Response Action Contract for
Remedial, Enforcement Oversight, and Non-Time Critical
Removal Activities at Sites of Release or Threatened Release of
Hazardous Substances in
EPA Region VIII

U. S. EPA Contract No. 68-W5-0022

Final
Focused Feasibility Study Report
for
Bountiful/Woods Cross
5th South PCE Plume (OU2)
Davis County, Utah

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Acronyms

ARARs	applicable or relevant and appropriate requirements
BFC	Bountiful Family Cleaners
bgs	below ground surface
CAH	chlorinated aliphatic hydrocarbons
CDM	CDM Federal Programs Corporation
CERCLA	Comprehensive Environmental Response Compensation and Liability Act
cis-DCE	cis-1,2, dichloroethene
cm/sec	centimeter per second
COC	contaminant of concern
COPC	chemicals of potential concern
CWA	Clean Water Act
DEP	David Early Property
DNAPL	dense non-aqueous phase liquid
DOE	U.S. Department of Energy
DPE	dual phase extraction
DW	domestic well
EAB	enhanced anaerobic bioremediation
ECD	electron capture detector
EPA	U.S. Environmental Protection Agency
FFS	focused feasibility study
FS	feasibility study
ft	feet
ft^3	cubic feet
FWQC	Federal Water Quality Criteria
GAC	granulated activated carbon
gpm	gallons per minute
GRA	general response action
HHERA	human health and ecological risk assessment
IC	institutional control
I-15	Interstate 15
LGAC	liquid granulated activated carbon
MCL	maximum contaminant level
MCLG	maximum contaminant level goal
mg/L	milligrams per liter
MIP	membrane interface probe
MTBE	methyl tert-butyl ether
MW	monitoring well
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NPL	National Priorities List
NPDES	National Pollutant Discharge Elimination System
O&M	operation and maintenance
OU	operable unit
PA	preliminary assessment

PAC	powdered activated carbon
PCE	tetrachloroethene
ppb	parts per billion
POTW	publicly owned treatment works
PRB	permeable reactive barrier
PRP	potentially responsible party
PVC	polyvinyl chloride
RAC	Response Action Contract
RAO	remedial action objectives
RCRA	Resources Conservation and Recovery Act
RI	remedial investigation
ROD	record of decision
SAP	sampling and analysis plan
SARA	Superfund Amendments and Reauthorization Act of 1986
scfm	standard cubic feet per minute
SDWA	Safe Drinking Water Act
Site	Bountiful/Woods Cross OU2 Superfund Site
SPME	solid phase microextraction
SRC	Syracuse Research Corporation
START	Superfund Technical and Response Team
SVE	soil vapor extraction
TBC	to be considered
TCE	trichloroethene
TMDL	total maximum daily load
UAC	Utah Administrative Code
UDEQ	Utah Department of Environmental Quality
UPDES	Utah's Pollution Discharge Elimination System
μg/L	micrograms per liter
USC	U.S. Code
UV	ultraviolet
VC	vinyl chloride
VGAC	vapor granulated activated carbon
VOC	volatile organic compound

Section 1
Introduction

1.1 Purpose and Organization of Report

This Focused Feasibility Study (FFS) report identifies, screens, evaluates, and compares potential remedial alternatives that address contaminated groundwater within the Bountiful/Woods Cross 5th South PCE Plume Operable Unit (OU) 2 (Site) in Bountiful, West Bountiful, and Woods Cross, Utah. This FFS was prepared for the U.S. Environmental Protection Agency (EPA) Region VIII under work assignment 114-RICO-088G of EPA's Response Action Contract (RAC) 68-W5-0022.

The FFS was prepared in accordance with *Guidance for Conducting Remedial Investigations (RI) and Feasibility Studies Under Comprehensive Environmental Response Compensation and Liability Act (CERCLA)* (EPA 1988), *A Guide to Developing and Documenting Cost Estimates During the Feasibility Study* (EPA 2000a), and the National Oil and Hazardous Substances Pollution Contingency Plan (NCP). This FFS will be updated and revised as the final FFS based on the comments received from EPA, the State of Utah, and the potentially responsible party (PRP) for OU2.

Section 1 of this report contains information on site background, contaminants of concern, and previous response actions implemented by EPA. Section 2 identifies potential applicable remedial technologies and contains a preliminary screening of these technologies. Potentially applicable or relevant and appropriate requirements (ARARs) and site-specific cleanup criteria are also evaluated in Section 2. Section 3 presents the remedial action alternatives developed from combinations of the screened technologies and screens these alternatives against the broad criteria of effectiveness, implementability, and cost. Section 4 presents the detailed alternative evaluation and a comparative analysis of the alternatives. Section 5 contains references used to prepare this report.

1.2 Site Background Information

The Site is located in southern Davis County, Utah, approximately 10 miles north of Salt Lake City (Figure 1-1). Specifically, the boundaries inclusive of OU1 and OU2 are approximately 750 South Street to 300 North Street and 500 West Street to 1400 West Street in the cities of Bountiful, West Bountiful, and Woods Cross, Utah (Figure 1-2).

A discussion of historical investigations/response actions and summaries of the RI findings of each phase is presented in Section 1.3 and Section 1.4, respectively.

1.3 Site Enforcement History

Detections of tetrachloroethene (PCE) and trichloroethene (TCE) in groundwater at the site were first noted in 1984. Golder Associates conducted an investigation in May 1987 at the Woods Cross (former Phillips 66) refinery to identify potential sources of PCE detected in shallow groundwater. PCE was detected in the parts per billion (ppb) range in groundwater both upgradient and downgradient of the refinery (Golder Associates 1987). No source was identified during that investigation.

In 1996, EPA's Superfund Technical and Response Team (START) contractor sampled residential wells downgradient and cross gradient of the former Phillips 66 Refinery (now owned by Holly Refining & Marketing Company). Tap water sampled from four homes along 1100 West contained PCE contamination above 5 micrograms per liter (µg/L), which is the PCE maximum contaminant level (MCL) for drinking water. These wells correspond to domestic well DW17 and others in the vicinity of DW12 where homes are now abandoned (CDM 2004). Initially, these households were given bottled drinking water, and eventually, two of the four homes were connected to the municipal water supply.

In 1996, the Utah Department of Environmental Quality (UDEQ) conducted a preliminary assessment (PA). Groundwater was identified as the primary exposure pathway. The PA identified the oil refinery, several dry cleaners, and various automotive maintenance facilities as potential sources of the PCE contamination in groundwater.

In 1997, a Geoprobe® investigation at the Hatchco/Kelly property (located directly south of the refinery's petroleum trucking terminal) detected concentrations of chlorinated aliphatic hydrocarbons (CAHs), primarily TCE, with concentrations as high as 3,750 ppb in shallow groundwater (UDEQ 1999).

In the fall of 1998, UDEQ collected five groundwater samples by cone penetrometer on the east side of Interstate 15 (I-15). One sample, collected downgradient of one of the dry cleaners contained PCE at 8 ppb. A definitive PCE source/facility was not identified as part of the investigation (UDEQ 1999).

Annual sampling conducted by Phillips Petroleum Company during the late 1990s has shown elevated PCE and TCE concentrations above MCLs in three downgradient monitoring wells (MWs) on the western side of the refinery (MW02S, -2D, and -3S). Additionally, samples collected by EPA in 2000 confirmed the presence of PCE, TCE, and vinyl chloride in various groundwater monitoring and domestic wells in the local area.

EPA conducted a passive soil gas survey in March and September 2001 and identified several potential PCE source areas between 200 West Street and I-15 in Bountiful and West Bountiful, Utah. Due to the potential impact to drinking water in the area, EPA placed the Site on the National Priorities List (NPL) in October 2001. Following the listing, the Site was subdivided into two OUs (OU1 and OU2). Formerly, the OU1 area was called the "Woods Cross 800 West Plume," and OU2 was the 5^{th} South PCE Plume with an unknown source, or the "Unknown Source Plume."

The PRP for OU1 (Hatchco/Kelly) completed an RI/focused feasibility study (FFS) for onsite and offsite contaminant plumes of CAHs extending to the west northwest (HDR 2003a and 2003b). In addition, EPA has drafted a proposed plan, which includes a pilot study implementation plan for enhanced anaerobic bioremediation (EAB) for OU1 (CDM Federal Programs Corporation [CDM] 2005a).

During subsequent investigations co-mingled methyl tert-butyl ether (MTBE) was identified in MW03U and other shallow groundwater samples (CDM 2004). The MTBE plume is currently being addressed with a Corrective Action Plan that has been implemented by Holly and regulated by the State of Utah (Division of Water Quality).

1.4 Remedial Investigation

In 2002, CDM was tasked with conducting an RI at the Bountiful/Woods Cross OU2 Site. This investigation included primarily groundwater and limited soil/soil gas sampling. The RI was completed in three phases as discussed below to determine source areas and extent of contamination. The RI sampling was completed in April 2005 and the final RI is planned for submittal in June 2005.

1.4.1 Phase 1 Field Investigation (OU2)

The Phase 1 field investigation identified the Bountiful Family Cleaners/David Early Property (BFC/DEP) as the source of shallow PCE/TCE groundwater contamination for the OU2 Unknown Source Plume (see the red plume on Figure 1-3). The depth to groundwater in the source area is approximately 70 feet (ft). The Phase 1 investigation also provided preliminary evidence of at least two separate sources potentially contributing contamination to the deeper domestic wells (DW) along 1100 West Street and the shallow former Phillips 66 (now Holly Refining and Marketing) MWs, respectively. Conclusive evidence of a BFC/DEP impact on the domestic wells could not be determined with only the shallow groundwater data available. However, the Phase 1 investigation helped distinguish separate and distinct plumes within the Site (CDM 2002).

1.4.2 Phase 2 Field Investigation (OU2)

The Phase 2 field investigation delineated the vertical and horizontal extent of the OU2 PCE/TCE plume (Figure 1-3), quantified contamination levels in the groundwater for support of risk assessment studies, and conducted quarterly monitoring from existing and newly installed permanent MWs of the chemicals of potential concern (COPC) identified in the initial baseline risk assessment (SRC 2004). Results from the Phase 2 field investigation concluded that there is a clear pathway and high probability that contaminants (i.e., primarily PCE with minor amounts of degradation compounds) emanating from the BFC/DEP are reaching the domestic wells completed in the artesian zones of the aquifer to the west of the Holly Refinery.

1.4.3 Phase 3 Field Investigation (OU2 and OU1)

The Phase 3 field investigation involved collecting environmental samples and other information from the source area (BFC/DEP) and retail stores to the west. The Phase 3 sampling provided supplemental information toward isolating the specific high PCE concentration areas and identifying the source of indoor air and sub slab air PCE contamination (Figure 1-4). The electron capture detector (ECD) results shown in the figure were confirmed as primarily PCE by speciation of the off gas (CDM 2005b).

A comprehensive groundwater sampling effort was also conducted as part of Phase 3 in OU2 and OU1 (CDM 2005b). A total of 40 wells were sampled and analyzed for volatile organic compounds (VOCs) and natural attenuation parameters.

The sampling results reinforce that the likely source of the PCE contamination is the BFC property, with the highest vadose zone PCE soil vapor concentrations (196,650 ppb) occurring at the northwest corner of the BFC building (Figure 1-4). These high concentrations that were measured at a depth of 8 ft strongly suggest that a shallow source exists approximately 25 ft by 25 ft in this vicinity. Historical aerial photography and documentation from the South Davis Sewer District suggest that this "hot spot" may have been the approximate location of the original dry cleaner septic system drain field, prior to BFC hooking up to the city mainline sewer in 1966 (CDM 2005b).

A site conceptual model as presented in the *Baseline Human Health and Ecological Risk Assessment Addendum for Bountiful/Woods Cross Site* (Syracuse Research Corporation 2005) was formulated based on investigation results and indicate an extensive PCE plume is present at various levels (upper, middle, and lower) within the shallow East Shore aquifer. The plume extends from the source area at BFC/DEP to the west approximately 1.5 miles. This aquifer is highly productive and is extensively developed for municipal and industrial water supplies. Several water supply wells (some artesian) are located in the vicinity of the plume although most municipal and industrial wells produce their water from intervals that are deeper than the PCE plume.

A simplified analytical groundwater model was implemented during the RI to assess the potential for continued migration of the PCE plume under both no action and source remediation alternatives (CDM 2005b). The modeling analysis indicates that expansion of the plume will likely occur even if the source is removed. However, it is anticipated that the groundwater restoration timeframe will decrease once the source is removed.

1.5 Risk Assessments Summary

Analysis of groundwater samples collected by CDM from the Phase 1 and 2 field investigations were supplied to Syracuse Research Corporation (SRC) for the purpose of conducting the baseline human health and ecological risk assessment (HHERA).

The Phase 1 and 2 RI groundwater data showed PCE levels above the MCLs for drinking water in both the source and plume areas of the Bountiful/Woods Cross OU2. PCE is a solvent used to clean machinery, electronic parts, and clothing. PCE and TCE (a degradation compound) are suspected carcinogens and abundant environmental pollutants (along with other CAHs) in the groundwaters of the United States. In some groundwater environments, these compounds undergo reductive dechlorination, catalyzed by anaerobic bacteria, that yields vinyl chloride (known human carcinogen) and other degradation compounds. PCE and TCE can also volatilize from either groundwater or soil, posing a potential inhalation threat to human receptors (SRC 2004).

The HHERA performed using Phase 1 and Phase 2 analytical data concluded the following:

- The only noncancer risk under the hypothetical inhalation of VOCS released during indoor use of groundwater exposure scenario evaluated in the *Baseline Human Health and Ecological Risk Assessment for the Bountiful/Woods Cross Site* (SRC 2004) is from MTBE . The monitoring well (MW03U) from which this exceedance of MTBE occurred is located on the Holly Refinery property which is currently being investigated as the source of the MTBE. No samples from wells taken within the Site contained COCs at levels high enough to pose a non cancer threat.

- Cancer risk exceeded the EPA's target range of 1 in 10,000 at 62 groundwater sample locations under the residential exposure scenario and 41 groundwater sample locations under a temporary worker exposure scenario. In most cases, the primary sources of cancer risk were from PCE and TCE, with minor influence from vinyl chloride, benzene, and MTBE (Note: This assessment included groundwater results from an extension of the OU1 plume).

Where PCE is the major concern, the primary exposure pathway is ingestion of groundwater with less contribution from inhalation. Where TCE is the main concern, the relative contribution of the two exposure pathways depends on the slope factor used to calculate the risk.

Analytical results from the Phase 3 indoor air and sub-slab vapor samples were also supplied to SRC to conduct a supplementary risk analysis and update to their baseline HHERA, as appropriate (SRC 2005).

There are three main sources of VOCs in indoor air:

- Sources within the building
- Intrusion of vapors released from contaminated soil and groundwater beneath the building
- Contamination in ambient air

The analysis of indoor and sub slab area samples collected during the Phase 3 field investigation showed elevated levels of PCE in both the indoor and sub-slab air. The HHERA addendum analysis of these samples showed a cancer risk greater than the 1×10^{-4} EPA acceptable exposure limit via inhalation of primarily PCE in both indoor air and sub-slab air in the BFC.

1.6 Extent of Contamination

Based on the information from all phases of the field investigation and subsequent risk assessments, PCE is the major contaminant of concern (COC) for both groundwater and indoor air in the Bountiful/Woods Cross OU2. Limited soils sampled in the source area did not contain PCE at levels high enough for soils to pose risks to human health. Since the contaminated soils themselves do not pose a threat to human health, source area soils remediation will not be evaluated in this FFS. However, the contamination contained in these soils is the source for both groundwater and indoor air contamination. Therefore, some traditional soil remediation technologies will be evaluated as part of both groundwater and indoor air alternatives in this FFS.

Section 2
Identification and Screening of Technologies

2.1 Introduction

Section 300.430 (e) of the NCP required the remedial alternative development process be initiated by developing remedial action objectives (RAOs), identifying general response actions that address these RAOs, and performing an initial screening of applicable remedial technologies. As part of this process, an evaluation of potential ARARs is conducted.

Section 2.2 identifies chemical-specific, action-specific, and location-specific ARARs that each remedial action alternative for groundwater and indoor air at the Bountiful/Woods Cross OU2 must comply with to be considered a viable alternative. Guidance documents to be considered are also identified.

Section 2.3 provides the RAOs developed for groundwater and indoor air. The objectives consist of medium-specific goals for protecting human health and the environment and specify contaminant(s) of concern, exposure route(s), and receptor(s). Section 2.4 identifies the general response actions that were developed to satisfy the groundwater and indoor air RAOs.

Section 2.5 presents the identification, screening, and evaluation of technology types and process options. In accordance with the NCP, the potentially applicable technologies and process options for each general response action are initially screened based on technical implementability. These options are then evaluated based on:

- Effectiveness
- Technical implementability
- Relative cost

Technical implementability is defined as the ability for a technology to address the waste media at a site and the ability of the technology to perform under specific site conditions. Any technologies not meeting the technical implementability requirements is screened out of the FS process.

2.2 Potentially Applicable or Relevant and Appropriate Requirements (ARARs)

The NCP requires that the selected remedy for all remedial actions must attain or exceed the ARARs in environmental and public health laws. It also required removal actions to attain ARARs to the greatest extent practicable. The distinction between applicable and relevant and appropriate determines the constraints imposed on remedial alternatives by environmental regulations other than CERCLA.

Identification of ARARs must be done on a site-specific basis and involves a two-part analysis: first, determining whether a given requirement is applicable and second, determining if a requirement that is not applicable is both relevant and appropriate.

2.2.1 Definition of ARARs

Section 121 (d) of CERLA as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA) requires that remedial actions attain a degree of cleanup that ensures protection of human health and the environment. Section 121 (d)(2) of CERCLA, 42 U.S. Code (USC) Section 9621 (d)(2) limits federal ARARs to those federal environmental laws that set a standard, requirement, criterion, or limitation that is legally applicable or relevant and appropriate to those hazardous substances, pollutants, or contaminants that will remain on site following remediation.

For contaminants that will be transferred off site, Section 121 (d) of CERCLA requires that the transfer be to a facility that is operating in compliance with applicable federal and state laws. Section 121(d) of CERCLA, as amended by SARA, also requires attainment of ARARs, including state environmental or facility siting laws, when the promulgated state requirements are more stringent than federal laws and are identified by the state in a timely manner. It should be noted that the NCP final rule states that potential state ARARs must be applicable to all remedial situations described in the requirement and not just to CERCLA sites.

In addition to applicable or relevant and appropriate requirements, the NCP provides a list of federal non-promulgated criteria, advisories and guidance, and state standards to be considered (TBC). CERCLA also provides limited circumstances in which ARARs could be waived.

2.2.1.1 Applicable Requirements

The NCP final rule for CERCLA defines applicable requirements as:

> "…those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility siting law that specifically address a hazardous substance, pollutant, contaminant, remedial action, location or other circumstance found at a CERCLA site. Only those state standards that are identified by a state in a timely manner and that are more stringent than federal requirements may be applicable."

State requirements are more stringent than federal requirements if the state program has federal authorization and the state requirements are at least as stringent. Applicable requirements must be met to the full extent required by law or waived by EPA.

2.2.1.2 Relevant and Appropriate Requirements

If it is determined that a requirement is not applicable to a specific release, the requirement may still be relevant and appropriate to the circumstances of the release. The NCP final rule for CERCLA defines relevant or appropriate requirements as:

> "…those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that, while not "applicable" to a hazardous substance, pollutant, contaminant, remedial action, location or circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site. Only those state standards that are identified by a state in a timely manner and that are more stringent than federal requirements may be relevant and appropriate."

Distinguishing a regulation that is relevant and appropriate is determined using best professional judgment, taking into account the purpose of the requirement. In some cases, a requirement may be relevant but not appropriate given a site-specific circumstance. Therefore, such a requirement is not an ARAR for the Site.

2.2.1.3 Other Requirements To Be Considered

In addition to ARARs, TBC criteria are evaluated and utilized to determine the necessary level of cleanup for protection of human health or the environment. The TBCs are nonpromulgated advisories, regulations, or guidance issued by federal or state government that are not legally binding and are not generally enforceable but may have specific bearing on all or part of the action. TBCs can be used to determine the necessary level of cleanup for protection of human health or the environment where no specific ARARs exist for a chemical or situation or where such ARARs are not sufficient to be protective.

2.2.1.4 Waivers

The Superfund law specifies situations under which the ARARs requirements may be waived (Section 212(d)(4)). The situations eligible for waivers include:

- Interim remedies
- Remedies in which attainment of the ARAR would pose a greater risk to human health or the environment than would non-attainment
- Technical impracticability of attainment
- Inconsistent application or enforcement of a state requirement
- Fund balancing (financial restriction within the Superfund program)
- Attainment of equivalent performance without the ARAR

2.2.1.5 Application of ARAR

ARARs will be determined based upon an analysis of which requirements are applicable or relevant and appropriate to the distinctive set of circumstances and action contemplated at a specific site. The NCP requires attainment of ARARs during the implementation of the remedial action, completion of the action, and when carrying out removal actions to the extent practicable.

For the ease of identification, EPA divides ARARs into three categories: chemical specific, location specific, and action specific, depending on whether the requirement is triggered by the presence or emission of a chemical, by a vulnerable or protected location, or by a particular action. These ARAR categories are briefly described below.

- Chemical-specific requirements are usually health risk or technology based numerical values that may define acceptable exposure levels. These values establish the acceptable amount of concentration of a chemical that can be discharged or left in the ambient environment.

- Location-specific requirements set restrictions on the concentrations of compounds or on activities within specific locations, such as floodplains or wetlands.

- Action-specific requirements are generally technology or activity based requirements that set controls on activities pertaining to a particular treatment or disposal method.

2.2.2 Bountiful/Woods Cross OU2 ARARs

When considering the ARAR classifications for Bountiful/Woods Cross OU2, the appropriateness of federal and state regulations were evaluated with respect to the nature and extent of contamination, the location and circumstances of the Bountiful/Woods Cross OU2, and potential remedial actions. Relevant guidance documents are regarded as TBC items.

2.2.2.1 Chemical-Specific ARARs

Selected chemical-specific ARARs are presented in Table 2-1. Included in the chemical-specific ARARs are requirements for protecting air, surface water, and groundwater.

Air. Air is a medium of concern due to elevated levels of VOCs that pose a risk to human health in both indoor air and sub-slab air in the BFC. VOCs are also present in groundwater and the vadose zone and may be subject to volatilization and subsequent airborne transport in other areas of the Site. In addition, any drilling activities implemented during remedial action implementation may create fugitive dust. Air quality standards have been established under the Federal Clean Air Act and are enforced by UDEQ in accordance with Utah Administrative Code (UAC)

UAC-R307. Chemical-specific ambient air quality standards are not ARARs for the Site since, in its passive state, the Site is not a major source of air pollutants.

Surface Water. CERCLA § 121(d) states that remedial actions shall attain federal water quality criteria where they are relevant and appropriate under the circumstances of a release or threatened release (EPA 1989). This determination is to be based on the designated or potential use of the water, the media affected, the purposes of the criteria, and current information. The Federal Water Quality Criteria (FWQC) are non-enforceable guidance developed under the Clean Water Act (CWA) § 304 and are used by the state, in conjunction with a designated use for a stream segment, to establish water quality standards under CWA § 303.

Utah's Pollution Discharge Elimination System (UPDES) regulations (UAC R317-8) provide for regulation of the discharge of pollutants from any point source into the waters of the state. Storm water point discharges are specifically included in the regulation requirements. Groundwater discharges are not included in the UPDES regulation. National Pollutant Discharge Elimination System (NPDES) regulations are therefore not ARARs for groundwater.

Groundwater. The Safe Drinking Water Act (SDWA) establishes MCLs and maximum contaminant level goals (MCLGs) for drinking water supplied by a public water supplier. CERCLA directs that MCLGs, set at levels above zero, may be relevant and appropriate remedial actions involving ground or surface waters that are current or potential sources of drinking water. If the MCLG is zero, the corresponding MCL will be relevant and appropriate instead. The state of Utah has, in UAC R317-6-2, provided groundwater quality standards that are relevant and appropriate standards for the protection of uncontaminated groundwater and standards for corrective action. These standards are the same as MCLs, with few exceptions. These chemical-specific ARARs for groundwater are listed in Table 2-2.

2.2.2.2 Action-Specific ARARs

The action-specific ARAR analysis was performed considering potential remedial actions that could be performed for groundwater and indoor air. A summary of the action-specific ARARs selected for groundwater and indoor air is presented in Table 2-3.

Potential groundwater and indoor air remedial actions involve the removal of contaminated groundwater, treatment of contaminated groundwater, and disposal of treated groundwater and spent treatment media. In addition, some general construction activities can be expected.

2.2.2.3 Location-Specific ARARs

The identification of potential location-specific ARARs for the Bountiful/Woods Cross OU2 is presented in Table 2-4.

2.2.2.4 To Be Considered

There are no additional guidance documents or regulations that are to be considered for the remediation of groundwater and indoor air at Bountiful/Woods Cross OU2 other than the ARARs already identified and the documents referenced in the text of this FFS.

2.2.2.5 Waivers

ARAR waivers are not being sought for any of the remedial actions presented in this FFS.

2.3 Remedial Action Objectives

The Bountiful/Woods Cross OU2 groundwater is a potential source of drinking water for communities surrounding the Site. BFC is an operating commercial facility, housing workers who are exposed to PCE in indoor air in most sections of the building. In addition, further volatilization of PCE from shallow soils may pose a health threat to residents and businesses located within other parts of the Bountiful/Woods Cross OU2. Therefore, the RAOs developed for groundwater and indoor air at the Bountiful/Woods Cross OU2 are as follows:

Protect human health by:

- Preventing direct ingestion of untreated groundwater as a drinking water
- Preventing exposure via inhalation of VOCs in contaminated groundwater that are released into indoor air from indoor water uses
- Preventing exposure via inhalation of VOCs released from groundwater and soils that migrates upward through soil into indoor and sub-slab air
- Restoring groundwater to beneficial use.

2.4 General Response Actions

General response actions are proposed for treatment of contaminated groundwater and indoor air at the Bountiful/Woods Cross OU2 with the intent of satisfying the remedial action objectives stated in Section 2.3 and meeting the requirements of the NCP. Each remedial action objective can be accomplished by implementing one or more general response actions. The NCP sets out the types of remedies that are expected to result from the remedy selection process defined below:

- Treat principal threats, wherever practicable. Principal threats are characterized as:
  - Areas contaminated with high concentrations of toxic compounds
  - Liquids and other highly mobile materials
  - Contaminated media that pose significant risk of exposure

- Media containing contaminants several orders of magnitude above health-based levels

- Appropriate remedies often will combine treatment and containment.

- Containment will be considered for wastes that pose a relatively low long-term threat or where treatment is impracticable.

- Institutional controls are most useful as a supplement to engineering controls for short- and long-term management.

- Innovative technologies should be considered if they offer the potential for comparable or superior treatment performances or lower costs for similar levels of performance than demonstrated technologies.

2.4.1 General Response Actions for Bountiful/Woods Cross OU2

A general response action (GRA) is a coarse form of a remedial alternative that is proposed then refined as the feasibility process proceeds. The GRAs proposed for treatment of Bountiful/Woods Cross OU 2 groundwater and indoor air contamination include the following:

- No Action
- Institutional Controls
- Monitoring
- Containment
- Active Restoration - Extraction/Treatment/Disposal
- *In situ* Treatment

Each of these GRAs is discussed in the following sections. While soils at the Bountiful/Woods Cross OU2 (with the exception of a small area of shallow soils in the BFC parking lot) do not pose a risk to human health or the environment at this time, GRAs for *in situ* treatment of source area soils are included in this FFS. Contamination in the source area soils is a source of contaminant loading to both groundwater and indoor air. Addressing this contamination can shorten the effective time required to operate any groundwater or indoor air remedial action alternatives. Therefore, *in situ* process options and technologies for the soil GRAs will be carried forward through the FS process as part of groundwater and indoor air remedial action alternatives.

2.4.1.1 No Action

The no action response provides a baseline for evaluating the remedial alternatives available as required by the NCP. The no action response would not be effective in preventing human exposure to the groundwater and indoor air. However, in accordance with CERCLA Section 121(c), a review/reassessment of the conditions at the Site is required at 5-year intervals to determine if other remedial action efforts are warranted.

2.4.1.2 Institutional Controls

Institutional controls (ICs) represent non-engineered administrative or legal controls that limit land or resource use and are considered a limited action remedial alternative. ICs can be a stand-alone remedy or can serve as a supplement to an engineering control remedial action throughout all stages of the cleanup process. The use of ICs as a sole remedy is not encouraged unless all other remedial actions are determined to be impractical. ICs are particularly beneficial when incorporated as a layered component of the cleanup process to provide overlapping assurances of protection from contamination.

2.4.1.3 Monitoring

Monitoring groundwater would be a limited remedial action alternative that should provide data to assess the occurrence of monitored natural attenuation of groundwater at a site. Under the EPA guidance documents *EPA Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action and Underground Storage Tank Sites* (EPA 2001) and *Performance Monitoring of MNA Remedies for VOCs in Groundwater* (EPA 2004), historic data should demonstrate a clear trend of decreasing or stabilized concentrations of COCs at the plume boundaries. By monitoring groundwater throughout the 5-year review period for a selected remedy, the required historical data can be collected while the cleanup of a site is being evaluated.

Monitoring would verify the effectiveness of the natural attenuation processes and show that remediation of a groundwater aquifer can occur within a reasonable time frame without active treatment. The natural attenuation processes include a variety of physical, chemical, or biological processes that, under favorable conditions, act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contamination in groundwater.

2.4.1.4 Containment

Containment response actions are used to isolate the contaminated media and to restrict migration of contaminants. Since containment response actions do not have a treatment component, they do not reduce the concentration or volume of contaminants.

Containment response actions include physical barriers and hydraulic controls for groundwater containment. Options such as excavation and disposal of contaminated soils are considered to be source control measures. Containment options may be combined with treatment options such as this to form feasible alternatives for both indoor air and groundwater.

2.4.1.5 Active Restoration - Extraction/Treatment/Discharge

The active restoration general response action involves reducing COC concentrations in groundwater to levels below cleanup criteria by extracting groundwater to the surface, removing the contaminants, and discharging the clean water. Groundwater extraction combined with treatment and discharge would reduce the concentration of contaminants.

2.4.1.6 *In Situ* Treatment

The *in situ* treatment general response action provides for reducing COC concentrations in groundwater to levels below cleanup criteria by treatment of groundwater and soils in place. Permeable reactive barrier walls, surfactant flushing, in-well air stripping, soil vapor extraction, air sparging, multi-phase extraction, biological treatment, and *in situ* oxidation are considered remedial action technologies under this action.

2.5 Identification, Screening, and Evaluation of Technology Types and Process Options

In this step of the FS process, technology types and process options are identified for each of the general response actions listed in Section 2.4. Each of these technologies and process options are then evaluated or screened with respect to technical implementability at the Bountiful/Woods Cross OU2. These steps are described in further detail in the following section.

2.5.1 Identification of Remedial Technologies and Process Options

For each of the general response actions identified in Section 2.4, potentially applicable remedial technologies and associated process options have been identified for groundwater and indoor air. These technologies and process options are discussed in the following sections and are summarized in Table 2-5.

2.5.1.1 No Action

This response action assumes that no active remedial or non-engineered measures will be implemented at the Site to address contamination. The purpose of this response is to assist in the baseline comparison of groundwater and indoor air remedial options.

2.5.1.2 Institutional Controls (ICs)

ICs are defined as non-engineering measures, usually but not always legal controls, intended to affect human activities to reduce exposure to hazardous substances through restricting the use of land and/or groundwater. The objectives of implementing ICs are to:

- Assure that future groundwater use at the site is protective of human health and the environment
- Provide for preservation and maintenance of remedial structures on the site
- Identify a system for enforcing restrictive covenants and other land use restrictions that supplement the remedial action

The components of ICs can be grouped into the following four IC categories:

- Governmental controls
- Proprietary controls
- Enforcement and permit tools with IC components
- Informational devices

2.5.1.3 Monitoring

Monitoring is a technology utilized under monitored natural attenuation general response action. Groundwater monitoring is performed to demonstrate compliance with the performance standards established, evaluate long-term performance of natural attenuation, meet ARAR-based requirements for monitoring, and demonstrate protectiveness. Monitoring requirements are generally established in a plan during remedial design.

Groundwater monitoring is performed by installing a network of wells at specific locations and depth intervals, collecting samples periodically from each well, and analyzing the samples for selected parameters. Wells are established within contaminated groundwater to monitor natural attenuation and both within and beyond the limits of contamination to monitor migration and compliance.

2.5.1.4 Containment

Containment options may be combined with groundwater and indoor air treatment options to form feasible alternatives. Two types of groundwater containment, subsurface and hydraulic, are considered in the following discussion.

As previously discussed under Section 1.6, The Extent of Contamination, source area containment options such as excavation and disposal are also presented in the following discussion. Both excavation and disposal are soil treatment technologies. Even though the Bountiful/Woods Cross OU2 RI does not show contaminated soils to be a media of concern, these technologies can be used in conjunction with other treatment technologies to address source loadings of COCs to both air and groundwater. They are therefore included in the FFS.

Subsurface Barriers

Subsurface barriers include technologies that prevent or reduce the migration of contaminants by installation of a physical barrier in the subsurface. Common technologies for subsurface barriers may include sheet piling, grout curtains, or slurry walls.

Sheet piling is used to contain groundwater or divert groundwater flow. Sheet pile walls have been used in many applications for civil engineering and remediation. Steel is the most common material used for sheet piling because of its high durability, low cost, and high flexibility. Steel sheet pilings are constructed by driving individual sections of interlocking steel sheets into the ground with impact or vibratory hammers to form a continuous impermeable barrier.

Grout curtains are fixed underground physical barriers created by injecting grout into the aquifer material. The grout sets after injection and forms a low-permeability barrier to groundwater flow and contaminant migration. Construction of grout curtains involves injection grouting or deep mixing of the grout mixture into the subsurface. Pressure grouting and jet grouting are two forms of injection grouting in which a grout mixture is injected into the pore spaces of the soil or rock. Pressure injection points are usually arranged in a triple line of primary and secondary grout holes. A predetermined quantity of grout is pumped into the primary holes. After the grout in the primary holes had time to set, the secondary holes are injected. Grouting materials are added during the mixing process to produce the subsurface barrier. The composition of grout is governed by several considerations, including installation technique, soil properties, groundwater quality, required barrier properties, and cost.

Slurry walls are subsurface barriers that are commonly used to capture, contain, and/or divert the flow of clean water through contaminated areas or control migration of contaminated groundwater. Slurry wall construction material generally consists of a soil-bentonite mixture. The slurry material is designed to provide a low permeability barrier (hydraulic conductivity [K] on the order of $1x10^{-7}$ centimeters per second [cm/sec] or lower) that will be durable and resistant to degradation from the contaminants present. Slurry walls are typically keyed into an underlying aquitard or aquiclude to prevent flow under the wall. Compatibility testing between the groundwater and slurry wall material is recommended. Soil-bentonite slurry walls can be installed by excavating a trench that is backfilled with the slurry mixture or through mix-in-place procedures. Mixed-in-place installation methods include deep mixing that uses augers to mix the native soil with bentonite.

Hydraulic Barriers

Hydraulic barriers are technologies that provide containment of contaminated groundwater through interception or gradient reversal and extraction of contaminated groundwater using a system of wells or trenches. Hydraulic barriers evaluated in this report include extraction wells and french drains.

Extraction wells may be used to control groundwater flow. Their purpose is to contain plume migration by removing contaminated groundwater and using the induced gradients to redirect groundwater from source areas or control groundwater plumes by creating preferential flow patterns. Extraction wells are typically constructed from polyvinyl chloride (PVC) and/or stainless steel and use pumps to remove contaminated groundwater from the aquifer. Extraction of groundwater draws down the water table in the vicinity of the well, forming a cone of depression. The extent and slope of the cone of depression is dependent on pumping rates, duration of pumping, and properties of the aquifer material. Generally, groundwater within the cone of depression is captured by the vertical extraction well, thereby providing containment. Extraction wells can be installed adjacent to each other to provide containment over an area of a contaminated aquifer. Extraction wells can provide the following benefits for remediation of a contaminated aquifer:

- Mass removal of contaminated groundwater for treatment
- Gradient control for the purpose of plume containment
- Increased groundwater flux rates through the subsurface to enhance the rate of chemical mass removal

French drains consist of buried structures designed to have greater permeability than the surrounding aquifer material, providing for interception and collection of groundwater. French drains are generally constructed by excavating a trench that slopes to one or more collection sumps. Perforated pipe is installed along the bottom of the trench to provide a conduit for gravity flow of groundwater to the sump(s). The trench is typically filled with gravel (or similar material) to an elevation that corresponds to the maximum anticipated groundwater elevation. The remainder of the trench is backfilled with soil that was excavated from the trench. Groundwater is extracted from the drain at the sump(s) using conventional pumps.

Excavation and Disposal
While excavation and disposal technology is traditionally considered for contaminated soils, it is proposed for the Bountiful/Woods Cross OU2 as a source control measure for both air and groundwater. Excavation and disposal of contaminated source soils would be used in conjunction with other treatment technologies to address existing human health exposure risks.

Excavation involves removal of contaminated source materials using conventional earth-moving equipment, such as a front end loader, excavator, or draglines with a clamshell. The excavated waste is stockpiled, then transported in covered vehicles to either an onsite or offsite Resources Conservation and Recovery Act (RCRA) permitted landfill for disposal. Dust suppression and surface water run on/run off measures to prevent migration of COCs during excavation and disposal are included as part of these technologies.

2.5.1.5 Active Restoration

Active restoration involves moving the contaminated groundwater from an aquifer to the surface using extraction wells or french drains, removing the contaminants using an appropriate treatment technology, and discharging the treated groundwater either back into the aquifer, to surface water, or to a publicly owned treatment works (POTW). Possible treatment technologies are described below.

Granular Activated Carbon (GAC) Adsorption
Liquid-phase granular activated carbon can be used to remove VOCs from groundwater. Adsorption occurs when an organic molecule is brought to the activated carbon surface by diffusion and held there by physical and/or chemical forces. Activated carbon is manufactured from coal, coconut shells, lignite, and other sources of carbonaceous material. Liquid-phase activated carbon is most often applied in a granular (GAC) or powdered (PAC) form. The two most common reactor

configurations for carbon adsorption systems are the fixed bed and the pulsed or moving beds. Periodic replacement or regeneration of saturated carbon is required.

Air Stripping
Air stripping is a physical mass transfer process of contaminants from water to air and is generally considered as the best available technology for many VOCs present in contaminated groundwater. Air stripping uses relatively clean air to remove contaminant VOCs dissolved in water and transfers the contaminants into the gaseous phase. Aeration methods include packed towers, diffused aeration, tray aeration, and spray aeration.

Ultraviolet (UV) Oxidation
UV oxidation is a destruction process that oxidizes organic constituents by the addition of strong oxidizers and irradiation with UV light. The oxidation reactions are achieved through the synergistic action of UV light in combination with ozone and/or hydrogen peroxide as water flows into the treatment tank.

2.5.1.6 *In Situ* Treatment

In situ treatment technologies considered for the Bountiful/Woods Cross OU2 include technologies that treat soils. These technologies are considered as source control measures for both indoor air and groundwater contamination and are evaluated as such.

Surfactant Flushing
Surfactant flushing involves injecting a surfactant using injection wells and recovering the contaminant and the surfactant using conventional extraction wells. Surface-active agents (surfactants) have been shown to increase the apparent solubility of contaminants in the water. Increasing the apparent solubility of the contaminants increases the mass removal of the contaminant. Recovered contaminant-laden surfactant solution is treated to remove the contaminant. In general, the high cost of surfactants requires recovery and reuse of surfactant for cost-effective application of this technology. Because the injected surfactant solution is diluted with native groundwater, the surfactant must be concentrated in the recovered solution before reinjection.

Permeable Reactive Barriers
Permeable treatment walls involve installation of a pervious treatment material across the flow path of contaminated plume. As contaminated groundwater moves through the treatment wall, contaminants are removed or treated by physical, chemical, or biological process. Removal mechanisms may include precipitation, sorption, oxidation/reduction, fixation, and degradation. These barriers may contain nutrients and oxygen, chelating agents, metal-based catalysts, or other agents. Treatment wells might also be installed immediately downgradient of a contaminated source to prevent plume formation or source migration. In general, this technology is comprised of the following three components:

- Impermeable barrier to direct or capture groundwater flow through the treatment media. The barrier may involve a variety of installation methods, barrier materials, and configurations.

- Treatment media. The media would be tailored to the site-specific contaminants, groundwater geochemistry, and performance requirements.

- Treatment media packaging design. Generally packaging design options include retrievable cassettes or permanent emplacements.

The most common of the permeable treatment walls is the zero-valent iron treatment wall. It is made of zero-valent iron or iron-bearing materials that chemically reduce chlorinated contaminants, such as TCE. As the iron is oxidized, the contaminant is reduced, removing a chlorine atom from the compound. The chlorinated compounds are reduced to nontoxic and readily degradable byproducts.

Permeable treatment walls using zero-valent iron provide an alternative to pump-and-treat methods for groundwater with contamination from chlorinated hydrocarbons.

In-Well Air Stripping

In-well air stripping (also known as in-well vapor stripping or *in situ* vapor stripping) is used for the remediation of solvent contaminated groundwater. The in-well stripping process, an extension of air sparging technology, involves the creation of a groundwater circulation cell around a well through which contaminated groundwater is cycled. The well is double-cased with separated upper and lower screened intervals within the same saturated zone. The lower screen, through which groundwater enters, is placed at or near the bottom of contaminated aquifer and the upper screen, through which groundwater is discharged, is installed across or above the water table. Air is injected into the inner well casing, decreasing the density of the groundwater in the casing and allowing it to rise within the inner casing. VOCs in the groundwater are transferred from the groundwater to the vapor in the rising air bubbles. The contaminated vapor rises to the water surface where vapors are drawn off and treated using a soil vapor extraction (SVE) system. The partially treated groundwater flows to the outer casing and moves through the upper-screened interval into the vadose zone or the upper portion of the aquifer. The cycling of water in the area around the well creates a hydraulic circulation pattern or cell that allows continuous cycling of groundwater through the air stripping process. Groundwater is repeatedly circulated through the system until sufficient contaminant removal has taken place.

Soil Vapor Extraction

SVE is an *in situ* remediation technology that removes VOCs from the unsaturated vadose zone and capillary fringe soils. SVE withdraws vapor from the subsurface using vacuum blowers and vapor extraction wells. The contaminated vapor is collected at the surface and is treated and/or discharged to the atmosphere. The induced advection of air draws clean air through the contaminated vadose zone, promoting transfer of contaminants from the subsurface soil matrix to the vapor phase. In addition, SVE may stimulate biological degradation by increasing the oxygen content of the soil.

Air Sparging
Air sparging is an innovative *in situ* treatment technology, which is often used in conjunction with vacuum extraction systems to remove the stripped contaminants. *In situ* air sparging involves injecting a gas (usually air/oxygen) under pressure into the saturated zone below or within the areas of contamination. Air channels form as the air rises to subsurface, and volatile chemicals are removed from the contaminated groundwater. In addition, air sparging can promote biodegradation by increasing groundwater and vadose zone oxygen concentrations.

Multi-Phase Extraction
Multi-phase extraction (MPE) technologies involve removal of contaminated groundwater and soil vapors from a common extraction well. MPE systems may use high vacuum blowers to remove liquid and gas from a low permeability or heterogeneous formations. The MPE well includes a screened section in the contaminated vadose zone and groundwater. MPE technologies lower the water table around the well, exposing more of the formation to vacuum extraction. Once above the ground, the extracted vapors, liquid-phase organics, and groundwater are separated and treated.

Three basics types of MPE have been developed. Differentiation among types of MPE is based on methods used for extraction of each physical phase (i.e., vapor and groundwater). Each of the MPE technologies is described below.

- ***Drop-Tube Entrainment Extraction***
  Applying an extraction vacuum to a tube inserted below the water table in a standard vapor extraction well performs drop-tube entrainment. Vacuum is applied to the drop tube and soil vapors entering from the vadose zone entrain groundwater in the drop tube. Groundwater and soil vapors entering from the extraction well in a common pipe manifold are separated in a vapor/liquid separator and then treated. Stripping of VOCs from the liquid phase occurs during extraction, thereby reducing groundwater contaminant concentrations.

- ***Well-Screen Entrainment Extraction***
  Well-screen entrainment extraction consists of extracting groundwater and soil vapors from a common borehole screened in the vadose zone and saturated zone. Groundwater is aspirated into the vapor steam at the well screen, transported to the treatment system in a common pipe manifold, separated in a vapor/liquid separator, and then treated. This type of MPE is the simplest to construct.

- ***Dual Phase Extraction (DPE)***
  DPE technology uses a groundwater pump with concurrent application of vacuum to the extraction well to extract contaminated groundwater and vapors from a common well. Groundwater and vapors are removed in separate pipe manifolds and then treated. Groundwater pumping draws down the water table and increases

the vadose zone that is available for vapor extraction. This technology is similar to SVE with dewatering.

In Situ Biological Treatment

In situ biological technologies involve addition of gasses and/or nutrients (and sometimes microorganisms) to the subsurface to stimulate degradation of contaminants by creating a favorable environment for the proliferation of microorganisms. Microbial degradation can be either aerobic or anaerobic.

In general, most chemicals degrade more rapidly and completely aerobically (Pankow and Cherry 1995). Successful degradation of TCE has been demonstrated in both aerobic and anaerobic environments under controlled laboratory and pilot-scale conditions. However, PCE is not susceptible to aerobic degradation, either by direct or cometabolic oxidation. Therefore, the most appropriate biological technology for PCE contamination at the Site is enhanced anaerobic bioremediation (EAB).

The feasibility of EAB treatment depends on numerous factors, which include biodegradability of the organic contaminants and environmental factors such as pH, temperature, redox conditions, and site hydrogeology. During EAB, chlorinated ethenes are degraded via anaerobic reductive dechlorination, which involves the sequential replacement of a chlorine atom by a hydrogen atom, ultimately resulting in the production of ethene. During this process, the contaminants are used as electron acceptors, which imply that an adequate supply of electron donor is present. At some sites, the process may stall at cis-1,2, dichloroethene (cis-DCE). If this occurs despite the presence of sufficient electron donor, then the indigenous microbial community may not be capable of complete dechlorination of PCE to ethene. In this case, a biological culture containing microbes known to perform complete dechlorination may be added to the subsurface, a process known as bioaugmentation.

In Situ Oxidation

In situ oxidation involves injection of an oxidizing agent and water mixture upgradient of the contaminated area and extraction downgradient. This approach, which reduces the likelihood of mobilizing contaminants below the treatment area, allows for recycling of the oxidizing agent. The use of strong oxidants such as hydrogen peroxide (H_2O_2) and potassium permanganate ($KMnO_4$) has been shown effective in destroying TCE *in situ* (EPA 1997). The U.S. Department of Energy (DOE) Office of Science and Technology completed a full-scale demonstration of an *in situ* oxidation using hydrogen peroxide to convert chlorinated solvents and hydrocarbons to nontoxic byproducts, including carbon dioxide (CO_2), chloride ion (Cl^-), and water (H_2O) (Fenton's reaction). Oxidation byproducts of TCE using potassium permanganate include carbon dioxide, chlorine gas (Cl_2), chloride ion, and manganese oxide (MnO_2); none of which pose a problem in groundwater at the levels typically involved (Pankow and Cherry et. al 1995).

2.5.2 Screening of Technologies and Process Options

In this section, the remedial technologies and process options presented in Section 2.5.1 are evaluated through a two-step screening process. First, process options and entire technology types are evaluated based on technical implementability. Second, process options considered to be implementable are screened in greater detail on the basis of effectiveness, implementability (in additional detail), and cost.

2.5.2.1 Technical Implementability

A given technology or process option may be eliminated from further consideration on the basis of technical implementability if site characterization data indicate that the option cannot be effectively implemented at the site. Comments regarding the technical implementability of the technology and process options are summarized in Table 2-5.

The following technologies or process options are eliminated from further consideration based on implementability at the site:

Sheet Piling

Sheet piling has long been used for a wide variety of civil engineering applications, but its use in environmental situations has been limited. Although sheet-pile walls are extremely strong and steel will not hydrofracture, the interlocking joints can present a leakage problem. Sheet piles are typically used in loosely packed soils extending to bedrock or low permeability strata with shallow depth restrictions (EPA 1987). Since these design considerations are not characteristic of the Site, sheet piling was eliminated from further consideration.

Grout Curtains

Grout curtains are limited by the depth of the installation and the inability to verify a curtain's continuity across the installation length. Grout curtains can have setting and durability problems in contaminated groundwater. Compatibility testing between the contaminated groundwater and the grouting materials is recommended. Therefore, grout curtains were eliminated from further consideration.

Surfactant Flushing

Technology limitations for surfactant flushing include limited demonstration of the technology, potential operation and maintenance problems associated with fouling of injection wells, and the uncertainty of ensuring capture of the desired area. Surfactant flushing is most appropriate for areas containing residual or free phase dense non-aqueous phase liquid (DNAPL). In addition, this technology is most effective in homogeneous, high-permeability aquifers that afford uniform distribution and relatively high flow rates of the injected surfactant solution. Previous demonstrations of surfactant flushing have been most effective in sandy soils. Bountiful/Woods Cross OU is a heterogeneous aquifer with moderately low PCE concentrations that are not indicative of significant amounts of DNAPL contamination. Therefore, surfactant flushing is eliminated from further consideration.

In-Well Air Stripping

Most in-well air strippers have been demonstrated in pilot stages; as a result, the full field application costs are not available for this technology. There are limitations to the removal efficiency obtained with in-well air strippers. The amount of air that can be released in a well is limited due to the pumping action that it creates in the well. In addition, the length of contact between air and water are limited to the depth and positioning of contaminated plume. Another consideration is the water circulation through the well. Macro geological conditions such as sand or clay lenses will limit water circulation. In addition, the aquifer must be able to handle large amounts of rechargeable water created by the circulation in the well. High mounding of water over the recharge area will make the process relatively inefficient and limit the area of effectiveness of the well. Low solubility of PCE limits effectiveness. Therefore, in-well air stripping has been eliminated from further consideration.

Drop-Tube Entrainment Extraction

Drop-tube entrainment extraction is eliminated from further evaluation because the depth of the groundwater at the Bountiful/Woods Cross OU2 fluctuates between 70 ft and 80 ft below the surface. Drop-tube entrainment extraction effectiveness is limited by pressure drop in piping and maximum vacuums that can be applied at the wellhead. In general, drop-tube entrainment is not effective at sites with water depths greater than 27 ft below the surface.

2.5.2.2 Effectiveness, Implementability, and Cost

Each of the technically implementable process options were evaluated against effectiveness, implementability, and cost as follows:

Effectiveness

This evaluation of the effectiveness of a process option focuses on:

- The effectiveness in handling the estimated volumes of media and meeting RAOs
- Potential impacts to human health and the environment during implementation
- How proven the technology is with respect to the contaminants and conditions at the site

Implementability

A given technology or process option may be eliminated from further consideration on the basis of technical implementability if site characterization data indicate that the option cannot be effectively implemented at the site.

Technically implementable process options are evaluated with respect to the institutional aspects of implementability, such as the ability to obtain permits for offsite disposal of treated groundwater; the availability of treatment, storage, and disposal services; and the availability of necessary equipment and skilled workers.

Cost

The cost of a process option is evaluated based on engineering judgment and is ranked as high, moderate, or low relative to other process options in the same technology type.

2.5.2.3 Screening Results

The screening results for each process option are summarized in Table 2-5. Processes eliminated from further consideration as a result of this evaluation are shaded. The rationale for elimination of process options is provided in the following paragraphs.

Institutional Controls

The use of ICs as a stand-alone option has also been eliminated as part of this screening. ICs alone are not effective and cannot meet RAOs.

The NCP cautions against the use of ICs as a sole remedy unless active response measures are determined to be impracticable. In addition, the NCP requires state assurance of the implementation of ICs when appropriate. ICs will be considered as a part of other remedial alternatives. The state must assure that any ICs implemented as part of the remedial act at a site are in place, reliable, and will remain in place after the initiation of operation and maintenance (O&M).

Containment – Subsurface Barrier

The installation of subsurface barriers for containment of contaminated groundwater is eliminated from further consideration based on effectiveness and cost.

Vertical barriers such as sheet piling and slurry walls must tie into an impermeable clay zone or bedrock in order to divert groundwater around the contamination source Groundwater contamination likely extends to about 120 to 130 ft below ground surface (bgs), with no confirmed confining or continuous clay layer below. As a result, cost of a vertical containment barrier is so high that it is eliminated from further consideration.

Containment – Hydraulic Barrier

French drain is eliminated from further consideration based on cost. French drains are limited to shallow depths. Although it is technically feasible to excavate a trench to almost any depth, the cost of shoring and dewatering make drains cost prohibitive at depths of more than 100 ft (EPA 1985).

Active Restoration - Groundwater Physical/Chemical Treatment

The following treatment process options were considered:

- GAC adsorption
- Air stripping
- UV oxidation

UV oxidation requires a complex system, complex operating requirements, and resulting higher costs as compared to the GAC. Therefore, UV oxidation was eliminated from consideration.

In Situ Treatment Technologies

Well-Screen Entrainment Extraction

Well-screen entrainment extraction is most effective at sites with groundwater tables less than 10 ft bgs but has been used to depths of approximately 27 ft. The groundwater table fluctuates between 70 and 80 ft bgs, which makes well-screen entrainment only marginally effective. Therefore, well-screen entrainment extraction is eliminated from consideration due to effectiveness based on technology limitations and site conditions.

In Situ Chemical Oxidation

Chemical oxidation is not effective in heterogeneous aquifers because it is difficult to circulate the solution throughout every portion of the contaminated zone. In some instances, oxidation byproducts may be toxic and groundwater may require further treatment. *In situ* oxidation may also oxidize metals and other organics, thereby, increasing the amount of oxidizing agent required and potentially fouling the aquifer and injection wells. In addition, this technology is generally most appropriate for high contaminant concentrations typically associated with residual DNAPL saturation. *In situ* chemical oxidation is an emerging technology in the preliminary stages of development and is not appropriate for the relatively low groundwater concentrations present at the Site. Therefore, *in situ* chemical oxidation will be eliminated from further consideration due to effectiveness and implementability.

Permeable Reactive Barrier

The installation of a permeable reactive barrier (PRB) for *in situ* treatment of contaminated groundwater has been eliminated from further consideration based on effectiveness and cost. The installation of a deep barrier is not feasible due to the great depth required to reach the clay layer beneath the contaminated groundwater. In addition, PRB technology is primarily related to its early stage of development and relative lack of field experience. The high cost of this installation eliminates this process option from further consideration.

2.5.2.4 Summary of Retained Process Options

The summary of the process option evaluation is presented in Table 2-6. These process options will be combined in Section 3.0 of this FFS to form remedial alternatives.

Section 3
Development and Screening of Alternatives

In this section, remedial action alternatives are developed using combinations of technologies and process options that passed the screening in Section 2 and summarized in Table 2-6. These alternatives, in accordance with the guidance from the NCP, are screened using the broad criteria of effectiveness, implementability, and cost. Alternatives that pass these broad criteria screening are evaluated in more detail in Section 4.0.

3.1 Development of Alternatives

The process options for remediation of contaminated groundwater and indoor air summarized in Table 2-6 for the Bountiful/Woods Cross OU2 have been combined into four remedial alternatives. These alternatives are:

- Alternative 1: No Action
- Alternative 2: DPE/SVE, Excavation, Disposal, Groundwater Extraction, Treatment, Discharge, and Monitoring
- Alternative 3: EAB, SVE, Excavation, Disposal, and Monitoring
- Alternative 4: Air Sparging, SVE, Excavation, Disposal, and Monitoring

These alternatives have been formulated according to the NCP [40 CFR 300.430 (e)] and are intended to meet RAOs. Each alternative is presented in the following paragraphs in sufficient detail to allow effective screening by broad criteria. Alternatives that are retained for detailed analysis are developed in more detail in Section 4.

3.1.1 Alternative 1: No Action

This alternative is required by the NCP so that a baseline set of conditions can be established against which other remedial actions may be compared. This alternative allows the site to remain in its current state with no remedial actions being implemented. Five-year reviews are included in this alternative.

3.1.2 Alternative 2: DPE/SVE, Excavation, Disposal, Groundwater Extraction, Treatment, Discharge, and Monitoring

Source Area

Alternative 2 includes excavation of shallow source area soil in the parking lot of the BFC to address the ongoing exposure of workers in the BFC to VOC emissions. The excavated area would be filled in with clean back fill and covered with asphalt.

Alternative 2 also provides for installation of both DPE and SVE wells throughout the source area. SVE well installation is required to adequately treat the vadose zone due to the 70 ft depth to groundwater in the Bountiful/Woods Cross OU2. DPE will treat the saturated zone of the aquifer to a maximum depth of 15 ft below the water table. DPE and SVE wells will be installed in the sections of the source area containing the highest known concentrations of PCE.

One groundwater extraction well will be installed to treat contaminated groundwater at up to 50 ft below the water table. Extracted water from this deep well will be combined with extracted groundwater from the DPE wells and treated in the same facility.

Vapors from both DPE and SVE systems will be treated using the same vapor granular activated carbon (VGAC) system. Groundwater extracted from DPE wells and deeper extraction wells will be treated using either air stripper or liquid granular activated carbon (LGAC) systems. Treated groundwater will either be re-injected in the source area, providing hydraulic containment of the plume, or reused as a drinking water source through the local POTW.

Permanent soil gas probes will be located in the source area to monitor the effectiveness of the SVE system.

Plume Area

Monitoring wells will be installed at strategic locations in the plume area to determine trends of contaminant concentrations. Samples will be collected monthly for the first 6 months then quarterly for the life of the remedy and analyzed for VOCs. These analyses will be used to determine the overall performance of this Alternative. This data will also be used to determine any occurrences of natural attenuation within the plume. Therefore, the results of these analyses will be loaded into a database as specified by the State of Utah and maintained by EPA/UDEQ for the first 5 years of operations of this remedy. At that time, this data will be analyzed for evidence of both the effectiveness of the source area cleanup and natural attenuation of the PCE plume. Institutional controls prohibiting the use of water in the plume area for a drinking water source will be in place during these first 5 years.

Based on the findings of the 5-year review of the selected remedial action at the Bountiful/Woods Cross OU2, the plume monitoring component of this alternative would remain, be changed to monitored natural attenuation, or switched to groundwater containment.

3.1.3 Alternative 3: EAB, SVE, Excavation, Disposal, and Monitoring

Source Area
Alternative 3 includes excavation of shallow source area soil in the parking lot of the BFC to address the ongoing exposure of workers in the BFC to VOC emissions. The excavated area would be filled in with clean back fill and covered with asphalt.

This alternative also provides for installation of injection and extraction wells in the source area, creating recirculation cells for EAB treatment. EAB groundwater will be extracted, mixed with electron donor and possibly a bioaugmentation consortium, and then re-injected into the recirculation cell. The EAB extraction and recirculation cells will be installed at a depth of approximate 130 ft bgs in the saturated zone of the aquifer. The EAB technology will be augmented by SVE well(s) that will treat vadose zone contamination to approximately 70 ft bgs. Vapors extracted from the SVE system will be treated in a VGAC system similar to the one described in Alternative 2.

Permanent soil gas probes will be located in the source area to monitor the effectiveness of the SVE system.

Plume Area
Monitoring wells will be installed at strategic locations in the plume area to determine trends of contaminant concentrations. Samples will be collected monthly for the first 6 months then quarterly for the life of the remedy and analyzed for VOCs. These analyses will be used to determine the overall performance of this Alternative. This data will also be used to determine any occurrences of natural attenuation within the plume. Therefore, the results of this analysis will be loaded into a database as specified by the State of Utah and maintained by the state for the first 5 years of operations of this remedy. At that time, this data will be analyzed for evidence of both the effectiveness of the source area cleanup and natural attenuation of the PCE plume. Institutional controls prohibiting the use of water in the plume area for a drinking water source will be in place during these first 5 years.

Based on the findings of the 5-year review of the selected remedial action at the Bountiful/Woods Cross OU2, the plume monitoring component of this alternative would remain, be changed to monitored natural attenuation, or switched to groundwater containment.

3.1.4 Alternative 4: Air Sparging, SVE, Excavation, Disposal, and Monitoring

Source Area
Alternative 4 includes excavation of shallow source area soil in the parking lot of the BFC to address the ongoing exposure of workers in the BFC to VOC emissions. The excavated area would be filled in with clean back fill and covered with asphalt.

This alternative is comprised of an air sparging system operated in conjunction with the SVE system. Both the air sparging and SVE wells will be located in the areas of highest contamination. The air sparging system forces air through the vadose zone and into the aquifer where it volatilizes contaminants in and groundwater. These vapors are collected via the SVE system and routed to a VGAC system for treatment.

Plume Area
Monitoring wells will be installed at strategic locations in the plume area to determine trends of contaminant concentrations. Samples will be collected monthly for the first 6 months then quarterly for the life of the remedy and analyzed for VOCs. These analyses will be used to determine the overall performance of this Alternative. This data will also be used to determine any occurrences of natural attenuation within the plume. Therefore, the results of this analysis will be loaded into a database as specified by the State of Utah and maintained by the state for the first 5 years of operations of this remedy. At that time, this data will be analyzed for evidence of both the effectiveness of the source area cleanup and natural attenuation of the PCE plume. Institutional controls prohibiting the use of water in the plume area for a drinking water source will be in place during these first 5 years.

Based on the findings of the 5-year review of the selected remedial action at the Bountiful/Woods Cross OU2, the plume monitoring component of this alternative would remain, be changed to monitored natural attenuation, or switched to groundwater containment.

3.2 Screening Evaluation of Alternatives

The purpose of this screening evaluation is to reduce the number of alternatives that may undergo a more thorough and extensive analysis in Section 4. Therefore, alternatives will be evaluated more generally in this section than in the detailed analysis. Per the NCP guidance, each alternative will be screened on effectiveness, implementability, and cost.

Effectiveness relates to the ability of the remedial alternative to satisfy five evaluation criteria:

- Overall protection of human health and the environment (meets RAOs)
- Compliance with ARARS
- Short-term effectiveness (during remedial construction) and immediately after implementation of the remedy
- Long-term effectiveness and permanence (following remedial construction)
- Reduction of toxicity, mobility, or volume through treatment

Effectiveness of each alternative is judged as follows:

- High: The alternative is effective in meeting all of the above criteria.

- Moderate: The alternative is effective in the overall protection of human health and the environment and compliance with ARARS, but one or more of the remaining three criteria are not met.

- Low: The alternative is not protective of human health and the environment.

The effectiveness evaluation is based on theoretical cleanup times determined from a rough hydrogeologic model of the site. Information gathered from pilot studies can be used to adjust the operations and maintenance time frame required for each alternative.

Implementability relates to the technical and administrative feasibility of constructing, operating, and maintaining the alternative. Technical feasibility relates to the practical aspects of construction, operation, and maintenance. Administrative feasibility relates to the ability to obtain permits; procure treatment, storage, and disposal services; and procure the needed land, equipment, and expertise. Technologies have been previously screened in Section 2 and infeasible technologies eliminated. Implementability of the alternatives is therefore judged solely as follows:

- High: The alternative is readily implemented and relies on proven technologies. Administrative elements are standard to the jurisdictional agencies.

- Moderate: The alternative is implementable and relies largely on proven technologies. Use of less available or innovative technology or more study may be required. Some administrative elements are not standard to jurisdictional agencies.

- Low: The alternative relies on less available or innovative technology or more study may be required. Many administrative elements are not standard to jurisdictional agencies.

The approximate present worth cost for each of the alternatives is estimated using relative costs rather than detailed estimates. At this state of the FS process, the cost analyses are subjectively made based on engineering judgment. Estimated operations and maintenance costs are assumed for each alternative based on the calculated time required for each alternative to restore the aquifer to beneficial use. The cost of each alternative is judged as follows:

- High: Over $1,500,000

- Moderate: Over $500,000 to $1,500,000

- Low: Under $500,000

A detailed description of the evaluation of each alternative is present in the following subsections.

3.2.1 Alternative 1: No Action

Effectiveness

Low. This alternative does not provide any reduction in contaminant concentrations or protection of human health and the environment. Lack of containment or treatment of the groundwater and indoor air is not protective of human health since the contaminants present in groundwater and indoor air are not removed from the human health exposure pathway. Therefore, this alternative does not meet ARARs.

Implementability

High. The alternative requires no changes in the present administration of the site.

Cost

Low. Costs are incurred related to performing 5-year reviews. Present worth cost is anticipated to be no greater than $40,000.

Screening Result

This alternative is retained for detailed evaluation as it provides a basis for comparison as required by the NCP.

3.2.2 Alternative 2: DPE/SVE, Excavation, Disposal, Groundwater Extraction, Treatment, Discharge, and Monitoring

Effectiveness

High: Alternative 2 has provisions for reduction of toxicity, mobility, and volume of contamination through treatment. Therefore, it is protective of human health and the environment and meets ARAR requirements. Since the excavation and disposal of the shallow source area material will provide an immediate benefit to human health by eliminating an inhalation pathway, Alternative 2 is highly effective in the short term for contaminated air. In addition, Alternative 2 poses little risk to site workers or the community during construction activities. The DPE, SVE, and extraction components of this alternative treat both point sources of contamination and groundwater simultaneously, reducing the time required for completion of the remedy. Therefore, Alternative 2 is highly effective in long-term restoration of the aquifer.

Implementability

High. Installation of DPE, SVE, extraction, and monitoring wells utilizes proven technology easily implemented at the Bountiful/Woods Cross OU2. Excavation and disposal utilize proven technologies easily implemented in the parking lot of the BFC. Surface treatment of extracted groundwater utilizes skid-mounted technology, making it also easy to implement at the site. Very few ICs (i.e., limiting groundwater well development and prohibiting use of the artesian wells in the plume area as drinking water sources) need to be established and should be easily enforceable.

Cost
High. The present worth cost of excavation, disposal, extraction well installation, skid mounted treatment systems installation, institutional control establishment, and 5-year review preparation is anticipated to be greater than 1.5 million dollars.

Screening Result
This alternative is retained for detailed analysis.

3.2.3 Alternative 3: EAB, SVE, Excavation, Disposal, and Monitoring

Effectiveness
High: Alternative 3 has provisions for reduction of toxicity, mobility, and volume of contamination through treatment. Therefore, it is protective of human health and the environment and meets ARAR requirements. Since the excavation and disposal of the shallow source area material will provide an immediate benefit to human health by eliminating an inhalation pathway, this alternative is highly effective in the short term for contaminated air. In addition, Alternative 3 poses little risk to site workers or the community during construction activities. The EAB, SVE, and extraction components of this alternative treat both point sources of contamination and groundwater simultaneously, which reduces the time required for completion of the remedy. Therefore, Alternative 3 is highly effective in short-term restoration of the source area aquifer. While long-term effectiveness will be impacted by the effectiveness of IC component, Alternative 3 is considered highly effective based on the treatment time anticipated for restoration of the aquifer.

Implementability
High. Installation of SVE, EAB, and monitoring wells utilizes proven technologies easily implemented at the Bountiful/Woods Cross OU2. The development of a monitoring plan to track contaminant levels is also easily implemented. Very few ICs (i.e., limiting groundwater well development and prohibiting use of the artesian wells in the plume area as drinking water sources) need to be established and should be easily enforceable.

Cost
Moderate. The present worth cost of extraction well installation, skid mounted treatment systems installation, institutional control establishment, and 5-year review preparation is anticipated to be approximately 1 million dollars.

Screening Results
This alternative is retained for detailed analysis.

3.2.4 Alternative 4: Air Sparging, SVE, Excavation, Disposal, and Monitoring

Effectiveness

Low. The alternative has provisions for reduction of toxicity, mobility, and volume of contamination through treatment. Therefore, it is protective of human health and the environment and meets ARAR requirements. Since the air sparging, SVE, and extraction components of this alternative treat both point sources of contamination and groundwater, implementation of this alternative could greatly shorten the time required for completion of the remedy. However, the effectiveness of the air sparging technology in a heterogeneous vadose zone with interspersed clay lenses is low. Alternative 4 poses little risk to site workers or the community during construction activities. Therefore, the short-term effectiveness of this alternative is moderate. Long-term effectiveness is low since the air sparging technology will be less effective than Alternatives 2 and 3 for the Bountiful/Woods Cross OU2.

Implementability

High. Installation of air sparging and SVE wells utilizes proven technology and is therefore easily implementable. Treatment of collected condensate and vapors with GAC skid mounted units uses proven technologies and is easily implemented at the site. The development of a monitoring plan to track contaminant levels is also easily implemented. Very few ICs (i.e., limiting groundwater well development and prohibiting use of the artesian wells in the plume area as drinking water sources) need to be established for Alternative 4 and should be easily enforceable.

Cost

High. The present worth cost of air sparging compressors, extraction well installation, skid mounted treatment systems installation, institutional control establishment, and 5-year review preparation is anticipated to be 2 million dollars.

Screening Results

This alternative is eliminated from further analysis due to low effectiveness and high costs.

Section 4
Detailed Analysis of Alternatives

The following remedial alternatives passed the general screening process in Section 3:

- Alternative 1: No Action
- Alternative 2: DPE/SVE, Excavation, Disposal, Groundwater Extraction, Treatment, Discharge and Monitoring
- Alternative 3: EAB, SVE, Excavation, Disposal, and Monitoring

In this section of the FFS, these alternatives are developed in more detail and evaluated against nine criteria as outlined by the NCP. This evaluation includes a comparative analysis of the relative performance of each alternative to the same nine criteria. The evaluation criteria are discussed in Section 4.1, alternatives are further developed and evaluated in Section 4.2, and the comparative analysis is presented in Section 4.3.

4.1 Evaluation Criteria

The detailed evaluation applies nine evaluation criteria to each alternative listed above. These criteria are grouped into the following three categories: threshold criteria, primary balancing criteria, and modifying criteria. A discussion of each threshold and primary balancing criterion is presented in this section. The two modifying criteria (i.e., state acceptance and community acceptance), which reflect the support of the state and the community in selection of the proposed remedy, are not evaluated at this stage of the FS process. These criteria will be considered after public comments on the proposed plan are received, and will be addressed in the record of decision (ROD) prepared for Bountiful/Woods Cross OU2.

4.1.1 Threshold Criteria

Two threshold criteria relate directly to the statutory compliance of the alternative in question: (1) overall protection of human health and the environment and (2) compliance with ARARs. A given alternative must meet these criteria to be considered as a remedy.

4.1.1.1 Overall Protection of Human Health and Environment

Under this criterion, the adequacy of the protection afforded by a remedial action must be addressed. The means by which risks will be eliminated, reduced, or controlled through treatment, engineering controls, or ICs must be described.

4.1.1.2 Compliance with ARARs

Under this criterion, the means by which a given remedial alternative would meet the ARARs identified in Section 2 must be established. Compliance with the chemical-and action-specific ARARs must be attained by the alternative to be considered as a remedy.

4.1.2 Primary Balancing Criteria

Five primary balancing criteria address the technical and cost criteria for each alternative: (1) long-term effectiveness and permanence; (2) reduction of toxicity, mobility, or volume through treatment; (3) short-term effectiveness; (4) implementability; and (5) cost.

4.1.2.1 Long-Term Effectiveness and Permanence

Under this criterion, the effectiveness and permanence of the remedial action is established in terms of risk remaining at the site after the remedial action. The adequacy and reliability of ICs required with the alternative are evaluated to determine if appropriate risk management of the treatment residuals or untreated waste is in place.

4.1.2.2 Reduction of Toxicity, Mobility, or Volume through Treatment

Under this criterion, the degree and quantity of contaminant toxicity, mobility, and/or volume reduction by use of the specified treatment is evaluated. The anticipated performance of a treatment technology employed by remedial action in terms of long-term reliability of the treatment process and the type and quantity of treatment residuals is discussed.

4.1.2.3 Short-Term Effectiveness

Under this criterion, the impacts on the community, site workers, and the environment during the construction and implementation phase are evaluated. This phase lasts through the construction phase of the remedial action. The duration until protection is achieved is also considered. In addition to the impacts on human health, the potential adverse environmental impacts during the construction are evaluated.

4.1.2.4 Implementability

Under this criterion, the technical and administrative feasibility of implementing the alternative is evaluated. The availability of needed materials and services is also considered. The technical feasibility considerations include the technical difficulties anticipated in construction, reliability of the selected technology, and ease of implementing the remedy. Administrative feasibility considers coordination of interested parties, as well as any required permits.

4.1.2.5 Cost

Under this criterion, estimates are made of capital costs, engineering expenses, and the present worth of future O&M and periodic costs. Cost estimates are developed according to *A Guide to Developing and Documenting Cost Estimates During the Feasibility Study* (EPA 2000a). All alternatives have the same future land use and site development cost components. While flexibility has been incorporated into each alternative for the location of remedial facilities, the selection of cleanup levels, and the period in which remedial action will be completed, the project scope and duration must be defined in order to provide a cost estimate. As a result, a number of assumptions must be made to provide cost estimates for the various remedial alternatives. Important assumptions specific to each alternative are summarized in the description of the alternative. Additional assumptions are included in the detailed cost estimates in Appendix A.

The levels of detail employed in making these estimates are approximate but are considered appropriate for making choices between alternatives. The information provided in the cost estimate is based on the best available information regarding the anticipated scope of the remedial alternatives. Changes in the cost elements may occur as a result of new information and data collected during the treatability study conducted simultaneously with the preparation of the FFS. Any changes in time of remedy or effectiveness of a remedial action will be revised in the final FFS.

The cost estimate is expected to be within -30 to +50 percent of the actual cost. The costs are discussed with respect to the following items:

- Capital costs consist of direct (construction) and indirect (non-construction and overhead) costs.

- O&M costs refer to post-construction cost items necessary to ensure the continued effectiveness of a remedial action and typically consist of long-term labor, power, and material costs.

- Periodic costs include items that are required intermittently at greater than 1-year intervals.

A present worth analysis has been used to normalize all capital, O&M, and periodic costs of a remedial alternative. In this analysis, all capital costs are assumed to be incurred within the first year of implementation. Future O&M and periodic costs are included and reduced by the appropriate future value/present worth discount factor of 7 percent as outlined in *AGuide to Developing and Documenting Cost Estimates During the Feasibility Study* (EPA 2000a).

4.2 Analysis of Alternatives

4.2.1 Alternative 1: No Action

Alternative 1 contains no remedial actions that address the groundwater plumes or contaminant loadings to air at the site. The purpose of providing a no action alternative is to provide a baseline against which the other remedial alternatives can be compared.

4.2.1.1 Overall Protection of Human Health and the Environment

Implementation of this alternative does not meet the remedial action objectives established in Section 2 and is not protective of human health or the environment. Groundwater and air contamination would continue to be present into the future. The overall risk of contaminant exposure of future human populations to contaminated groundwater and soil would not be significantly reduced.

4.2.1.2 Compliance with ARARs

Since Alternative 1 does not address the PCE contamination in groundwater or air, it is not compliant with ARARs.

4.2.1.3 Short-Term Effectiveness

The no action alternative does not entail any actions at the Bountiful/Woods Cross OU2 and, therefore, would not have any short-term impacts on workers, the community, or the environment resulting from implementation.

4.2.1.4 Long-Term Effectiveness and Permanence

This alternative does not provide any long-term effectiveness and permanence. The groundwater would remain contaminated and the potential for exposure through future use of the aquifer as a drinking water source would remain. VOCs from the shallow soil contamination would continue to contaminate the indoor and sub slab air at the BFC.

4.2.1.5 Reduction of Toxicity, Mobility, or Volume through Treatment

No reduction in toxicity, mobility, or volume of the contaminated groundwater or air is associated with this alternative.

4.2.1.6 Implementability

No actions are associated with this alternative.

4.2.1.7 Cost

The 5-year present worth cost of this alternative is estimated to be $39,100. The no action alternative is a baseline for comparing alternatives and, therefore, has only the 5-year review costs associated with it. A summary of the cost for Alternative 1 is shown in Table 4-1. The detailed cost breakdown for items in the summary table is provided in a series of cost worksheet tables in Appendix A.

4.2.2 Alternative 2: DPE/SVE, Excavation, Disposal, Groundwater Extraction and Treatment

4.2.2.1 Detailed Description of Alternative

This alternative provides for the remediation of the aquifer through a combination of DPE and SVE systems operated in the source area. DPE wells would be located in portions of the source area containing the highest groundwater contaminant concentrations. DPE wells would be installed to a depth of approximately 20 ft below the water table. SVE wells would be installed in targeted vadose zone areas and permanent soil gas probes would be installed to provide points for monitoring SVE performance.

Vapors from both the DPE and SVE wells would be piped to a common manifold and treated in a common VGAC system. Extracted groundwater from the DPE wells would be piped to a common collection header and treated with LGAC or an air stripper. For purposes of this FFS, the LGAC option was assumed for costing purposes. Should an air stripper be selected as the preferred treatment option for extracted groundwater in the detailed design, vapors from the air stripper would be routed to the same VGAC system used to treat SVE and DPE vapors. Treated groundwater would either be reinjected into the aquifer or sent to a local POTW.

Excavation of shallow source area soil in the parking lot of the BFC would address the ongoing exposure of workers in the BFC to VOC emissions. This excavation would involve removing approximately a 25 x 25 foot area beneath the parking lot adjacent to the BFC in the source area. The excavated area would be filled in with clean back fill and covered with asphalt.

Monitoring wells would be installed in the source area and plume area downgradient of the Warm Springs fault line and as a "first detection" before municipal water supply wells. Samples will be collected monthly for the first 6 months then quarterly for the life of the remedy and analyzed for VOCs. The results of these analyses would be entered into a database maintained by the state for the first 5 years of operations of this remedy. At that time, these data would be analyzed for evidence of both the effectiveness of the source area cleanup and natural attenuation of the PCE plume. Institutional controls prohibiting the use of groundwater in the plume area as a drinking water source would be in place during these first 5 years. Depending on the effectiveness of this alternative, the ICs may be modified after completion of the 5-year review report.

Alternative 2 involves active remediation of the aquifer. The pumping performed will also serve to limit the migration of contamination during remediation.

The components of Alternative 2 are described in more detail in the following paragraphs.

DPE Wells and Ancillary Equipment

It is anticipated that 11 DPE wells would be installed at depths of approximately 95 ft in the source area. Each well would be 4 inches in diameter and would be screened 1 foot above the current water table elevation to a depth of 15 ft below the water table. The radius of influence for each DPE well is estimated to be 25 ft in the saturated zone and 100 ft in the vadose zone under a vacuum of 14 inches of Hg. A vacuum blower system, consisting of vapor/liquid separator, air filter, vacuum blower, and associated controls and instrumentations, would be used to extract vapors from the DPE well. A submersible pump would extract groundwater. Estimated vapor production from each DPE wells is assumed to be approximately 75 standard cubic feet per minute (scfm). The vacuum blower would be sized to maintain up to 15 inches of mercury vacuum at the wellheads. A transfer pump would be included in the blower skid to transfer the water from a vapor/liquid separator to a groundwater equalization tank. Vapor piping would consist of 2-inch PVC pipe.

SVE Wells and Ancillary Equipment

It is anticipated that one SVE well would be installed at a depth of approximately 75 ft in the vadose zone of the source area. The SVE well would be 4 inches in diameter and would be screened from 5 ft bgs to a depth of 75 ft. The assumed radius of influence for the SVE well is 100 ft at an applied vacuum of 12 inches of Hg. A vacuum blower system, consisting of vapor/liquid separator, air filter, vacuum blower, and associated controls and instrumentations, would be used to extract vapors from the SVE wells. It is assumed that the SVE well will produce approximately 100 scfm of vapors. The vacuum blower would be sized to maintain up to 12 inches of mercury vacuum at the well. A condensate transfer pump will be included in the blower system to transfer the water from a vapor/liquid separator to a groundwater equalization tank. Vapor piping for the system would consist of 2-inch PVC pipe. Vadose zone monitoring probes would be installed in the source area to provide a means to measure SVE system performance.

Groundwater Extraction

One groundwater extraction well would be installed to a total depth of 130 ft bgs and would extract approximately 5 gallons per minute (gpm) of groundwater. The radius of influence for the groundwater extraction well is assumed to be 100 ft. The extracted groundwater from this well would be combined with the groundwater from the DPE wells via a common subgrade manifold piping to a groundwater treatment system.

Groundwater Treatment System

Submersible pumps in the DPE and extraction wells would deliver contaminated groundwater to an equalization tank for process control purposes. The contaminated groundwater would then be processed through LPGAC units sized to handle a maximum nominal throughput of 10-gpm influent.

Discharge

Treated effluent from the groundwater treatment facility would be pumped into a small holding tank for control purposes. The treated groundwater would then be either reinjected into the aquifer or sent to the South Davis Sewer District POTW.

Off-Gas Treatment

Extracted vapors would be treated prior to discharge to the atmosphere by a VGAC unit when total VOC concentrations in the vapors exceed the *de minimis* standards.

Source Area Excavation and Disposal

The source area excavation would be accomplished using a small trackhoe. Dust suppression equipment would be used during the excavation to mitigated fugitive dust emissions. The excavation depth would be approximately 8 ft. Confirmation sampling (analyzing for PCE in the soils) would be accomplished upon completion of the excavation. Sampling methods and acceptable levels of PCE remaining after excavation will be determined during detailed design of this Alternative.

Excavated material would be transported to a RCRA landfill for disposal in a permitted hazardous waste landfill. The trucks used to transport the excavated material would be covered to mitigate fugitive dust emissions from the waste during transportation. Dust suppression measures consisting of spraying water on the soils will be implemented during excavation to mitigate fugitive emissions into the air.

ICs

ICs would be implemented to control exposure to the contaminated groundwater as well as soil exposures during potential excavations for building in the source area. The specific ICs would be described in the ROD.

Groundwater Monitoring

New monitoring wells will be installed and used in both the source and plume areas for monitoring purposes. Monitoring at these wells would be conducted in accordance with plans developed during the remedial design. Monitoring would include water level measurement and collection of samples for chemical analyses. Analytical parameters would include COCs and potential degradation products.

For cost estimating purposes, it is assumed that groundwater monitoring would involve sampling of 5 wells, each installed to a depth of 100 ft. It is assumed that each well will be sampled monthly for the first 6 months of the remedy then quarterly for the life of the remedy.

5-Year Reviews

Periodic reviews are required to evaluate the effectiveness of the remedial alternative. These reviews would be performed at least every 5 years as long as hazardous substances, pollutants, or contaminants remain above levels that allow unrestricted use and unlimited exposure.

4.2.2.2 Overall Protection of Human Health and the Environment

Alternative 2 would be protective of human health and environment and can meet all the RAOs. Groundwater contamination above cleanup goals is predicted to persist for approximately 3 years in the source area under this alternative. ICs would provide restrictions on groundwater use allowed on and downgradient of the Site. The indoor air quality will be immediately addressed by removal of the shallow source area soils.

4.2.2.3 Compliance with ARARs

The active treatment component in Alternative 2 is assumed to reduce VOC concentrations in groundwater and air to levels that meet ARARs. Therefore, this alternative is compliant with ARARs.

4.2.2.4 Short-Term Effectiveness

Alternative 2 would require a small-scale construction effort of approximately 2 months duration. Since all the groundwater and vapor treatment facility components would be packaged systems, construction time and site preparation for the treatment facility would be minimized. Fugitive dust emissions from the excavation of source material and water treatment system site preparation could potentially impact workers and the environment during implementation and would, therefore, be controlled and monitored during construction.

Based on groundwater modeling simulations performed in support of this FFS, the time estimated to reduce the concentrations of VOCs in the source area to concentrations required by ARARs using this alternative is 3 years (CDM 2005). With DPE, plus groundwater extraction and treatment, immediate reductions are expected in VOC concentrations in groundwater. Excavation of the shallow source area material and SVE will also provide an immediate reduction in soil contamination, followed by a reduction in indoor air emissions. Therefore, this alternative is highly effective in the short term.

4.2.2.5 Long-Term Effectiveness and Permanence

Based on experience at similar sites, Alternative 2 will require an estimated 3 years to remediate the aquifer to beneficial use. If implemented and maintained for this life expectancy, Alternative 2 would be highly effective in the long-term.

4.2.2.6 Reduction of Toxicity, Mobility, or Volume through Treatment

Alternative 2 would achieve a reduction in the toxicity, mobility, and volume of contaminated groundwater through treatment if operated throughout the estimated time frame of 3 years. Contaminants would be permanently removed from the source area via the treatment process. The source area removal, however, does not reduce toxicity, mobility, or volumes as it is not a treatment option.

4.2.2.7 Implementability

Alternative 2 can be readily implemented with available and proven technologies. Construction and O&M of the groundwater and vapor treatment systems have been implemented at many sites and utilize well-proven technologies. The systems may require periodic replacement of pumps, piping, and vessels comprising both the extraction well system and the water treatment facility. However, coordination with several property owners and businesses in the source area will require a significant effort on the part of the construction contractor to prevent a negative impact on local businesses. Therefore, Alternative 2 is moderately implementable.

4.2.2.8 Cost

The 5-year present worth cost of this alternative is estimated to be $1,648,000, with a capital cost of $893,000. The main component of the capital cost results from the treatment facility equipment costs and installation. A summary of the cost estimate is presented in Table 4-2. The detailed cost breakdown for items in the summary table is provided in a series of cost worksheet tables in Appendix A.

4.2.3 Alternative 3: EAB, SVE Excavation, Disposal, and Monitoring

4.2.3.1 Detailed Description of Alternative

Alternative 3 has many of the same elements as Alternative 2 except that it replaces DPE and deep groundwater pump-and-treat with EAB. The similar elements include the SVE well and ancillary equipment, the source area excavation and disposal, ICs, the groundwater monitoring program, and 5-year reviews. Descriptions of those elements that are shared with Alternative 2 are not repeated here. The general elements of the alternative are presented in Section 4.2.2. Each of the elements that are unique to Alternative 3 is described in more detail in the following paragraphs.

EAB Wells

This alternative provides for the remediation of the aquifer through installation of an EAB system consisting of three injection and four extractions wells in the source area. It is assumed that these wells would be installed to a total depth of approximately 105 ft bgs and would be screened from the water table to this depth. These wells will be operated such that a recirculation cell is created in the source area for EAB treatment of groundwater contamination. The extracted groundwater would be amended with electron donor (and possibly a bioaugmentation consortium) and then re-injected into the aquifer, forming a recirculation cell.

Based on modeling simulations, it is anticipated that 500 gallons of 60 percent sodium lactate solution will be injected at a concentration of approximately 0.5% to 1% every 2 months at a combined flowrate of 15 gpm. The duration of each injection event is estimated to be approximately 5 days and will be performed using semi-automated equipment. It is assumed that the recirculation system will operate continuously and amendment will be pulsed in periodically. Above ground treatment of the extracted groundwater is assumed to not be required per EPA's recent interpretation of RCRA 3020(b). In a recent memorandum providing guidance on the interpretation of RCRA 3020(b), the EPA Office of Solid Waste and Emergency response stated that the treatment of groundwater necessary under RCRA 3020(b) could occur either before or after reinjection of the water (EPA, 2000b). Specifically, it was stated that, "…the 'substantial reduction' may occur either before or after reinjection. To be more specific, the reduction may occur 'in-situ' after reinjection of the ground water into the aquifer (that is, within the formation that is the target zone for the injected fluid). The intended treatment must reasonably be expected to reduce levels of contamination and must be part of a legitimate effort to achieve cleanup of such contamination." The memorandum went on to note that, "This clarification is particularly relevant to in-situ ground-water bioremediation." The injection strategy (i.e. flow rate, concentration, volume, and/or frequency) may be changed as the remedy is optimized.

Monitoring of the downgradient plume will be conducted as described for Alternative 2 in Section 4.2.2.1. In addition, EAB performance monitoring will be conducted in the source area through sampling of the extraction wells. Initially, the extraction wells will be sampled once per month, approximately 1 week and 5 weeks following completion of an injection event. Parameters to be monitored will include contaminants and degradation products, redox sensitive parameters, biological activity indicators, and water quality parameters. Monitoring for microbial community profiling and individual species detection (i.e. *Dehalococcoides* sp.) may also be performed. The frequency, locations, and parameters monitored may be adjusted during EAB operations if data suggest that changes are appropriate.

Based on groundwater modeling simulations performed in support of this FFS and the relatively low PCE concentrations present in the source area, it is expected that remedial activities for this alternative will be conducted for a period of 2 years.

4.2.3.2 Overall Protection of Human Health and the Environment

Alternative 3 would be protective of human health and environment and can meet all the RAOs. Groundwater contamination in the source area is predicted to persist for approximately 2 years under this alternative. Alternative 3 would immediately address indoor air contamination in the source area by removal of the shallow source area soils. ICs would provide restrictions on groundwater use allowed on the Site.

4.2.3.3 Compliance with ARARs

The active treatment component in Alternative 3 would reduce VOC concentrations in groundwater to levels that meet ARARs. Therefore, this alternative is compliant with ARARs.

4.2.3.4 Short-Term Effectiveness

Alternative 3 requires a small-scale construction effort of approximately 1-month duration. Since all the EAB and SVE and vapor treatment facility components are packaged systems, construction time and site preparation for the water treatment facility is minimized. Fugitive dust emissions from the source area excavation and water treatment system site preparation could potentially impact workers and the environment during implementation and would, therefore, be controlled and monitored during construction.

The time estimated to remediate the aquifer to beneficial use using this alternative is approximately 2 years. Therefore, this alternative is highly effective for groundwater cleanup in the short term.

4.2.3.5 Long-Term Effectiveness and Permanence

Based on experience at similar sites, Alternative 3 will require approximately 2 years to remediate the source area aquifer to beneficial use. If this alternative is implemented and maintained for this life expectancy, Alternative 3 would be highly effective in the long term.

4.2.3.6 Reduction of Toxicity, Mobility, or Volume through Treatment

Alternative 3 would achieve a reduction in the toxicity, mobility, and volume of contaminated groundwater through treatment if operated throughout the estimated period of approximately 2 years for this alternative. Contaminants would be permanently removed from the source area via the treatment process. Because contaminants are completely destroyed *in situ* rather than being transferred to another medium, the reduction of toxicity, mobility, or volume is high for this alternative. The source area soil removal, however, does not reduce toxicity, mobility, or volumes as it is not a treatment option.

4.2.3.7 Implementability

Alternative 3 can be readily implemented with available and proven technologies. Construction and O&M of EAB and SVE treatment systems have been implemented at many sites and utilize well-proven technologies. However, coordination with several property owners and businesses in the source area will require a significant effort on the part of the construction contractor to prevent a negative impact on local businesses. Therefore, Alternative 3 is moderately to highly implementable.

4.2.3.8 Cost

The 5-year present worth cost of this alternative is estimated to be $1,075,000, with a capital cost of $615,000. The main component of the capital cost results from the injection/extraction well system and electron donor injection equipment. A summary of the cost estimate is presented in Table 4-3. The detailed cost breakdown for items in the summary table is provided in a series of cost worksheet tables in Appendix A.

4.3 Comparative Analysis of Alternatives

Table 4-4 presents a comparative analysis of each of the four alternatives, including the following:

- Protection of human health and the environment
- Compliance with ARARs
- Short-term effectiveness
- Long-term effectiveness
- Reduction of toxicity, mobility, or volume through treatment
- Implementability
- Present worth cost

This analysis is presented in detail in the following sections.

4.3.1 Overall Protection of Human Health and the Environment

As shown in Table 4-4, all alternatives except Alternative 1 no action provide protection of human health and the environment by preventing exposure to contaminated groundwater and indoor air through treatment of the groundwater, removal of the source of contaminant loading to indoor and subslab air, and treatment of contamination.

4.3.2 Compliance with ARARs

All the alternatives except Alternative 1 no action would comply with ARARs.

4.3.3 Short-Term Effectiveness

Alternative 1 would be ineffective in limiting short-term exposure to contaminated indoor air in the BFC. Alternative 1 would also be ineffective in short-term mitigation of contaminated groundwater. Implementation of either Alternative 2 or 3 would result in reductions in PCE levels in groundwater and indoor air within a short time after construction completion. The removal component of both alternatives would provide an immediate reduction in indoor air contamination at the BFC. Therefore, both Alternatives 2 and 3 are highly effective in the short term.

4.3.4 Long-Term Effectiveness

Alternatives 2 and 3 provide long-term effectiveness and permanence by treating groundwater and the source of contaminant loading to both groundwater and indoor air. Under Alternative 3, it is estimated that the cleanup goals should be reached sooner than Alternative 2.

4.3.5 Reduction of Toxicity, Mobility, or Volume through Treatment

Alternative 1 has no treatment component and therefore provides no reduction of toxicity, mobility, or volume of PCE in either indoor air or groundwater. Both Alternatives 2 and 3, however, treat groundwater and remove/dispose of the soils containing a source of groundwater and indoor air contamination. Therefore, both Alternatives 2 and 3 provide a reduction of toxicity, mobility, and volume of PCE through treatment. In addition, Alternative 3 would provide destruction of PCE groundwater contamination through EAB while Alternative 2 removes the contaminants and transfers them to another medium that will require disposal.

The removal component of these alternatives, while eliminating the pathway for PCE to contaminate indoor air at the BFC, provides no treatment of the soils removed from the shallow source area. Therefore, these alternatives do not provide for reduction of toxicity, mobility, or volume of the PCE in the soils removed from the source area.

4.3.6 Implementability

Both Alternatives 2 and 3 use proven technologies and skid mounted treatment systems, which are easily implemented at a site. However, drilling wells for either Alternative 2 or 3 in the source area will require coordination with businesses and land owners in the source area. Alternative 2 will require installation of 11 DPE wells, 1 groundwater extraction well, and 1 SVE well. Alternative 3 will require installation of three injection and four extraction wells and an electron donor injection system, which will consist of off the shelf items. Therefore, Alternative 2 is considered moderately implementable while Alternative 3 is moderately to highly implementable.

4.3.7 Present Worth Cost

The present worth costs for each alternative are presented in Table 4-4.

Section 5
References

Anderson, P.B., D.D. Susong, S.R. Wold, V.M. Heilweil, and R.L. Basin. 1994. Hydrogeology of Resource Areas and Water Quality of the Principal Aquifers Along the Wasatch Front and Adjacent Areas, Utah. U.S. Geological Survey Water-Resourced Investigations Report 93-4221, Salt Lake City, Utah.

Bountiful Water Department. 2004. City Water Department. Letter from David Wilding to Mario Robles. March.

CDM Federal Programs Corporation (CDM). 2005a. *Final Pilot Study Implementation Plan for Operable Unit 1 – Enhanced Anaerobic Bioremediation at the Bountiful/Woods Cross 5th South PCE Plume Superfund Site, Davis County, UT. May.*

______. 2005b. *Draft Remedial Investigation Addendum Report for Bountiful/Woods Cross 5th South PCE Plume (OU 2), Davis County, UT.*

______. 2004. *Draft Final Remedial Investigation Report for Bountiful/Woods Cross 5th South PCE Plume (OU 2), Davis County, UT.*

______. 2002. *Phase 1 Data Analysis Report for Bountiful/Woods Cross 5th South PCE Plume (OU 2), Davis County, UT.*

Environmental Cost Handling Options and Solutions (ECHOS). 1995. *Environmental Restoration Assemblies Cost Book.*

U. S. Environmental Protection Agency. 2004. *Performance Monitoring of MNA Remedies for VOCs in Groundwater* (EPA 2004)

_____. 2001. *EPA Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action and Underground Storage Tank Sites.*

_____. 2000a. *Guide to Developing and Documenting Cost Estimates During the Feasibility Study.*

_____. 2000b. "Applicability of RCRA Section 3020 to In-Situ Treatment of Ground Water." Memorandum from Elizabeth Cotsworth, Director, Office of Solid Waste, U.S. EPA Office of Solid Waste and Emergency Response, to RCRA Senior Policy Advisors, RCRA Enforcement Managers, and Superfund Regional Policy Managers. December 27.

_____. 1997. Analysis of Selected Enhancement for Soil Vapor Extraction. Office of Solid Waste and Emergency Response, Washington, D.C., EPA/542/R-97/007.

_____. 1989. CERCLA *Compliance with other Laws Manual: Interim Final*. Office of Emergency and Remedial Response, Washington, D.C. EPA/540/G-89/006.

_____. 1988. *Guidance for Conducting Remedial Investigations (RI) and Feasibility Studies (FS) Under Comprehensive Environmental Response Compensation and Liability Act (CERCLA), Interim Final.* Office of Emergency and Remedial Response, Washington, D.C.,EPA/540/G-89/004.

_____. 1987. Data Requirements for Selecting Remedial Action Technologies. EPA 600/2-87/001. January.

_____.1985. Handbook Remedial Action at Waste Disposal Sites (Revised). Office of Emergency and Remedial Response, Office of Solid Waste and Emergency Response, Washington, D.C., EPA 625/6-85/006.

Federal Register. 1990. Environmental Protection Agency, 40 CFR Part 300, National Oil and Hazardous Substance Pollution Contingency Plan; Final Rule. Pp.8732.

Golder Associates. 1987. Final Report to Phillips Petroleum, Groundwater and Soil Investigation, Phillips Petroleum Refinery, Woods Cross, Utah. August.

HDR. 2003a. Former W.S. Hatch CO Facility, Remedial Investigation Final Report. December.

_______. 2003b. FFS Report. July.

Howard, P.H. 1990. Fate and Exposure Data for Organic Chemicals, Lewis Publishers.

McCarty, P.L., M.N. Goltz, G.D. Hopkins, M.E. Dolan, J.P. Allan, 1998. Full Scale Evaluation of *In Situ* Cometabolic Degradation of Trichloroethylene in Groundwater Through Toluene Injection. Environmental Science Technology, 32, pg. 88-100.

Pankow, J.F and J.A. Cherry. 1995. Dense Chlorinated Solvents and Other DNAPL in Groundwater. Waterloo Press.

SRC. 2005. Draft Baseline Human Health and Ecological Risk Assessment for the Bountiful/Woods Cross Site (OU2), Bountiful, Utah. Addendum. May.

SRC. 2004. Baseline Human Health and Ecological Risk Assessment for the Bountiful/Woods Cross Site (OU2), Bountiful, Utah. July.

Tetra Tech. 1996c. (RE: the "c" see comment on Page 2-20)

Tetra Tech. 1990. Multi-Phase Extraction, State of the Practice.

Appendix A
Detail Cost Worksheets

Figures

Tables