater downgradient from the on-facility sources. Therefore, this technology is considered to have high effectiveness.

Implementability: Moderate

In general, the equipment, methods, and materials needed are conventional and easily obtainable. However, the location of the trench between former Pond 3 and the Conrail Railroad tracks poses an access and construction challenge for installation of the trench. As an alternative, collection performed by installation of a horizontal perforated pipe may be considered during the design stage. In addition, if the existing treatment plant (with modifications) is used, installation of piping through the existing culvert below the Conrail Railroad tracks would be required. Therefore, this method is expected to have a moderate level of implementability.

Cost: High

Due to possible upgrades to the treatment facility or construction of a new treatment facility, as well as the operating and maintenance costs of the treatment system and maintaining a trench pumping system, the cost associated with this technology is expected to be high relative to other technologies that address RAO-3.

Status: Retained

Because this method has high effectiveness it has been retained for further consideration.

4.2.3.3 Off-Facility Collection Via Shallow Extraction Wells and Treatment Via New or Modified Treatment Plant

Description

This method is similar to the trench design (Section 4.2.3.2) in that groundwater will be collected and then pumped to the treatment facility. However, instead of a collection trench, shallow groundwater extraction wells would be installed east of the Conrail Railroad tracks along and to the southeast of former Pond 3. Treatment of the extracted groundwater would be the same as that described in Section 4.2.3.2.

Effectiveness: Low

This method has low effectiveness because of the low permeability of the soils in this area. A closely spaced well network would be required to maximize capture due to the low soils permeability. Effectiveness of the capture of groundwater capture will still be a concern with this method and therefore interceptor trenches are the preferred alternative for shallow groundwater collection (USEPA, 1996b)

Implementability: Moderate

This system has a moderate level of implementability. While the equipment, methods, and materials are conventional and easily obtainable, installation of the wells could be a problem due to limited space for maneuvering machinery between former Pond 3 and the Conrail Railroad tracks. In addition, because of the low permeability, wells would have to be spaced relatively closely in order to capture sufficient groundwater. In addition, if the existing treatment plant (with modification) is used, the extracted water would require a piping system through the existing culvert under the Conrail Tracks.

Cost: High

With the operating and maintenance costs as well as the expansion costs for the treatment facility, it is expected that this technology would have a high cost as compared to other RAO-3 technologies.

Status: Eliminated

Due to low effectiveness and high cost, this technology has been eliminated from further consideration.

4.2.3.4 In-Situ Treatment Via Reactive Iron Wall

Description

Reactive iron walls, often called Permeable Reactive Barriers (PRBs), are capable of passively treating a wide range of chemicals in groundwater. This technology consists of excavating a trench as discussed in Section 4.2.3.2 and installing a wall made of zero-valent iron (ZVI) metal. The wall is permeable so that groundwater will flow through it. The ZVI will reduce chemicals in both aqueous and non-aqueous phase liquid (NAPL) form. Iron PRBs have been effective at treating sites where chlorinated solvents, such as PCE and TCE, are the main chemicals of concern.

Effectiveness: High to Low

Depending on the chemicals of concern and the geochemical conditions, iron PRBs can have high to low effectiveness. At this Site, an iron PRB would be most effective at treating chlorinated compounds, such as chlorinated ethenes and ethanes. Other compounds have also been shown to be treatable, including trihalomethanes, chlorobenzene, PCBs and chlordane (Battelle, 2000).

Limitations of PRBs include the oxidation of iron if excessive dissolved oxygen is present in the influent groundwater, which can cause clogging and reduce the treatment effectiveness of the wall. The longevity of the effectiveness of PRBs has not been established, due to the relatively recent acceptance of PRBs on a wide scale (Battelle, 2000).

Implementability: Moderate

Iron walls are moderately implementable. Iron PRBs are utilized extensively for groundwater remediation, and the equipment, methods, and materials are relatively easily obtained. However, performance monitoring is relatively extensive, including VOCs and geochemical parameters, and hydraulic performance monitoring is also required, including evaluations of potential pore clogging.

Cost: Moderate

Costs for installing and maintaining a reactive iron wall are expected to be moderate.

Status: Eliminated

Due to the treatment effectiveness limitation, this technology has been eliminated as a stand along technology. This technology may be worth further consideration if combined with other in-situ treatment technologies.

4.2.3.5 Staged In-Situ Treatment by Iron PRB, Accelerated Biodegradation and Activated Carbon

Description

A design flow estimate of 3 gpm from a shallow groundwater collection trench was presented in Section 4.2.3.2. This estimate was conservatively based on maximum overburden hydraulic conductivities and historic flow data from LCS-2. These conservative estimates were generated in order that the treatment plant sizing and costs were not underestimated. However, it is likely that the design flow estimated for the extraction trench in Section 4.2.3.2 is greater than what would flow through the trench in an in-situ treatment condition.

Based on the anticipated average horizontal hydraulic conductivity of the overburden presented in Section 2.5.3, approximately 1 to 2 gpm of shallow groundwater would be intercepted (assuming 600 feet in effective length and a 4- to 9-foot saturated thickness). In addition, as discussed in Section 4.2.3.1, the “base flow” at LCS-1 during non-precipitation periods is expected to be on the order of 1 gpm. Therefore, it is expected that the flow rate that would need to be treated in an in-situ treatment trench would be approximately 1 to 2 gpm. Furthermore, the construction of a low permeability cap (as discussed in Section 4.2.3.7) over the area upgradient of the in-situ treatment trench would further reduce this flow rate, likely to be about 1 gpm or less. At this flow rate (e.g., 1 gpm or less) in-situ treatment becomes a viable alternative to ex-situ treatment.

As discussed above, the relatively low groundwater flux in the overburden allows for the consideration of a staged in-situ treatment system. This method includes construction of a groundwater collection trench as discussed in Section 4.2.3.2 with an impermeable membrane on the downgradient side so that impacted shallow groundwater is effectively contained within the trench. The trench is backfilled with a higher-permeability medium (such as sand and/or gravel) and slotted PVC pipes to conduct groundwater to the treatment area, located at the southern end of the trench as shown on Figure 4-10. Conceptually, the treatment system would consist of multiple reactor cells, comprised of a ZVI PRB cell followed by an accelerated biodegradation treatment cell, with a final polishing step of activated carbon adsorption, if necessary. The specification of the multiple reactor cell treatment processes and the potential need for the final activated carbon step would be determined during detailed design.

Reactors would be organized in series so that residual material not treated in one cell will be targeted in the next section of the treatment system. The iron reaction cell will primarily treat chlorinated compounds, and the enhanced biological reactor cell will treat BTEX and other compounds with addition of an electron acceptor and nutrients. A carbon adsorption cell may be initially installed to remove residual impacts, and maintained for use as needed. Injection points are installed in the treatment cells for periodic amendments of biological nutrient substrate. The critical design parameters for the reaction cells are contact time with the reactive substrate. Treatability studies would be conducted as necessary to optimize the design of the treatment cells. Due to the low permeability of the overburden, it may be necessary to discharge the effluent of the system to an infiltration gallery to the south of the Crane-Deming building. The specifications and layout of the infiltration gallery be determined during design. Monitoring of the system is important given the complexity of the treatment process. Geochemical, VOC/SVOC, metals, and hydraulic performance parameters would be part of the monitoring program. Regular inspection and maintenance, and change-out of the reactive materials is required.

Effectiveness: High

The effectiveness of this treatment is potentially high, with a staged system of reactors that includes both redundant and unique treatment processes. While the design of this multiple reactor system is innovative, the individual technologies are more conventional and have been proven to reliably treat the targeted chemicals. The effectiveness of sequentially utilizing these technologies in closely spaced cells improves as the flow rate decreases. Notably, a flow rate of approximately 1 gpm is anticipated for this trench, particularly if a low permeability cap is constructed over upgradient areas. Treatability studies will be conducted to verify effectiveness and provide design criteria. In addition, the PDI will also assess shallow groundwater chemistry and hydraulics in the vicinity of the trench. This treatment will require comprehensive monitoring and maintenance to ensure effectiveness.

Implementability: Moderate

The equipment, methods, and materials follow industry standards for trench construction. The technical challenges associated with the design and construction of the sequenced treatment components are expected to have a moderate level of implementability.

Cost: Moderate

The cost of this in-situ treatment technology is expected to be moderate compared to ex-situ treatment technologies.

Status: Retained

This technology has been retained due to its potentially high effectiveness and for comparison to ex-situ treatment methods in the detailed analysis.

4.2.3.6 In-Situ Treatment Via Collection Trench and Chemical Oxidation

Description

As described in Section 4.2.1.3, chemical oxidation involves addition of chemical oxidants to destroy contaminants by converting them into innocuous compounds. This technology can be applied to groundwater in various ways, including through injection into a treatment trench. This technology therefore includes construction of a groundwater collection trench (described in Section 4.2.3.2) that would be backfilled with a higher permeability medium with injection points installed to periodically inject the chemical oxidants.

Similar to the staged in-situ treatment (as described in Section 4.2.3.5), treatability studies would be conducted, as necessary, to optimize treatment. This system would require extensive monitoring and regular inspection and maintenance.

Effectiveness: High to Low

Chemical oxidation is expected to have a high to low degree of effectiveness. High effectiveness is anticipated due to the ability of chemical oxidation to treat a variety of organic chemicals. Low effectiveness is anticipated due to potential poor delivery of chemical oxidants to the subsurface and substantial clogging within the trench due to oxidized metals (i.e., iron). Furthermore, chemical oxidation will alter the groundwater geochemistry and will adversely impact the existing favorable natural attenuation processes.

Implementability: Difficult

This technology is considered difficult to implement. Injection of chemical oxidants is somewhat risky because of the potential for highly energetic reactions and the generation of noxious vapors. In addition, some chemical oxidants require special aquifer conditions (for example, one requires that groundwater be acidified before injecting the chemical oxidant), which increases the difficulty of implementation. Oxidizing reduced (dissolved) metals, etc., iron, will form precipitates that could clog the treatment trench and reduce the effective distribution of chemical oxidants.

Cost: Moderate

Use of in-situ chemical oxidation is expected to have moderate cost compared to other treatment technologies being considered for this RAO.

Status: Retained

This technology has been retained for further consideration due to its potential high effectiveness.

4.2.3.7 Infiltration Reduction via Low Permeability Cap

Description

The purpose of infiltration reduction is to reduce the amount of impacted shallow groundwater that requires treatment. Since, this technology does not achieve the goal of mitigating shallow groundwater impacts and discharges to the off-facility seep on its own, it is designed to be used in combination with other technologies to enhance their effectiveness. For example, if this technology was used in conjunction with in-situ treatment of eastern shallow groundwater, the effectiveness of the in-situ treatment technology would be increased due to the lower amounts of groundwater requiring treatment. This technology also offers additional benefits by mitigating potential sources of groundwater impacts from Exclusion Area A, Exclusion Area B, and former Pond 7, and also addresses direct contact concerns for ecological receptors.

The footprint of the area of the low permeability cap is shown on Figure 4-11. The southwestern boundary of the cap lies along the shallow overburden groundwater divide as shown on Figure 2-9. The northwest extent of the cap covers former Pond 7 (and the adjacent sludge/soil pile) and Exclusion Area B, and the southeast extent of the cap covers Exclusion Area A. The eastern extent of the cap extends on-facility to the Conrail right-of-way and off-facility over the Crane-Deming seepage area.

Infiltration reduction via low permeability capping of on-facility areas would include regrading to promote positive drainage. It is anticipated that the sludge/soil pile would be graded into former Pond 7. The total coverage of the low permeability cap is approximately 11 acres. Once grading is completed, the low permeability cap would be constructed and may include a subbase cushion layer of imported material or a non-woven geotextile cushion, overlain by a geosynthetic membrane and drainage layer, with soil cover. The need for and details of the earthen or geosynthetic cushion layer will be assessed during detail design. In addition, the selection of the geomembrane would also be made during detailed design. Currently, it is envisioned that a 20 mil PVC or HDPE membrane would be sufficient to provide adequate strength for this application. The drainage layer above the geosynthetic membrane would consist of granular material or a geocomposite drainage layer. The thickness of the final cover soil and vegetative layer will vary based on the type of drainage material selected. Figure 4-11 shows a conceptual cross section of the low permeability cap. All components of the low permeability cap will be selected during detailed design. For example, a soil cap consisting of low permeably soil (e.g., clay) could be used to achieve the same objective. A low permeability clay cap would only be considered if a low cost and readily available source of clay is identified near the site.

Effectiveness: High

This technology will be highly effective at complimenting other technologies (both in-situ and ex-situ technologies) by reducing the amount of shallow groundwater requiring treatment.

Implementability: Easy

Significant advances have been made recently that make construction of low permeability caps relatively easy. Although a specialist constructor will need to be used to place geosynthetic materials, if used, it is anticipated that construction of the cap will be easy to implement.

Cost: Moderate

The cost of this technology is expected to be moderate compared to other technologies.

4.2.3.8 In-Situ Treatment of Southern Area Overburden via Injection Wells and Nanoscale Zero Valent Iron and/or Enhanced Biodegradation

Description

Injection of nanoscale zero-valent iron (NZVI) is a relatively new technology that has been shown to be highly effective at treating a large variety of chemicals (through reduction pathways). Nanoscale iron particles, consisting of 1-100 nanometer sized particles of zero valent iron, provide rapid destruction of a wide range of chemicals based on an oxidation-reduction process where the chemical serves as an electron acceptor and NZVI as the electron donor. Chemicals such as trichloroethene (TCE) can accept electrons from ZVI and be reduced to non-toxic end products including ethene and ethane. Other compounds have been shown to be treatable also, including trihalomethanes, chlorobenzene, PCBs and chlordane (Battelle, 2000). There has been recent evidence that treatment of some BTEX compounds has occurred with NZVI, although the mechanism has not been fully determined. The reactivity of ZVI can be substantially enhanced by depositing a small amount (<1%) of a second metal (e.g., palladium) on the iron particle surface to create a bimetallic particle. Compared to PRBs that employ granular iron, NZVI particles have been shown to be substantially more reactive and extremely effective for the transformation of a wide variety of environmental contaminants because of the increased surface area, greater subsurface distribution potential, and longer contact times. In addition, NZVI particles are more readily placed in the subsurface than traditional iron RPBs. The particles are introduced by injection of a slurry with water, and due to their small size remain suspended in the groundwater flow. A relatively small groundwater mound is developed during injections, which dissipates rapidly after injection is completed. The iron particles will travel some distance from the injection well, and due to their higher density, the particles will settle after the initial migration. A diffuse reactive zone is formed around the injection point. Some particle remobilization may occur during subsequent injection events. With time the iron particles will partially dissolve and their reactivity declines.

Treatment by NZVI has been shown to be immediately effective and sustained for an extended period. Following treatment by NZVI, the groundwater will likely be in a highly reduced state, as dissolved oxygen will be eliminated, oxidation-reduction potential (ORP) will be greatly lowered, and pH will slightly decrease. Examples of typical geochemical changes from a field experience are included in Appendix C. Elimination of dissolved oxygen present in the groundwater (<10 milligrams per liter) will have a minor effect on the amount of iron available for plume treatment as the treatment area already contains low DO concentrations. Similarly, concentrations of nitrate/nitrite, which can react with NZVI, are low in the treatment areas relative to the iron concentration (1-10 grams per liter). The strongly reducing conditions created by NZVI are favorable for stimulating the growth of anaerobic bacteria capable of degrading chemicals not treated directly by the NZVI particles. If needed, this natural microbial degradation can be enhanced through the addition of nutrients and an electron acceptor or energy source (such as sulfate, lactate, emulsified oil, chitin or whey powder) and is therefore referred to as enhanced biodegradation.

The primary chemicals of concern in the southern area include chlorinated solvents, benzene, 1,2-dichlorobenzene and chlorobenzene which are confined primarily within the sandy seams of the glacial till comprising the shallow overburden (as shown on Figure 2-29). Treatment of the southern area overburden groundwater would be performed using NZVI, with injection wells installed within areas of elevated concentrations in the southern area of the site, i.e., in the vicinity of wells PZ-3S and PZ-7. This treatment is expected to consist of the use of approximately five wells for injection and monitoring over a period of approximately two years, as shown on Figure 4-12. Existing monitoring wells may also be used. The extent of groundwater, impacts will be evaluated during PDI activities. Based on current data, it is anticipated that three wells in the vicinity of the PZ-3 well nest, and two wells in the vicinity of the PZ-7 well nest will be required for injections. A simple scoping calculation indicates that, assuming a PCE-equivalent concentration of 25,000 ug/L over a total impacted area of 30,000 sq.ft. and a depth of 10 ft, equals 60 kg of PCE-equivalent mass. Assuming that the efficiency of treatment is (conservatively) 20%, and the stoichiometric relationship of iron to PCE is 1.3:1, the mass of iron required is approximately 400 kg. NZVI injection spread over five wells during eight separate quarters would result in approximately 10 kg per well per quarter.

During the PDI, NZVI injection pilot testing will be performed to evaluate the dispersion of NZVI within the overburden in the localized area. Options for enhancing distribution of NZVI include increasing the number of injection wells, or utilizing extraction wells on a temporary basis to spread the iron over a wider area than could be achieved under gravity-fed conditions. For costing purposes, a total of eight wells have been assumed as a conservative estimate that includes possible enhancements.

Applications of NZVI are expected to immediately reduce the chemical concentrations in the subsurface, however, concentration rebound can occur as the NZVI is used up. It is anticipated that additional NZVI treatment would eliminate the impacts of chemicals treatable by NZVI. Application of a biological treatment may be performed following NZVI treatment if it is determined that longer term or additional treatment is required that can more effectively be accomplished by enhanced biodegradation. The treatability studies that will be conducted during the PDI will enable assessment of whether follow-up enhanced biological treatment is required. To the extent necessary, PDI treatability studies may also assess accelerated biological treatment.

Other concerns identified for the southern shallow groundwater impact area include potential impacts to groundwater in downgradient residential wells to the south and southeast (see Figure III-1 in Appendix A for residential well locations) and soil vapor migration to residential structures to the south and southeast. Notably, residential groundwater wells at adjacent properties have been monitored and no site-related chemicals have been detected in these residential wells. However, both of these pathways will be assessed further during the PDI to evaluate whether remedial actions need to be modified to address these pathways. In particular, the PDI will include the following:

- Additional monitoring of off-property residential wells south and southeast of the on-facility area; and,
- Conducting an active soil gas monitoring program along the south and southeastern perimeters of the on-facility area and, as necessary, any additional soil vapor evaluations determined to be appropriate to assess impacts from southern shallow groundwater.

The details of these PDI activities will be developed in cooperation with the Agencies. Based on the results of the PDI activities, further investigation or the implementation of modified remedial actions may be considered.

Effectiveness: High

The effectiveness of this technology is expected to be high.

Implementability: Easy

Implementability of this technology is easy due to the ease of application of the NZVI and biological treatments.

Cost: Low

Costs associated with this treatment are expected to be low. Costs include material costs of NZVI and/or nutrients and energy sources, monitoring and injection well installation, and monitoring costs. Well maintenance and replacement will be nominal.

Status: Retained

This technology is expected to be effective and thus it has been retained for further consideration in the detailed analysis.

4.2.3.9 In-Situ Treatment of Southern Shallow Groundwater via Injection Wells and Chemical Oxidation

Description

Many, but not all, VOC and SVOC compounds can be oxidized using chemicals with strong oxidizing potential (see the description of chemical oxidation in Section 4.2.1.3). This technology can be applied to the southern shallow groundwater via an array of injection wells. The network of wells would be expected to be similar to that described for the NZVI/accelerated biodegradation injection treatment discussion (Section 4.2.3.8).

Effectiveness: High to Low

Chemical oxidation is expected to have a high to low degree of effectiveness. High effectiveness is anticipated due to the ability of chemical oxidation to treat a variety of organic chemicals. Low effectiveness is anticipated due to potential poor delivery of chemical oxidants to the subsurface, clogging from oxidized metals (such as iron precipitates) and the likely long-term need to address rebounding chemical concentrations. Also, chemical oxidation will alter the geochemistry and adversely impact beneficial natural attenuation processes.

Implementability: Moderate to Difficult

This technology is considered moderate to difficult to implement. Injection of chemical oxidants is somewhat risky because of the potential for highly energetic reactions. In addition, some chemical oxidants require special aquifer conditions (for example, one requires that groundwater be acidified before injecting the chemical oxidant) which increases the difficulty of implementation. Oxidizing reduced (dissolved) metals, e.g., iron will form precipitates that can clog the subsurface and reduce the effective distribution of the chemical oxidants.

Cost: High

Use of chemical oxidation is expected to have high costs due to multiple treatments, and the potential for frequent well maintenance/replacement due to well formation fouling.

Status: Retained

Due to the potential high effectiveness, chemical oxidation has been retained as an in-situ treatment technology for the shallow southern groundwater.

4.2.4 Screening of Technologies / Process Options for RAO-4 (MKS Groundwater, Source Area and Plume)

The long-term objective of RAO-4 is to provide restoration of groundwater quality throughout the eastern plume to health-protective levels. As discussed in Section 2.8, natural attenuation processes are effectively reducing chemical concentrations in the MKS plume.

The following sections present a description and screening level evaluation of the technologies/process options identified to address RAO-4. Table 4-4 lists the response actions and technologies/process options, summarizes the screening level evaluation and indicates whether the technology was retained for further consideration.

4.2.4.1 MKS Source Area Hydraulic Containment via Extraction Wells and New or Modified Groundwater Treatment Plant

Description

This method includes installation of extraction wells downgradient of the MKS groundwater source area and construction of a new treatment plant or upgrades to the current treatment plant to treat the collected groundwater. The extraction wells would be located east of the Conrail right-of-way and west of the Crane-Deming building in order to capture the MKS groundwater source area impacts including the elevated concentrations in the PZ-6B well nest. Five (5) wells would be installed along a north-south line along the west side of the Crane-Deming Building as shown on Figure 4-13. The wells would be spaced approximately 140 feet apart and collectively capture approximately 15 gpm groundwater. The spacing was determined from capture zone analysis included in Appendix F. The extracted groundwater would contain elevated levels of VOCs, SVOCs and metals. Ongoing natural degradation processes would continue to treat residual chemical impacts downgradient of the extraction system.

Effectiveness: Moderate to Low

Groundwater pump and treat technology has been shown over the last several decades to be largely an ineffective technology for the restoration of aquifers to remedial goals. In a survey of USEPA-lead Superfund sites with groundwater pump and treat remedies, the following statistics were reported (USEPA, 2002):

- 60 of the 67 operating systems have groundwater restoration as a goal, but 21 of the 60 do not have estimates of the progress toward that restoration. Of the 39 systems that have both groundwater restoration as a goal and an estimate of progress toward restoration, only 7 (18%) are estimated to have made more than 80% progress toward restoration;

- 53 of the 88 pump and treat systems (including 21 pre-operational systems) are associated with sites where residual product has *not* been observed or suspected; and,

- Only 40 of 67 operating systems (less than 60%) are reported to be controlling plume migration.

These statistics indicate that pump and treat systems are not effective for achieving aquifer restoration, even at Sites with only dissolved chemical impacts (i.e., no DNAPL or LNAPL). Furthermore, pump and treat systems are not consistently effective for achieving hydraulic control.

The effectiveness of extracting groundwater from heterogeneous bedrock formations is variable. Effectiveness of containment can be maximized with adequate testing and design considerations, including well testing design and analysis. Wells in sandstone formations are particularly prone to fissure plugging, sand production, and casing failure (Driscoll, 1986). Proper design of the sand filter pack and well screen are important in these designs. As such, the influence of pumping wells can not be adequately determined, and so effectiveness of containment could be high to low depending on bedrock conditions.

Based on the above considerations, this technology is considered to have moderate to low effectiveness.

Implementability: Moderate

The equipment, methods, and materials for the installation and operation of extraction wells are established and easily obtainable. One potential difficulty at this site is the installation and maintenance of the extraction piping beneath the Conrail Railroad tracks. The construction and operation of a new treatment plant would require the installation of common treatment components and, as such, is implementable. The discharge of an increased amount of effluent would require obtaining the applicable permits equivalencies. Therefore, this technology is considered moderately difficult to implement.

Cost: High

This technology includes a new treatment plant, or major modifications to the existing treatment plant, as well as aggressive pumping and treatment over an extended period. As such, the cost of this technology is expected to be very high relative to other alternatives.

Status: Retained

This technology is retained because it has the potential for moderately effective containment of the MKS source area groundwater. However, for the reasons discussed above and as discussed in Section 4.2.4.4, extraction of groundwater to achieve hydraulic containment of the entire MKS plume is not retained.

4.2.4.2 MKS Source Area In-Situ Treatment via Injection Wells and Reactive Iron (NZVI) and Possibly Accelerated Biodegradation

Description

Injection of NZVI is a new technology that has been shown to be highly effective in treating a variety of chemicals (through reduction pathways). A full description of the NZVI technology is presented in Section 4.2.3.8. The particles range in size from 1-100 nm in diameter and are injected under gravity feed as a slurry with water. Control of particle size is advantageous for customized treatment design based upon pore size of the aquifer. The 1-100 nm size particles will easily “fit” within typical rock fractures of 0.1-0.2 mm (Bear, et al., 1993) and will travel along impacted groundwater flow paths. The treatment of groundwater chemical impacts utilizing NZVI has been shown to be rapidly effective and irreversible. Bench and field scale studies have been conducted which demonstrate the effectiveness of NZVI on many of the chemicals present at this site and in fractured bedrock aquifers. Appendix G presents several references describing the effectiveness of this technology.

In order to control the source area, the NZVI slurry would be injected through wells, both upgradient and downgradient of former Ponds 1 and 2 as shown on Figure 4-14. Groundwater treatment by NZVI, will result in the further reduction of the already low oxidation/reduction potential to a highly reduced state. This geochemical condition will further stimulate the growth of anaerobic bacteria capable of degrading chemicals potentially not treated by the iron particles. Notably, as discussed in Section 2.8, natural biodegradation processes are already occurring and the use of NZVI will stimulate these existing processes. This microbial degradation can be accelerated (if necessary) by addition of nutrients and an energy source (such as sulfate, lactate, ethanol, chitin or whey powder). It is anticipated that NZVI injections would be conducted quarterly for a period of 1 to 2 years. After this initial 1 to 2 year NZVI injection period, consideration will be given to continuing with the NZVI injections and/or implementing enhanced biological treatment injections, which may be a more effective long-term treatment measure. An enhanced biodegradation system can be implemented utilizing the same injection well network and is a complementary treatment following NZVI, in that the reducing conditions enhanced by NZVI are optimal for the continued degradation of most site chemical impacts. Natural attenuation, including degradation and dilution, will continue to occur in the downgradient portion of the MKS plume and within the MFLBC buried valley. Both NZVI and accelerated biological treatment are expected to enhance the natural attenuation of chemical impacts in the downgradient portion of the plume area.

Treatability studies will be conducted during the PDI to define design and operational variables for the NZVI technology and to help assess whether follow-up accelerated biological treatment is required. If necessary, the PDI treatability studies may also define design and operational variables for accelerated biological treatment.

Effectiveness: High

This technology is expected to have a high degree of effectiveness. Experience has shown the capability of NZVI in effectively treating a large number of chlorinated compounds. Biological treatment is also expected to have a high level of effectiveness. An anaerobic treatment system incorporating the proper electron donor would be effective in treating chemicals such as BTEX compounds that may not be fully treated with NZVI as rapidly as with a biological system. The biological system would continue to treat the chlorinated compounds addressed by the NZVI.

Implementability: Moderate

The implementability of this technology is considered to be moderate when compared to other methods.

Cost: Moderate

The cost of this technology is expected to be moderate.

Status: Retained

Because NZVI has the potential to be highly and immediately effective, and enhanced biodegradation has the potential to be an effective, complementary and long-term treatment measure, this technology has been retained for further evaluation.

4.2.4.3 MKS Source Area In-Situ Treatment via Injection Wells and Chemical Oxidation

Description

Many VOC and SVOC compounds can be oxidized using chemicals with strong oxidizing potential (see the description of chemical oxidation in Section 4.2.1.3). Oxidation chemicals can be applied to groundwater via an array of injection wells. The network of wells would be expected to be similar to that described for the NZVI injection treatment discussed in Section 4.2.4.2.

Effectiveness: High to Low

Chemical oxidation is expected to have a high to low degree of effectiveness as discussed in Section 4.2.3.6. The high effectiveness results from the potential ability of the technology to treat a wide variety of organic chemicals. The low effectiveness results from potential clogging concerns which will limit the delivery of the oxidants, and the altered geochemistry which will adversely impact the beneficial natural attenuation processes that are occurring throughout the plume and are responsible for stabilization and chemical concentration reduction within the plume.

Implementability: Moderate to Difficult

This technology is considered moderate to difficult to implement. Injection of chemical oxidants is somewhat risky because of the potential for highly energetic reactions. In addition, some chemical oxidants require special aquifer conditions (for example, one requires that groundwater be acidified before injecting the chemical oxidant) which increases the difficulty of implementation. Oxidizing reduced metals, e.g., iron, may clog fractures limiting the implementability of oxidant distribution throughout the plume.

Cost: High

Use of chemical oxidation is expected to have high costs due to multiple treatments required to address rebounding groundwater chemical concentrations, and the potential for high well maintenance/replacement due to well formation fouling.

Status: Retained

Because the chemical oxidation technology has a potentially high degree of effectiveness for treating a wide variety of chemicals, this technology has been retained for further consideration.

4.2.4.4 MKS Plume Hydraulic Containment via Extraction Wells and New Groundwater Treatment Plant

Description

This technology includes the installation of groundwater extraction wells in the source area as described in Section 4.2.4.1. In addition, two to three lines of wells, parallel with and downgradient of the source area wells, would also be installed in the MKS, surrounding, and to the east of the Crane-Deming building in order to achieve hydraulic capture of groundwater throughout the MKS plume. Such a system may not be able to ensure complete hydraulic containment. Much higher groundwater extraction and treatment rates would be required, necessitating the construction of a new and higher capacity groundwater treatment plant than the treatment plant needed for only MKS source area groundwater.

Effectiveness: Low

The effectiveness of this method is expected to be low. As described in 4.2.4.1, the fractured nature of the MKS formation could adversely impact the effectiveness of this method. In addition, this technology is not expected to be any more effective (and may ultimately be less effective for stabilizing and restoring the MKS plume) than the existing natural attenuation processes. A plume-wide extraction system will encounter the same effectiveness limitations as a source-based system (Section 4.2.4.1). However, the limitations are amplified due to the necessity to achieve hydraulic capture over a much greater area. The mass removal rates achieved by pump and treat systems decline steadily and substantially over time, such that the total mass removed reaches an effective maximum amount at a level much less than the total plume mass. Mass removal limitations are associated with mass that remains in the formation within fine-grained materials, hydrodynamic isolation (dead spots within well fields), and from dissolution of residual contamination.

Implementability: Difficult

Although the equipment, methods, and materials are easily obtainable for this method, there are other concerns that decrease the implementability. Construction of a new treatment plant would be required as well as drilling of new wells and installation of a piping network. This treatment option would impact a large amount of land on the Site and is expected to be difficult to monitor.

Cost: Extremely High

The cost of this treatment method is expected to be extremely high because of the need for a new and substantially larger treatment plant, and long-term treatment requirements.

Status: Eliminated

Due to the potentially low effectiveness, low implementability, and extremely high cost and because natural attenuation processes have already stabilized and are restoring the MKS plume, this technology has been eliminated from further consideration.

4.2.4.5 MKS Plume In-Situ Treatment via Injection Wells and Reactive Iron (NZVI) and/or Accelerated Biodegradation

Description

This process would be identical to that explained in Section 4.2.4.2 except that the amount and duration of NZVI and biological reagent injections into the MKS source area would be increased thereby allowing the treatment zone to propagate further out into the MKS plume. Preliminary estimates indicate that this alternate approach will result in an effective treatment zone within the MKS plume. Monitored natural attenuation (MNA) would be used to remediate the downgradient portions of the plume.

Effectiveness: High to Moderate

The effectiveness of this technology is expected to be high to moderate. The combination of an expanded NZVI and enhanced biodegradation treatment zone is expected to effectively treat the MKS plume chemical impacts and accelerate the already occurring natural attenuation process for restoring the MKS groundwater quality. However, monitoring the effectiveness of treatment throughout the MKS plume is expected to be moderately difficult.

Implementability: Moderate

This technology would be moderately difficult to implement because of the dispersed nature of the contaminant plume and the required monitoring.

Cost: Moderate

It is expected that this technology would have moderate relative costs.

Status: Retained

This technology has been retained because of its potential for high effectiveness.

4.2.4.6 MKS Plume In-Situ Treatment via Monitored Natural Attenuation

Description

This alternative would include MNA for chemical impacts in groundwater in the MKS plume. There is strong evidence to suggest that natural attenuation is effectively occurring. A detailed discussion of natural attenuation indicator parameters, and evaluation of existing conditions is provided in Section 2.8. This technology would include a network of wells for monitoring of the MKS source, plume and overburden in the MFLBC valley over a period of approximately 30 years. The details of the monitoring program would be developed on cooperation with the Agencies during design.

Field parameters and natural attenuation parameters to be monitored include dissolved oxygen, oxidation-reduction potential, turbidity, pH, specific conductance, methane, ethane, ethene, total organic carbon, alkalinity, total suspended solids, nitrate, sulfate, sulfide, ferrous iron, and chloride. Water levels are measured during each sampling and equipotential maps will be constructed to monitor groundwater flow and direction.

Effectiveness: High to Moderate

The effectiveness of MNA is high to moderate and combined with a source reduction or elimination technology, MNA is an effective means of reducing chemical concentrations to health-protective levels. Degradation of chemical impacts is clearly occurring in the bedrock plume; the plume is stable and is decreasing in size. The discharge of the MKS plume into the buried bedrock valley results in substantial dilution and further attenuation, as evidenced by the fact that no detections have occurred in the wells nests adjacent to the MFLBC. The geochemical conditions of the buried bedrock valley are similar to the MKS plume in maintaining a reducing environment for microbial processes to occur and favorable for reduction of chemical concentrations. The MFLBC valley is currently monitored by five well nests comprised of 21 wells (nests D, E, F, K and J).

Implementability: Easy

The MNA remedial alternative is easy to implement, since it relies on natural biochemical and physical processes that already exist and that do not require enhancement. The services and materials required to implement this alternative are standard within the industry and readily available.

Cost: Low to Moderate

Depending on the frequency and number of wells requiring monitoring, the cost of MNA is expected to be moderate. Costs include regular sampling of wells, laboratory chemical analyses, data evaluation, and well maintenance costs.

Status: Retained

As a result of its high potential effectiveness and easy implementability, this technology has been retained for further consideration.

4.2.4.7 MKS Plume In-Situ Treatment via Injection Wells and Chemical Oxidation

Description

Treatment of the MKS plume would occur in the same way as for the source area (Section 4.2.4.3) except that injection wells would also be installed to the east of the Crane-Deming Building rather than just near the source area.

Effectiveness: Moderate to Low

This method will have variable effectiveness (moderate to low) depending on site conditions and on the chemical oxidant chosen for injection (see Section 4.2.4.3). A long and indefinite period of treatment is likely since rebound from residuals in the MKS groundwater will occur and biological natural attenuation will be eliminated. Substantial amounts of chemical oxidants will be required to be injected throughout the entire plume and the uniform delivery and treatment throughout the plume is questionable.

Implementability: Difficult

This method will be difficult to implement because of the disperse nature of the plume and other reasons as described in Section 4.2.4.3.

Cost: High

Costs associated with this treatment are expected to be high given the anticipated long and indefinite chemical injection period.

Status: Eliminated

Due to the low to moderate effectiveness, difficult implementability and the resulting elimination of biological natural attenuation processes, this technology has not been retained for further consideration.

4.2.4.8 DNAPL Recovery Technologies

As discussed in Section 2.7.1, DNAPL has been detected within and in the immediate vicinity of former Ponds 1 and 2. The DNAPL does not exist in discrete homogeneous pools, rather, it occurs sporadically within the overburden and bedrock adjacent to former Ponds 1 and 2.

It is widely recognized that the distribution of DNAPL is complex and difficult to predict, especially in fractured bedrock settings such as the Washingtonville shale and MKS. Therefore, it is likely impossible to create a systematic extraction system that will effectively remove a meaningful quantity of the DNAPL. As a result, in-situ groundwater treatment technologies that more broadly target DNAPL zones including dead-end or reduced accessibility fractures and within the primary porosity of the rock (such as NZVI and in-situ biodegradation) are preferred. Notwithstanding the above, small amounts of DNAPL have been detected in certain monitoring wells at the Site in the vicinity of former Ponds 1 and 2 and periodic direct removal efforts can be evaluated.

For the reasons stated above, pumping systems designed to provide systematic recovery of DNAPL would not be effective. However, efforts could be made to remove DNAPL from existing or newly installed wells where sufficient volumes accumulate to make recovery practicable. A focused investigation of DNAPL will be conducted during the PDI to assess its presence and recoverability in existing and any newly installed monitoring wells. Depending on the particular well conditions, recovery technologies may include periodic pumping (peristaltic or vacuum lift pumps), bailing, or use of absorbents. The specific method of DNAPL removal will be determined during detailed design and may vary between individual wells. The recovered DNAPL would be temporarily stored on-property until sufficient quantities are accumulated for off-site treatment and disposal.

The remediation of former Ponds 1 and 2 will address any DNAPL that still exists within the sludge of these former ponds. Chemicals in DNAPL occurring outside of the former Ponds 1 and 2 treatment area that dissolve into groundwater will also be addressed via shallow groundwater remediation technologies discussed in Section 4.2.3 and MKS groundwater remediation technologies discussed in Section 4.2.4

This technology will effectively recover DNAPL where it exists and sufficiently accumulates in monitoring wells and can be implemented in a cost effective manner. This technology has been retained and will be included as a common component of all OU-2 remedial alternatives as discussed in Section 5.3.

4.2.5 Screening of Technologies / Process Options for RAO-5 (Groundwater Pathway Elimination)

The RAO-5 includes the elimination of on-property residential exposures to impacted soils, fill and sludge, and the elimination of both future residential and non-residential use of groundwater. These objectives can be effectively and efficiently achieved using institutional controls. Specifically, the property deeds will be legally modified to include prohibitions on the future residential use of the property and any future use of on-property groundwater. This approach will effectively meet RAO-5 and can be easily implemented in a cost effective manner. This technology has been retained and will be included as a common component of all OU-2-wide remedial alternatives as discussed in Section 5.3. Table 4-5 presents a summary of the screening results for technologies identified to address RAO-5.

4.2.6 Screening of Technologies / Process Options for RAO-6 (Surface Soil)

As discussed in the October 31, 2003 letter report to the Agencies, the EA identified potentially unacceptable risks for the future industrial worker and construction worker associated with exposure pathways related to indoor air, incidental ingestion and dermal contact with soil, inhalation of construction vapors and construction dust. Institutional controls in the form of deed restrictions and related engineering controls, including health and safety measures are proposed to control the inhalation exposure pathways, as follows:

- Engineering controls such as building vapor barriers and sub-slab depressurization systems would be required under the deed restrictions should buildings be constructed in areas where vapor intrusion could present an unacceptable risk for industrial workers.
- Engineering controls would also be required under the deed restrictions to mitigate vapor/dust and direct contact exposures during any construction. Such measures would include engineering controls to reduce dust and vapor generation, require appropriate personnel protective equipment and monitoring, and prohibit construction in certain areas such as former Ponds 1 and 2.

These institutional/engineering controls are effective in addressing potential risks to the future industrial worker and construction worker and can be easily implemented in a cost efficient manner. These institutional/engineering controls will be included as a common component in each OU-2-wide remedial alternative as discussed in Section 5.3.

In addition, risks to ecological receptors from potential exposure to mirex in on-facility surface soil (including surface soil within drainage ditches) were also identified in the EA. Therefore, the technologies evaluated for this RAO focus on addressing ecological exposure pathways of potential concern. Table 4-6 presents a summary of the screening results for technologies identified to address RAO-6.

4.2.6.1 Exposure Pathway Elimination via Containment Utilizing Soil Barrier Covers for Surface Soil and Drainage Ditch Soils

Description

Soil Barrier Covers

A minimum of 1-foot soil cover will be placed over areas where mirex concentrations in the surface soil exceed ecologically-based PRGs. Prior to placement of the soil barrier cover, the ground surface will be graded, bulky debris removed and existing vegetation cleared. A synthetic barrier layer will be placed on top of the ground surface as an additional barrier to mitigate direct contact exposures and to provide a marker layer to define the original ground surface and assist in future maintenance.

The soil barrier cover will consist of erosion resistant soils capable of supporting vegetation, and if necessary, or will incorporate an approximately 0.5-foot layer of topsoil to support vegetation. Soil barrier covers may also be incorporated as part of property redevelopment where paved areas and buildings can provide equivalent barriers to direct contact exposures.

Drainage Ditch Soil Barrier Covers

Covers will be constructed in drainage ditches over surface soils in areas that exceed ecologically-based PRGs. The objective is to mitigate ecological direct contact and erosional transport of impacted soil. The covers would consist of materials such as one of the following:

- A soil barrier cover as described above;
- Rip-rap placed over a non-woven geotextile barrier/marker layer; or
- Concrete lined channel.

The details of the soil barrier cover for surface and drainage ditch soil would be determined during detailed design. A detailed description and analysis of the soil barrier cover technology is presented in Appendix E.

Effectiveness: High

The effectiveness of these technologies to address potential direct contact exposures by ecological receptors is expected to be high.

Implementability: Easy

The equipment, methods and materials to construct these technologies are conventional and readily available. Thus the implementability of these technologies is easy.

Cost: Low to Moderate

Depending on the area of soil and drainage ditch coverage required, the cost of implementing this technology is expected to range from low to moderate compared to the other technologies.

Status: Retained

This technology has been retained for further consideration due to its high effectiveness and easy implementability.

4.2.6.2 Removal of "Hot-Spots" via Excavation

Description

Impacted on-facility surficial soil and drainage ditch soil may be excavated from select "hot-spot" areas having elevated mirex concentrations. For the purpose of this FS, "hot-spots" are defined as discrete and localized areas of surficial soil or surficial drainage ditch soil having mirex concentrations above ecologically-based PRGs. It may be determined during detailed design that removal of certain localized areas may be more effective than construction or soil barrier cover or drainage ditch liner. The ultimate placement of the material removed will be determined during design. Data collected during the PDI will allow a site-specific assessment of potential final placement options. As necessary, excavated areas will be backfilled with clean fill capable of supporting vegetation or will include a topsoil layer to support vegetation.

Effectiveness: High

The effectiveness of this technology to address potential direct contact exposures for ecological receptors is expected to be high.

Implementability: Easy

The equipment, methods and materials to construct this technology are conventional and readily available. Thus the implementability of this technology is easy.

Cost: Low to Moderate

The cost of this technology is expected to range variably from low to high. Low costs are anticipated where small volumes of material are removed and incorporated into the remediation of one or more of the former ponds. Moderate costs are anticipated where larger areas are excavated.

Status: Retained

This technology is expected to be effective and easily implementable and is thus retained for further consideration. This technology is retained only to the extent that excavated soil can be reused on-property. Should off-site disposal of excavated soil be required, then this technology does not address RAO-6 as efficiently as other less expensive technologies that equally meet the objective for mitigating direct contact exposures.

4.2.6.3 In-Situ Treatment Using Stabilization/Solidification

Description

Stabilization/solidification reagents would be mixed into the surface soil utilizing conventional mechanical equipment. Reagents could include cement, lime and/or kiln dust, and would be determined during design. Since reduction of infiltration is not a component of RAO-6, the technology would be used to encapsulate chemical impacts within the stabilized soil matrix and thus reduce their bioavailability to the direct contact ecological exposure pathway.   This type of in-situ stabilization/solidification is different than that being considered for former Ponds 1 and 2 since conventional equipment (backhoe, excavator) is used to mix reagents into the surface materials instead of auger mixing and air stripping of chemicals in deeper soil.

Effectiveness: Low to Moderate

The effectiveness of this technology is expected to be low to moderate. Moderate effectiveness is a result of modification of the surface soil matrix which will eliminate habitat and bioutilization of the surface soil media. However, the resulting elimination of habitat is undesirable and so the overall effectiveness is reduced.

Implementability: Easy

The equipment, methods and materials to construct these technologies are conventional and readily available. Thus the implementability of this technology is easy.

Cost: High

The cost for this technology is high compared to other technologies that would effectively meet this RAO.

Status: Eliminated

Given its low to moderate effectiveness and high cost as compared to other technologies, this technology is eliminated from further consideration for these media.

5.0 SCREENING OF REMEDIAL ALTERNATIVES FOR OU-2

5.1 Assembly of Alternatives

The retained technologies presented in Section 4.0 were assembled into eight OU-2 remedial action alternatives for further evaluation. A No Action (or in this case No Further Action) alternative (Alternative No. 1) was identified consistent with the NCP. The remaining alternatives were assembled as follows:

- Alternative 2 was assembled to actively remediate all source areas except the MKS groundwater (which would be allowed to naturally attenuate). This alternative was assembled for comparison to alternatives that actively remediate the MKS groundwater source area and plume.

- Alternatives 3, 4, and 8 were assembled to provide aggressive treatment of the primary source of groundwater impacts (former Ponds 1 and 2), treatment of shallow groundwater on the eastern and southern edges of the on-facility area, and treatment of the MKS source area. In-situ treatment and MNA of the MKS plume is also provided. Alternative 3 includes a low permeability cap which will enhance the potential effectiveness of an option for in-situ treatment of eastern shallow groundwater. Alternatives 4 and 8 also include in-situ treatment of eastern shallow groundwater but without the use of a low permeability cap. Institutional controls and barrier covers were included to mitigate future exposures to impacted fill/sludge in former Ponds 3, 4, and 7 and in on-facility soil.

- Alternatives 5 and 6 were assembled to provide less aggressive actions (i.e., containment) for former Ponds 1 and 2, treatment of shallow groundwater at the eastern and southern edges of the on-facility area, and extraction and treatment of the MKS source area groundwater. MNA is provided for the MKS plume. Institutional controls and barrier covers were included to mitigate future exposures to impacted fill/sludge in former Ponds 3, 4, and 7 and in on-facility soil.

- Alternative 7 – For comparison, this alternative was assembled to assess extraction and treatment in the MKS source area as well as throughout the MKS plume. Institutional controls and barrier covers were included to mitigate future exposures to impacted fill/sludge in former Ponds 3, 4, and 7 and in on-property soil.

A description and screening level evaluation of each alternative is presented below and a summary of the Alternatives is presented in Table 5-1. The screening level evaluation is based on the same NCP criteria used for the screening of remedial technologies as described in Section 4.2.

5.2 Alternative No. 1 – No Further Action

5.2.1 Description

Other than the continued operation of LCS-1 and LCS-2 (eastern shallow groundwater collection and on-site treatment), no other remedial actions would be implemented at the site. The following summarizes the major components of Alternative 1:

RAO	Action
RAO-1 Former Ponds 1 and 2	No Further Action
RAO-2 Former Ponds 3, 4, 7	No Further Action
RAO-3A Eastern Shallow Groundwater	Continued Operation of LCS-1 & LCS-2
RAO-3B Southern Shallow Groundwater	No Further Action
RAO-4A MKS Groundwater Source	No Further Action
RAO-4B MKS Groundwater Plume	No Further Action
RAO-4C DNAPL	No Further Action
RAO-5 Groundwater Residential Use	No Further Action
RAO-6 Surface and Drainage Ditch Soils	No Further Action

5.2.2 Effectiveness

A summary of the effectiveness of this alternative is presented below:

- This alternative does not address the mitigation of future releases from former Ponds 1 and 2 (RAO-1). However, the collection of shallow groundwater from LCS 2 directly downgradient of former Ponds 1 and 2 does collect a portion of the shallow groundwater impacts from the former ponds. In addition, LCS-1 addresses shallow groundwater downgradient for Exclusion Area A.

- This alternative does not address mitigation of exposures to former Ponds 3, 4, and 7 surficial fill/sludge (RAO-2).

- This alternative does not completely address shallow groundwater impacts (RAO-3), however, LCS-1 and LCS-2 do provide collection and treatment of shallow groundwater and reduce the potential impacts. This alternative does not address the Crane Deming seepage area.

- It is not believed that this alternative will enhance the restoration of the MKS groundwater plume (RAO-4). However, the extent of migration of the MKS plume has been largely defined, is being controlled, and as discussed in Section 2.8, natural attenuation processes (both abiotic and biotic) are effectively reducing downgradient chemical concentrations (i.e., the MKS plume is stable and is undergoing natural restoration). This alternative does not include any additional monitoring to assess the ongoing rate of natural restoration and to continue to confirm plume stability.

- This alternative does not address RAO-5 as no deed restrictions would be placed on the property limiting future use and preventing groundwater exposures.

- This alternative does not address RAO-6 as no institutional controls would be put in place requiring engineering controls of vapor intrusion into future buildings and procedural controls to protect future construction workers. In addition, no barriers to prevent direct contact exposure to impacted on-property soil will be constructed.

In summary, this alternative does not fully control the primary sources of chemical impacts to site media and it does not control future exposures to impacted site media. Therefore, the effectiveness of this alternative in providing protection of human health and the environment is low.

5.2.3 Implementability

This alternative is easily implemented.

5.2.4 Cost

The cost of this alternative is low relative to the other alternatives, although the cost to continue to operate and maintain LCS-1 and LCS-2 is substantial, on the order of $5,000,000.

5.2.5 Status: Retained

This alternative has been retained as Alternative A[26] for detailed analysis in Section 6.0 consistent with the NCP.

5.3 Common Remedial Alternative Elements

The common remedial elements presented below address former Ponds 1 and 2 (RAO-1), former Ponds 3, 4, and 7 (RAO-2), on-property groundwater and residential use (RAO-5), and on-facility surface and drainage ditch soil (RAO-6). Each of these common remedial elements is included in each of the remaining alternatives assembled and screened in Section 5.0. These common remedial elements include remedial action components as well as PDI activities and are summarized below.

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[26] A letter based identification system is used for the retained alternatives.

Common Remedial Action Components

Former Ponds 1 and 2 Cover and Institutional Controls

All of the assembled alternatives will include either a soil barrier cover or a low permeability cap placed over the footprint of former Ponds 1 and 2 following remediation of the subsurface material. The soil barrier cover will be similar to that described for on-facility surface soils in Section 4.2.6.1 and in Appendix E. The low permeability cap is discussed in Section 4.2.3.7. Institutional controls will be implemented in the form of deed restrictions to prohibit future disturbance of remediated area and final cover. Annual inspections will be conducted to document future land use and conditions of the final cover. Regular maintenance and repair (as necessary) of the final cover will be conducted.

Former Ponds 3, 4, and 7 Covers and Institutional Controls

All of the assembled alternatives utilize a soil barrier cover to address RAO-2, i.e., mitigate potential ecological exposures to mirex in surface soil/fill, as described in Section 4.2.2.1 and in Appendix E. Where necessary, soil stabilization technologies will be implemented to provide structural support of the soil barrier covers in former Ponds 3 and 7 (see Section 4.2.2.2). Institutional controls will be implemented in the form of deed restrictions to limit future land use within the footprints of the former pond areas to open, infrequently used green space and to prohibit future disturbance of the soil barrier covers. Annual inspections will be conducted to document future land use and conditions of the soil barriers. Regular maintenance and repair (as necessary) of the soil barrier covers will be conducted.

Periodic DNAPL Removal

Periodic DNAPL removal is included as a common remedial component for each of the assembled remedial alternatives. A description of this component is presented in Section 4.2.4.8 and is summarized below.

Existing and any new monitoring wells in the vicinity of the former Ponds 1 and 2 source area will be monitored using an interface probe, or an equivalent free-phase liquid monitoring device. Where sufficient quantities have accumulated, DNAPL will be periodically removed from the wells using one of several different techniques such as pumping using a peristaltic pump or vacuum lift system with tubing extending to the base of the boring, disposable absorbent materials and/or disposable bailers. The recovered DNAPL will be properly disposed of off-site. Since the DNAPL is likely to take a substantial amount of time to re-accumulate in these wells, if at all, periodic measurements of the DNAPL wells will be conducted in order to develop an estimated removal frequency. The accumulation of DNAPL in monitoring wells will be assessed during the PDI and the most appropriate method of periodic removal will be developed during detailed design.

Institutional Controls for Residential and Groundwater Use

Institutional controls, as described in Section 4.2.5, are included in all the assembled alternatives to address RAO-5. These institutional controls, in the form of deed restrictions, will prohibit future residential use of the property and any future use of on-property groundwater until the residential and groundwater remedial goals are achieved.

Surface and Drainage Ditch Soil Covers

Each of the assembled alternatives has several common elements which address RAO-6, including surface soil barrier covers, drainage ditch soil covers (liners), and institutional controls, which are described in detail in Sections 4.2.6.1 and 4.2.6, respectively. Soil barrier covers will be constructed over on-facility surface soil and drainage ditch soil, to the extent necessary to mitigate potential ecological exposures to mirex at concentrations above ecologically-based cleanup levels. It may be determined during the detailed design that localized areas of surface and drainage ditch soil that exceed the mirex PRG may be more effectively remediated via "hot-spot" removal and re-use in one of the former ponds. Data collected in the PDI will be used to determine the appropriateness of on-property soil/fill removal. Institutional controls, in the form of deed restrictions, will be implemented to limit the future use of the property to non-residential use and require engineering controls that will mitigate soil vapor intrusion into buildings and construction worker exposures as discussed in Section 4.2.6. Annual inspections will be conducted to document future land use and conditions of the barrier covers. Regular maintenance and repair (as necessary) of the soil barrier covers will be conducted.

Surface Water Management

The remediation of the former ponds, surficial soil, and drainage ditch soils described in the above common remedial elements will result in considerable surface earthwork construction. A property-wide surface water management system will be developed during remedial design and constructed during remedial action to provide for the effective control of surface water runoff and to minimize future soil erosion from these areas. The property-wide surface water management system will consist of the following components:

- A grading plan that integrates final surface topography in the remediated areas into the surrounding areas;
- The use of proper slopes, berms, channels, etc., and surface armoring using natural vegetation and/or synthetic materials to efficiently convey surface water runoff off the remediated areas and provide erosion protection; and,
- A program of regular inspection, maintenance and repair (as necessary) to assume continued effectiveness of the surface water management system.

The property-wide surface water management system will be developed during detailed design in accordance with state and local soil erosion and sedimentation control requirements.

Common PDI Activities

The following summarizes the PDI activities that are included in all of the assembled alternatives (except for No Further Action). A PDI work plan will be completed and submitted to the agencies which describes the activities in detail. Notably, the details of all PDI activities would be developed in cooperation with the Agencies. Additional alternative-specific PDI activities are listed for each alternative retained for further consideration.

Former Ponds 3, 4, and 7 (RAO-2)

- Installation and sampling of groundwater monitoring wells downgradient of former Ponds 4 and 7 would be completed to evaluate the potential for these ponds as sources of groundwater impacts. Pending the results of this evaluation, additional investigation and/or remedial actions may be considered.
- A field investigation will be conducted to determine the type and extent of soil barrier covers required over former Ponds 3, 4, and 7, as discussed in Section 4.2.2.1.

Shallow Groundwater (RAO-3)

- A groundwater monitoring program at existing and potential new shallow groundwater monitoring wells will be conducted to establish baseline groundwater conditions for use in the design of both the eastern and southern shallow groundwater remedies (e.g., ex-situ treatment or in-situ treatment). Baseline groundwater quality will also be used to assess remedy effectiveness during the initial 5-year review process.
- Field hydraulic testing of the eastern shallow groundwater will be completed to determine flow rates for the design of the eastern shallow groundwater collection trench, ex-situ treatment, and/or in-situ treatment technologies. It is currently envisioned that this

testing would include a combination of slug testing of monitoring wells and pilot recovery testing of a small trench section in the area of the proposed collection trench alignment.

- The PDI will also provide a further evaluation of potential impacts to residents from southern shallow groundwater. Specifically, the following will be conducted:

    - Conduct additional residential well sampling program south and east of the area in question to verify that these wells have not been impacted by southern shallow groundwater; and,
    - Conduct a soil gas study along the southern and southeastern facility property boundary to assess the potential for vapor migration.

  Provisions will be included to conduct follow-up investigation and/or remediation activities based on the PDI results.

- Surface soil in the vicinity of the Crane-Deming seepage area will be investigated to determine whether a soil barrier cover is needed in this area. Subsurface soil along the alignment of the eastern shallow groundwater collection trench will also be investigated to assess ultimate placement of soil/fill removed from the trench.

MKS Source Area and Plume Groundwater (RAO-4)

- A groundwater monitoring program at existing and proposed new MKS monitoring wells will be conducted to establish baseline groundwater conditions for use in the design of the groundwater remedies (e.g., In-situ NZVI and MNA). Baseline groundwater quality will also be used to assess remedy effectiveness during the 5-year review period.

- A new groundwater monitoring well cluster will be installed east of existing monitoring well D-9, approximately one-half of the distance between Allen Road and the MFLBC to verify the downgradient extent of the MKS plume. Sampling of this well cluster and existing monitoring wells in this area will be included in the baseline groundwater monitoring program.

- A focused investigation of DNAPL will be conducted to assess its presence in and recoverability from existing and new monitoring wells. Where possible, one or more DNAPL samples will be collected and analyzed to assess physical and disposal characteristics.

Surface and Drainage Ditch Soil (RAO-6)

- Similar to defining the extent of the soil barrier covers for former Ponds 3, 4, and 7, an evaluation of surficial on-facility and drainage ditch soil will be conducted to assess the type and extent of the soil barrier cover in these areas. The PDI will focus on horizontal delineation, as no vertical profiling is needed except to the extent necessary to assess "hot-spot" removal, i.e., characterize mirex levels in soil directly below the removal area.

Flood Plain/Wetlands

An assessment of the 100-year flood plain and the presence/absence of wetlands in areas of remediation will be conducted during the PDI to provide data for design.

Wastewater Treatment Plant Sludge Cells

- ROC and other parties engaged in future remedial activities will work with the City of Salem to ensure that the WWTP area is appropriately controlled, such that no exposures occur in the event of future intrusive activities occur at the WWTP and its environs.

- If control of exposures to these sludges cannot be guaranteed, then a more thorough characterization of these areas will be necessary in order to quantify the risks to future receptors resulting from potential exposures to mirex in these materials. This characterization could include additional information on disposal practices at the WWTP or further sampling and analysis of the former sludge bed areas.

5.4 Alternative No. 2

5.4.1 Description

The common remedial elements presented in Section 5.3 are included in Alternative 2. In addition, this alternative includes alternative specific remedial components. A summary of Alternative 2 is presented below:

RAO	Action
RAO-1 Former Ponds 1 and 2	In-situ Mixing (S/S/S)
RAO-2 Former Ponds 3, 4, 7	Soil Barriers and Institutional Controls
RAO-3A Eastern Shallow Groundwater	Ex-situ Treatment
RAO-3B Southern Shallow Groundwater	No Further Action
RAO-4A MKS Groundwater Source	No Further Action
RAO-4B MKS Groundwater Plume	No Further Action
RAO-4C DNAPL	Recovery and Off-site Disposal
RAO-5 Groundwater Residential Use	Institutional Controls
RAO-6 Surface and Drainage Ditch Soils	Soil Barriers and Institutional Controls

Former Ponds 1 and 2 (RAO-1)

Alternative No. 2 provides in-situ treatment of former Ponds 1 and 2 fill/sludge through in-situ soil mixing/air-stripping and stabilization/solidification as described in Section 4.2.1.2. Substantial quantities of VOCs and some of the more volatile SVOCs will be extracted from the fill/sludge via air stripping during soil mixing. Due to the heat generated by the large air compressors used, the air injected into the continually mixed fill/sludge matrix will be warmer than ambient, further facilitating volatilization of VOCs and some SVOCs. In general, the lower volatility SVOCs and pesticides are less mobile in the environment, and thus are more amenable for stabilization/solidification treatment. These remnant chemicals will be rendered immobile within a stabilized/solidified matrix. Treatability testing will be conducted during the PDI to determine design parameters and performance standards. Section 4.2.1.2 provides a detailed description of this technology.

Eastern Shallow Groundwater (RAO-3)

Chemical impacts remaining in the vicinity of former Ponds 1 and 2 following remediation and within Exclusion Areas A and B, will be addressed via the continued operation of LCS-1 and LCS-2 and/or the collection of shallow groundwater with a collection trench and ex-situ treatment of the collected groundwater as described in Sections 4.2.3.1 and 4.2.3.2. It is expected that further engineering and hydrogeologic analyses completed during detailed design will demonstrate that the simultaneous operation of these two systems are redundant (i.e., both intercept the same or similar shallow groundwater impacts). Therefore, it will likely be determined that it is more appropriate to install and operate the new shallow groundwater collection trench with treatment via a new or modified system (see Section 4.2.3.2) as opposed to operating both shallow groundwater collection systems. If this conclusion is reached during remedial design, then LCS-1 and LCS-2 would be decommissioned.

To the extent necessary, surface soil in the Crane-Deming seepage area will be covered by a soil barrier cover or reused on-property as determined during design. This area will be evaluated further during the PDI as discussed in Section 5.3.

Southern Shallow Groundwater (RAO-3)

This alternative does not directly address the southern shallow groundwater. Should the PDI determine that there are complete exposure pathways to adjacent residents then follow-up investigation or remediation would be conducted as determined during remedial design.

MKS Source Area and Plume Groundwater (RAO-4)

While no direct treatment of the MKS source area groundwater is included in this alternative, it is important to note that the extent of migration of the MKS plume has been largely defined, is controlled, and natural attenuation processes are effectively reducing the downgradient chemical concentrations, i.e., natural restoration of the plume is occurring (see Section 2.8). In addition, there are no reported receptors to impacted MKS groundwater.

5.4.2 Effectiveness

Alternative 2 will effectively achieve remedial action objectives RAO-1, RAO-2, RAO-5 and RAO-6. Alternative 2 will also achieve RAO-3 for eastern shallow groundwater but not for southern shallow groundwater. Alternative 2 does not enhance the restoration of MKS groundwater and thus does not achieve RAO-4. However, as discussed in Section 2.8, the MKS plume is controlled and is naturally attenuating, and there are no current receptors to this groundwater.

In summary, while Alternative 2 is effective for achieving RAO-1, RAO-2, RAO-5 and RAO-6, it does not fully address RAO-3 and RAO-4.

5.4.3 Implementability

The soil barrier cover and institutional control technologies for this alternative are easily implemented. The in-situ soil mixing/air stripping and stabilization/solidification and shallow groundwater treatment technologies are considered moderately difficult to implement.

5.4.4 Cost

The relative cost of this alternative is moderate.

5.4.5 Status: Eliminated

This alternative is eliminated from further consideration as it does not fully address RAO-3 and RAO-4.

5.5 Alternative No. 3

5.5.1 Description

The common remedial elements presented in Section 5.3 are included in Alternative 3. In addition, this alternative includes alternative-specific remedial components. A summary of Alternative 3 is presented below:

RAO	Action
RAO-1 Former Ponds 1 and 2	In-situ Mixing (S/S/S)
RAO-2 Former Ponds 3, 4, 7	Soil Barriers, Low Permeability Cap over Former Pond 7, and Institutional Controls
RAO-3A Eastern Shallow Groundwater	In-situ Treatment or Ex-Situ, Low Permeability Cap
RAO-3B Southern Shallow Groundwater	In-situ Treatment with NZVI/Bio
RAO-4A MKS Groundwater Source	In-situ Treatment with NZVI/Bio
RAO-4B MKS Groundwater Plume	In-situ Treatment with NZVI/Bio and MNA
RAO-4C DNAPL	Recovery and Off-site Disposal
RAO-5 Groundwater Residential Use	Institutional Controls
RAO-6 Surface and Drainage Ditch Soils	Low Permeability Caps, Soil Barriers and Institutional Controls

Alternative 3 includes the same alternative specific remedial components as Alternative No. 2. In addition, Alternative 3 provides additional remedial components that will fully achieve RAO 3 and RAO 4. Figure 5-1 shows a conceptual diagram and Figure 5-2 shows a conceptual layout of Alternative 3.

Eastern Shallow Groundwater (RAO-3)

For RAO-3, this alternative includes the same eastern shallow groundwater collection and ex-situ treatment components described for Alternative 2. Alternative 3 also includes a low permeability cap over a large portion of the surface upgradient of the eastern shallow groundwater collection trench, as described in Section 4.2.3.7. This alternative also includes an option for consideration of in-situ treatment of eastern shallow groundwater, in lieu of ex-situ treatment, during detailed design. Notably, the low permeability cap will reduce the already low flow rates anticipated to require treatment and will thus increase the potential effectiveness of in-situ treatment.

Southern Shallow Groundwater (RAO-3)

The isolated area of shallow groundwater impacts on the southern side of the on-facility area will be treated via in-situ NZVI and accelerated biodegradation. As discussed in Section 4.2.3.8, injection wells will be installed and screened within the area of groundwater impacts. Several NZVI injections will be conducted in new and/or existing wells followed by monitoring to assess the degree of effectiveness. Should on-going rebound be observed, then the system may be modified to include an accelerated biodegradation program of nutrient injections and monitoring. The initial NZVI treatment will produce reductive groundwater geochemical conditions ideal for implementing accelerated biological degradation, if necessary, or will enhance existing natural attenuation mechanisms for the treatment of the remaining chemical impacts.

MKS Source Area and Plume Groundwater (RAO-4)

For RAO-4, in-situ treatment of the MKS groundwater source area will be accomplished utilizing NZVI and/or enhanced biodegradation. As described in Section 4.2.4.2, a series of injection wells will be installed within the MKS groundwater source area as shown on Figure 5-3. Injections of NZVI will be conducted on an approximately quarterly basis until the treatment zone (indicated by the potential NZVI concentrations of 0.10%) expands throughout the MKS groundwater source area. Figures 5-4 through 5-9 show how the NZVI treatment zone will propagate throughout the MKS source area and then into the MKS plume, providing both in-situ treatment of the source area and plume, as well as facilitating the natural biodegradation processes already occurring. Higher quantities of injections over a longer time period may be required to develop an effective treatment zone throughout the plume. Figures 5-3 through 5-8 present the output of a two-dimensional fate and solute transport simulation using WinTran^{TM} software. The isoconcentration contours indicate the percentage of the initial NZVI slurry concentration. The following table provides the input data to the simulation.

WinTran Solute Transport Modeling - Input Data

Hydraulic Gradient (I)	0.01	ft/ft
Hydraulic Conductivity (K)	0.00067	cm/s
Hydraulic Conductivity (K)	1.9	ft/day
Effective Porosity	2	[%]
Slurry Injection Rate (q)	1.0	gpm
Slurry Injection Rate (q)	200	ft3/day
Slurry Injection Time (t)	48	ho
Slurry Injection Time (t)	2.00	Days
Slurry Volume Injected (v)	2992	gallons
Slurry Volume Injected (v)	11328.4	Liters
Iron Injected	50	kg
Iron Concentration	4.41	g/L
Longitudinal Dispersivity	100	feet
Transverse Dispersivity	30	feet

While NZVI is most effective for treating chlorinated organic compounds, it will also treat certain non-chlorinated organic compounds. The location and design of the injection wells and the amount and frequency of NZVI injections will be determined during detailed design. Treatability testing will also be conducted during the PDI to provide additional design and operational data.

Should the NZVI injections not be sufficiently effective for treating all organic compounds and/or should rebound affects be noted in groundwater due to the presence of highly concentrated groundwater and/or the presence of DNAPL in isolated fractures within the MKS, then accelerated biodegradation may be implemented to more effectively complete the groundwater treatment. Recent advances in accelerated biological treatment have shown a high degree of effectiveness for treating organic compounds immediately adjacent to residual DNAPL sources where other technologies such as groundwater extraction are less effective. Nutrient injections (with or without bioaugmentation) will be utilized to develop an enhanced biodegradation treatment zone within the source area that will effectively address rebounding chemical concentrations and chemical impacts from isolated fractures. Notably, the use of NZVI will result in optimum reduced groundwater geochemistry and thus will facilitate enhanced biodegradation treatment. These same induced geochemical conditions will also enhance the existing natural attenuation processes that are currently treating chemicals in the MKS plume system. Enhanced bioremediation is expected to effectively treat remaining organic compounds that may be released to groundwater or that have not been sufficiently treated by NZVI. In addition, nutrient injection will also enhance the existing natural attenuation processes that are occurring within the MKS plume and will thus further stabilize the plume. Additional laboratory studies and/or field trials may be conducted during the PDI to develop the design and operational details (nutrient type and amounts) of an accelerated biodegradation system.

MNA will be implemented for the downgradient portion of the MKS plume to regularly assess (1) the extent of ongoing natural attenuation occurring in the MKS plume; (2) reduction of the MKS plume concentrations; and, (3) continued plume stability/configuration. The design of the MNA system will be completed during detailed design.

During the PDI, an additional well pair (shallow and deep overburden pair) will be installed east of existing monitoring well D-9, approximately one-half the distance between the MFLBC and Allen Road. This well will be sampled to further define the MKS plume configuration and boundaries. The data from this well, along with the baseline groundwater sampling results, will be used in the design of the MNA system.

5.5.2 Effectiveness

Alternative 3 will effectively achieve all RAOs and provide protection of human heath and the environment. Not only will the NZVI/accelerated biodegradation technology be effective for remediating groundwater in the MKS source area, the established treatment zone will propagate into the MKS plume to provide additional treatment and enhance the existing natural attenuation processes for restoration of the downgradient portion of the plume.

5.5.3 Implementability

The technologies included in Alternative 3 are expected to be easily implemented or moderately difficult to implement.

5.5.4 Cost

The cost of Alternative 3 relative to the other alternatives is expected to be moderate to high.

5.5.5 Status: Retained

Alternative 3 has been retained as Alternative B for detailed analysis.

Alternative 3 Specific PDI Activities

The PDI activities required specifically for this alternative include the following:

- As discussed in Section 4.2.1.2, a treatability study would be conducted as part of the PDI to develop design parameters and performance specifications for in-situ soil mixing/air stripping and stabilization/solidification of former Ponds 1 and 2;

- Treatability studies will be conducted to determine design and operational variables (including well spacing and injection rates, frequency, and amounts) for in-situ NZVI groundwater treatment (both southern shallow groundwater and MKS source area groundwater). The NZVI treatability study would include laboratory studies and/or field trials. Depending on the results of the NZVI studies, similar studies may be completed for accelerated biological treatment; and,

- Treatability studies may be completed for the design of the eastern shallow groundwater in-situ treatment system.

5.6 Alternative No. 4

5.6.1 Description

The common remedial elements presented in Section 5.3 are included in Alternative 4. Each of these common elements are included as part of this alternative. In addition, Alternative 4 includes alternative-specific remedial components. A summary of Alternative 4 is presented below:

RAO	Action
RAO-1 Former Ponds 1 and 2	In-situ Thermal Desorption
RAO-2 Former Ponds 3, 4, 7	Soil Barriers and Institutional Controls
RAO-3A Eastern Shallow Groundwater	In-situ Treatment with Iron PRB/Biological Cell/Carbon
RAO-3B Southern Shallow Groundwater	In-situ Treatment with NZVI/Bio
RAO-4A MKS Groundwater Source	In-situ Treatment with NZVI/Bio
RAO-4B MKS Groundwater Plume	In-situ Treatment and MNA
RAO-4C DNAPL	Recovery and Off-site Disposal
RAO-5 Groundwater Residential Use	Institutional Controls
RAO-6 Surface and Drainage Ditch Soils	Soil Barriers and Institutional Controls

Alternative No. 4 includes the same remedial components as Alternative No. 3 (see Section 5.5.1) except that the remediation of the former Ponds 1 and 2 fill/sludge would be accomplished by in-situ thermal desorption (instead of in-situ soil mixing/air stripping and stabilization/solidification used in Alternative No. 3) and the remediation of shallow groundwater on the east side of the on-facility area would be accomplished via an in-situ treatment trench without the installation of a low permeability cap over the upgradient area.

A description of the in-situ thermal desorption technology applied to former Ponds 1 and 2 is presented in Section 4.2.1.4. A description of the in-situ treatment trench applied to shallow groundwater on the east side of the on-facility area is presented in Section 4.2.3.5.

Figure 5-10 shows a conceptual diagram of Alternative 4.

5.6.2 Effectiveness

Although there are some technical limitations that would need to be overcome, particularly for the in-situ thermal treatment of former Pond 1 and, to a lesser extent, 2 and in-situ treatment of shallow groundwater, Alternative No. 4 has the potential to effectively achieve all RAOs and result in conditions that are protective of human health and the environment.

5.6.3 Implementability

Similar to effectiveness evaluation for this alternative, the same technical limitations associated with the in-situ thermal desorption and in-situ shallow groundwater treatment components of this alternative would need to be overcome in order for this alternative to be implementable. Therefore, this alternative is considered to have a moderate to difficult implementability.

5.6.4 Cost

The cost of this technology relative to the other alternatives is considered to be high.

5.6.5 Status: Retained

Even though the technical limitations associated with in-situ thermal desorption and in-situ shallow groundwater treatment may reduce the effectiveness and implementability of this alternative and the cost of this alternative is high, the potential ability to achieve all of the RAOs warrants further consideration of this alternative in the detailed analysis. Therefore, Alternative 4 has been retained as Alternative C.

PDI Activities

The PDI Activities required specifically for this alternative include the following:

- As discussed in Section 4.2.1.4, a treatability study would be conducted as part of the PDI to develop the performance specifications for in-situ thermal desorption of former Ponds 1 and 2.

- Treatability studies would be completed for the design of the eastern shallow groundwater in-situ treatment system.

- Treatability studies will be conducted to determine design and operational variables (including well spacing and injection rates, frequency, and amounts) for in-situ NZVI groundwater treatment (both southern shallow groundwater and MKS source area groundwater). The NZVI treatability study would include laboratory studies and/or field trials. Depending on the results of the NZVI studies, similar studies may be completed for accelerated biological treatment.

5.7 Alternative No. 5

5.7.1 Description

The common remedial elements presented in Section 5.3 are included in Alternative 5. In addition, this alternative includes alternative-specific remedial components. A summary of Alternative 5 is presented below:

RAO	Action
RAO-1 Former Ponds 1 and 2	Containment
RAO-2 Former Ponds 3, 4, 7	Soil Barriers and Institutional Controls
RAO-3A Eastern Shallow Groundwater	Ex-situ Treatment
RAO-3B Southern Shallow Groundwater	In-situ Treatment with NZVI
RAO-4A MKS Groundwater Source	Ex-situ Treatment
RAO-4B MKS Groundwater Plume	MNA
RAO-4C DNAPL	Recovery and Off-site Disposal
RAO-5 Groundwater Residential Use	Institutional Controls
RAO-6 Surface and Drainage Ditch Soils	Soil Barriers and Institutional Controls

Alternative No. 5 contains the same remedial components as Alternative No. 3 except for the following:

- Remediation of former Ponds 1 and 2 would be accomplished by a containment system (instead of soil mixing/air stripping and stabilization/solidification used in Alternative 3);
- There is no option for in-situ treatment of eastern shallow groundwater and a low permeability cap is not included;
- Groundwater extraction/ex-situ treatment would be used to remediate MKS source area groundwater (instead of in-situ treatment used in Alternative No. 3); and,
- MNA would be used to remediate the MKS groundwater plume (instead of in-situ treatment and MNA used in Alternative No. 3).

Figure 5-11 shows a conceptual diagram of Alternative 5.

5.7.2 Effectiveness

The containment system will potentially be effective for isolating chemical impacts within former Ponds 1 and 2; however, there are concerns for the effectiveness of the horizontal barrier within the fractured shale matrix that would be designed to mitigate downward migration of chemical impacts.

In addition, the effectiveness of the MKS groundwater source area extraction and ex-situ treatment component is believed to be limited to long-term hydraulic containment of impacted MKS source area groundwater, rather than active restoration. In addition, groundwater extraction and ex-situ treatment will not enhance natural biodegradation processes associated with the MNA component for the MKS plume.

All other remedial components of this alternative are anticipated to be effective for achieving their respective RAOs.

5.7.3 Implementability

All remedial components of this alternative are considered to be easy to moderately difficult to implement. The low bearing strength of the former Ponds 1 and 2 materials may make the installation of jet grouting wells difficult beneath the interior of the former ponds. In addition, creating a uniform horizontal barrier to mitigate vertical migration of former Ponds 1 and 2 chemical impacts is likely to be difficult to implement.

5.7.4 Cost

While the generally high cost of groundwater extraction and above ground treatment systems is somewhat off-set by the lower cost of the former Ponds 1 and 2 containment system, the overall cost of this alternative relative to other alternatives is expected to be high.

5.7.5 Status: Retained

Even though there are effectiveness and implementability challenges associated with the former Ponds 1 and 2 containment component and the groundwater extraction and ex-situ treatment component, Alternative 5 has been retained as Alternative D for detailed analysis to provide a comparison between in-situ and ex-situ MKS groundwater treatment systems.

PDI Activities

The PDI Activities required specifically for this alternative include the following:

- Treatability studies will be conducted to determine design and operational variables (including well spacing and injection rates, frequency, and amounts) for in-situ NZVI treatment of southern shallow groundwater. The NZVI treatability study would include laboratory studies and/or field trials. Depending on the results of the NZVI studies, similar studies may be completed for accelerated biological treatment.

- Hydraulic testing of MKS monitoring wells and additional hydrogeologic analyses may be required during the PDI to evaluate MKS groundwater extraction well capture zones needed to design the groundwater recovery system.

5.8 Alternative No. 6

5.8.1 Description

The common remedial elements presented in Section 5.3 are included in Alternative 6. In addition, Alternative 6 includes alternative-specific remedial components. A summary of Alternative 6 is presented below:

RAO	Action
RAO-1 Former Ponds 1 and 2	Containment
RAO-2 Former Ponds 3, 4, 7	Soil Barriers and Institutional Controls
RAO-3A Eastern Shallow Groundwater	In-situ Treatment with Chemical Oxidation
RAO-3B Southern Shallow Groundwater	In-situ Treatment with Chemical Oxidation
RAO-4A MKS Groundwater Source	In-situ Treatment with Chemical Oxidation
RAO-4B MKS Groundwater Plume	No further Action
RAO-4C DNAPL	Recovery and Treatment
RAO-5 Groundwater Residential Use	Institutional Controls
RAO-6 Surface and Drainage Ditch Soils	Soil Barriers and Institutional Controls

Alternative No. 6 contains the same remedial components as Alternative No. 5 with the exception of the following:

- In-situ treatment with chemical oxidation is used to remediate both eastern and southern shallow groundwater; and,
- In-situ treatment with chemical oxidation is used to remediate MKS source area groundwater. No additional treatment or MNA of the MKS plume is provided.

5.8.2 Effectiveness

The effectiveness concerns for containment of former Ponds 1 and 2 chemical impacts were discussed above in Section 5.7.2. As important, however, there are substantial effectiveness concerns associated with chemical oxidation of both shallow and MKS groundwater. While in general, chemical oxidation is a non-selective treatment technology and has the potential to effectively treat a wide range of organic compounds, two major limitations will severely reduce this technology's effectiveness to remediate shallow groundwater and MKS source area groundwater as summarized below.

Due to current reductive geochemical conditions, metals (such as iron) are present at substantial concentrations in their reduced state (such as ferrous iron or Fe^{+2}). This geochemical condition leads to two concerns: first, large amounts of chemical oxidants will be required to oxidize the reduced forms of the metals and would be unavailable to oxidize the organic chemicals of interest. Second, once the metals are oxidized they become insoluble forming precipitates/solids that will clog the injection well or portions of the formation, not allowing a uniform distribution of chemical oxidants to reach the organic chemical impacts. Injection wells, the formation around injection wells and/or the recharge side (outlet) of the shallow groundwater treatment trench would clog, rendering the wells/trench unusable.

In addition, the chemical oxidation of groundwater will destroy native microbial populations that have already been shown to be effectively degrading organic chemicals and will alter the groundwater geochemistry preventing the re-establishment of these microorganisms. As a result, the MNA of the MKS plume would be negatively impacted, since the reducing geochemical conditions are facilitating microbial reduction of chemicals.

As a result of the above, large quantities of chemical oxidants will need to be injected for a long time period (indefinitely). Furthermore, frequent injections of chemical oxidants will be needed to address rebounding groundwater chemical concentrations that will result from highly impacted groundwater and/or DNAPL in low flow, isolated and/or dead end fractures that are inaccessible to direct chemical oxidation doses.

Therefore, the remedial component of in-situ chemical oxidation in this alternative is not anticipated to be effective as compared to other alternatives for remediating shallow and MKS groundwater. Coupled with the concerns for containment of former Ponds 1 and 2 chemical impacts, the effectiveness of Alternative No. 6 is anticipated to be low.

5.8.3 Implementability

The implementability of all of the remedial components associated with this technology, except for containment and in-situ chemical oxidation, are expected to be easy to moderately difficult.

Implementability challenges associated with the horizontal barrier beneath former Ponds 1 and 2 were described above in Section 5.6.3. In-situ chemical oxidation in sufficient quantities presents implementability concerns. In addition to the difficulties associated with formation/well/trench clogging and being able to uniformly distribute chemical oxidants to chemical impacts in groundwater, injections of chemical oxidants can be somewhat risky, especially when encountering high organic chemical concentrations, such as those that exist at this site. The reactions caused by certain chemical oxidants are highly exothermic, which can cause disturbances in the groundwater and mobilize contaminants to previously unimpacted areas.

Overall, Alternative No. 6 is expected to be difficult to implement.

5.8.4 Cost

In order to overcome the effectiveness and implementability limitations discussed above, long-term (indefinite), and large quantity injections of chemical oxidants would be required. Some of these limitations may not be able to be overcome if portions of the groundwater bearing units become clogged and inaccessible to the chemical oxidants. In addition, frequent maintenance and/or construction of new injection wells/trenches would be required. Therefore, the cost of Alternative No. 6 is expected to be high.

5.8.5 Status: Eliminated

Due to the anticipated low effectiveness, difficult implementability, and high costs, Alternative No. 6 is eliminated from further consideration.

5.9 Alternative No. 7

5.9.1 Description

The common remedial elements presented in Section 5.3 are included in Alternative 7. In addition, Alternative 7 includes alternative-specific remedial components. A summary of Alternative 7 is presented below:

RAO	Action
RAO-1 Former Ponds 1 and 2	In-situ Thermal Desorption
RAO-2 Former Ponds 3, 4, 7	Soil Barriers and Institutional Controls
RAO-3A Eastern Shallow Groundwater	Ex-situ Treatment
RAO-3B Southern Shallow Groundwater	In-situ Treatment with NZVI
RAO-4A MKS Groundwater Source	Ex-situ Treatment
RAO-4B MKS Groundwater Plume	MNA
RAO-4C DNAPL	Recovery and Off-site Disposal
RAO-5 Groundwater Residential Use	Institutional Controls
RAO-6 Surface and Drainage Ditch Soils	Soil Barriers and Institutional Controls

Alternative No. 7 contains the same remedial components as Alternative No. 3 with the exception of the following:

- In-situ thermal desorption is used to remediate former Ponds 1 and 2 fill/sludge (instead of soil mixing/air stripping and stabilization/solidification);
- A low permeability cap is not included; and,
- Groundwater extraction and ex-situ treatment is used to remediate MKS source area groundwater (instead of in-situ treatment). Sections 5.6.1 and 4.2.5.1 present a description of groundwater extraction and ex-situ treatment. Also, MNA alone (without in-situ treatment) will be used for remediation of the MKS groundwater plume.

5.9.2 Effectiveness

The effectiveness of these remedial components has been discussed previously. Section 5.6.2 discussed the effectiveness of in-situ thermal desorption and Section 5.7.2 discussed the effectiveness of groundwater extraction and ex-situ treatment. In summary, while certain technical challenges would need to be overcome, this alternative has the potential to be effective.

5.9.3 Implementability

As a result of the technical challenges associated with the implementability of in-situ thermal desorption (see Section 5.6.3), this alternative is considered to have a moderate to difficult implementability.

5.9.4 Cost

This alternative utilizes most of the highest cost remedial components. As a result, the cost of this alternative is very high compared to the other alternatives.

5.9.5 Status: Eliminated

While this alternative has the potential to be effective, due to its moderate to difficult implementability and its very high cost when compared to other equally or more effective alternatives, this alternative is eliminated from further consideration.

5.10 Alternative 8

5.10.1 Description

The common remedial elements presented in Section 5.3 are included in Alternative 8. In addition, Alternative 8 includes alternative-specific remedial components. A summary of Alternative 8 is presented below:

RAO	Action
RAO-1 Former Ponds 1 and 2	In-situ Mixing (S/S/S)
RAO-2 Former Ponds 3, 4, 7	Soil Barriers and Institutional Controls
RAO-3A Eastern Shallow Groundwater	In-situ Treatment with Iron PRB/Biological Cell/Carbon
RAO-3B Southern Shallow Groundwater	In-situ Treatment with NZVI/Bio
RAO-4A MKS Groundwater Source	In-situ Treatment with NZVI/Bio
RAO-4B MKS Groundwater Plume	In-situ Treatment and MNA
RAO-4C DNAPL	Recovery and Off-site Disposal
RAO-5 Groundwater Residential Use	Institutional Controls
RAO-6 Surface and Drainage Ditch Soils	Soil Barriers and Institutional Controls

Alternative 8 contains the same remedial components as Alternative No. 3, except eastern shallow groundwater would be treated via in-situ treatment and a low permeability cap would not be installed.

Figure 5-12 shows a conceptual layout of Alternative 8.

5.10.2 Effectiveness

The technical limitations associated with in-situ shallow groundwater treatment are, to a large degree, related to the flow rate from the eastern shallow groundwater collection trench requiring treatment. If low flow rates (i.e., approximately 1 gpm) are determined during detailed design then it is expected in-situ treatment would be an effective treatment technology.

Although there are some technical limitations that would need to be overcome for the in-situ treatment of shallow groundwater, Alternative 8 has the potential to effectively achieve all RAOs and result in conditions that are protective of human health and the environment.

5.10.3 Implementability

Similar to effectiveness evaluation for this alternative, the same technical limitations associated with in-situ shallow groundwater components of this alternative would need to be overcome in order for this alternative to be implementable. Therefore, this alternative is considered to have moderate to difficult implementability.

5.10.4 Cost

This cost of this technology relative to other alternatives is considered low to moderate.

5.10.5 Status: Retained

Even though the technical limitations associated with in-situ shallow groundwater may reduce the effectiveness and implementability of this alternative, the potential ability to achieve all of the RAOs warrants further consideration of this alternative in the detailed analysis. Therefore, this alternative has been retained as Alternative E.

PDI Activities

The PDI activities required specifically for this alternative include the following:

- As discussed in Section 4.2.1.2, a treatability study would be conducted as part of the PDI to develop design parameters and performance specifications for in-situ soil mixing/air stripping and stabilization/solidification of former Ponds 1 and 2; and,

- Treatability studies will be conducted to determine design and operational variables (including well spacing and injection rates, frequency, and amounts) for in-situ NZVI groundwater treatment (both southern shallow groundwater and MKS source area groundwater). The NZVI treatability study would include laboratory studies and/or field trials. Depending on the results of the NZVI studies, similar studies may be completed for accelerated biological treatment.

- Treatability studies would be completed for the design of the eastern shallow groundwater in-situ treatment system.

6.0 DETAILED ANALYSIS OF OU-2 ALTERNATIVES

6.1 NCP Evaluation Criteria

The selection of a remedial alternative is based on an evaluation of nine criteria established in the NCP. Two criteria (state acceptance and community acceptance) will not be evaluated in this report because they will be evaluated during the public comment period after USEPA selects its Preferred Alternative. The remaining seven criteria are listed below.

Threshold criteria are those which must be met in order for a remedy to be eligible for selection. The two threshold criteria are described below.

- Overall Protection of Human Health and the Environment

  Under this criterion, an alternative should be assessed to determine whether it can adequately protect human health and the environment, in both the short-term and long-term, from unacceptable risks posed by hazardous substances, pollutants or contaminants present at the site, by eliminating, reducing or controlling exposures to chemical impacts in Site media. This criterion is an overall assessment of protection based on a composite of factors assessed under other evaluation criteria, especially long-term effectiveness and permanence and short-term effectiveness.

- Compliance with ARARs

  This criterion evaluates whether the alternative will likely be able to attain ARARs under federal environmental laws and state environmental or facility siting laws, or provides grounds for invoking a legal waiver of such requirements.

ARARs may relate to the substances addressed by the remedial action (chemical-specific), to the location of the remedial action (location-specific), or the manner in which the remedial action is implemented (action-specific). The remedial actions associated with OU-2 alternatives need comply only with the substantive aspects of ARARs, not with the corresponding administrative requirements (e.g., consultation, issuance of permits, documentation, record keeping, and enforcement).

- *Chemical-Specific ARARs:* Chemical specific ARARs were discussed in Section 3.2 and were used to set PRGs (MCLs) for groundwater. Each alternative will be evaluated with respect to its ability to meet the PRGs (MCLs).

- *Action-Specific ARARs:* As shown on Table H-1 in Appendix H, the action-specific ARARs are separated into the following four categories for discussion purposes: air pollution control, hazardous waste management, drinking water, and surface water.

Federal action-specific ARARs are listed separately. Each alternative will be evaluated with respect to its ability to comply with these action-specific ARARs.

- *Location-Specific ARARs:* Location-specific ARARs set restrictions on the conduct of remedial activities in particular locations (e.g. floodplains). Table H-1 (Appendix H) presents the potential State and Federal location-specific ARARs. These include the Federal Clean Water Act Section 404, Fish and Wildlife Coordination Act (16 USC 661-666c), Executive Orders on Floodplain Management and Wetlands Protection (CERCLA Floodplain and Wetlands Assessments-EO 11988 and 11990), Erosion and Sediment Control (OAC 1501-15-1), and Water Use Designation for the Little Beaver Creek Drainage Basin (OAC 3745-1-15).

- *TBCs Information:* As shown on Table H-1 (Appendix H), a number of regulations/guidance were identified as TBC information potentially pertaining to the retained alternatives. This TBC information will be considered during the detailed design. As discussed in Section 3.2, in addition to ARARs, the lead agency may, as appropriate, identify other advisories, criteria, or guidance to be considered for a particular remedial component.

Balancing criteria are used to weigh the alternatives in order to help determine the best selection for the Site. The five balancing criteria are described below.

- Short-Term Effectiveness

  This criterion evaluates the impacts of the alternative during implementation with respect to human health and the environment. The short-term impacts of an alternative are assessed considering: short-term risks that might be posed to the community during implementation of an alternative; potential impacts on workers during remedial action and the effectiveness and reliability of protective measures; potential environmental impacts of the remedial action and the effectiveness and reliability of mitigation measures during implementation. In addition, relative remediation time frames are discussed for each alternative.

- Reduction of Toxicity, Mobility, and Volume Through Treatment

  Under this criterion, the degree to which an alternative employs recycling or treatment that reduces toxicity, mobility, or volume are assessed, including how treatment is used to address the principal threats posed at the site. Factors that are considered include: the treatment or recycling processes; the alternatives employed and the materials they will treat; the amount of hazardous substances, pollutants or contaminants that will be destroyed, treated, or recycled; the degree of expected reduction in toxicity, mobility or volume of the waste due to treatment or recycling and the specification of which reduction(s) are occurring; the degree to which the treatment is irreversible; the type and quantity of residuals that will remain following treatment considering the persistence, toxicity, and mobility of such hazardous substances and their constituents; and the degree to which treatment reduces the inherent hazards posed by principal threats at the site.

- Long-Term Effectiveness and Permanence

  Under this criterion, an alternative is assessed for the long-term effectiveness and permanence it affords, along with the degree of uncertainty that the alternative will prove successful. Factors that are considered, as appropriate, include: the magnitude of residual risk remaining from untreated waste or treatment residuals remaining at the conclusion of the remedial activities; and the adequacy and reliability of controls such as containment systems and institutional controls that are necessary to manage treatment residuals and untreated waste.

- Implementability

  This criterion addresses the technical and administrative feasibility of implementing the alternative as well as the availability of various services and materials required.

- Cost

  Cost items evaluated include capital and O&M expenditures to implement the alternative, presented as a present worth estimate.

Each of the retained alternatives described in Section 5.0, and summarized in Table 6-1, are evaluated in accordance with the above seven NCP criteria in the following sections.

6.2 Alternative A

6.2.1 Overall Protection of Human Health and the Environment

The No Further Action alternative would be adequately protective of human health under current conditions because there are no predicted current risks posed by the Site that are outside of USEPA’s acceptable range. However, the No Further Action alternative provides no reduction in potential risk to human health posed by potential future exposures discussed in Section 3.0. Protection of the environment is also not afforded by this alternative since potential ecological exposure pathways to mirex in surface soil are not mitigated.

The existing natural attenuation processes would continue to remediate MKS groundwater and stabilize the MKS groundwater plume but this would not be verifiable given the absence of MKS groundwater monitoring.

6.2.2 Compliance with ARARs

This alternative would continue to comply with the action and location specific ARARs associated with the continued operation of LCS-1 and LCS-2. In addition, the No Further Action option relies upon natural attenuation for attainment of groundwater chemical specific ARARs (MCLs). Given adequate time, this option is expected to meet these standards, however, this time frame would be indeterminate as no MKS groundwater source control measures, except for shallow groundwater collection from LCS-1 and LCS-2, would be implemented.

6.2.3 Short-Term Effectiveness

No additional short-term risks to the community, workers, or the environment are posed by implementation of this alternative.

Due to the presence of DNAPL in bedrock, the time frame to achieve groundwater restoration goals is indeterminate, in excess of 30 years. However, since this alternative does not address the former Ponds 1 and 2 source area or the MKS source area groundwater, this alternative will have the longest remediation time.

6.2.4 Long-Term Effectiveness and Permanence

This alternative does not provide long-term effectiveness as it does not address potential future exposure pathways, does not mitigate shallow groundwater discharges and does not mitigate the primary MKS groundwater source (former Ponds 1 and 2). However, natural attenuation of groundwater chemical impacts in the MKS plume is an effective long-term measure that utilizes naturally occurring processes and is expected to continue to stabilize and restore the MKS plume. No groundwater monitoring is included to verify the continued effectiveness of natural attenuation processes.

Because chemical impacts would be left in place, a five-year review would be required to assess the continued effectiveness of this option.

6.2.5 Reduction of Toxicity, Mobility, and Volume Through Treatment

Natural attenuation, under favorable conditions, acts without human intervention to reduce the toxicity, mobility, and volume of chemicals in soil or groundwater. These processes include photolysis, biodegradation, dispersion, dilution, sorption, volatilization, chemical or biological stabilization, and transformation, among others (USEPA 1999). Ongoing natural attenuation processes at the Site, in particular biodegradation of MKS plume groundwater chemical impacts, will effectively reduce the toxicity and volume (mass) of organic chemicals in groundwater through irreversible biodegradation processes. However, the progress of natural attenuation would not be verifiable under this alternative given the absence of groundwater monitoring. This alternative would provide no reduction of toxicity, mobility or volume of chemicals found in the former ponds and in surface soil.

6.2.6 Implementability

The No Further Action alternative is straightforward and easy to implement.

6.2.7 Cost

A cost estimate for this remedial alternative is shown in Table 6-2A, 6-2B, and 6-2C. The only costs associated with this remedy would be those associated with the continued operation of LCS-1 and LCS-2. The total present worth cost for this alternative is $**4,700,000** based upon 30 years of O&M of LCS-1 and LCS-2.

6.3 Alternative B

6.3.1 Overall Protection of Human Health and the Environment

This alternative will provide both short-term and long-term protection of human health and the environment as a result of the following:

- Exposures to former Ponds 1 and 2 fill/sludge will be mitigated through chemical removal via in-situ soil mixing/air stripping and chemical stabilization/solidification in addition to the placement of a low permeability cap. Moreover, institutional controls will prohibit development and construction activities that could disturb this area.

- Exposures to mirex concentrations exceeding ecologically-based clean up levels in former Ponds 3 and 4 will be mitigated through the use of soil barrier covers. A low permeability cap will be used to mitigate potential ecological exposures in former Pond 7. Human exposures (potential maintenance workers and trespassers) to fill/sludge in former Ponds 3, 4, and 7 will also be mitigated via the soil barrier covers or low permeability caps. Deed restrictions will prohibit development of former Ponds 3, 4, and 7 or disturbance of the final covers.

- Exposures to mirex concentrations exceeding ecologically-based clean up levels in on-facility surface and drainage ditch soil (including surface soil in the State Route 14 drainage ditch) will be mitigated via soil barrier covers or a low permeability cap. Deed restrictions will mitigate potential indoor air and construction worker exposures. Notably, there were no unacceptable risks associated with industrial worker direct contact exposures to surface soil.

- Deed restrictions will prohibit residential development and use of groundwater in both on-facility and off-facility areas.

- Chemical impacts to MKS groundwater in off-property areas are and will be effectively stabilized and restored via ongoing natural attenuation processes that will be enhanced by in-situ treatment of the MKS groundwater source area. Monitoring will be provided to verify the stability of the plume and the progress of restoration.

- The source control component for former Ponds 1 and 2 and Exclusion Areas A and B (soil mixing/air striping and stabilization/solidification and low permeability capping) will mitigate the primary and potential sources of chemical impacts to MKS groundwater;

- The in-situ treatment of the MKS source will propagate into the MKS plume and along with natural attenuation processes will further reduce chemical concentrations and restore groundwater quality within the MKS plume.

- The source control component for shallow groundwater will mitigate shallow groundwater impacts. The low permeability cap over upgradient areas will improve the potential effectiveness of in-situ eastern shallow groundwater treatment as a viable alternative to ex-situ treatment. Monitoring will be provided to verify effectiveness.

6.3.2 Compliance with ARARs

Chemical Specific ARARs

In-situ treatment of the MKS groundwater source area and plume and natural attenuation of the downgradient portion of the MKS plume is expected to achieve compliance with chemical-specific ARARs (MCLs) in the MKS plume over time. While the timeframe to achieve the MCLs is uncertain, since this alternative addresses the primary source of MKS groundwater chemical impacts, the treatment effectiveness and time frame for compliance with groundwater restoration goals will improve as compared to Alternative A. Groundwater monitoring will be provided to regularly assess compliance.

Action and Location Specific ARARs

Table H-1 in Appendix H summarizes the potential action and location specific ARARS and TBC information pertaining to this alternative. In addition, the OEPA provided a list of potential ARARs (see Table H-1 in Appendix H) which will be considered during the design phase to the extent they apply to the selected remedy. The following discusses potential compliance issues associated with the ARARs and TBC information.

Potential State air pollution control ARARs pertain to this Alternative as a result of the following actions:

- Vapors generated during air stripping/soil mixing of former Ponds 1 and 2 fill/sludge will require collection and treatment to comply with State emissions standards;
- The ex-situ treatment of the eastern shallow groundwater may generate air emissions (e.g., from air stripping) and thus be required to comply with State emission standards. The current off-gas treatment system of the LCS-1 treatment plant includes air stripping and vapor phase granular activated carbon. It is anticipated that if an air stripper is used to treat off-gas from the additional streams (i.e. from the existing LCS-2 and from the eastern shallow groundwater collection trench), vapor phase granular activated carbon may also be used to comply with State emissions standards;
- Activities such as surface preparation for the barrier cover and/or low permeability cover over former Ponds 3, 4, and 7 may require measures to mitigate air pollution nuisances (e.g., dust). Potential actions to prevent nuisances may include water sprays, temporary covers, or odor foams and/or deodorants; and,
- Air monitoring to assess compliance with air emission controls may also trigger TBC information such as guidelines and methods of air quality measurement.

Drilling, operation, and maintenance of injection and monitoring wells may also trigger the Water Well Standards (OAC 3745-9) as an action-specific ARAR for this Alternative.

State and Federal requirements for solid and/or hazardous waste management facility low permeability caps are not considered ARARs for the soil barrier covers over former Ponds 3 and 4 and on-facility surface and drainage ditch soils or for the low permeability cap over former Ponds 1 and 2, former Pond 7, and portions of the on and off-facility areas. These requirements are applicable to landfills and Resource Conservation and Recovery Act (RCRA) facility closure, neither of which apply to the OU-2 remedy. However, certain portions of these regulations may be considered TBC information as they address cover systems and related controls. For example, Ohio EPA guidance document entitled *Final Covers for Hazardous Waste Surface Impoundments, Waste Piles and Landfills* provides general guidance and suggestions for evaluation of alternate final covers. Ohio EPA recognizes that the guidance document falls into the TBC category stating that “This policy does not have the force of law”. Parts of the guidance that pertain to surface water management, control of nuisances and vectors, soil erosion, and support of vegetation will be considered in the design of the soil barrier covers and the low permeability caps for this Site. Other portions of the guidelines specific to construction of low permeability caps will be considered for areas receiving low permeability caps.

To the extent that hazardous wastes (e.g., DNAPL) are transported off-site for treatment and/or disposal, some of the hazardous waste management regulations identified as TBC information will become ARARs.

Alternative B includes underground injection during in-situ NZVI injection and/or bioremediation nutrient injection into the southern shallow overburden groundwater and the MKS groundwater. The Ohio EPA underground injection control (UIC) regulations are considered ARARs for these activities. However, it is likely that the UIC requirements will not modify the action since remediation projects fall under an exemption called 5X26 Aquifer Remediation Projects. This exemption needs to be filed with Ohio EPA at least one month prior to the injections and it is expected that the exemption would be granted, based on Ohio EPA's concurrence with USEPA's remedy selection. This ARAR will be further evaluated during detailed design.

The potential action-specific surface water ARARs presented on Table H-1 in Appendix H pertain to meeting water quality standards for groundwater treatment plant discharges to surface water. Alternative B includes the collection and treatment of eastern shallow groundwater from a collection trench. This new groundwater stream will likely require modifications to the existing treatment system or construction of a new treatment system, therefore potential national pollutant discharge elimination system (NPDES) discharge permit equivalency may apply. The treatment system will be designed to meet the water quality and other related standards in order for the treated groundwater to comply with ARARs.

Several activities included in Alternative B involve disturbing surficial materials. The surface water management plan designed to control erosion from these areas will require compliance with the substantive requirements of the local and State Erosion and Sediment Control ARARs.

An evaluation of the specific requirements needed to comply with the action-specific ARARs will be conducted during detailed design. While there are several action-specific ARARs and TBCs that will be addressed during remedial design, none of the action-specific ARARs or TBCs are anticipated to be problematic and compliance with these requirements is expected.

Location-Specific ARARs

This Alternative includes activities that may affect wetlands including but not limited to, construction of barrier covers, shallow groundwater extraction trench installation, well installation and lowered groundwater levels in the vicinity of the off-facility seep. These activities may trigger ARARs that require protection of wetlands and flood plains. A wetlands assessment and floodplain evaluation will be conducted during the PDI and incorporated into the detailed design so that ARAR compliance can be achieved.

6.3.3 Short-Term Effectiveness

The activities associated with this alternative may result in some manageable short-term impacts to workers primarily as a result of the construction of the shallow groundwater collection trench. However, given the relatively small amount of material involved, the fact that the work is being done completely on-property (i.e., off-property transportation would not be required), and the relatively short-time frame within which the work would be completed, short-term impacts to workers are believed to be manageable through the use of engineering controls and appropriate health and safety measures. In addition, there would be little to no short-term impacts to the community.

Potential environmental impacts from this alternative may result from the installation of the in-situ treatment trench and construction of side slope armoring and soil barrier covers. The collection of shallow groundwater could alter groundwater levels and impact the hydrology of local wetlands (if and where present). A hydrogeologic assessment will be completed during detailed design to evaluate the potential degree of hydrologic impacts from the shallow groundwater extraction trench operation. In addition, a wetland assessment would be completed during the PDI, to determine if wetlands are present, and if necessary, what level of habitat quality and functional value are associated with those wetlands that might be impacted.

There are not expected to be any other short-term effectiveness concerns associated with the surface soil barrier covers, low permeability cap, former Ponds 1 and 2 source control and MKS groundwater source area and plume remedial actions.

Similar to Alternative A, the time frame for achieving remediation goals is indeterminate given the presence of DNAPL in bedrock. However, Alternative B provides substantial remediation of the OU-2 source areas and in-situ treatment of the MKS groundwater source area and plume and as a result, will achieve remediation goals in a much shorter time frame. It is possible that remediation goals in the off-property portion of the MKS plume may be able to be achieved in 30 years or less.

6.3.4 Long-Term Effectiveness and Permanence

Long-term permanent protection of human health and the environment is provided via the reduction of chemical concentrations in site media from the following treatment actions provided by Alternative B.

- Air stripping during soil mixing and vapor phase treatment of former Ponds 1 and 2 fill/sludge;
- Collection and treatment (either in-situ or ex-situ) of shallow groundwater from the extraction trench;
- In-situ treatment of the MKS groundwater source area and plume; and,
- Natural attenuation (biodegradation) of MKS plume.

All of the above processes are irreversible and will result in the permanent removal, and in many cases permanent destruction of chemical impacts, and thus will add to the long-term protection of human health and the environment afforded by this alternative. Operation, inspection, maintenance, and monitoring will be regularly conducted to ensure the continued effectiveness of the treatment components of the above actions.

Regular inspection, maintenance and repairs (when necessary) of the barrier covers and low permeability caps will provide long-term effectiveness. Regular inspections will also be conducted to verify the effectiveness of institutional controls and confirm that the required land uses are maintained.

There are potential long-term effectiveness concerns associated with the collection of shallow groundwater in a small northern portion of the trench. As discussed in Section 4.2.3.2, should a collection trench not be able to be constructed in this area, alternative means for extracting shallow groundwater would need to be considered which might not be as effective and/or would require additional maintenance compared to a typical collection trench. This condition may have an impact on the long-term effectiveness for this portion of the trench to address shallow groundwater, however, it is expected that these potential difficulties can be resolved during detailed design.

Because certain residual chemical impacts would be contained in place, five-year reviews would be required to assess the continued effectiveness of this option.

6.3.5 Reduction of Toxicity, Mobility and Volume through Treatment

The same remedial components that will result in the irreversible treatment actions discussed above will also result in the reduction of the toxicity and volume (mass) of chemical impacts present in on-site media.

Former Ponds 1 and 2 fill/sludge represents the principal threat and the source of MKS groundwater impacts. Source control actions for former Ponds 1 and 2 include soil mixing/ air stripping to remove and treat VOCs and some SVOCs and then stabilization/solidification of the remaining chemicals. As discussed above, the extraction and treatment of vapors from the mixed soil will reduce the toxicity and volume (mass) of chemicals in this source. Stabilization/solidification will result in substantial reduction of mobility for the remaining chemical impacts. In fact, as discussed in Section 4.2.1.2, treatability studies conducted at a site with similar conditions (sludge with high VOC, SVOC, and other heavy organic compounds) showed that stabilization and solidification reduced leachability by over 95%. This alternative therefore addresses the principal threat.

The low permeability cap will reduce the mobility of potential chemical impacts from Exclusion Areas A and B and the sludge/soil pile and former Pond 7 by essentially eliminating infiltration through the vadose zone and by lowering the groundwater surface in these areas. The barrier covers and low permeability cap will also provide substantial reduction of mobility of chemicals in fill/sludge within former Ponds 3, 4, and 7 and in on-facility surface soil. The covers will isolate the chemical impacts, mitigating potential direct contact and erosional mobility. Armoring the side slopes of former Ponds 3, 4, and 7, where required, will also mitigate potential erosional mobility.

Natural attenuation of residual chemical impacts in groundwater will also continue to reduce the toxicity, and volume (mass) of chemical impacts in MKS groundwater. Natural attenuation processes are restoring groundwater quality. Intermediate degradation products of natural attenuation have short half-lives and are not expected to contribute to future exposure risks.

6.3.6 Implementability

Except for 1) in-situ soil mixing/stripping and stabilization/solidification, 2) the north end of the shallow groundwater collection trench, and 3) in-situ groundwater treatment of MKS groundwater using NZVI, all remedial components provided by this alternative are easily implemented as they utilize well established practices and the services and materials required are standard within the industry and readily available. The long-term O&M requirements for all remedial components provided by this alternative can be readily performed and the personnel, equipment, and spare parts are expected to be readily available.

There are some potential implementability concerns associated with the following remedial components, as described below.

- In-situ soil mixing/stripping and stabilization/solidification of former Ponds 1 and 2 fill/sludge:
    - The low bearing strength of the fill/sludge may require sequentially stabilizing/solidifying the perimeter of the former pond before moving into the interior portions of the former ponds.
    - In general, this remedial component utilizes specialty services and materials, however, there are a number of experienced contractors who do this work.

- Shallow groundwater collection trench installation (north end):
    - Spatial constraints may restrict installation of a short section at the northern end of the trench. Alternate shallow groundwater extraction technologies may need to be implemented in this small area to address these conditions.

- In-situ treatment of southern shallow groundwater and MKS source area groundwater via NZVI:
    - In general, this remedial component utilizes specialty materials (NZVI), although NZVI is becoming a more common remedial technology and the manufacturing of NZVI is becoming more routine. The services, methods and equipment for injecting and monitoring the development of the treatment zone are straight forward and readily available.

All of the implementability concerns outlined above are believed to be manageable and are not expected to interfere with the effectiveness of the alternative. These potential difficulties can be addressed during the PDI and detailed design.

6.3.7 Cost

A preliminary cost estimate for Alternative B is presented in Tables 6-2A, 6-2D, and 6-2E. The total estimated present worth cost of Alternative B is $18,960,000.

The following remedial time frames were assumed for the estimation of the present worth of O&M costs for Alternative B.

- Final cover (all covers and caps) maintenance – 30 years;
- Eastern shallow groundwater treatment – 30 years;
- Southern shallow groundwater treatment – 5 years;
- MKS groundwater:
    - Treatment – 10 years
    - Monitoring/MNA – 30 years; and,
- Institutional controls inspection and documentation – 30 years

6.4 Alternative C

6.4.1 Overall Protection of Human Health and the Environment

This alternative will provide both short-term and long-term protection of human health and the environment as a result of the following:

- Exposures to former Ponds 1 and 2 fill/sludge will be mitigated via thermal desorption of organic compounds, barrier cover, and institutional controls that will prohibit future development and construction activities that could disturb this area following remediation.

- Exposures to mirex concentrations exceeding ecologically-based cleanup levels 1,000 ug/kg in former Ponds 3, 4, and 7 will be mitigated through the use of soil barrier covers. Human exposures (potential maintenance workers and trespassers) to fill/sludge in former Ponds 3, 4, and 7 will also be mitigated via the soil barrier covers (although no unacceptable current or future risks to human receptors has been predicted). Deed restrictions will prohibit development of former Ponds 3, 4 and 7 or disturbance of the barrier covers.

- Exposures to mirex concentrations exceeding ecologically-based cleanup levels in on-facility surface soil (including surface soil in the State Route 14 drainage ditch) will be mitigated via soil barrier covers. Deed restrictions will mitigate potential indoor air and construction worker exposures. Notably, there were no unacceptable risks associated with industrial worker direct contact exposures to surface soil.

- Deed restrictions will prohibit residential development and use of groundwater in both on-facility and off-facility areas.

- Chemical impacts to MKS groundwater in off-property areas is and will be effectively stabilized and restored via ongoing natural attenuation processes that will be enhanced by in-situ treatment of the MKS groundwater source area. Monitoring will be provided to verify the stability of the plume and the progress of restoration.

- The source control component for former Ponds 1 and 2 (thermal desorption) will mitigate the primary source of chemical impacts to MKS groundwater allowing natural attenuation processes to further reduce chemical concentrations and restore groundwater quality within the MKS plume.

- The in-situ treatment of eastern and southern shallow groundwater will mitigate shallow groundwater impacts. Monitoring will be provided to verify effectiveness.

However, as discussed below, there are a number of technical considerations that may limit the effectiveness and implementability of the in-situ thermal desorption of former Ponds 1 and 2 and the in-situ treatment of eastern and southern shallow groundwater components of this alternative. It is possible that these technical considerations cannot be resolved, particularly for the thermal desorption component, and consequently source control would not be fully achieved resulting in a reduced level of overall protection of human health and the environment.

6.4.2 Compliance with ARARs

Chemical Specific ARARs

In-situ treatment of the MKS groundwater source area and enhanced biodegradation/natural attenuation of the MKS plume is expected to achieve compliance with chemical-specific ARARs (MCLs) in the MKS plume over time. However, the potential long-term effectiveness concerns associated with the in-situ thermal desorption (discussed below) of former Ponds 1 and 2 fill/sludge may make it more difficult and increase the time it will take to achieve these ARARs as compared to other source control options.

Action and Location Specific ARARs

Table H-1 (Appendix H) summarizes the potential action and location specific ARARs and TBC information pertaining to this alternative. Additional potential ARARs and TBCs are provided in Table H-2 in Appendix H and will be evaluated further during the design phase.

The discussion of action and location specific ARARs and TBC information presented for Alternative B (Section 6.3.2) applies to Alternative C with the exception of the following:

- Vapors generated during thermal desorption of former Ponds 1 and 2 fill/sludge will require collection and treatment to comply with State emissions standards; and,
- In-situ treatment of eastern and southern shallow groundwater will not require above ground treatment and compliance with surface water discharge ARARs, however, in-situ treatment injections may require an exception from the State UIC program requirements.

6.4.3 Short-Term Effectiveness

The only substantial short-term impacts to human health would result from potential releases of steam and vapors from in-situ thermal desorption. Subsidence and/or differential settlement, which could result from superheating of the former Ponds 1 and 2 fill/sludge may compromise the seal between the silica heat resistant blanket and ground surface potentially resulting in the escape of vapors and steam.

As discussed in Alternative B, manageable short-term impacts to workers may potentially result from the construction of the shallow groundwater collection/in-situ treatment trench. There are only expected to be minimal short-term impacts to workers resulting from soil barrier cover construction and these impacts are manageable using standard OSHA health and safety practices.

Potential environmental impacts (temporary disturbances of wetlands) in the vicinity of the off-facility seep, portions of Feeder Creek, and former Ponds 3 and 4 (if and where wetlands are present) may result from the installation of the in-situ treatment trench and construction of side slope armoring and barrier covers in these areas as discussed for Alternative B.

Similar to Alternative A, the time frame for achieving remediation goals is indeterminate given the presence of DNAPL in bedrock. However, Alternative C has the potential to provide substantial remediation of the OU-2 source areas and in-situ treatment of the MKS groundwater source area and plume and as a result, will achieve remediation goals in a much shorter time frame than Alternative A. It is possible that remediation goals in the off-property portion of the MKS plume may be able to be achieved in 30 years or less. However, questions regarding the effectiveness of this alternative for treating the former Ponds 1 and 2 source area and due to the lack of a low permeability cap, Alternative C is not likely to achieve remediation goals as quickly as Alternative B.

6.4.4 Long-Term Effectiveness and Permanence

Long-term permanent protection of human health and the environment is provided via the reduction of chemical concentrations in site media from the following treatment actions provided in Alternative C.

- In-situ thermal desorption of former Ponds 1 and 2 fill/sludge;
- In-situ treatment of shallow eastern and southern groundwater;
- In-situ treatment of the MKS groundwater source area and plume; and,
- Natural attenuation (biodegradation) of MKS plume.

All of the above processes are irreversible and will result in the permanent destruction of chemical impacts and thus provide long-term protection of human health and the environment. Operation inspection, maintenance, and/or monitoring will be regularly conducted to help ensure the effectiveness of treatment components to the above actions.

The soil barrier covers will provide long-term effectiveness through regular inspection and repairs of the barriers. Regular inspections will also be conducted to verify the effectiveness of institutional controls and to confirm the required land use.

As discussed previously, there are a number of technical concerns that may limit the effectiveness of the in-situ thermal desorption technology for former Ponds 1 and 2 and the in-situ treatment of eastern shallow groundwater. The concerns pertaining to in-situ thermal desorption are listed below.

1. The saturated conditions of the fill/sludge (the majority of the fill/sludge is below the groundwater table) would lead to greatly extended treatment times since virtually all moisture must be vaporized before sludge temperatures increase and allow chemical desorption, increased permeability and subsequent extraction through the thermal treatment zone. A slurry wall or other hydraulic control or dewatering system may need to be installed to minimize groundwater inflow to the area. Visible steam emissions containing organic vapors may also be present and not be able to be effectively controlled.

2. Given the presence of chlorinated organic compounds, quantities of hydrogen chloride (HCl) would be generated, giving rise to the following concerns:
    - HCl could react with metals forming more soluble compounds (salts) that would be more mobile;
    - Condensation of HCl anywhere in the treatment system is expected to cause significant corrosion problems; and
    - Potential HCl emissions would likely require the addition of a scrubber to the treatment train.

3. While heating is expected to increase pneumatic permeability, well spacings would need to be very small to achieve adequate vapor extraction through the low permeability sludge.

4. Thermally treating the high levels of total organic carbon in the sludge/fill may cause ash and/or coke buildup around the wells. This, in turn, could "blind" the wells, or at least significantly reduce the overall efficiency of the wells to extract vapors and control potential releases at the surface.

5. The treatment temperatures would cause vaporization of metals which could, in turn, poison the thermal oxidizer resulting in poor treatment performance. Emissions standards may not be met.

6. The technology is relatively new and innovative and may not have been used in similar field conditions. As a result, a field pilot test would be required to establish its feasibility.

7. In addition, based on discussions with a vendor of thermal desorption technology (TerraTherm, Inc.) generating the superheated matrix required to desorb SVOC and pesticides may liquefy the fill/sludge thus creating subsidence which could damage or otherwise cause the loss of equipment.

All of the above factors may compromise the effectiveness and implementability of the in-situ thermal desorption component of Alternative C.

The following long-term effectiveness concerns have been identified for in-situ treatment of eastern shallow groundwater particularly since a low permeability cap would not be installed to reduce the flow of shallow groundwater requiring treatment:

- While the remedial technologies that will be used for in-situ treatment are all effective individually, incorporating them into a small sequential in-situ treatment zone may affect their performance. Variations in flow, especially elevated flow rates, would decrease residence time and may temporarily reduce the effectiveness of the reaction cells.

- The primary concern with the long-term effectiveness of this approach is fouling of the treatment zone. Fouling may occur in the biological treatment zone and/or activated carbon treatment zone due to particulate accumulations or from biological growth.

- In addition, the presence of oxygenated groundwater from surface water infiltration or from exposure of the collected water to atmospheric air in the trench may oxidize and clog the iron treatment zone or reduce the biological treatment zone effectiveness.

These effectiveness concerns are expected to be able to be resolved where only low flows (i.e., on the order of approximately 1 gpm) require treatment.

Because certain residual chemical impacts would be contained in place, five-year reviews would be required to assess the continued effectiveness of this option.

6.4.5 Implementability

Except for 1) in-situ thermal desorption of fill/sludge in former Ponds 1 and 2, 2) in-situ treatment of eastern and southern shallow groundwater, and 3) in-situ MKS groundwater treatment using NZVI, all remedial components provided by this alternative are easily implemented as they utilize well established practices and the services and materials needed are standard within the industry and readily available. The long-term O&M requirements for all remedial components provided by this alternative can be readily performed and the personnel, equipment, and spare parts are expected to be readily available. Implementability concerns associated certain remedial components are described below:

- In-situ thermal desorption: Many of the long-term effectiveness concerns discussed above could adversely affect this technology's implementation. In addition, this is a specialized technology and the equipment, methods, and materials are not readily available. Moreover, the installation of the heater wells in the interior of the former Pond 1 may be difficult due to soft ground conditions.

- In-situ treatment of eastern and southern shallow groundwater: The construction of the in-situ treatment system will be moderately difficult to implement, and monitoring the system effectiveness and maintaining the system hydraulic performance will be difficult to implement. However, these concerns diminish as the flow rate requiring treatment diminishes.

- In-situ treatment of MKS source area groundwater via NZVI:
    - In general, this remedial component utilizes specialty materials (NZVI), although NZVI is becoming a more common remedial technology and the manufacturing of NZVI is become more routine. The services, methods and equipment for injecting and monitoring the development of the treatment zone are straight forward and readily available.

6.4.6 Cost

A preliminary cost estimate for Alternative C is presented in Tables 6-2A, 6-2F, and 6-2G. The total estimated present worth cost is $24,650,000.

The following remedial time frames were assumed for the estimation of the present worth of O&M costs for Alternative C.

- Final cover (all covers and caps) maintenance – 30 years;
- Eastern shallow groundwater treatment – 20 years (30 year monitoring);
- Southern shallow groundwater treatment – 5 years;
- MKS groundwater:
    - Treatment – 10 years
    - Monitoring/MNA – 30 years; and,
- Institutional controls inspection and documentation – 30 years

6.5 Alternative D

6.5.1 Overall Protection of Human Health and the Environment

This alternative will provide both short-term and long-term protection of human health and the environment as a result of the following:

- Exposures to former Ponds 1 and 2 fill/sludge will be mitigated through containment and institutional controls will prohibit future development and construction activities that disturb the containment system.

- Exposures to mirex concentrations exceeding ecologically-based cleanup levels in former Ponds 3, 4, and 7 surface materials will be mitigated through the use of soil barrier covers. Human exposures (potential maintenance workers and trespassers) to fill/sludge in former Ponds 3, 4, and 7 will also be mitigated via the barrier covers (although no unacceptable current or future risks to human receptors have been predicted). Deed restrictions will prohibit future development of former Ponds 3, 4 and 7 or future disturbance of the barrier covers.

- Exposures to mirex concentrations exceeding ecologically-based cleanup levels in on-facility surface and drainage ditch soil (including surface soil in the State Route 14 drainage ditch) will be mitigated via soil barrier covers. Deed restrictions will mitigate potential indoor air and construction worker exposures. Notably, there were no unacceptable risks associated with industrial worker direct contact exposures to surface soil.

- Deed restrictions will prohibit residential development and use of groundwater in both on-facility and off-facility areas.

- Chemical impacts to MKS groundwater in off-property areas is and will be effectively stabilized and restored via ongoing natural attenuation processes; extraction and ex-situ treatment of the MKS groundwater source area will not enhance these processes and will primarily service to contain, rather than restore, the groundwater source area. Monitoring will be provided to verify the stability of the plume and the progress of restoration.

- The source control component for former Ponds 1 and 2 is expected to significantly reduce the primary source of chemical impacts to MKS groundwater, however, the horizontal barrier to mitigate vertical migration of chemical impacts within former Ponds 1 and 2 may not be fully effective.

- The source control component for eastern shallow groundwater extraction and ex-situ treatment and in-situ treatment of southern impacted shallow groundwater will mitigate shallow groundwater impacts. Monitoring will be provided to verify effectiveness.

6.5.2 Compliance with ARARs

Chemical Specific ARARs

Containment of Ponds 1 and 2 and extraction and treatment of the MKS groundwater source area would hydraulically contain (not treat) the source. Natural attenuation of the MKS plume is expected to achieve compliance with chemical-specific ARARs (MCLs) in downgradient areas over time.

Action and Location Specific ARARs

Table H-1 in Appendix H summarizes the potential action and location specific ARARS and TBC information pertaining to this alternative. Additional potential ARARs and TBCs that will be considered during the design phase are included in Table H-2 in Appendix H.

The discussion of action and location specific ARARs and TBC information presented for Alternative B (Section 6.3.2) applies to Alternative D with the exception of the following:

- Vapors will not be generated from the containment of former Ponds 1 and 2 fill/sludge and thus will not require treatment to meet State emissions standards; and,

- The collection and treatment of MKS source area groundwater will create an additional groundwater stream requiring treatment and compliance with NPDES discharge requirements.

6.5.3 Short-Term Effectiveness

The short-term effectiveness concerns for Alternative D are the same as for Alternative B. However, less short-term impacts are expected from Alternative D since a containment system will be constructed for the former Ponds 1 and 2 fill/sludge.

Similar to Alternative A, the time frame for achieving remediation goals is indeterminate given the presence of DNAPL in bedrock. However, Alternative D provides containment of former Ponds 1 and 2 and is therefore believed to be able to achieve remediation goals in a much shorter time frame than Alternative A. It is possible that remediation goals in the off-property portion of the MKS plume may be able to be achieved in 30 years or less. However, questions regarding the effectiveness of this Alternative D for containing the former Ponds 1 and 2 source area, and due to the lack of a low permeability cap, Alternative D is not likely to achieve remediation goals as quickly as Alternative B.

6.5.4 Long-Term Effectiveness and Permanence

Long-term permanent protection of human health and the environment is provided via the reduction of chemical concentrations in site media from the following treatment actions provided by Alternative D.

- Continued operation of LCS-1 and LCS-2 and treatment of the collected groundwater;
- Collection and treatment of shallow groundwater from the collection trench;
- Extraction of groundwater from the MKS source area and treatment; and,
- Natural attenuation (biodegradation) of MKS plume.

All of the above processes are irreversible and will result in the permanent removal, and in many cases permanent destruction of chemical impacts and thus provide long-term protection of human health and the environment. Operation, inspection, maintenance, and/or monitoring will be regularly conducted to help ensure the effectiveness of the treatment components to the above actions.

Regular inspection, maintenance and repairs (when necessary) of the barrier covers will provide long-term effectiveness. Regular inspections will also be conducted to verify the effectiveness of institutional controls and confirm that the required land uses are maintained. Containment of

Ponds 1 and 2 sludge/fill and MKS groundwater source zones is expected to be mostly effective but does not provide permanent destruction of chemical impacts.

Because certain chemical impacts would be contained in place, five-year reviews would be required to assess the continued effectiveness of this option.

6.5.5 Reduction of Toxicity, Mobility and Volume through Treatment

The same remedial components that will result in the irreversible treatment actions discussed above for Alternative D will also reduce the toxicity and volume (mass) of chemicals present in on-site media. The reduction of toxicity, mobility and volume through treatment provided by Alternative D is expected to be the same as that provided by Alternative B with the following exceptions:

- The mobility of chemical impacts in former Ponds 1 and 2 will be reduced via the containment system. No treatment of these impacts will be provided by Alternative D.
- While some reduction of toxicity and volume (mass) of chemical impacts will be achieved by extraction and treatment of the MKS groundwater source area, groundwater extraction and treatment is primarily a containment technology and thus will primarily only achieve reduction of mobility of chemical impacts in groundwater.

6.5.6 Implementability

Except for the subsurface horizontal containment of former Ponds 1 and 2 fill/sludge and extraction of groundwater from the north end of the shallow groundwater collection trench, all remedial components provided by this alternative are expected to be easily implemented as they utilize well established practices and the services and materials needed are standard within the industry and readily available. The long-term O&M requirements for all remedial components provided by this alternative can be readily performed and the personnel, equipment, and spare parts are expected to be readily available. Implementability concerns associated with the following remedial components are described below:

- Former Ponds 1 and 2 subsurface horizontal containment: The implementation of this remedial component is expected to be difficult due to limited accessibility for drilling jet grout boreholes in the interior of former Pond 1 and difficulties with construction and verifying a continuous horizontal subsurface barrier.

- Shallow groundwater collection trench installation (north end): Site conditions may result in spatial constraints for installing a short section of the northern portion of the trench. Alternate shallow groundwater extraction technologies may need to be implemented in this small area to address these conditions.

6.5.7 Cost

A preliminary cost estimate for Alternative D is presented in Tables 6-2A, 6-2H, and 6-2I. The total estimated present worth cost of Alternative D is $21,350,000.

The following remedial time frames were assumed for the estimation of the present worth of O&M costs for Alternative D.

- Final cover (all covers and caps) maintenance – 30 years;
- Eastern shallow groundwater treatment – 30 years;
- Southern shallow groundwater treatment – 5 years;
- MKS groundwater:
  - Treatment – 30 years
  - Monitoring/MNA – 30 years; and,
- Institutional controls inspection and documentation – 30 years

6.6 Alternative E

6.6.1 Overall Protection of Human Health and the Environment

This alternative will provide both short-term and long-term protection of human health and the environment as a result of the following:

- Exposures to former Ponds 1 and 2 fill/sludge will be mitigated through chemical removal via in-situ soil mixing/air stripping and chemical stabilization/solidification. In addition, institutional controls will prohibit development construction activities that disturb this area.

- Exposures to mirex concentrations exceeding ecologically-based cleanup levels in former Ponds 3, 4 and 7 will be mitigated through the use of soil barrier covers. Human exposures (potential maintenance workers and trespassers) to fill/sludge in former Ponds 3, 4, and 7 will also be mitigated via the soil barrier covers (although no unacceptable current or future risks to human receptors have been predicted). Deed restrictions will prohibit development of former Ponds 3, 4, and 7 or disturbance of the barrier covers.

- Exposures to mirex concentrations exceeding ecologically-based cleanup levels in on-facility surface and drainage ditch soil (including surface soil in the State Route 14 drainage ditch) will be mitigated via soil barrier covers. Deed restrictions will mitigate potential indoor air and construction worker exposures. Notably, there were no unacceptable risks associated with industrial worker direct contact exposures to surface soil.

- Deed restrictions will prohibit residential development and use of groundwater in both on-facility and off-facility areas.

- Chemical impacts to MKS groundwater in off-property areas is and will be effectively stabilized and restored via ongoing natural attenuation processes that will be enhanced by in-situ treatment of the MKS groundwater source area. Monitoring will be provided to verify the stability of the plume and the progress of restoration.

- The source control component for former Ponds 1 and 2 (soil mixing/air stripping and stabilization/solidification) will mitigate the primary source of chemical impacts to MKS groundwater, allowing natural attenuation processes to further reduce chemical concentrations and restore groundwater quality within the MKS plume.

- The in-situ treatment of eastern shallow groundwater will mitigate shallow groundwater impacts. Monitoring will be provided to verify effectiveness.

6.6.2 Compliance with ARARs

Chemical Specific ARARs

In-situ treatment of the MKS source area and plume and natural attenuation of the downgradient portions of MKS plume is expected to achieve compliance with chemical-specific ARARs (MCLs) in downgradient areas over time. While the timeframe to achieve the MCLs is uncertain, since this alternative addresses the primary source of MKS groundwater chemical impacts, the treatment effectiveness and time frame for compliance with MCLs will improve as compared to Alternative A. Groundwater monitoring will be provided to regularly assess compliance.

Action Specific ARARs

Table H-1 in Appendix H summarizes the potential action and location specific ARARS and TBC information pertaining to this alternative. Additional potential ARARs and TBCs that will be considered during the design phase are included in Table H-2 in Appendix H.

The discussion of action and location specific ARARs and TBC information presented for Alternative B (Section 6.3.2) applies to Alternative E with the exception of the following:

- In-situ treatment of eastern shallow groundwater will not require above ground treatment and compliance with surface water discharge ARARs, however, in-situ treatment injections may require an exception from the State UIC program requirements.

Location-Specific ARARs

This Alternative includes activities that may affect wetlands including but not limited to, construction of soil barrier covers, shallow groundwater collection/treatment trench installation, well installation and lowered groundwater levels in the vicinity of the off-facility seep. A wetlands/floodplain assessment will be conducted during the PDI and incorporated into the detailed design so that appropriate wetland and floodplain compliance issues can be addressed.

6.6.3 Short-Term Effectiveness

As discussed in Alternative B, manageable short-term impacts to workers may potentially result from the construction of the shallow groundwater treatment trench and possibly other construction activities. However, these potential short-term impacts are manageable through the use of engineering controls and health and safety measures. In addition, there would be little to no short-term impacts to the community.

Similar to Alternative A, the time frame for achieving remediation goals is indeterminate given the presence of DNAPL in bedrock. However, Alternative E provides remediation of former Ponds 1 and 2 and in-situ treatment of the MKS groundwater source area and plume and as a result will achieve remediation goals in a shorter time frame than Alternative A. It is possible that remediation goals in the off-property portion of the MKS plume may be able to be achieved in 30 years or less. However, since Alternative E does not provide a low permeability cap, it is not likely to achieve remediation goals as quickly as Alternative B.

6.6.4 Long-Term Effectiveness and Permanence

Long-term permanent protection of human health and the environment is provided via the reduction of chemical concentrations in site media from the following treatment actions provided by Alternative E.

- Air stripping during soil mixing and vapor phase treatment of former Ponds 1 and 2 fill/sludge;
- In-situ treatment of eastern shallow groundwater from the treatment trench;
- in-situ treatment of southern shallow groundwater;
- In-situ treatment of the MKS groundwater source area and plume; and,

- Natural attenuation (biodegradation) of MKS plume.

All of the above processes are irreversible and will result in the permanent removal, and in many cases permanent destruction, of chemical impacts and thus will add to the long-term protection of human health and the environment afforded by this alternative. Operation, inspection, maintenance, and monitoring will be regularly conducted to ensure the continued effectiveness of the treatment components of the above actions.

Regular inspection, maintenance and repairs (when necessary) of the barrier covers will provide long-term effectiveness. Regular inspections will also be conducted to verify the effectiveness of institutional controls and confirm that the required land uses are maintained.

The following long-term effectiveness concerns have been identified for in-situ treatment of eastern shallow groundwater particularly since a low permeability cap would not be installed to reduce the flow of shallow groundwater requiring treatment:

- While the remedial technologies that will be used for in-situ treatment are all effective individually, incorporating them into a small sequential in-situ treatment zone may affect their performance. Variations in flow, especially elevated flow rates, would decrease residence time and may temporarily reduce the effectiveness of the reaction cells.

- The primary concern with the long-term effectiveness of this approach is fouling of the treatment zone. Fouling may occur in the biological treatment zone and/or activated carbon treatment zone due to particulate accumulations or from biological growth.

- In addition, the presence of oxygenated groundwater from surface water infiltration or from exposure of the collected water to atmospheric air in the trench may oxidize and clog the iron treatment zone or reduce the biological treatment zone effectiveness.

These effectiveness concerns are expected to be able to be resolved where only low flows (i.e., on the order of approximately 1 gpm) require treatment.

Because certain residual chemical impacts would be contained in place, five-year reviews would be required to assess the continued effectiveness of this option.

6.6.5 Reduction of Toxicity, Mobility and Volume through Treatment

The same remedial components that will result in the irreversible treatment actions discussed above will also result in the reduction of the toxicity and volume (mass) of chemical impacts present in on-site media.

Former Ponds 1 and 2 fill/sludge represents the principal threat at the site and the source of MKS groundwater impacts. Source control actions for former Ponds 1 and 2 include air stripping/soil mixing to remove and treat VOCs and some SVOCs and then stabilization and solidification of the remaining chemicals. As discussed above, the extraction and treatment of vapors from the mixed soil will reduce the toxicity and volume (mass) of chemicals in this source. Stabilization/solidification of the fill/sludge will result in substantial reduction of mobility for the remaining chemical impacts. In fact, as discussed in Section 4.2.1.2, treatability studies conducted at a site with similar conditions (sludge with high VOC, SVOC, and other heavy organic compounds) showed that stabilization and solidification reduced leachability by over 95%. This alternative therefore addresses the principal threat.

The soil barrier covers will also provide reduction of mobility of chemicals in fill/sludge within former Ponds 3, 4, and 7 and in on-facility surface soil. The covers will isolate the chemical impacts, mitigating potential direct contact and erosional mobility. Armoring the side slopes of former Ponds 3, 4, and 7, where required, will also mitigate potential erosional mobility.

Natural attenuation of residual chemical impacts in groundwater will also continue to reduce the toxicity, and volume (mass) of chemical impacts in MKS groundwater. Natural attenuation processes are restoring groundwater quality. Intermediate degradation products of natural attenuation have short half-lives and are not expected to contribute to future exposure risks.

6.6.6 Implementability

Except for 1) in-situ soil mixing/stripping, stabilization and solidification, 2) in-situ treatment of eastern and southern shallow groundwater, and 3) in-situ MKS source area groundwater treatment using NZVI, all remedial components provided by this alternative are easily implemented as they utilize well established practices, and the services and materials required are standard within the industry and readily available. The long-term O&M requirements for all remedial components provided by this alternative can be readily performed and the personnel, equipment, and spare parts are expected to be readily available.

There are some potential implementability concerns associated with the following remedial components, as described below.

- In-situ soil mixing/stripping, stabilization and solidification of former Ponds 1 and 2 fill/sludge:
    - The low bearing strength of the fill/sludge may require sequentially stabilizing/solidifying the perimeter of the former pond before moving into the interior portions of the former ponds.
    - In general, this remedial component utilizes specialty services and materials, however, there are a number of experienced contractors who do this work.

- In-situ treatment of eastern shallow groundwater: The construction of the in-situ treatment system will be moderately difficult to implement, and monitoring the system effectiveness and maintaining the system hydraulic performance will be difficult to implement. However, these concerns diminish as the flow rate requiring treatment diminishes.

- In-situ treatment of MKS source area groundwater via NZVI:
    - In general, this remedial component utilizes specialty materials (NZVI), although NZVI is becoming a more common remedial technology and the manufacturing of NZVI is become more routine. The services, methods and equipment for injecting and monitoring the development of the treatment zone are straight forward and readily available.

All of the implementability concerns outlined above are believed to be manageable and are not expected to interfere with the effectiveness of the alternative. These potential difficulties can be addressed during the PDI and detailed design.

6.6.7 Cost

A preliminary cost estimate for Alternative E is presented in Tables 6-2A, 6-2J, and 6-2K. The total estimated present worth cost of Alternative E is $13,780,000.

The following remedial time frames were assumed for the estimation of the present worth of O&M costs for Alternative E.

- Final cover (all covers and caps) maintenance – 30 years;
- Eastern shallow groundwater treatment – 20 years (30 year monitoring);
- Southern shallow groundwater treatment – 5 years;

- MKS groundwater:
  - Treatment – 10 years
  - Monitoring/MNA – 30 years; and,
- Institutional controls inspection and documentation – 30 years

7.0 COMPARATIVE EVALUATION OF ALTERNATIVES

7.1 Overall Protection of Human Health and the Environment

Under the current use scenario, all retained OU-2 alternatives, including the No Further Action alternative, provide protection of human health. However, the No Further Action alternative does not provide current protection of ecological receptors nor does it address potential future human and ecological exposures of concern. Table 6-1 provides a list of all the OU-2 alternatives evaluated in detail in Section 6.0, and their associated remedial components as described in Section 5.0.

Alternatives B, C, D, and E will all provide future protection of human health and the environment. However, the degree of protection provided by Alternatives C and D is considered to be lower than Alternative B and E due to their potential lower effectiveness for addressing former Ponds 1 and 2 fill/sludge, the principal source of groundwater impacts. In addition, the protectiveness of Alternative C is rated lower than Alternative D because of the specific effectiveness and implementability issues associated with thermal treatment of the former Ponds 1 and 2 fill/sludge source and in-situ treatment of shallow groundwater without the use of a low permeability cap to reduce flows. The MKS source area groundwater extraction and ex-situ treatment component of Alternative D does not provide any additional protectiveness compared to the in-situ treatment of the MKS source area, and in fact, as discussed below under the long-term effectiveness criteria, MKS groundwater extraction and treatment is expected to primarily provide containment, and thus will be less protective, in the long-term, than in-situ treatment of the MKS groundwater source area. The highest levels of protection of human health and the environment are provided by Alternatives B and E with Alternative B being most protective as a result of the additional low permeability cap.

7.2 Compliance with ARARs

Although the No Further Action alternative could eventually comply with chemical-specific ARARs for groundwater after a very long period of time, there would be no monitoring component to verify attainment. Alternatives B, C, D, and E are expected to be able to comply with chemical-specific, action-specific, and location-specific ARARs and include monitoring to demonstrate compliance. However, the degree of compliance to chemical-specific ARARs afforded by Alternatives C and D is expected to be less than that provided by Alternatives B and

E due to questions regarding the effectiveness to address former Ponds 1 and 2, the primary groundwater source.

7.3 Short-Term Effectiveness

Alternative A will result in the least short-term adverse impacts. While Alternatives B, C, D, and E result in a similar degree of short-term impacts. Alternative D will result in less impacts as the fill/sludge in former Ponds 1 and 2 will be contained rather than disturbed during in-situ treatment (Alternatives B, C, and E) which could result in some degree of short-term effects (e.g., odors) during construction. Alternative C is expected to have a higher potential for short-term effects than Alternative B and E due to questions in regards to controlling extreme heat generated from steam and vapors. Since Alternatives B and E include in-situ treatment of shallow groundwater, they are not anticipated to have as great an impact to local wetlands (if and where present) as Alternative D.

Due to the presence of DNAPL in bedrock, the time frames for achieving groundwater restoration goals is indeterminate. However, Alternative B will result in the shortest remediation time frames as a result of it providing the greatest amount of source control and it providing in-situ treatment of the MKS source and plume. Alternative E is expected to have the next shortest remediation time frame followed by Alternatives C. As discussed in Section 7.4 below, Alternative D, which includes groundwater extraction and ex-situ treatment of MKS groundwater, is expected to have longer remediation times than Alternatives B, C, and E which provide in-situ treatment. Alternative A will have the longest remediation time frame.

7.4 Long-Term Effectiveness and Permanence

The long-term effectiveness and permanence of Alternatives B and E are expected to be higher than for Alternatives C and D due to the anticipated higher degree of effectiveness of the remedial components (soil mixing/stripping and stabilization/solidification) that addresses the former Ponds 1 and 2 fill/sludge. Former Ponds 1 and 2 fill/sludge source control remedial components provided by Alternative C (in-situ thermal desorption) and Alternative D (containment) both have effectiveness and implementability concerns that are likely to reduce their long-term effectiveness and permanence.

Alternatives B, C, and E are expected to provide a higher degree of long-term effectiveness and permanence than Alternative D relative the remediation of the MKS source area groundwater. In particular, in-situ NZVI possibly followed by accelerated biological treatment of the MKS groundwater source area included in Alternatives B, C, and E provide several substantial technical advantages over the groundwater extraction and ex-situ treatment components of Alternative D as follows:

- NZVI will rapidly treat a large component of the dissolved organic chemical mass and will create geochemical conditions that are ideal for accelerated biological treatment and that will enhance natural attenuation. Accelerated in-situ biological treatment is potentially able to provide more effective remediation of source area impacts, particularly if residual source materials (i.e., DNAPL) are present in fractures, and will thus result in reduced cleanup times. For example, microorganisms will propogate into isolated locations such as dead-end or low permeability fractures within the source that cannot be extracted using pumping but would slowly release constituents to groundwater. In addition, both NZVI and the biological amendments will treat groundwater adjacent to source area residuals, thus increasing the constituent dissolution rate for those residuals and decrease cleanup times.

- As discussed in Section 2-8, natural biological attenuation processes are active within the MKS source area and the downgradient MKS plume. Injections of NZVI and nutrients associated with accelerated in-situ bioremediation will enhance the existing in-situ biological treatment processes that are already naturally occurring and can improve the conditions and rates of biological attenuation.

Moreover, accelerated in-situ bioremediation can potentially overcome many of the technical limitations associated with groundwater extraction and treatment systems in fractured bedrock. These limitations include, but are not limited to, the following:

- Fractured bedrock potentially contains substantial discontinuities and dead-end or reduced accessibility fractures where chemicals are isolated from the extracted groundwater. In addition, chemical impacts can exist within the primary porosity of the fractured rock and concentration rebound can exist following groundwater extraction. Under these circumstances often a small percentage of fractures are responsible for contributing the bulk of the groundwater flow. Groundwater extracted through these fractures trends on a much higher velocity (10 to 1,000 times) than the average groundwater velocity and is much higher than the rate of dissolution. The consequence of these conditions is the inefficient extraction of large quantities of groundwater containing small amounts of chemical mass.

- The distribution of potential residuals within the source area is complex and difficult to predict. Thus it is impossible to target an extraction system to remove the residuals and prevent them from acting as long-term (> 30 year) sources of groundwater impacts. Extraction systems generally do not substantially increase the mixing in the vicinity of the residuals and thus do not substantially increase the concentration gradient between the

> residuals and groundwater, which would result in shortening the duration of treatment. Biological treatment microorganisms will preferentially grow towards the highest concentration of organic chemicals, including residuals within the primary and secondary porosity of the bedrock. Thus, increasing the concentration gradient, which increases the rate of dissolution and shortens the remediation time frame.

In summary, in-situ NZVI and accelerated in-situ bioremediation is expected to more effectively treat the MKS source area groundwater and as a result, will reduce the time of remediation as compared to groundwater pumping and treatment.

7.5 Reduction of Toxicity, Mobility, and Volume Through Treatment

The reduction of toxicity, mobility, and volume through treatment is higher for Alternatives B, C, and E since they provide in-situ treatment of former Ponds 1 and 2 fill/sludge. Alternatives B, C and E also provide a higher degree of reduction of toxicity, mobility, and volume than Alternative D because they provide in-situ treatment of MKS source area groundwater, which as described in Section 7.4 above, is a more effective means for treating groundwater chemical impacts in bedrock where residual source materials are believed present. In addition, Alternatives B, C, and E provide a higher degree of treatment of downgradient chemical impacts in the MKS plume through the improvement of natural biological attenuation conditions. Alternative B and E are rated higher than Alternative C due to the implementability concerns associated with in-situ thermal desorption treatment of former Ponds 1 and 2, which may result in reduced treatment effectiveness and thus less reduction of toxicity, mobility, and volume.

7.6 Implementability

In general, all five alternatives are implementable. Alternative A is the easiest to implement, followed by Alternatives B and E. Alternatives C and D are equally the most difficult to effectively implement.

7.7 Cost

The present worth costs for each of the alternatives is listed below in order of increasing costs:

- Alternative A – $4,700,000
- Alternative E – $13,780,000
- Alternative B – $18,960,000
- Alternative D – $21,350,000
- Alternative C – $24,650,000

7.8 Summary

The following table provides a summary of the relative rankings of the five retained OU-2 remedial alternatives for each of the seven NCP threshold and balancing criteria. Remedial alternatives assigned a rank of "First" were considered to be the most preferable in the associated category (i.e., most effective, most easily implemented, etc.).

Relative Ranking	*Protection of Human Health and Environment*	*Compliance With ARARs*	*Short-Term Effectiveness*		*Long-Term Effective-ness*	*Reduction of Toxicity, Mobility, Volume*	*Implementability*	*Cost*
			Potential Short-Impacts	*Remediation Time Frame*				
*First**	Alt. B	Alt. A, B, C, D, E	Alt. A	Alt. B	Alt. B	Alt. B	Alt. A	Alt. A
Second	Alt. E		Alt. D	Alt. E	Alt. E	Alt. E	Alt. E	Alt. E
Third	Alt. D		Alt. B, C, E	Alt. C	Alt. C	Alt. C	Alt. B	Alt. B
Fourth	Alt. C			Alt. D	Alt. D	Alt. D	Alt. C	Alt. D
Fifth	Alt. A			Alt. A	Alt. A	Alt. A	Alt. D	Alt. C

* Indicates most preferable alternative(s) in given category.

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