U.S. Army Corps of Engineers

Omaha District

Focused Engineering Evaluation/Cost Analysis
Groundwater Plumes
Interim Corrective Measure

Former Air Force Plant PJKS
Waterton Canyon, Colorado

Revision 1

September 12, 2005

Shaw® Shaw Environmental, Inc.

9201 East Dry Creek Road
Centennial, CO 80112

FOCUSED ENGINEERING EVALUATION/COST ANALYSIS
GROUNDWATER PLUMES
INTERIM CORRECTIVE MEASURES

FORMER AIR FORCE PLANT PJKS
WATERTON CANYON, COLORADO

REVISION 1

Prepared for:

U.S. ARMY CORPS OF ENGINEERS
Omaha District
Omaha, Nebraska
Contract DACA 45-96-D-0007

Prepared by:

Shaw Environmental, Inc.
9201 East Dry Creek Road
Centennial, Colorado 80112

September 12, 2005

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont.)

TABLE OF CONTENTS (Cont.)

TABLES

FIGURES

APPENDICES

ABBREVIATIONS AND ACRONYMS

ARAR	applicable or relevant and appropriate requirement
ARD	anaerobic reductive dechlorination
ASC	Aeronautical Systems Center
Bedrock Pilot Study	*Pilot Study, Brush Creek/Lariat Gulch Groundwater Plumes*
CBSG	Colorado Basic Standards for Groundwater
CDPHE	Colorado Department of Public Health and Environment
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CHWA	Colorado Hazardous Waste Act
COC	contaminant of concern
DCE	dichloroethene
DERP	Defense Environmental Restoration Program
EE/CA	Engineering Evaluation/Cost Analysis
EPA	U.S. Environmental Protection Agency
Lockheed Martin	Lockheed Martin Space Systems Company
MCL	maximum contaminant level
µg/L	microgram(s) per liter
NCP	National Oil and Hazardous Substance Pollution Contingency Plan
NDMA	*N*-nitrosodimethylamine
O&M	operation and maintenance
OSWER	Office of Solid Waste and Emergency Response
OU	operable unit
PJKS	former Air Force Plant PJKS
RCRA	Resource Conservation and Recovery Act
SACM	Superfund Accelerated Cleanup Model
SRI	Supplemental Remedial Investigation
TBC	to be considered
TCE	trichloroethene
USACE	U.S. Army Corps of Engineers
USAF	U.S. Air Force
USC	United States Code
VOC	volatile organic compound

FOCUSED ENGINEERING EVALUATION/COST ANALYSIS
GROUNDWATER PLUMES
INTERIM CORRECTIVE MEASURE
FORMER AIR FORCE PLANT PJKS
WATERTON CANYON, COLORADO

1.0 INTRODUCTION

This report presents the results of focused investigations and alternatives evaluations for interim corrective measures specific to groundwater at former Air Force Plant PJKS (PJKS) located near Waterton Canyon, Colorado. Interim corrective measures are needed for depletion of chlorinated solvents in groundwater at multiple sites. Shaw Environmental, Inc. (Shaw) prepared this document under the U.S. Army Corps of Engineers (USACE) Total Environmental Restoration Contract No. DACA-45-96-D-0007. The Aeronautical Systems Center (ASC) at Wright-Patterson Air Force Base, Ohio, manages the environmental programs at PJKS, which are currently being implemented through the USACE and the Air Force Center for Environmental Excellence contracts. The U.S. Air Force (USAF) owned the PJKS property until February 2001, when ownership was transferred to the Lockheed Martin Space Systems Company (Lockheed Martin), the long-time operator of the facility. PJKS is located near Waterton Canyon, Colorado, and is surrounded by Lockheed Martin's larger facility (Figure 1).

The USAF has entered into an agreement with Colorado Department of Public Health and Environment (CDPHE), Hazardous Waste Materials Management Division, through the *Compliance Order on Consent* (Order on Consent) *Number 98-10-08-01* (State of Colorado, 1998). The Order on Consent ensures integration of regulatory and responsible parties, defines authorities, sets schedules for actions, and ensures compliance with all applicable regulations. The U.S. Environmental Protection Agency (EPA) also has regulatory input to all reports and decisions related to PJKS. The Order on Consent became effective on December 29, 1998.

This Focused Engineering Evaluation/Cost Analysis (EE/CA) has been developed to meet the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) requirements outlined in the Order on Consent. This document evaluates two potential actions to address contamination in groundwater: No Action and In Situ Bioremediation. The evaluation was performed within the context of and to satisfy a removal action under Title 40 Code of Federal Regulations (CFR) Section 300.415; the Order on Consent for PJKS dated December 29, 1998; and State of Colorado groundwater regulations. As such, this EE/CA discusses factors used to evaluate the remediation in terms of: (1) addressing a threat to the public health/welfare or to the environment; (2) consistency with anticipated long-term remedial actions; (3) attainment of applicable or relevant and appropriate requirements (ARARs) under federal or state environmental laws; and (4) cost.

A non-time-critical removal action is the result of an EE/CA under the CERCLA process. However, to meet the requirements of the Order on Consent, both Resource Conservation and Recovery Act (RCRA) and CERCLA terminology are used in this document, and the resulting action from this EE/CA will be termed an interim corrective measure.

1.1 EE/CA APPROACH

This EE/CA was prepared using the guidelines described in the EPA Office of Solid Waste and Emergency Response (OSWER) Directive 9360.0-32, *Guidance on Conducting Non-Time-Critical Removal Actions under CERCLA* (EPA, 1993) and the streamlining approach outlined in 40 CFR 300.430(e)(1). Two streamlining initiatives are used in this EE/CA and are based on the Superfund Accelerated Cleanup Model (SACM) developed by EPA in 1990. The two initiatives are designed to accelerate and streamline the selection and implementation of removal actions/interim corrective measures. The two SACM initiatives are the presumptive (or for this specific site, the "PJKS preferred") remedies initiative and the plug-in approach.

1.1.1 PJKS Preferred Remedy Initiative

A preferred remedy initiative involves the identification of a preferred alternative for common categories of source areas. The preferred remedy initiative is consistent with all of the selection criteria specified in the National Oil and Hazardous Substance Pollution Contingency Plan (NCP). The preferred remedy is determined based on historic remedy selection, and scientific and engineering evaluation of performance data on technology implementation for source areas that exhibit similar physical characteristics and contaminants. In an effort to accelerate cleanup at PJKS, the USAF has implemented a pilot test for technologies to address groundwater source area contamination. The preferred remedy for groundwater source areas is In Situ Bioremediation. There are several hundred documented success stories using this technology for a variety of contaminants, including chlorinated solvents (EPA, 2001).

Because no soil sources for contaminants in groundwater have been identified at PJKS after multiple investigations, it is likely that any residual source of contamination in groundwater has accumulated in the bedrock formations. Over time, groundwater containing the contaminants of concern (COCs) moves from the bedrock aquifer into the alluvial groundwater regime. Reducing the chemical load in groundwater will assist in any final remedy that will be implemented for the downgradient portion of the groundwater plumes.

1.1.2 Plug-In Approach

The plug-in approach is a way of repetitively implementing a remedy for multiple source areas that are physically similar and have comparable contaminants. This approach eliminates the need to perform individual EE/CAs at source areas where the interim corrective measure for contaminants in groundwater will use the same technology. This will also reduce the need for multiple Action Memoranda for each source area.

The range of conditions that a preferred remedy is capable of addressing is called the preferred remedy profile. The existing conditions present at a source area being considered for remedial action in the plug-in approach is termed the existing source area profile. To determine whether a preferred remedy is applicable to a source area at PJKS, the existing source area profile will be compared to the preferred remedy profile. The comparison of the existing source area profile to the remedy profile is termed the plug-in evaluation determination. If a source area exhibits conditions that are beyond the remedy profile, then the remedy profile can be increased by the use of technical enhancements. For source areas where the remedy profile meets the existing source area profile, a plug-in evaluation determination will be prepared along with a work plan that presents the details for a specific source area. An example of a source area that would not meet the preferred remedy profile would include areas where the permeability of the aquifer are low and inhibit the distribution of the substrates that are injected into the aquifer to biodegrade the contaminants that pose an unacceptable risk to human health or the environment.

1.2 EE/CA REPORT ORGANIZATION

This report is organized into nine sections. Section 2 briefly describes the site characterization. Regulatory requirements, including ARARs, and the interim corrective action objectives are discussed in Section 3. Section 4 provides a description and detailed analysis of the alternatives. A comparative analysis of the alternatives is included in Section 5. Section 6 describes the remedy enhancements, while Section 7 outlines the preferred remedy initiative. Section 8 summarizes the recommended remedial action alternative. References cited are in Section 9.

2.0 SITE CHARACTERIZATION

This section contains information on the site background, the groundwater standards, and a recent pilot study in the D-1 Area.

2.1 SITE DESCRIPTION AND BACKGROUND

Information in this section has been provided in previous documents. For the purpose of brevity, that information is not repeated here. References are provided to documents containing relevant information.

2.1.1 Site Location and History

The location and history of PJKS have been described extensively in various volumes of the *Supplemental Remedial Investigation* (SRI) *Report* (Parsons Engineering Science [Parsons], 1998, 1999a, 1999b, 1999c). The regional geology and hydrogeology at PJKS have been further described in the *Supplemental Remedial Investigation Addendum 1, OU4 – Lariat Gulch Groundwater Plume* (Stone & Webster, 2001) and the *Supplemental Remedial Investigation Addendum, Operable Unit 5 – Brush Creek Groundwater Plume* (Shaw, 2003a). Sensitive ecosystems are described in the SRI Report and the *Screening Ecological Risk Assessment for Avian Receptors* (Shaw, 2005).

2.1.2 Surrounding Land Use and Populations

Before 1956, when the PJKS site and the surrounding acreage were bought for industrial development, the land was used for cattle ranching. Today, the PJKS land is surrounded entirely by Lockheed Martin property. The Lockheed Martin property is used for industrial purposes, although some undeveloped areas exist within the approximately 4,700-acre parcel. Both PJKS and Lockheed Martin properties are zoned by the county for industrial use (I-2 industrial). Properties immediately beyond Lockheed Martin boundaries are zoned for agriculture (Parsons, 1999c) or planned development – single family residences.

Recreational areas located within approximately 5 miles of PJKS include Waterton Canyon, Roxborough State Park, Deer Creek Canyon, and Chatfield State Recreation Area. These areas are used heavily for hiking, fishing, biking, picnicking, boating, and other seasonal recreational activities.

Nearby residential subdivisions and houses independent of housing developments include: Deer Creek Mesa, Sunshine Acres, Plum Creek Acres, View Ridge, Roxborough Village, Roxborough Park North, Deer Creek Canyon, South Deer Creek Road, areas southeast of Waterton Canyon, and areas southeast of Chatfield Reservoir.

2.2 GROUNDWATER STANDARDS

Compounds in groundwater at PJKS that have exceeded their respective Colorado Basic Standard for Groundwater (CBSG) include trichloroethene (TCE), *cis*-1,2-dichloroethene *(cis*-1,2-DCE), and vinyl chloride. CBSGs for the COCs are as follows:

Compound	CBSG
Trichloroethene	5 μg/L
cis-1,2-Dichloroethene	70 μg/L
trans-1,2-Dichloroethene	100 μg/L
Vinyl Chloride	2 μg/L
Ethene	No Standard
Ethane	No Standard
NDMA, where applicable	0.00069 μg/L

The Order on Consent identifies state groundwater standards as the cleanup goals for groundwater.

2.3 PILOT STUDY SUMMARY

A pilot study was performed at the D-1 Area as part of the *Pilot Study Work Plan, Brush Creek/Lariat Gulch Groundwater Plumes* (Bedrock Pilot Study) (Shaw, 2003b). The Bedrock Pilot Study evaluated anaerobic reductive dechlorination (ARD). The successful results from the Bedrock Pilot Study provide the basis for proposing the implementation of ARD as an interim corrective measure at multiple groundwater source areas.

The main objective for the Bedrock Pilot Study in the D-1 Area was to evaluate the effectiveness of in situ anaerobic biodegradation of TCE and *N*-nitrosodimethylamine (NDMA) in Precambrian bedrock source areas. The study evaluated the effectiveness of sodium lactate to stimulate bioremediation of TCE and NDMA in the fracture flow system that typifies the Precambrian bedrock aquifer.

Bedrock Pilot Study field activities included well installation, packer testing, injection of the carbon substrate into groundwater, and groundwater performance monitoring. Two injections and 10 subsequent sampling events occurred between the months of October 2003 and January 2005.

During the Bedrock Pilot Study, the initial TCE contamination in Well 5-M07 decreased from a maximum concentration of 12,000 micrograms per liter (μg/L) in October 2003 to a minimum concentration of 740 μg/L in January 2005. Figure 2 illustrates the in situ bioremediation success for TCE and TCE degradation products from May 2000 to January 2005 in Well 5-M07.

The Bedrock Pilot Study resulted in the biodegradation of TCE in groundwater, including the production of all of the by-products and the end-product, ethene. These results indicate that the source area for groundwater in the D-1 Area is amenable to anaerobic bioremediation via in situ injection techniques. TCE concentrations in Well 5-M07 have been reduced two orders of magnitude in approximately one year. As expected from TCE degradation, the concentrations of the by-product *cis*-1,2- DCE increased from 140 μg/L to a maximum peak value of 5,800 μg/L. After the maximum peak value of *cis*-1,2-DCE, concentrations decreased as predicted concurrent with the appearance of the by-products vinyl chloride and ethene. The indicator of successful and complete anaerobic TCE degradation in groundwater at the D-1 Area has been most notably demonstrated by the presence of ethene. Metabolic acid data further supports the successful bioremediation conclusion with evidence of electron donors being metabolized and therefore having provided a hydrogen source for the biodegradation to occur.

The Bedrock Pilot Study evaluation of the NDMA bioremediation did not show any evidence of a reduction in groundwater concentrations. Concentrations of NDMA in groundwater remained constant throughout the course of the Bedrock Pilot Study.

3.0 INTERIM CORRECTIVE MEASURE SCOPE

This section summarizes the regulatory requirements and identifies the preliminary objectives for the interim corrective measure within the source area. All source area profiles evaluated for this interim corrective measure will follow the same ARAR criteria, and any modifications will be included in the plug-in evaluation determination.

3.1 REGULATORY REQUIREMENTS

The Order on Consent between the USAF and the State of Colorado establishes, among other things, requirements and schedules for the remediation of any releases of hazardous waste, constituents, and/or substances at, or relating to, PJKS. Paragraph 27 of the Order on Consent (State of Colorado, 1998) states that the USAF is required to comply with the CERCLA, RCRA, Colorado Hazardous Waste Act (CHWA), Defense Environmental Restoration Program (DERP), and NCP. The Order on Consent further provides for the integration of RCRA and CERCLA provisions as outlined in 42 USC 6905(b). Although this proposed activity is based on a CERCLA model as discussed in the next two paragraphs, the interim corrective measure will also comply with RCRA and State of Colorado regulations (CHWA and the Colorado Water Quality Control Act).

Section 120 of CERCLA provides guidelines for the remediation of media containing hazardous constituents released from federal facilities. CERCLA also states that each department, agency, and federal facility is subject to and must comply with the Act. Therefore, all guidelines, rules, regulations, and criteria carried out under CERCLA (including the NCP) and the National Environmental Policy Act are applicable to federal facilities.

Section 121 of CERCLA, the Superfund Amendments and Reauthorization Act, and the NCP require that ARARs be identified during the development of remedial alternatives. ARARs are federal and state human health- and environmental-based requirements and guidelines used to: (1) determine the appropriate levels of site cleanup; (2) define and formulate remedial action alternatives; and (3) govern implementation and operation of the selected remedial action.

As a matter of law, ARARs only apply to final remedial actions. Generally, interim corrective measures do not have to attain ARARs, but they must meet ARARs to the extent possible. Corrective action objectives are, however, typically based on the identification of potential ARARs. This is because a comparison of site conditions with potential ARARs can often be used to readily indicate a need for action and standards for protectiveness for interim actions. Further, because final remedial actions must attain ARARs, an identification and evaluation of potential ARARs can be helpful in determining the extent to which an interim corrective measure may be consistent with anticipated final remedies.

The purpose of this interim corrective measure is specific to source area depletion of contaminants in groundwater at PJKS. The interim corrective measure is not designed to directly achieve federal and state drinking water standards for contaminants in groundwater, but to focus on the source areas and deplete the contributions of residual phase contaminants to groundwater.

3.1.1 Definition of ARARs

The NCP defines two ARAR components: (1) applicable requirements, and (2) relevant and appropriate requirements. The NCP also identifies a third category of guidance termed "information to be considered." These components are defined below.

3.1.1.1 Definition of "Applicable" Requirements

Applicable requirements include federal and state cleanup standards, controls, or environmental legislation that "specifically address a hazardous substance, pollutant, contaminant, remedial action, location or other circumstance" (EPA, 1988). An example of an applicable requirement is the use of maximum contaminant levels (MCLs) for a site where groundwater contamination enters a public water supply.

3.1.1.2 Definition of "Relevant and Appropriate" Requirements

Relevant and appropriate requirements include federal and state requirements that are not legally applicable as defined above but may also be considered. These requirements are considered if they "address problems or situations sufficiently similar to those encountered at the site," and "their use is well suited to the site" (EPA, 1988). Relevant and appropriate requirements are intended to have the same weight and consideration as applicable requirements. The term relevant was included so that a requirement initially screened as non-applicable because of jurisdictional restrictions could be reconsidered and, if appropriate, included as an ARAR for the site. For example, MCLs would be relevant and appropriate requirements at a site where groundwater contamination could affect potential (rather than actual) drinking water sources.

3.1.1.3 Other Requirements "To Be Considered"

Other requirements to be considered (TBC) include federal and state advisories or guidelines that are not legally binding and do not have the status of potential ARARs. However, if no specific ARAR for a chemical or site condition exists, or if existing ARARs are not deemed sufficiently protective, then guidance or advisory criteria should be identified and used to ensure human health and environmental protection.

3.1.2 Identification of ARARs

The identification of ARARs is an iterative process to be considered throughout the CERCLA process. Therefore, the list of identified requirements and their relevance may change as more information is obtained, the preferred alternative is chosen, and the design and approach to remediation is refined.

As defined, federal and state requirements must be considered for identification of site-specific ARARs. Federal and state requirements include ARARs that are:

- Chemical-specific (i.e., govern the level or extent of site remediation in relation to a specific constituent),
- Location-specific (i.e., pertain to existing site features), and
- Action-specific (i.e., pertain to proposed site remedies and govern implementation of the selected site remedy).

3.1.2.1 Chemical-Specific ARARs

Chemical-specific ARARs are usually health- or risk-based standards that limit COC concentrations found in or discharged to the environment. These ARARs can govern the extent of site remediation by providing cleanup levels or a basis for calculating cleanup levels. Potential chemical-specific ARARs that relate to the COCs and media of concern at PJKS are identified in Table 1 and include the following.

Federal chemical-specific ARARs:

Safe Drinking Water Act. Provides national primary drinking water regulations and establishes health-based standards for public water systems (MCLs).

Resource Conservation and Recovery Act (RCRA). Allows for alternate groundwater concentration limits (TBC).

State chemical-specific ARARs:

Colorado Basic Standard for Groundwater. Provides groundwater standards to protect public health and environment.

Colorado Primary Drinking Water Regulations. Establishes health-based standards for the public water systems.

Colorado Hazardous Waste Regulations. Provides identification and listing of hazardous wastes.

3.1.2.2 Location-Specific ARARs

Location-specific ARARs place restrictions on contaminant concentrations or remedial activities solely based on site setting or location (e.g., within or adjacent to wetlands, floodplains, existing landfills, disposal areas, and places of historical or archaeological significance). There are no potential location-specific ARARs involved with either alternative. Both alternatives do not require any earth-moving tasks, any field tasks that will involve heavy equipment, or any tasks that threaten the site setting or location based on ecological, historical, or archaeological significance.

3.1.2.3 Action-Specific ARARs

Action-specific ARARs establish controls or restrictions on activities related to the management of hazardous waste. After remedial alternatives are developed, action-specific ARARs pertaining to proposed site remedies provide a basis for assessing the feasibility and effectiveness of the remedies. The potential action-specific ARARs are identified in Table 2 and include the following.

Federal action-specific ARARs:

Resource Conservation and Recovery Act (RCRA). Outlines requirements for corrective action requirements for release of hazardous constituents at interim status units.

Safe Drinking Water Act. Provides the specification for Underground Injection Control permits for the injection of fluids to groundwater through wells.

State action-specific ARARs:

Colorado Hazardous Waste Regulations. Provides requirements for groundwater monitoring program to determine impact on the quality of groundwater (TBC).

3.2 INTERIM CORRECTIVE ACTION OBJECTIVES

The objective of an interim corrective measure is to effectively mitigate hazards to, minimize threats to, and provide adequate protection of public health, welfare, and the environment. Specific objectives are established to focus the scope of a particular interim corrective measure in terms of chemicals of concern, areas/volumes of contamination (e.g., points of compliance), routes of exposure, and levels of contamination to be addressed. Corrective action objectives are generally based on ARARs, and attaining these objectives is meant to effectively mitigate hazards/threats to public health, welfare, and the environment.

The objective established here is also used as a means to compare the interim corrective measure alternatives under consideration. This corrective action objective is considered preliminary and will be re-evaluated if additional data become available. The preliminary objective for this interim corrective measure is to significantly reduce, if not entirely deplete, the source of contaminants to groundwater to levels that are protective of human health. A secondary objective is to establish a groundwater sampling program to monitor the effectiveness of the in situ bioremediation progress.

4.0 DESCRIPTION OF ALTERNATIVES AND DETAILED ANALYSIS

As part of this focused EE/CA, only two alternatives were considered to mitigate risks associated with contaminants in groundwater within the PJKS site. The two alternatives contain individual or combined technologies and/or process options that are tailored to achieve the preliminary objectives established for PJKS. A brief description and evaluation of each alternative is presented in the following text. The two alternatives are:

- Alternative 1: No Action, and
- Alternative 2: In Situ Bioremediation.

4.1 ALTERNATIVE 1: NO ACTION

4.1.1 Description

No action is defined as no monitoring or corrective measures being taken at the site.

4.1.2 Analysis

The No Action Alternative establishes a baseline for alternative comparison.

4.1.2.1 Effectiveness

The effectiveness of Alternative 1 is evaluated using the following criteria:

- Overall protection of human health and environment,
- Compliance with ARARs,
- Long-term effectiveness,
- Reduction of toxicity, mobility, and volume through treatment, and
- Short-term effectiveness.

Overall Protection of Human Health and Environment
Under this alternative, the source area in groundwater would remain as it currently exists with no active effort to minimize contaminant levels or migration pathways. No efforts would be made to reduce any potential risks to human health and the environment. If no action is taken, the source areas will continue to contribute TCE into the bedrock and alluvial groundwater systems and degrade the shallow aquifer. Some natural biodegradation may occur; however, the No Action Alternative does not include long-term monitoring of groundwater to assess the effects of any natural biodegradation.

Compliance with ARARs
Alternative 1 is not compliant with the chemical-specific ARARs, specifically the CBSGs. CBSGs are established to be protective of human health and waters of the State of Colorado, and the No Action Alternative provides no means to determine whether the ARARs for groundwater have been met.

Long-term Effectiveness
Alternative 1 does not provide long-term effectiveness or permanent remedy for the groundwater contamination. This alternative does not manage or reduce risks associated with the groundwater contamination.

Reduction of Toxicity, Mobility, and Volume through Treatment
The No Action Alternative would not provide an active treatment to reduce toxicity, mobility, or volume of contaminated groundwater at the PJKS site.

Short-term Effectiveness
The No Action Alternative is not protective of the community and is not protective of workers who would encounter shallow groundwater during excavations. There are no environmental impacts to implement this alternative; however, the environmental quality of groundwater will continue to be degraded. Corrective action objectives may be achieved; however, a monitoring program is not included with this alternative and any natural biodegradation would not be measured. The length of time until protection is achieved is indefinite under this alternative.

4.1.2.2 Implementability

The implementability of Alternative 1 is evaluated below with respect to the following criteria:

- Technical feasibility,
- Administrative feasibility,
- Availability of services and materials, and
- State and community acceptance.

No technical or administrative feasibility concerns are associated with implementing Alternative 1 because no actions are being taken. State or community acceptance is unknown for this alternative; however, it is anticipated that the No Action Alternative would not be considered an appropriate alternative for remediation.

This alternative can include limited environmental monitoring to assess the impacts associated with no remedial response action. Alternative 1 would also require long-term maintenance of the area including periodic inspections and worker monitoring during construction activities, such as utility repairs or upgrades as required by Lockheed Martin. The services and materials necessary to implement this alternative are readily available.

4.1.3 Cost

As shown Appendix A, Tables A-1 and A-2, the estimated capital cost to implement Alternative 1 is approximately $22,000. The establishment of a worker monitoring program is an initial capital cost. The only long-term costs for the No Action Alternative would include environmental fees for covenants or deed restrictions, inspections, and annual reports; these are carried out for 15 years. For each year, the annual fee cost is estimated to be approximately $2,500. The present worth of the total cost of this alternative is estimated to be $60,000.

4.2 ALTERNATIVE 2: IN SITU BIOREMEDIATION

A description and detailed analysis of in situ bioremediation is presented below. The PJKS preferred remedy for source areas in groundwater is in situ bioremediation. This remedy includes long-term monitoring.

4.2.1 Description

In situ technologies consist of introducing specific substrates or chemicals directly into the aquifer to enhance chemical or biological processes that degrade contaminants. Substrates are injected into the aquifer through groundwater wells, and the contaminant biodegradation occurs in the subsurface aquifer.

In situ biodegradation of a variety of contaminants (including TCE) has been proven effective at many sites across the United States. In the natural environment, however, this microbially mediated process may proceed at extremely slow rates. To enhance the process for the biodegradation of chlorinated solvents, microbial population growth is stimulated by artificially supplying a carbon source (substrate) such as carbohydrates (i.e., sugar) and, if necessary, other essential nutrients such as nitrogen and phosphorus. As the sugar degrades, metabolic acids are released. Microbes, in a process that releases hydrogen ions, metabolize the acids. The free hydrogen is used by other microbes to complete the reductive dechlorination process.

Common substrates for chlorinated solvent anaerobic biodegradation can include natural sugars such as molasses, manufactured compounds such as sodium lactate (see Appendix B), or artificial sweeteners such as sorbitol. Compounds with low viscosity and high solubility, such as sodium lactate, move readily through fractured flow aquifers. These properties do result in a shorter lifespan in the subsurface; thus, sodium lactate requires periodic re-injection.

For groundwater source areas contaminated with chlorinated solvents at PJKS, sodium lactate would be injected into either existing or newly installed injections wells. For the bedrock pilot scale test, 42.5 gallons of water, 8.5 gallons of sodium lactate, and 29 pounds of Restore 375® (nutrient) were used at the D-1 Area (Shaw, 2003b). In order to prevent fracturing of the formation, injection pressures would not exceed 0.5 pound per square inch per foot of depth. Both the amount of sodium lactate and the injection pressures would be adjusted based on field conditions. Pressure in the isolated interval would be maintained for a long enough time to allow the sodium lactate volume to move into the formation. In order to eliminate the possibility that the biological process is nutrient limited, Restore 375® nutrient solution would be added at the time of treatment injection. A 10 part to 1 part (10:1) carbon to nitrogen ratio would be used to estimate nitrogen demand. The carbon concentration is determined from the amount of sodium lactate that would be used.

For chlorinated solvents, a successful source area treatment would result in the stepwise biodegradation of TCE to the degradation by-products *cis*-1,2-DCE and vinyl chloride. The final degradation by-products of TCE are non-chlorinated hydrocarbons (ethane, ethene) and chloride.

The injection of a substrate would require groundwater monitoring to determine treatment effectiveness and plume migration. Monitoring would include sampling of groundwater wells for volatile organic compounds (VOCs), ethane, ethene, methane, metabolic acids, and water quality parameters. The number of groundwater wells would be specified in a work plan that would be submitted with the plug-in evaluation determination. Typically, the wells would be monitored quarterly for the first 2 years, then on a semiannual basis for the next 3 years, and annually for the following 10 years for a total lifespan of 15 years.

A long-term monitoring program would be implemented to monitor the effectiveness of the biodegradation process. VOC results (analyzed using EPA Method SW 8260) would be used to determine whether TCE biodegradation is occurring (i.e., TCE concentrations are decreasing), to monitor any increase in daughter products (e.g., DCE and vinyl chloride), and to determine whether the degradation pathway has been completed. Gases (analyzed using EPA Method RSK 175) that are by-products of the final step of reductive dechlorination of TCE (e.g., ethane, ethene) would be monitored to assist in the evaluation of TCE degradation to ensure the process is complete. Metabolic acids (analyzed using EPA Method SW 8015) would be monitored to evaluate whether the electron donors are being metabolized and are providing a hydrogen source for the reaction. Groundwater sampling would be collected following the procedures outlined in the *Interim Groundwater Monitoring Plan* (Stone & Webster, 2002).

NDMA is another COC at PJKS that has yet to be conclusively determined inappropriate for bioremediation techniques via anaerobic biodegradation. Depending on the source area, NDMA (analyzed using EPA Method SW 8070) could also be sampled as part of the long-term monitoring program to monitor the possibility of delayed anaerobic biodegradation.

4.2.2 Analysis

This technology offers several advantages over conventional groundwater treatment methods. Since treatment occurs in situ, no groundwater pumping would be required, thus eliminating the ongoing need for an energy source. Equipment such as well pumps, filters, and air strippers would not be needed, eliminating the associated operations and maintenance (O&M) costs, and no active oversight of the system is required with the exception of routine compliance monitoring and preparation of O&M reports to satisfy State requirements. Additionally, technical and regulatory problems related to discharge requirements of effluents from pump and treat systems would be avoided.

4.2.2.1 Effectiveness

The effectiveness of Alternative 2 is evaluated using the following criteria:

- Overall protection of human health and environment,
- Compliance with ARARs,
- Long-term effectiveness,
- Reduction of toxicity, mobility, and volume through treatment, and
- Short-term effectiveness.

<u>Overall Protection of Human Health and Environment</u>
Alternative 2 is protective of human health and environment because it reduces the concentrations of COCs in groundwater source areas. Land use controls would be in place to

restrict the installation of shallow groundwater wells for potable drinking water until the groundwater is fully remediated below CBSGs.

<u>Compliance with ARARs</u>
Alternative 2 would comply with all potential ARARs through a combination of groundwater source area treatment and future land use controls.

<u>Long-term Effectiveness</u>
This alternative will achieve long-term effectiveness by treating groundwater contaminants through a non-reversible process of biodegradation with no waste products or residuals. This corrective measure would be complete when long-term groundwater monitoring confirms the contaminant concentrations at the source areas have been depleted to meet ARARs or the reduction becomes asymptotic. Additional injections and enhancements may be required during the first 2 years of implementation if the degradation process appears to be incomplete.

<u>Reduction of Toxicity, Mobility, and Volume through Treatment</u>
This alternative would use in situ biodegradation to irreversibly reduce the toxicity and volume of contaminated groundwater by converting COCs to non-toxic by-products (i.e., ethene by-product from TCE degradation). However, this technology does not reduce the mobility of untreated groundwater. The amount of contaminants treated will be site specific and would satisfy the preference for treatment.

<u>Short-term Effectiveness</u>
Alternative 2 is protective of the community and workers because it decreases the toxicity of source areas contributing to the groundwater contamination. There is no direct risk to site workers to implement in situ bioremediation (injecting a substrate into groundwater wells). However, if it is determined that additional wells need to be installed in order to expand the monitoring well or injection well network, then there would be a slight increase to environmental impacts and worker risks from well installation. Any potential impact to workers would be mitigated by using the proper personal protective equipment. There is no increase in environmental impacts or risk to personnel or the community during the long-term O&M activities. The time to achieve significant source area reduction is estimated to be 2 years. Corrective action objectives would be reached in a timely manner following the source area reduction.

Results from the 2003-2004 Bedrock Pilot Study at the D-1 Area (see Section 2.3) demonstrate the short-term effectiveness of this technology on the source area depletion of TCE in bedrock groundwater.

4.2.2.2 Implementability

The implementability of Alternative 2 is evaluated below with respect to the following criteria:

- Technical feasibility,
- Administrative feasibility,
- Availability of services and materials, and
- State and community acceptance.

Technical Feasibility

The required personnel and operation of Alternative 2 is technically feasible for sites that fit the preferred remedy profile. This alternative can be implemented using straightforward injection techniques. This technology has been successfully used at numerous sites across the country and at the PJKS site to remediate TCE. This technology is simple to operate and requires minimal maintenance. The climate, terrain, and seasonal changes routinely encountered at the PJKS site would not impact the implementability of Alternative 2.

Administrative Feasibility

The coordination of multiple offices or agencies would not be required to implement Alternative 2. This alternative would be implemented entirely on site and, as a result, would not require any offsite permits. Interim corrective measures implementation and funding using this EE/CA would be the responsibility of the USAF and, as a result, the statutory limits ($2 million or 12 months) would not apply.

Availability of Services and Materials

The equipment, materials, and resources required for this alternative are readily available. The major components of the alternative are the substrate material and then the means to inject the substrate to groundwater (i.e., via pumps and an appropriate energy source). The personnel, groundwater sampling equipment, and laboratory services necessary to implement a long-term monitoring program are readily available. If injection wells are needed to be installed at source areas, the alternative can still be implemented using industry standard techniques that are readily available.

State and Community Acceptance

The state and community have been introduced to ARD during the Bedrock Pilot Study and have been receptive to this type of technology being used as an interim corrective measure. However, acceptance of this technology as a formal interim corrective measure is unknown. A public comment period will follow the submittal of this EE/CA. Acceptance will be judged based on the nature and extent of comments received.

The time required to implement this alternative would be approximately 15 years. That timeline includes four semiannual injections of sodium lactate and quarterly groundwater monitoring for 2 years, followed by semiannual monitoring for 3 years, and annual monitoring for 10 years. Long-term monitoring would be required to monitor the performance of the bioremediation. The re-injection of substrate is possible if contaminant concentrations increase over time.

4.2.3 Cost

The costs for Alternative 2 have been prepared using the successful results from the Bedrock Pilot Study as an example. The cost to implement this alternative would include the capital cost to design and implement the technology (direct and indirect cost) and annual O&M for the monitoring program. As shown in Appendix A, Tables A-3 and A-4, the annual estimated capital cost to implement Alternative 2 at the D-1 source area is approximately $72,000. At other source areas, the cost to implement this remedy may be increased if injection wells need to be installed or if enhancements are required. Long-term monitoring of groundwater, including

O&M reports, is the only anticipated maintenance cost. For Years 3 through 5, the annual maintenance cost is estimated to be approximately $29,000 which includes sampling six monitoring wells and all associated analytical costs; for the remaining 10 years, the annual maintenance cost is estimated to be approximately $20,000. At other source areas, the long-term monitoring requirements may be either increased by adding more wells to monitor or reduced, therefore impacting the total annual maintenance cost. The present worth of the total cost of this alternative at the D-1 source area is estimated to be approximately $333,000.

Table 3 shows the generic costs of bioremediation injections based on the D-1 source area Bedrock Pilot Study (sodium lactate substrate) and extrapolated for varying injection and monitoring requirements. Final cost for a specific source area will depend on the actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope, and other variable factors. As a result, the final project cost may vary from the estimates in this EE/CA.

5.0 COMPARATIVE ANALYSIS OF ALTERNATIVES

The following section compares the alternatives presented in Section 4.0 on the basis of effectiveness, implementability, and cost. Tables 4 and 5 list the alternatives considered and summarize the effectiveness, implementability, and cost comparison for each alternative.

5.1 EFFECTIVENESS

Alternative 1, No Action, is not protective of human health and the environment and does not meet the corrective action objective established for this site. The ARARs identified for the groundwater medium would not be met using this alternative. This alternative would not provide an effective long-term or permanent remedy and would not reduce the current risks. An active treatment to reduce the toxicity, mobility, or volume of groundwater contaminants would not be provided using this alternative. The No Action Alternative would not provide an effective short-term remedy that would be protective of workers or the community. The corrective action objectives may be achieved using this alternative; however, a monitoring program is not included to measure any natural biodegradation effects. The length of time until protection is achieved using this alternative is indefinite.

Alternative 2 would reduce the source contamination and eliminate unacceptable risks associated with the exposure pathways and receptors to the groundwater medium. In situ bioremediation is protective of human health and the environment and will provide a basis for meeting the corrective action objective established for the PJKS site. This alternative would meet the ARARs for the COCs applicable to in situ bioremediation technologies. Alternative 2 would provide short-term effectiveness to the community and site workers as shown by the Bedrock Pilot Study results. The long-term effectiveness has been proven reliable and can be verified by the same technology that has been applied successfully at contaminated groundwater sites across the United States. This technology is irreversible and does not produce any waste by-products or residuals. This alternative would reduce the toxicity and volume of the contaminated groundwater but will not reduce the mobility.

5.2 IMPLEMENTABILITY

Alternative 1 would require no implementation. The services and materials required to implement periodic inspections and worker awareness training are readily available.

Alternative 2 is neither invasive nor disruptive of Lockheed Martin operations. Alternative 2 uses equipment that is commercially available and has been successfully employed during the Bedrock Pilot Study. The personnel and materials required to implement this alternative are readily available.

5.3 COST

The total present worth cost was estimated for each alternative. The total present worth cost includes the capital, O&M, monitoring, and review costs. The cost estimates presented in this EE/CA are order of magnitude costs ranging from -30% to +50%. A 15-year life was assumed for each alternative. The detailed cost estimates for each alternative are provided in Appendix A. The total present worth of each alternative is summarized below in order of increasing cost.

Alternative 1: No Action	$60,000
Alternative 2: In Situ Bioremediation	$333,000

Alternative 1 has limited long-term maintenance costs, including environmental covenant fees required by the State of Colorado or deed restrictions, inspections, worker awareness training, and annual reporting. The No Action Alternative has the lowest cost, although it will not meet any corrective action objectives established for the site or PJKS.

Alternative 2 will provide a means for achieving the corrective action objectives established for this site as shown through the Bedrock Pilot Study. Long-term O&M requirements for Alternative 2 include long-term groundwater monitoring and O&M reporting. Additionally, long-term monitoring could be reduced and eliminated if the chosen technology completely reduces all concentrations of groundwater contaminants below the CBSGs.

Alternative 2 reduces source area concentrations and contaminant loading to the aquifers. Thus, it would contribute to the overall long-term remediation and would not preclude the implementation of the selected final remedy.

6.0 ENHANCEMENTS

This section discusses enhancements to the in situ biodegradation technology and discusses how they would be used to meet corrective action objectives. Enhancements may be required in some groundwater source areas at PJKS to accomplish the following objectives:

- Create better distribution of substrate into the aquifer. This will allow more substrate to be in contact with a greater source area and therefore create a quicker biodegradation of contaminants.
- Augment the aquifer with the appropriate microbiological species to target a greater number of source areas that can be considered for the plug-in approach.
- Inject a different substrate to target the bioremediation of other COCs.
- Trace the pathways of groundwater and fluid migration velocity for the injection of substrates.
- Increase the frequency of injections to target a source area and aid in accelerated biodegradation.

It is expected that in most source areas the objective of the enhancements will be to increase the rate of biodegradation of contaminants, thereby shortening the overall cleanup times and cost. In such cases, in situ bioremediation may be effective with or without the enhancement, but it is more economically feasible to include the enhancements.

6.1 PHYSICAL ENHANCEMENTS

Physical enhancements to the in situ bioremediation technology include the installation of additional injection wells and bioaugmentation. An evaluation of different substrates may also be appropriate for a particular contaminant.

6.1.1 Installation of Additional Injection Wells

Additional injection wells would be installed to increase the pathways for the substrate to enter the aquifer. Injection wells could be installed to either focus on a specific interval that appears to be distribution limited or could be installed with a screen that spans the length of the saturated thickness. Injection wells can be installed relatively easily using hollow stem auger, air rotary, or rotosonic drilling techniques.

6.1.2 Bioaugmentation

Bioaugmentation is the process of adding specific microorganisms to enhance biodegradation in a given media. *Dehalococcoides ethenogenes* has been successfully identified as the microorganism that breaks down chlorinated solvents in groundwater. Testing has shown the presence of the *D. ethenogenes* at some locations at PJKS and the absence of the microorganism at other locations. A low population of the microorganism may result in slower biodegradation rates for chlorinated solvents, therefore augmenting the population would help expedite the biodegradation.

The *D. ethenogenes* culture would be extracted from the D-1 Area at PJKS and grown in the laboratory to create additional biomass. It may require up to 10 weeks to produce sufficient biomass before injection. The newly created culture would be introduced into groundwater at the same time the substrate is injected. It is likely that the culture would be introduced in areas where testing indicated the absence of *D. ethenogenes.* However, it is possible that additional *D. ethenogenes* could be injected in source areas that have confirmed the presence of this microorganism, but these source areas have not shown biodegradation of chlorinated solvents from previous substrate injections.

6.1.3 Injection of Different Substrates

Chlorinated solvents have proven amenable to the use of an electron donor substrate to enhance anaerobic biodegradation. However, degradation by-products may then require a different substrate for continued biodegradation. An example of this is the anaerobic biodegradation of TCE to vinyl chloride. After vinyl chloride accumulates, then a substrate specifically designed for microorganisms that degrade vinyl chloride (e.g., an oxygen donor) may be injected.

Recent work at PJKS failed to identify an in situ bioremediation technique for NDMA. However, numerous research studies are currently focused on in situ bioremediation of NDMA. NDMA biodegradation may occur more readily with a substrate that is currently undefined. Once that substrate is determined, it would be injected into the aquifer to target that specific compound.

6.1.4 Tracer Test

Tracers have proven to be successful in identifying the travel time and travel pathways for injected substrates. In source areas that have not been fully hydraulically investigated, tracers may be used prior to the injection of substrate as a way to optimize the injection schedule and location of injection wells and/or performance monitoring wells.

6.1.5 Recirculation of Groundwater

In order to increase the hydraulic gradient and thereby increase the groundwater velocity, groundwater may be extracted downgradient of the source area and re-injected at the source area. The collection and reinjection of treated groundwater back into the source area would accelerate treatment time by increasing the groundwater gradient as well as serve as a means to flush out any residual contaminant bound in unsaturated soil. A groundwater collection system would be installed downgradient of the source area to collect groundwater that had been treated by in situ bioremediation. The collected groundwater would be used as injection fluid at the source area. This will create an additional hydraulic head at the source area and increase the hydraulic gradient in the immediate area that can be controlled.

6.2 OPERATIONAL ENHANCEMENTS

Operational enhancements include an increased frequency of substrate injection into the aquifer. Currently, the proposed frequency for injection is on a semi-annual basis. Different source areas may require a more aggressive injection schedule than is currently proposed.

7.0 PJKS PREFERRED REMEDY INITIATIVE

The following section outlines the specific requirements for PJKS source area sites as they relate to the preferred remedy profile and the implementation of the plug-in evaluation.

7.1 PJKS PREFERRED REMEDY PROFILE

The preferred remedy profile describes the range of physical conditions that in situ bioremediation can address. As long as a groundwater source area has conditions that can fit the preferred remedy profile, then in situ bioremediation can be applied. If the source area has some conditions that fall outside of the remedy profile, either an enhancement will be required or in situ bioremediation will not be able to effectively address the source area.

The Bedrock Pilot Study performed at PJKS has produced a preferred remedy profile for which in situ bioremediation was successful. The PJKS preferred remedy profile for site conditions includes:

- Groundwater with persistent concentrations of COCs,
- Areas that are contributing to downgradient groundwater contamination, and
- Contaminants in exceedance of CBSGs.

7.2 PLUG-IN EVALUATION

For source areas that meet the preferred remedy profile, the interim corrective measure selected in this EE/CA can be applied via a plug-in evaluation. As source areas are formally evaluated and shown to meet the preferred remedy profile, a letter work plan will be submitted to CDPHE and EPA and will outline applicability and reference this EE/CA. A section of the work plan will present the plug-in evaluation and will quantify the criteria used to compare the existing source area profile to the preferred remedy profile.

8.0 RECOMMENDED REMEDIAL ACTION ALTERNATIVE

Alternative 2, In Situ Bioremediation, is a technically sound approach that could be applied to the site to treat the source areas of groundwater exhibiting contaminant concentrations that currently exceed CBSGs. This conclusion is based on the following facts:

- Alternative 2 has significantly reduced TCE in bedrock groundwater as demonstrated by the Bedrock Pilot Study;
- This alternative has been successfully applied to other contaminated groundwater sites across the country and has proven to have long-term effectiveness; and
- This alternative could be implemented using basic field techniques.

Alternative 2 has a degree of performance uncertainty associated with it. Although site conditions and the Bedrock Pilot Study indicate that in situ bioremediation would operate effectively, the actual degradation rate cannot be determined conclusively. Therefore, it is possible that after the initial 2-year injection timeframe, additional sodium lactate injections would be required to complete the source area depletion.

Once implemented, re-injection or enhancement costs (if required), groundwater monitoring costs, and O&M reporting would be the only long-term investment required.

9.0 REFERENCES

Parsons Engineering Science, Inc. (Parsons). 1998. *Installation Restoration Program (IRP) Supplemental Remedial Investigation Report for Air Force Plant PJKS, Colorado. Volumes II and V*. Prepared for U.S. Air Force Aeronautical Systems Center, Wright-Patterson Air Force Base, Ohio. September 1998.

Parsons Engineering Science, Inc. (Parsons). 1999a. *Installation Restoration Program (IRP) Supplemental Remedial Investigation Report for Air Force Plant PJKS, Colorado. Volume IV*. Prepared for U.S. Air Force Aeronautical Systems Center, Wright-Patterson Air Force Base, Ohio. March 1999.

Parsons Engineering Science, Inc. (Parsons). 1999b. *Installation Restoration Program (IRP) Supplemental Remedial Investigation Report for Air Force Plant PJKS, Colorado. Volumes I and VIII*. Prepared for U.S. Air Force Aeronautical Systems Center, Wright-Patterson Air Force Base, Ohio. April 1999.

Parsons Engineering Science, Inc. (Parsons). 1999c. *Installation Restoration Program (IRP) Supplemental Remedial Investigation Report for Air Force Plant PJKS, Colorado. Volume XIV*. Prepared for U.S. Air Force Aeronautical Systems Center, Wright-Patterson Air Force Base, Ohio. May 1999.

Shaw Environmental, Inc. (Shaw). 2003a. *Supplemental Remedial Investigation Addendum, Operable Unit 5 – Brush Creek Groundwater Plume, Former Air Force Plant PJKS, Waterton Canyon*, Colorado. Revision 2. Prepared for the U.S. Army Corps of Engineers, Omaha District. July 1, 2003.

Shaw Environmental, Inc. (Shaw). 2003b. *Pilot Study Work Plan, Brush Creek/Lariat Gulch Groundwater Plumes, Former Air Force Plant PJKS, Waterton Canyon, Colorado*. Revision 3. Prepared for the U.S. Army Corps of Engineers, Omaha District. September 2, 2003.

Shaw Environmental, Inc. (Shaw). 2005. *Draft Screening Ecological Risk Assessment for Avian Receptors.* Revision 0. Prepared for the Air Force Center for Environmental Excellence. February 9, 2005.

State of Colorado. 1998. *Compliance Order on Consent in the Matter of Air Force Plant PJKS Site, Number 98-10-08-01*. Effective December 29, 1998.

Stone & Webster, Inc. 2001. *Supplemental Remedial Investigation Addendum 1, OU4 – Lariat Gulch Groundwater Plume, Former Air Force Plant PJKS, Waterton Canyon, Colorado*. Revision 1. Prepared for the U.S. Army Corps of Engineers, Omaha District. May 24, 2001.

Stone & Webster, Inc. 2002. *Interim Groundwater Monitoring Plan, Former Air Force Plant PJKS, Waterton Canyon, Colorado*. Revision 2. Prepared for the U.S. Army Corps of Engineers, Omaha District. September 13, 2002.

U.S. Environmental Protection Agency (EPA). 1988. *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA.* Office of Solid Waste and Emergency Response. OSWER Directive 9335.3-01. Interim Final. October 1988.

U.S. Environmental Protection Agency (EPA). 1993. *Guidance on Conducting Non-Time-Critical Removal Actions under CERCLA.* Office of Solid Waste and Emergency Response, OSWER Directive 9360.0-32. EPA 540/F-94/009. December 1993.

U.S. Environmental Protection Agency (EPA). 2001. *Use of Bioremediation at Superfund Sites*. Office of Solid Waste and Emergency Response. EPA 540-R-01-019. September 2001.

TABLES

TABLE 1
POTENTIAL CHEMICAL-SPECIFIC ARARS, CRITERIA, ADVISORIES, AND GUIDANCE

STANDARD, REQUIREMENT, CRITERIA, OR LIMITATION	CITATION	STATUS	DESCRIPTION
FEDERAL			
SAFE DRINKING WATER ACT			
National Primary Drinking Water Regulations	40 CFR 141, Subparts B and G	Relevant and Appropriate	Establishes health-based standards in the form of maximum contaminant levels for the public water systems for constituents (i.e. volatile organic compounds [VOCs]).
RESOURCE CONSERVATION AND RECOVERY ACT			
Alternate Concentration Limits	OSWER 9481.00 6C	To Be Considered	Allows for alternate groundwater concentration limits based on risk screen for human health exposure in lieu of using maximum concentration levels.
STATE OF COLORADO			
COLORADO DEPARTMENT OF PUBLIC HEALTH AND ENVIRONMENT			
Colorado Basic Standard for Groundwater	5 CCR 1002-41	Applicable	Establishes statewide health-based standards for waters of the state including NDMA. State standards that are more stringent than federal standards are considered applicable.
Colorado Primary Drinking Water Regulations	5 CCR 1003-1	Relevant and Appropriate	Establishes drinking water standards that apply to specific contaminants and have been determined to have an adverse effect on human health.
Colorado Hazardous Waste Regulations	6 CCR 1007-3, Part 261	Relevant and Appropriate	Identifies and lists hazardous wastes (i.e. VOCs and NDMA).

Notes:
CCR = Colorado Code of Regulations CFR = Code of Federal Regulations NDMA = *N*-nitrosodimethylamine
OSWER = Office of Solid Waste and Emergency Response VOC = volatile organic compound

TABLE 2
POTENTIAL ACTION-SPECIFIC ARARS, CRITERIA, ADVISORIES, AND GUIDANCE

STANDARD, REQUIREMENT, CRITERIA, OR LIMITATION	CITATION	STATUS	DESCRIPTION
FEDERAL			
RESOURCE CONSERVATION AND RECOVERY ACT			
Corrective Action	RCRA 3004(h)	Relevant and Appropriate	Outlines requirements for corrective action requirements for release of hazardous constituents including facility investigations, corrective measure studies, and remedial actions.
SAFE DRINKING WATER ACT			
Underground Injection Control	40 CFR Parts 9, 144, 145, 146	Relevant and Appropriate	Outlines requirements for the injection of fluids for aquifer remediation into the groundwater via injection wells.
STATE OF COLORADO			
COLORADO DEPARTMENT OF PUBLIC HEALTH AND ENVIRONMENT			
Colorado Hazardous Waste Regulations	6 CCR 1007-3, Part 265, Subpart F	To Be Considered	Provides requirements for groundwater monitoring program for solid waste management units that specifies sample collection and sampling frequency.

Notes:
CCR = Colorado Code of Regulations CFR = Code of Federal Regulations RCRA = Resource Conservation and Recovery Act

TABLE 3
GENERIC OPERATIONS AND MAINTENANCE COST ESTIMATE FOR IN SITU BIOREMEDIATION

Number of Wells for Quarterly Monitoring	Sodium Lactate Injection Frequency per Year	Capital Costs		Contingency (15%)	First Year Costs	O&M Semi-annual Monitoring Cost/Year (Years 3-5)	O&M Annual Monitoring Cost/Year (Years 6-15)	5-Year Review	Present Worth (7% Discount Factor)
		Direct	Indirect						
1 injection well, one source area									
6	2	$ 16,682	$ 45,488	$ 9,326	$ 71,496	$ 29,390	$ 19,700	$ 10,000	$ 333,000
6	4	$ 18,795	$ 45,488	$ 9,642	$ 73,925	$ 29,390	$ 19,700	$ 10,000	$ 338,000
6	8	$ 20,908	$ 45,488	$ 9,959	$ 76,355	$ 29,390	$ 19,700	$ 10,000	$ 342,000
12	2	$ 31,502	$ 59,888	$ 13,709	$ 105,099	$ 36,890	$ 23,450	$ 10,000	$ 436,000
12	4	$ 33,615	$ 59,888	$ 14,025	$ 107,528	$ 36,890	$ 23,450	$ 10,000	$ 441,000
12	8	$ 35,728	$ 59,888	$ 14,342	$ 109,958	$ 36,890	$ 23,450	$ 10,000	$ 446,000
2 injection wells same source area									
6	2	$ 16,712	$ 46,388	$ 9,465	$ 72,565	$ 29,390	$ 19,700	$ 10,000	$ 335,000
3 injection wells same source area									
6	2	$ 16,742	$ 47,288	$ 9,605	$ 73,635	$ 29,390	$ 19,700	$ 10,000	$ 337,000

TABLE 4
ALTERNATIVE IDENTIFICATION AND SCREENING

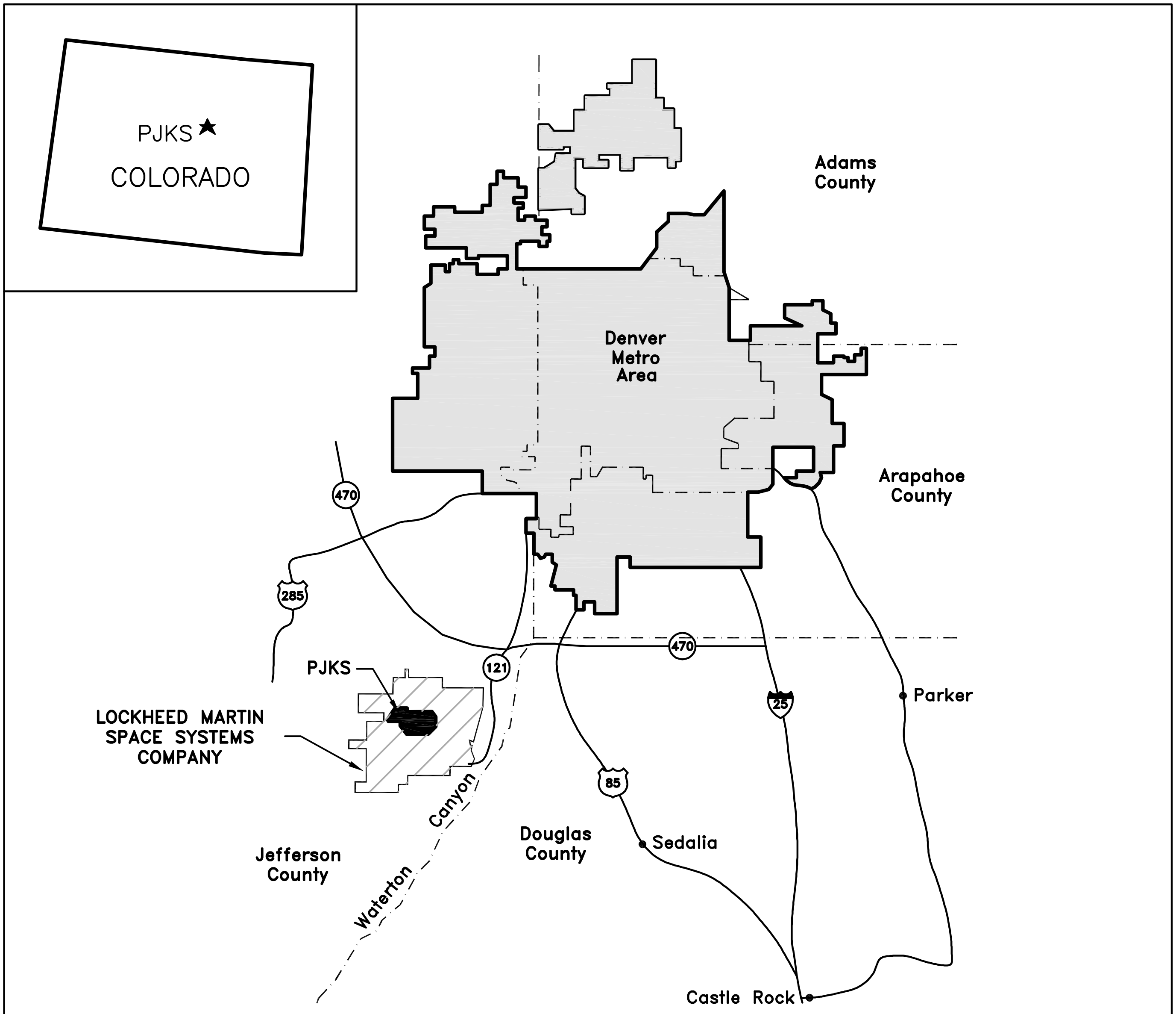
GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTIONS	DESCRIPTION
No Action	None	None	None
In Situ Bioremediation	Substrate Injection (i.e. Sodium Lactate)	Contaminants degraded by biological means when substrate is injected into groundwater.	Inject sodium lactate into single injection well semiannually for a minimum of 2 years. Sample groundwater quarterly for 2 years, semiannually for 3 years, and annually for 10 years to measure success and effectiveness of injection. Perform long-term monitoring.

TABLE 5
COMPARATIVE ANALYSIS SUMMARY

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	LONG-TERM EFFECTIVENESS	SHORT-TERM EFFECTIVENESS	REDUCTION IN TOXICITY, MOBILITY, OR VOLUMES OF WASTES	IMPLEMENTABILITY	COST (Total Present Worth)
No Action	None	No risk reduction or management. Long-term effectiveness or permanent remedy not provided. Is not protective of the environment.	Does not achieve preliminary objectives. Does not reduce risk to environment or community. No direct risk to site workers.	Does not provide active treatment measures to reduce toxicity, mobility, or volume of contaminated groundwater.	Not applicable.	$60,000
In Situ Bioremediation	Substrate Injection (i.e. Sodium Lactate)	This alternative mitigates risks posed by groundwater. This alternative is non-reversible for treated groundwater. Long-term monitoring is required. Additional injection may be required if degradation process is incomplete.	Achieves objectives in a timely manner. Protective of human health and environment. No direct risk to site workers using proper PPE during implementation. Time to achieve significant source area reduction is estimated to be 2 years.	Achieves reduction of toxicity and volume of contaminated groundwater by converting chlorinated solvents to a non-toxic by-product (ethene). Does not reduce mobility of untreated groundwater.	Implemented using non-traditional injection methods. Long-term monitoring is required. Re-injection of substrate is possible if contaminant concentrations increase over time.	$333,000

Notes:
PPE = personal protective equipment

FIGURES



LEGEND

- Former Air Force Plant PJKS
- Lockheed Martin Space Systems Company
- Denver Metro Area
- County Line

U.S. ARMY CORPS OF ENGINEERS
OMAHA DISTRICT

FORMER AIR FORCE PLANT PJKS

FIGURE NUMBER 1

PJKS LOCATION MAP

Shaw™ Environmental, Inc.

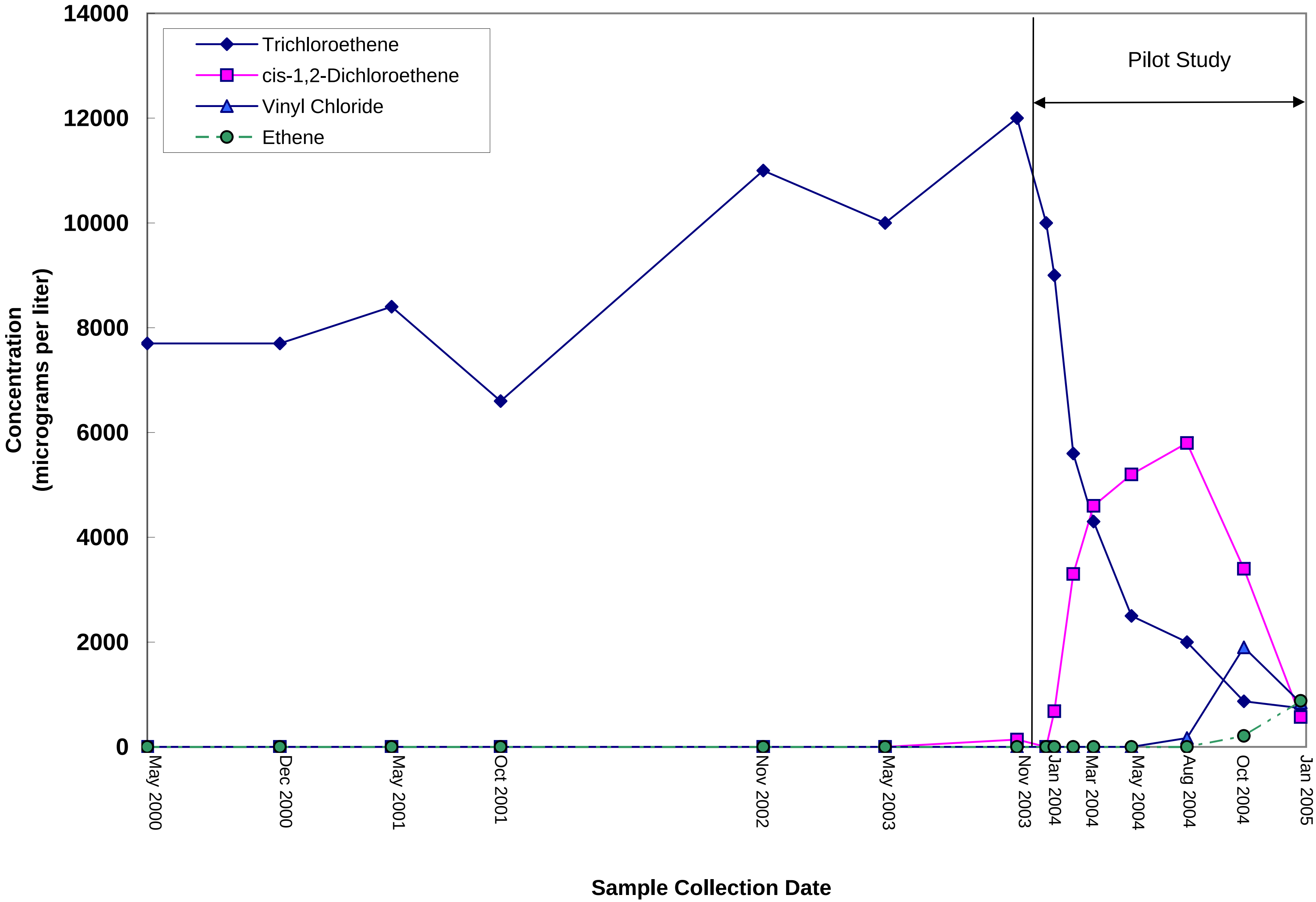
PROJECT NO.	REV.	FILE NAME
843883.0312	0	843883H070

REVISION	DESCRIPTION	CHKD	APPR	DATE
0	ISSUED TO AGENCIES	LWG	PSM	07/13/05

	BY	DATE		BY	DATE		BY	DATE		BY	DATE
DSGN	LWG	06/07/05	DRAWN	MEC	06/07/05	CHKD	LWG	06/14/05	APPR	PSM	06/14/05

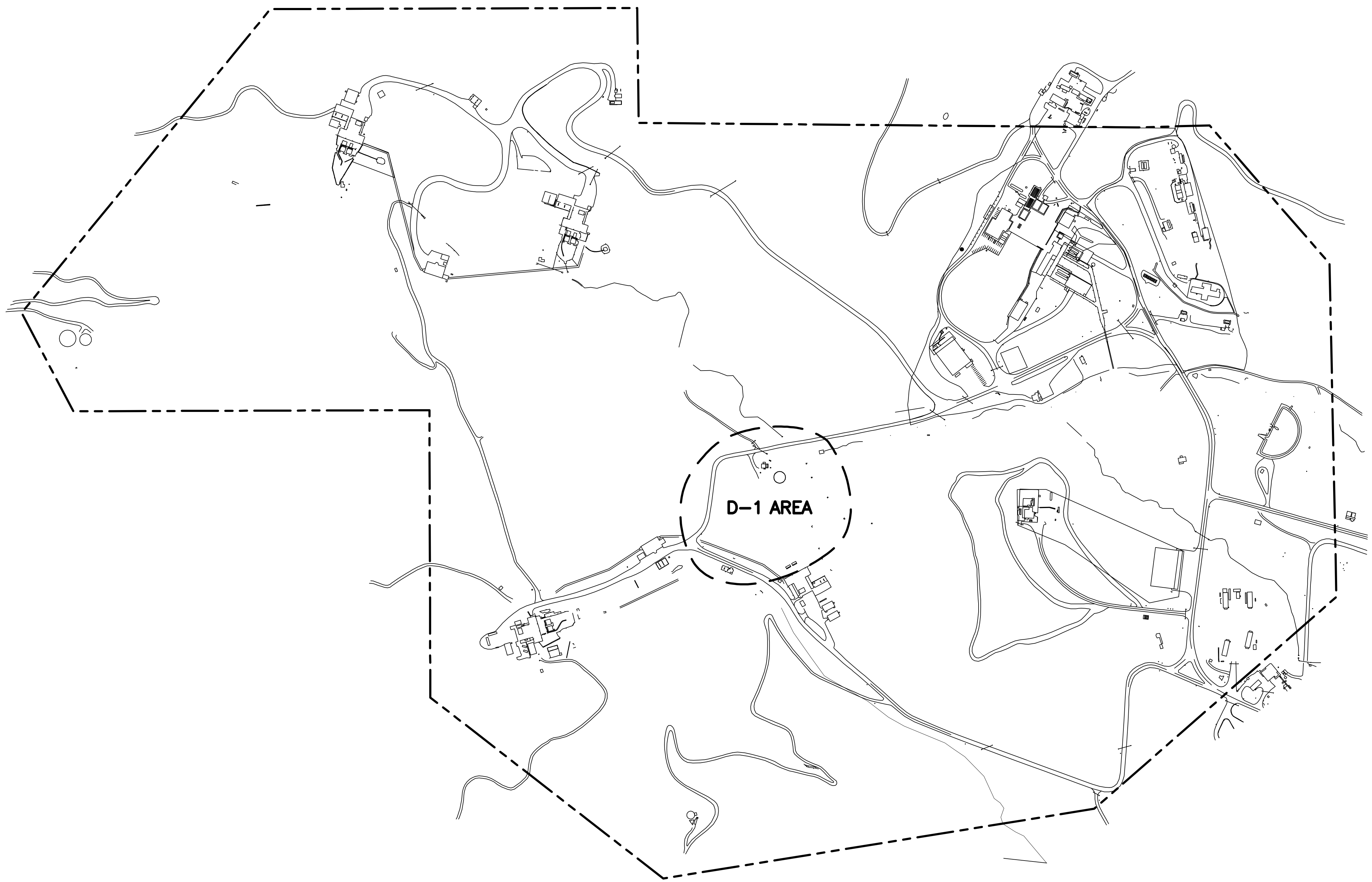
WED, SEP 21, 2005 01:08 P MEC O:\PJKS\843883\H-0312\REV-0\843883H070.DWG

Figure 2
In Situ Bioremediation Results
Well 5-M07



LEGEND

PJKS BOUNDARY



0 300 600

SCALE: 1" = 600'

0	ISSUED TO AGENCIES	SBC	PSM	07/13/05
REVISION	DESCRIPTION	CHECKED	APPROVED	DATE

U.S. ARMY
CORPS OF ENGINEERS
OMAHA DISTRICT

FORMER AIR FORCE PLANT PJKS

FIGURE NUMBER 3

D–1 PILOT STUDY AREA

Shaw™ Environmental, Inc.

	BY	DATE		BY	DATE	PROJECT NO.	REV.	FILE NAME
DSND	LWG	06/07/03	CHKD	LWG	06/14/05	843883.0312	0	843883H060
DRAWN	MEC	06/07/05	APPR	PSM	06/14/05			

WED, SEP 21, 2005 01:03 P MEC O:\PJKS\843883\H-0312\REV-0\843883H060.DWG

APPENDIX A

COST ESTIMATES FOR ALTERNATIVES 1 AND 2

TABLE A-1
ALTERNATIVE 1
NO ACTION
ANNUAL COST SUMMARY

Task	Totals
Direct Capital Costs:	
No Direct Capital Costs	
Total Direct Capital Costs	**$0**
Indirect Capital Costs:	
Establishment of Worker Monitoring Program	$19,000
Total Indirect Capital Costs	**$19,000**
Total Engineering & Construction Costs Contingency	$19,000 $2,850
Total Capital Costs	**$21,850**
O&M Costs (15-year):	
5-Year Review (every 5 years) Annual Post-Closure Care	$10,000 $2,420
TOTAL PRESENT WORTH (from Table A-2 with 7% discount factor)	**$60,000**

Notes:
O&M = operations and maintenance

TABLE A-2
ALTERNATIVE 1
NO ACTION
COST BREAKDOWN DETAILS

Task	Unit	Quantity	Unit Cost	Subtotals	Totals
Direct Capital Costs:					
No Direct Capital Costs					
Indirect Capital Costs:					
Establishment of Worker Monitoring Program	lump sum	1	$19,000	$19,000	
Total Indirect Capital Costs					**$19,000**
Total Engineering & Construction Costs (Direct Capital Costs + Indirect Capital Costs)					$19,000
Contingency (Approximately 15% of Total Indirect & Direct E&C Costs)					$2,850
Total Capital Costs					**$21,850**
O&M Costs (15-year):					
Post-Closure Care					
Environmental Fees	year	1	$1,000	$1,000	
Site Inspection/Reporting	year	1	$1,200	$1,200	
Yearly Subtotal				$2,200	
Contingency Costs (10%)			$220		
				Post-Closure Care Costs (15-year)	**$2,420**
Future Costs (15 years)					
Cost for each 5-Year Site Review	site	1	$10,000	$10,000	
				Future Costs	**$10,000**
Total Present Worth of Alternative (includes 7% discount factor)					**$60,000**

TABLE A-2
ALTERNATIVE 1
NO ACTION
COST BREAKDOWN DETAILS

PRESENT WORTH ANALYSIS					
Year	**Capital Costs**	**Total Annual Expenditure**	**Periodic Costs**	**Discount Factor (7%)**	**Present Worth**
1	$21,850	$21,850	$0	1.0000	$21,850
2		$2,420	$0	0.9346	$2,262
3		$2,420	$0	0.8734	$2,114
4		$2,420	$0	0.8163	$1,975
5		$2,420	$10,000	0.7629	$9,475
6		$2,420	$0	0.7130	$1,725
7		$2,420	$0	0.6663	$1,612
8		$2,420	$0	0.6227	$1,507
9		$2,420	$0	0.5820	$1,408
10		$2,420	$10,000	0.5439	$6,755
11		$2,420	$0	0.5083	$1,230
12		$2,420	$0	0.4751	$1,150
13		$2,420	$0	0.4440	$1,074
14		$2,420	$0	0.4150	$1,004
15		$2,420	$10,000	0.3878	$4,816
TOTAL PRESENT WORTH					**$60,000**

Notes:
O&M = operations and maintenance

TABLE A-3
ALTERNATIVE 2
IN SITU BIOREMEDIATION
ANNUAL COST SUMMARY

Task	Totals
Direct Capital Costs:	
Injection	$177
Sampling - Analytical Services	$16,505
Total Direct Capital Costs	$16,682
Indirect Capital Costs:	
Labor - Mob/Demob	$2,800
Labor - Injection	$1,800
Labor - Groundwater Sampling Collection	$21,600
Labor - Data Validation	$9,408
Labor - Annual Report	$9,880
Total Indirect Capital Costs	$45,488
Total Engineering & Construction Costs	$62,170
Contingency	$9,326
Total Capital Costs for injection/sampling	**$71,496**
O&M Costs:	
Post-Injection Care Years 3-5	$29,390
Post-Injection Care Years 6-15	$19,700
TOTAL PRESENT WORTH (from Table A-4 with 7% discount factor)	**$333,000**

Notes:
O&M = operations and maintenance

TABLE A-4
ALTERNATIVE 2
IN SITU BIOREMEDIATION
COST BREAKDOWN DETAILS

Task	Unit	Quantity	Unit Cost	Subtotals	Totals	Comments
Direct Capital Costs:						
Injection						
Mob/Demob						
Shaw Field Trucks Rental	day	2	$40	$80		1 truck, 1 day per semiannual injection event
Fuel for Vehicles	day	2	$32	$64		1 truck, 1 day per semiannual injection event
		Mob/Demob Subtotal		$144		
Supplies/Materials						
Sodium Lactate	gallon	30	$1	$30		Semiannual injection, approx. 13 gal. per injection
Fertilizer additive (Restore 375®)	pounds	3	$1	$3		10:1 fertilizer to sodium lactate
	Supplies/Materials Subtotal			$33		
			Injection Subtotal		$177	
Sampling						
Mob/Demob						
Shaw Field Trucks Rental	week	4	$120	$480		1 truck, 1 week per quarterly sampling event
Fuel for Vehicles	week	4	$32	$128		1 truck, 1 week per quarterly event
		Mob/Demob Subtotal		$608		
Supplies/Materials						
Water Quality Meter	day	12	$25	$300		1 meter, 3 days per quarterly event - YSI®
Calibration Solution	lump sum	1	$427	$427		pH, ORP, conductivity, turbidity standards
Bailers	case	2	$205	$410		12 bailers per case
Bailer Cord	roll	2	$40	$80		
Photoionization Detector	day	12	$16	$192		1 PID, 3 days per quarterly event - 11.7 eV
PPE/Field Supplies	lump sum	1	$240	$240		Storage bags, ice, cal gas, nitrile gloves
Drinking Water	week	4	$15	$60		
DI Water for Decon and Sampling	cases	8	$9	$72		6 gal/case
Misc. Equipment	lump sum	1	$500	$500		VOC tips, paper towels, ziplocs, incidentals, etc.
	Supplies/Materials Subtotal			$2,281		
Analytical						
VOCs (8260)	each	32	$100	$3,200		6 groundwater wells, QC samples, quarterly monitoring
NDMA (8070A)	each	28	$150	$4,200		
RSK 175 (Ethane, Ethene, Methane)	each	28	$91	$2,548		
Metabolic Acids	each	28	$131	$3,668		
		Analytical Subtotal		$13,616		
			Sampling Subtotal		$16,505	
Total Direct Capital Costs					**$16,682**	

TABLE A-4
ALTERNATIVE 2
IN SITU BIOREMEDIATION
COST BREAKDOWN DETAILS

Task	Unit	Quantity	Unit Cost	Subtotals	Totals	Comments
Indirect Capital Costs:						
Labor - Mob/Demob	days	4	$700	$2,800		
Labor - Injection	days	2	$900	$1,800		Semiannual, 2-person team, 1/2 day per injection
Labor - Groundwater Sampling	days	12	$1,800	$21,600		Quarterly, 2-person team, 3 days per event
Labor - Data Validation	event	4	$2,352	$9,408		
Labor - Annual Report	lump sum	1	$9,880	$9,880		
Total Indirect Capital Costs for injection/sampling					**$45,488**	Assumes 1 year of injection/sampling cycle
Total Engineering & Construction Costs (Direct Capital Costs + Indirect Capital Costs)					$62,170	
Contingency (Approximately 15% of Total Indirect & Direct E&C Costs)					$9,326	
Total Annual Capital Costs for injection/sampling					**$71,496**	

TABLE A-4
ALTERNATIVE 2
IN SITU BIOREMEDIATION
COST BREAKDOWN DETAILS

Task	Unit	Quantity	Unit Cost	Subtotals	Totals	Comments
O&M Costs:						
Post-Injection Care Years 3-5						
Environmental Fees	year	1	$1,000	$1,000		
Long-term GM	event	2	$5,400	$10,800		Semiannual monitoring, 3 days, 2-person team
Laboratory Analysis	sample	14	$487	$6,818		7 samples (6 wells, 1 QC sample) per semiannual event for Years 3-5
Data Validation/Reporting	report	1	$6,900	$6,900		
Site Inspection/Reporting	year	1	$1,200	$1,200		
Yearly Subtotal				$26,718		
Contingency Costs (10%)			$2,672			
				Post-Injection Care Years 3-5	**$29,390**	
Post-Injection Care Years 6-15						
Environmental Fees	year	1	$1,000	$1,000		
Long-term GM	event	1	$5,400	$5,400		Annual monitoring, 3 days, 2-person team
Laboratory Analysis	sample	7	$487	$3,409		7 samples (6 wells, 1 QC sample) per annual event for Years 6 - 15
Data Validation/Reporting	report	1	$6,900	$6,900		
Site Inspection/Reporting	year	1	$1,200	$1,200		
Yearly Subtotal				$17,909		
Contingency Costs (10%)			$1,791			
				Post-Injection Care Years 6-15	**$19,700**	
Future Costs (15 years)						
Cost for each 5-Year Site Review	site	1	$10,000	$10,000		
				Future Costs	**$10,000**	
Total Present Worth of Alternative (includes 7% discount factor)					**$333,000**	

TABLE A-4
ALTERNATIVE 2
IN SITU BIOREMEDIATION
COST BREAKDOWN DETAILS

PRESENT WORTH ANALYSIS					
Year	**Capital Costs**	**Total Annual Expenditure**	**Periodic Costs**	**Discount Factor (7%)**	**Present Worth**
1	$71,496	$0	$0	1.0000	$71,496
2	$71,496	$0	$0	0.9346	$66,820
3		$29,390	$0	0.8734	$25,669
4		$29,390	$0	0.8163	$23,991
5		$29,390	$10,000	0.7629	$30,050
6		$19,700	$0	0.7130	$14,046
7		$19,700	$0	0.6663	$13,126
8		$19,700	$0	0.6227	$12,267
9		$19,700	$0	0.5820	$11,465
10		$19,700	$10,000	0.5439	$16,154
11		$19,700	$0	0.5083	$10,013
12		$19,700	$0	0.4751	$9,359
13		$19,700	$0	0.4440	$8,747
14		$19,700	$0	0.4150	$8,175
15		$19,700	$10,000	0.3878	$11,518
TOTAL PRESENT WORTH					**$333,000**

Notes:
DI = de-ionized water
eV = electrovolt
GM = groundwater monitoring
NDMA = n-nitrosodimethylamine
O&M = operations and maintenance
ORP = oxygen reduction potential
PID = photoionization detector
PPE = personal protective equipment
QC = quality control
RTK = real-time kinematic
VOC = volatile organic compound

APPENDIX B

SODIUM LACTATE INFORMATION

WILCLEAR™
Sodium Lactate
For Bioremediation Applications

Description

JRW Technologies' WILCLEAR™ Sodium Lactate for bioremediation is a clear, slightly viscous liquid that is 60% solids by weight in USP purified water. WILCLEAR™ Sodium Lactate provides the lowest metals content, as measured by a nationally recognized analytical laboratory, of any sodium lactate available and exceeds US Pharmacopoeia standards. It is the only sodium lactate that meets all primary MCL's (maximum contaminant levels) for drinking water in a 60% form, thus minimizing concern for underground injection.

Specifications

	Specification	Typical
Sodium Lactate, % by wt.	60 ± 1.2	60 ± 0.5
H_2O	40 ± 1.2	40 ± 0.5
pH	7.0 ± 0.5	6.8 - 7.2
Color, APHA	25 max.	10
Iron, ppm	2 max	<5
Specific Gravity	1.3100-1.3400	
Citrate, Oxalate, Phosphate, Tartrate	none detected	
Sulfate	none detected	
Sugars	none detected	
Sodium, %	12.3 ± 0.2	
Odor	Practically odorless	

Applications

WILCLEAR™ Sodium Lactate is used to enhance the microbial activity in situ for biodegradation and reduction of chlorinated solvents. Technical support for bioremediation applications is provided through an exclusive agreement with SRP Technologies, developers of Bioavailability Enhancement Technology (B.E.T.™), patent pending).

Packaging

55 gallon (600 lbs. Net) Polyethylene Drums; 2.850 lb IBC's

Storage

Store unopened under dry conditions at ambient temperatures.