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Mr. Corey Lam, Environmental Restoration Manager
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1801 10th Street
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Dayton, Ohio 45433-7626

Re: RA Completion Report and PCOR, Former Air
Force Plant PJKS, Waterton Canyon, Colorado

Dear Mr. Lam:

Thank you for submitting the Remedial Action Completion Report and Preliminary Close-Out Report for SWMU1 (SS034), SWMU2 (SS021), and SWMU3 (SS022), Former Air Force Plant PJKS, Waterton Canyon, Colorado, dated December 6, 2013. The document serves two purposes:

- Remedial Action Report for the ground water solid waste management units to confirm all construction is completed and the remedy is operational and functional for those units.
- Preliminary Close-Out Report to confirm Air Force completion of all physical construction throughout the site necessary to complete the CERCLA response action.

Based on the EPA's review, the submitted document contains the appropriate information and detail. The EPA concurs with the document as final.

With the last remedy in place, the EPA considers the former Air Force Plant PJKS as "construction complete." Remedial response activity that remains under the Record of Decision is operation and maintenance as well as five-year reviews, to assess and maintain protectiveness of the remedy.

The EPA appreciates the cooperation and effort provided by the Air Force in reaching this milestone. The overall site team, including the Air Force, CDPHE, the EPA and associated contractors, commendably worked through difficult technical and administrative issues to get to this point.

Please contact David Rathke at (303) 312-6016 or rathke.david@epa.gov with questions or comments.

Sincerely,

Martin Hestmark
Assistant Regional Administrator
Office of Ecosystems Protection and Remediation

cc: David Rathke, EPA Region 8
Rob Stites, EPA Region 8
David Walker, CDPHE





The Air Force Center for Engineering and the Environment

**2261 Hughes Avenue, Suite 155
Lackland AFB, Texas 78236-9853
Contract FA8903-08-D-8780, Task Order 0053**

**Remedial Action Completion Report and
Preliminary Close-Out Report
for SMWU 1 (SS034), SWMU 2 (SS021), and
SWMU 3 (SS022)
(CDRL A001B)**

**Former Air Force Plant PJKS
Waterton Canyon, Colorado**

Revision 0

6 December 2013


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**REMEDIAL ACTION COMPLETION REPORT
(CDRL A001B)
AND
PRELIMINARY CLOSEOUT REPORT

FORMER AIR FORCE PLANT PJKS
WATERTON CANYON, COLORADO**

REVISION 0



Prepared for:

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ABBREVIATIONS AND ACRONYMS

µg/L	micrograms per liter
AFCEE	Air Force Center for Engineering and the Environment
ARAR	Applicable or Relevant and Appropriate Requirements
ARD	anaerobic reductive dechlorination
BCMW	Brush Creek Monitoring Well
CAD	Corrective Action Decision
CBSG	CDPHE Basic Standards for Groundwater
CDPHE	Colorado Department of Public Health and the Environment
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CERCLIS	Comprehensive Environmental Response, Compensation and Liability Information System
COC	contaminant of concern
CSI	combined soils additional investigation
CSSA	Central Support Storage Area
cy	cubic yard
D-1	D-1 Landfill Area
DCE	dichloroethane
DHC	dehalococcoides
EE/CA	Engineering Evaluation/Cost Analysis
EEO	Emulsified Edible Oil
EPA	U.S. Environmental Protection Agency
EPL	Engineering Propulsion Laboratory
FSA	Fuel Storage Area
IC	Institutional Control
ICM	Interim Corrective Measures
IRP	Installation Restoration Program
Lockheed Martin	Lockheed Martin Space Systems Company
LUC	Land Use Control
MCS	media cleanup standards
NDMA	N-nitrosodimethylamine
Order of Consent	Compliance Order on Consent, No 98-10-08-01
OTL	Ordnance Testing Laboratory
OU	operable unit
Parsons	Parsons Engineering Science, Inc.
PCB	polychlorinated biphenyls
PJKS	former U.S. Air Force Plant PJKS
RACR	Remedial Action Completion Report
RAO	Remedial Action Objective
RCRA	Resource Conservation and Recovery Act
RI/FS	Remedial Investigation/Feasibility Study
ROD	Record of Decision
SCA	Systems and Components Area
Shaw	Shaw Environmental, Inc.
SRI	Supplemental Remedial Investigation

ABBREVIATIONS AND ACRONYMS (cont'd)

SRO	soil remediation objective
SWMU	solid waste management unit
T-8A	T-8A Pumphouse
TI	technical impracticability
USAF	U.S. Air Force
VC	vinyl chloride
VOC	volatile organic compound

1.0 INTRODUCTION / BACKGROUND

The purpose of this document is to summarize the remedial actions and construction activities that have taken place at the former U.S. Air Force (USAF) Plant PJKS (PJKS), U.S. Environmental Protection Agency (EPA) Site Identification Number CO7570090038, in accordance with the *Compliance Order on Consent in the Matter of the Air Force Plant PJKS Site* (Order of Consent) Number 98-10-08-01 (State of Colorado, 1998), signed on December 29, 1998. This Remedial Action Completion Report (RACR) serves the dual purpose of a Remedial Action Report for the final operable unit (OU), which addresses groundwater and serves as a Preliminary Closeout Report (PCOR) to document site construction completion and what activities remain to final closeout.

PJKS is located near Waterton Canyon in Jefferson County, Colorado (**Figure 1**). The former plant, which encompasses 464 acres, is situated in the foothills of the Colorado Front Range, and located approximately 15 miles south-southwest of downtown Denver. As a government-owned, contractor-operated facility, PJKS was operated by Lockheed Martin Space Systems Company (Lockheed Martin) primarily to support the development and assembly of Titan rockets. The USAF owned the PJKS property until February 2001, when ownership was transferred to Lockheed Martin, the long-time facility operator. The former plant is completely surrounded by Lockheed Martin's 4,700-acre facility. The PJKS facility was used from 1957 to 1968 as the main test facility for Titan rocket activities, including rocket assembly, engine testing, and research and development. Fuel development, purification, and testing also occurred on site. Smaller engines and related apparatus have been tested since 1968. Groundwater contamination at PJKS resulted from activities associated with the development of rocket launch equipment, engine testing, and/or fuels development, purification, and testing.

The United States Air Force is the lead agency for response actions at the site. The former Air Force Plant PJKS was proposed for listing on the National Priorities List (NPL) in the Federal Register on July 6, 1989 (Volume 54, Number 134, Pages 29820-29825). Listing on the NPL was finalized in the November 21, 1989 Federal Register (Volume 54, Number 223, Pages 48184-48189). In 1998, the USAF entered into an agreement with the Colorado Department of Public Health and the Environment (CDPHE) and Hazardous Materials and Waste Management Division through the Order on Consent (State of Colorado, 1998). PJKS was managed under a Resource Conservation and Recovery Act (RCRA) Section 3006 Order, which addresses most of the requirements of a Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Section 120 Federal Facilities Agreement. All state and federal regulations applicable to PJKS, including CERCLA, Defense Environmental Restoration Program, RCRA, National Oil and Hazardous Substance Pollution Contingency Plan, and Colorado Hazardous Waste Act, were merged in this agreement. Because response/corrective measures at PJKS must

comply with the applicable requirements of the multiple programs and legislation listed above; each with its own set of unique terms, for clarity, this report will use either RCRA or CERCLA terminology, where appropriate.

Investigation and response actions have been conducted on 56 solid waste management units (SWMUs) identified in the RCRA assessments. PJKS was divided into four OUs (OUs 1-3 and OU 6) that include all 53 soil SWMUs and two OUs (OUs 4 and 5) that contain the three groundwater SWMUs. Those SWMUs were grouped into six OUs for tracking in the Comprehensive Environmental Response, Compensation and Liability Information System (CERCLIS) database. The SWMUs are identified on **Table 1** of the Final Record of Decision (ROD) dated May 2013.

1.1 REMEDIAL ACTION OBJECTIVES

PJKS is currently an operating industrial use facility with future land use expected to remain industrial. The overall site management strategy has been to investigate and remediate the SWMUs through interim measures pursuant to the Order on Consent to prevent or minimize disruption to continuing operations. The current owner of the PJKS property, Lockheed Martin, has agreed to the industrial use cleanup level for the site (included in the quit claim deed) and has requested that CDPHE issue a Restrictive Notice on the PJKS property (PJKS Restrictive Notice or restrictive notice) and the adjacent portion of Lockheed Martin's property pursuant to Section 25-15-321.5 of the Colorado Revised Statutes (Colorado Environmental Covenant Act). This includes impacted groundwater leaving PJKS property per the March 9, 2010 signed memorandum of agreement on the property (Lockheed Martin, 2010). For ease of implementation, the PJKS Restrictive Notice will specify that all of the property that comprises PJKS will only be used for industrial purposes until unlimited use/unrestricted exposure levels are met. The restrictive notice is expected to be issued by the end of December 2013.

Remedial Action Objectives (RAOs) for soil were based on CDPHE's Tier 2 Soil Remediation Objectives (SROs) (CDPHE, 2003), and were established specifically for PJKS using guidance from the *Proposed Soil Remediation Objectives Policy Document* (State of Colorado, 1997). The Tier 2 SROs are human health risk-based concentrations applied to possible land uses, which for PJKS are unrestricted at some sites and industrial at others. The Tier 2 Soil-to-Groundwater values also were calculated to ensure the CDPHE Basic Standards for Groundwater (CBSG) were not exceeded as a result of any residual soil contamination. The Tier 2 SROs are comparable to or more stringent than EPA-established soil screening levels for protection of human health or groundwater. Based on the current and foreseeable land uses at PJKS, the Tier 2 SROs were selected as the cleanup criteria for PJKS (See **Table 1** below). The RAOs for soil SWMUs are:

- Excavation and proper off-site disposal of contaminated soils where practicable. Most of these areas have been excavated to meet residential standards.
- Prevent exposure to soils above industrial standards through engineering and/or institutional controls.

TABLE 1
RAOs FOR SOILS WHERE REMAINING CONTAMINATION EXISTS

Contaminants of Concern	Remedial Action Objectives (mg/kg)
Total PCBs	0.62
PCB-1016	0.62
PCB-1254	0.62
PCB-1260	0.62

Notes:
mg/kg = milligram per kilogram
PCB = polychlorinated biphenyl
RAO = remedial action objective

RAOs are based on CDPHE's Tier 2 SROs for an industrial scenario (State of Colorado, 1997) established for PJKS.

For groundwater remediation, Alternative 2, in situ bioaugmentation, was selected as the preferred alternative, combined with the PJKS Restrictive Notice that restricts groundwater use to protect human health and the environment. This decision is reflected in the ROD completed in May 2013.

Preliminary RAOs were established for the entire groundwater medium at PJKS at a meeting among USAF, EPA, and CDPHE on December 7, 2005. Additional refinement of the RAOs and methods for demonstrating when RAOs have been achieved were presented in letters provided by CDPHE and EPA on January 25, 2006 and February 8, 2006. The data necessary to prepare the groundwater medium RAOs were available from the numerous investigations, risk analyses, and treatability studies that have been completed or are in progress. The USAF, EPA, and CDPHE recognize that it is not always possible to remediate all COCs in groundwater to achieve unlimited use/unrestricted exposure levels. Because of geological variability, the RAOs for the PJKS site were divided by the type of aquifer. The source areas were located on exposed bedrock for rocket engine testing. Contaminants migrated laterally from these areas into an alluvial aquifer. A technical impracticability waiver is recorded in the Record of Decision for NDMA in the crystalline bedrock due to geological and technological limitations, although the volatile organic compounds in the bedrock are expected to meet MCLs. Restoration to beneficial use is a general remedial action objective for the alluvial aquifer.

The groundwater COCs and associated CBSG are listed below in **Table 2**. Except for n-nitrosodimethylamine (NDMA), the CBSG standards are equivalent to federal MCLs. There is no federal MCL for NDMA but is promulgated by the state of Colorado in the CBSGs. The USAF, EPA, and CDPHE, with community agreement, developed the following PJKS-specific RAOs for PJKS groundwater:

- Reduce the concentration of trichloroethene (TCE) contaminated groundwater in the down gradient portion of the source areas at the transition points (where bedrock groundwater transitions to the alluvial system).
- Reduce the concentrations of TCE in bedrock groundwater source areas to concentrations that achieve CBSG for groundwater (see **Table 2** below).
- Protect human health by preventing contact with, and ingestion of, TCE or N-nitrosodimethylamine (NDMA)-contaminated groundwater until unlimited use/unrestricted exposure levels are achieved.
- Contain TCE and NDMA in the alluvium through the continued monitoring of the plume stability until the groundwater is remediated to beneficial use. The remedy will be re-evaluated during 5-Year Reviews. The 5-Year Review is a statutory review.
- Utilize a technical impracticability (TI) waiver for restoring NDMA within bedrock groundwater in a reasonable timeframe. Protectiveness in this zone will rely on Land Use Controls (LUCs) and monitoring.

TABLE 2
RAOs FOR GROUNDWATER

COC	CBSG (µg/L)
TCE	5
cis-1,2-DCE	70
trans-1,2-DCE	100
VC	2
1,1-DCE	5
NDMA	0.05

Notes:

CBSG = Colorado Basic Standards for Groundwater
CDPHE = Colorado Department of Public Health and Environment
DCE = dichloroethene
µg/L = micrograms per liter
NDMA = N-nitrosodimethylamine

PQL = practical quantitation limit
RAO = remedial action objective
TCE = trichloroethene
VC = vinyl chloride
RAOs are based on the CBSG (CDPHE, 2009)

The Colorado State Standard for NDMA is 0.00069 µg/L. Colorado regulations state that if a standard is below the PQL of the approved analytical method, the PQL is the enforcement standard. The PQL for the currently approved method is 0.05 µg/L.

1.2 REMEDIAL DESIGN

The overall site management strategy for PJKS is for continued industrial use and operations; therefore, the implementation of the selected remedies are consistent with the planned use of the site. The selected site remedies for the 53 soil sites fall into three categories: 1) Unrestricted Closure, 2) Restricted Closure with LUCs, and 3) Restricted Closure with LUCs and Limited Covers, respectively. The limited covers for soil sites requiring a barrier between workers and contaminated soil have all been constructed and have achieved regulator and community agreement under public comment on the various reports associated with the Interim Corrective Measures (ICMs) or Interim Remedial Actions. Therefore, no additional active remedial actions are required at these sites. The reports for these actions can be found in the Administrative Record. CDPHE restrictive notice LUC is expected to be issued by the end of December 2013 when the restrictive notice is recorded on the deed to the property.

All of the infrastructure necessary to implement the selected final remedy for groundwater SWMUs has already been constructed and is fully operational at PJKS (Figure 2). No additional components, modifications, or extra infrastructure will be required to implement the selected final remedy for groundwater. Numerous investigations and treatability studies have been completed at the groundwater SWMUs between 1986 and 2007. Collectively, the infrastructure from these efforts provide for full scale operation of the remedy. The results of these reports were used to determine the location of seven groundwater contaminant source areas, the lateral extent of the groundwater contaminant plumes, the effectiveness of in situ bioremediation on TCE and NDMA, and to evaluate the need and approach for ICM activities.

To evaluate the effectiveness of in situ ARD of TCE and NDMA in bedrock source areas, the Bedrock Pilot Study was conducted in three locations at PJKS: D-1 Landfill Area (D-1), Engineering Propulsion Laboratory (EPL), and Systems and Components Area (SCA). The groundwater in these areas is contaminated with either TCE or a combination of TCE and NDMA. The Supplemental Pilot Study fieldwork activities at the EPL Area were initiated on August 22, 2005. The *Focused Engineering Evaluation/Cost Analysis (EE/CA), Groundwater Plumes, Interim Corrective Measure*, (Shaw Environmental, Inc. [Shaw], 2005), was prepared using the results of the Bedrock Pilot Study and Supplemental Pilot Study. The ICMs were implemented in 2006.

The analytical groundwater results of the initial pilot study and the supplemental pilot study showing a decrease in TCE contamination initiated the expansion of an ICM in 2006, to further stimulate anaerobic reductive dechlorination (ARD) in the D-1 area groundwater plume. As part of the ICM, four injection/monitoring wells were constructed at the D-1 area for in situ bioremediation, which was the selected EE/CA remedy (Shaw, 2005). These four Brush Creek Monitoring Wells (BCMWs), BCMW-018-P through BCMW-021-P, were constructed in the

Precambrian bedrock at depths ranging from 62.0 to 64.0 feet below ground surface. Groundwater samples were collected from the initial two wells, BCMW-018-P and BCMW-019-P, and analyzed for volatile organic compounds (VOCs). TCE concentration results were used to determine if the wells were appropriately located in relationship to the known source area(s) and to confirm placement of additional wells. The high TCE results of 2,600 and 5,300 micrograms per liter ($\mu\text{g/L}$) for BCMW-018-P and BCMW-019-P, respectively, indicated that these two wells were located within the 5-M07 Monitoring Well treatment zone/source area.

The overall objectives of the D-1 Area Groundwater Plume ICM activities were to significantly reduce the source of TCE concentrations in the Precambrian bedrock groundwater using enhanced in situ anaerobic biodegradation and to establish a groundwater performance monitoring program to assess the effectiveness of the biodegradation processes.

Three tasks were completed during the D-1 Area ICM that achieved the overall objectives. Those tasks were:

1. Installing two wells (with a contingency of installing two additional wells) downgradient of the D-1 Landfill and collecting groundwater samples to establish baseline conditions;
2. Injecting sodium lactate into the D-1 Area Precambrian bedrock aquifer; and
3. Collecting groundwater samples to determine the effectiveness of the sodium lactate injection treatment for contaminant biodegradation.

Lithologic and preliminary groundwater data, showing high concentration of TCE contamination, indicate that the four wells constructed in the D-1 area are screened in the appropriate (Precambrian) aquifer and have adequate geochemistry for enhanced reductive dechlorination of TCE.

The analytical groundwater results of the initial pilot study and the supplemental pilot study showing a decrease in TCE contamination, initiated the expansion of an ICM in 2006 to further simulate ARD in the groundwater source areas. The ICM in these areas is a continuation and expansion at EPL and SCA, and new work at D-4 and the Central Support Storage Area (CSSA).

Ten horizontal directional injection wells were constructed in the Fountain Formation bedrock at the EPL and SCA. Four of these wells were constructed in the source area of EPL to target source area contamination as well as contamination downgradient in Lariat Gulch. Two horizontal wells were installed at SCA North, and four at SCA South. These wells target source area contamination as well as contamination downgradient in East Fork Brush Creek. Twelve vertical injection wells were constructed at CSSA, D-1 Tributary, EPL, Ordnance Testing Laboratory (OTL), and T-8A Pumphouse (T-8A). Eight vertical monitoring wells were

constructed at EPL and SCA. Additionally, two biobarriers were constructed in the unconsolidated overburden in the West and East Forks of Brush Creek near the PJKS boundary.

The horizontal and vertical injection wells were used to deliver sodium lactate, emulsified edible oil (EEO), nutrients, and dehalococoides (DHC) to the Fountain Formation aquifer. Groundwater quality parameters were also collected to monitor the movement of the injected substrate through the aquifer. The groundwater parameters included water levels, dissolved oxygen, oxygen reduction potential, pH, temperature, and conductivity. Upon completion of the ICM construction activities quarterly performance monitoring began in select wells to evaluate the performance of the ICMs in the groundwater source areas.

Groundwater samples are collected during the quarterly groundwater performance monitoring events from the newer wells and existing monitoring wells to survey the effects of the injections and biobarriers. Injections of the EEO substrate are ongoing and the Quarterly Technical Memorandum Report includes quarterly performance monitoring groundwater data, EEO injection locations, and injection amounts for the groundwater source areas.

The two biobarriers were constructed between April 23 and June 20, 2008, one originating from the SCA along a 300 foot linear alignment perpendicular to the East Fork of Brush Creek near the PJKS boundary, the other originating from the OTL/T-8A along a 150 foot linear alignment perpendicular to the West Fork of Brush Creek near the PJKS boundary. These two areas were selected to target the alluvial transition groundwater areas. The two biobarriers were constructed to provide a barrier to plume migration and to and further deplete TCE contamination in the plume extending downgradient from the PJKS property. The biobarriers were constructed by injecting a mixture of EEO, sodium lactate solution, and DHC into direct-push boreholes.

1.3 TECHNICAL IMPRACTICABILITY WAIVER

Under the provisions defined in CERCLA §121(d)(4)(C) and RCRA Sections 264.525(d)(2) and 264.531 of the Proposed Subpart S rule, in the event that an Applicable or Relevant and Appropriate Requirements (ARAR) or media cleanup standards (MCS) cannot be achieved, based on limiting site characteristics or engineering impracticability, one or more ARARs may be waived (EPA, 1993). A TI evaluation was completed for PJKS for NDMA in bedrock groundwater. The USAF submitted the “Technical Impracticability Waiver Report for Former USAF Plant PJKS” (Shaw, 2011) in October 2011. EPA and CDPHE agreed with USAF’s analysis that neither in situ bioremediation nor any other groundwater treatment technology was a technically practicable remedy for NDMA in PJKS bedrock groundwater. NDMA remedies have been actively studied at the PJKS site for the past seven years. To date, there is not a viable or economically feasible technology that is readily available to treat NDMA in groundwater in the bedrock aquifers at PJKS. In summary, the main reasons are: 1) numerous bench and pilot studies failed to identify an in situ treatment option, 2) fracturing in the bedrock provides a

complex hydrogeological environment to treat residual source areas, and 3) low permeability in the bedrock formations further impede any ex situ (pump and treat) remedies within a reasonable timeframe. Although groundwater contamination has migrated onto Lockheed Martin property, data presented in the most recent groundwater report has documented plume stability and possible slight plume contraction.

To date, human health is protected from NDMA-contaminated groundwater based on the current industrial land use of the PJKS property. Furthermore, the PJKS Restrictive Notice will be applied to the entire PJKS footprint that will exist in perpetuity and will be monitored by CDPHE. A long-term groundwater quality monitoring program will be implemented at PJKS. The primary purpose of the groundwater monitoring program will be to provide data to evaluate the progress of the in situ bioremediation treatment of TCE at the site. A selected number of essential wells will be monitored periodically in order to identify potential changes in NDMA concentrations and/or extent of NDMA plumes over time.

The actual progress of the in situ bioremediation treatment program for TCE will be subject to five-year review cycles. Each five-year review cycle will assess the overall performance of the PJKS groundwater treatment and monitoring system by specifically evaluating all changes in site hydrogeologic and contaminant conditions that have occurred over the review period. This will include the evaluation of changes in NDMA concentrations in groundwater, and/or changes in the size or shape of the NDMA plumes, and recommendations regarding changes that may be required to enhance the monitoring program.

The long-term monitoring plan will also incorporate a specific requirement to evaluate the availability of new, enhanced technology for the treatment of NDMA as part of the five-year review cycle. The report of results of the five-year review will include a specific statement that "no new proven NDMA treatment technologies have been identified", or a specific recommendation regarding newly identified NDMA treatment technologies that could be incorporated into the PJKS groundwater remedy.

1.4 NOTICES OF ENVIRONMENTAL USE RESTRICTIONS

The PJKS Notice of Environmental Use Restrictions (PKS Restrictive Notice) will be implemented at PJKS to restrict future land use to industrial use only, and to maintain the integrity of limited covers and select SWMUs. The restrictive notice for these sites will remain in effect until a ROD addendum or other documentation is prepared based on the intent to change land use. The current owner of the PJKS property, Lockheed Martin, has agreed to the industrial use cleanup level for the site (included in the quit claim deed) and has committed to allowing CDPHE to place a restrictive notice, pursuant to Section 25-15-321.5 of the Colorado Revised Statutes (the Colorado Environment Covenant Act), on the property. The PKS Restrictive Notice will specify that all of the property that comprises the PKS site will only be used for

industrial purposes. The three groundwater SWMUs require the restrictive notice to restrict groundwater use. However, Lockheed Martin has determined that a non-residential land use restriction will be applied to the entire property that encompasses the PJKS site for ease of implementation of the PJKS Restrictive Notice. The non-residential use restrictions are specified below in **Table 3**.

Performance objectives for the restrictive notice being implemented as an integral part of the final remedy at PJKS are to restrict current and future land use to industrial use and to ensure long-term viability of the final remedy. Because the restrictive notice will be placed on the entire property, the following performance objectives apply to all of PJKS groundwater:

- Place the PJKS Restrictive Notice on the property to limit PJKS to industrial use only.
- Protect human health by reducing rates of exposure to contaminated groundwater.
- Ensure that no wells are installed on the property or that the groundwater is in no other manner accessed or removed.
- Ensure that land use restrictions are maintained until the contaminants are reduced to levels that allow high-occupancy land use and the restrictive notice is no longer needed, or until the restrictive is no longer needed because site conditions have changed.
- Ensure that all future site users and environmental regulators are aware that contamination is present at the site at concentrations that may pose a risk under certain exposure scenarios.
- Ensure that all future site users and environmental regulators are aware that land use restrictions are imposed on the site to protect human health and the environment.
- Ensure that relevant records are maintained in the facility planning records and land use databases.

**TABLE 3
NON-RESIDENTIAL LAND USE RESTRICTIONS**

SWMU	COC Concentration	Limited Cover Required?	Area of Cover	Restrictions
13, 15, 16, 17, 19, 20, 21, 22, 24, 25, 33, and 34	SROs < COCs < RAOs	No	NA	Property will only be used for industrial purposes. Workers performing excavation or soil disturbing activities will have to be appropriately trained and wear the proper personal protective equipment.

				Groundwater in the area is restricted from use as drinking water.
8	RAOs < PCBs	Yes	T-8A Surface Impoundment Basin	Property will only be used for industrial purposes.
12	RAOs < PCBs	Yes	Valve Area 1; near Building T-5A	Workers performing excavation or soil disturbing activities will have to be appropriately trained and wear the proper personal protective equipment.
29	RAOs < PCBs	Yes	SCA Areas 4 and 5; near Buildings T-27 and T-28A	
31	RAOs < PCBs	Yes	Area near Building T-23	Groundwater in the area is restricted from use as drinking water. The integrity and ongoing effectiveness of the limited cover be maintained and checked annually.
CSA-3	RAOs < PCBs	Yes	>25 feet of backfill soil cover near former D-1 Landfill footprint	

Notes:

COC = contaminant of concern
CSA-3 = Contaminated Soil Area 3
NA = not applicable
PCB = polychlorinated biphenyl

RAO = remedial action objective
SCA = Systems and Components Area
SRO = Soil Remediation Objective
SWMU = solid waste management unit

1.5 OPERATIONS & MAINTENANCE AND MONITORING

The *Operations and Maintenance Plan, CSA-3, T8A Surface Impoundment, Combined Soils Units SWMUs 12, 29, 31* (Shaw, 2010a) and the *Operations and Maintenance/Long-term Monitoring Plan for SMWU 1 (SS034), SWMU 2 (SS021), and SWMU 3 (SS022), (CDRL A001C)* (Shaw, 2013) will be incorporated into the PJKS Restrictive Notice by reference and citation. The PJKS Restrictive Notice will refer to the latest version of the plans that must be followed. The USAF will pay for implementation of the PJKS Restrictive Notice and is ultimately responsible for complying with the Restrictive Notice requirements. However, the USAF has contracted with Lockheed Martin to implement the PJKS Restrictive Notice on behalf of the USAF. Under contract to USAF, Lockheed Martin will conduct maintenance of the covers and conduct the annual inspection of the PJKS site to ensure that the PJKS Restrictive Notice restrictions are being complied with and any problems are resolved.

Monitoring of the environmental use restrictions and controls will be conducted annually by the USAF. The monitoring results will be included in a separate report or as a section of another environmental report, if appropriate, and provided to the EPA and CDPHE. The annual monitoring report, submitted to the regulatory agencies by the USAF, will evaluate the status of the institutional controls (ICs) and how any IC deficiencies or inconsistent uses have been addressed. The annual evaluation will address whether the owners and state and local agencies were notified of the use restrictions and controls affecting the property, and whether use of the

property has conformed to such restrictions and controls. The annual monitoring reports will be used in preparation of the five-year review to evaluate the effectiveness of the remedy.

Because this remedy will result in hazardous substances, pollutants, or contaminants remaining on-site above level that allow for unlimited use and unrestricted exposure, a statutory review will be conducted within five years after initiation of remedial action to insure that the remedy is, or will be, protective of human health and the environment. The groundwater SWMUs and TI zone will be subject to five-year reviews until CBSGs are met. The soil SWMUs, which impose restricted use, will also be addressed in the five-year review.

The implementation of the Operations and Maintenance/Long-term Monitoring Plan will monitor the effectiveness of the ongoing in situ biodegradation process that was selected as the remedy for PJKS groundwater. Field tasks include taking water level measurements, monitoring well purging, groundwater sample collection, quality control sample procedures, and equipment decontamination. Based on evaluation of existing data from the Annual Groundwater and quarterly ICM monitoring events, the initial Long-term Monitoring Plan will consist of 45 monitoring wells that will be sampled on a semi-annual basis. The analytes of interest are VOCs, and NDMA. A select number of wells will also be analyzed for Dissolved Gases, Common Ions, and Total Organic Carbon, in addition to the VOCs and NDMA. Once operations of the in situ bioremediation injection systems have ceased, only VOCs and NDMA will be analyzed as part of the monitoring program.

The data evaluation process will lead to one of three conclusions regarding the effectiveness of the groundwater remedy for each of the seven PJKS groundwater source areas and the D-1 Tributary where treatment is occurring. These are:

- Conditions are appropriate for continued reduction of contaminants via biodegradation, if groundwater contaminant levels appear to be decreasing and continued monitoring is appropriate,
- Conditions indicate that additional injections of treatment chemicals, and/or bioaugmentation culture are required to return conditions to those considered optimum to continued biodegradation of contaminants, or
- Conditions indicate that treatment endpoint criteria have been met for one or more source area(s) wells, and it is appropriate to cease active injections and begin a rebound study, or formally end treatment.

The groundwater monitoring data will also be used to evaluate the effectiveness of the two alluvium “biobarriers” constructed to actively treat contaminants near the PJKS boundary in the East and West Forks of Brush Creek. The construction of the biobarriers involved the direct injection of the treatment chemicals into the groundwater matrix using direct push technology.

The biobarriers are intended to create a treatment zone that will remain in place for a long time without maintenance. While the biobarriers can be rejuvenated, the USAF and regulators have determined that the decision of whether or not to rejuvenate the biobarriers will be evaluated during the course of the first five-year review period.

1.6 PRE-FINAL INSPECTIONS

The various treatability studies resulted in sufficient injection and monitoring wells in place to conduct the remedy. As such, there is no complete post-ROD single remedial design package. The designs and specifications for the wells and injection rates were accepted by EPA and CDPHE in the context of those studies.

2.0 SUMMARY OF SITE CONDITIONS

The soil SWMU remedies implemented pursuant to the Order of Consent are consistent with the site management approach and the industrial long-term use of the site. The overall site management strategy has been to expedite the investigation and remediation of those soils and groundwater SWMUs known or suspected of having the highest risk to human health or the environment. The use of Interim Actions/Interim Corrective Measures allowed the high priority areas to be quickly addressed without having to delay remediation until a final remedy for the entire site was proposed and approved via a ROD.

PJKS was divided into four OUs (OUs 1-3 and OU 6) that include all 53 soil SWMUs and two OUs (OUs 4 and 5) that contain the three groundwater SWMUs. The SWMUs were assigned to one of the six OUs based on similarity of function, waste, or site characteristics. For example, OU1 consists of all of soil SWMUs within the Systems and Components Area where actual rocket fuel was used during tests to determine if various rocket components functioned properly. OU5, the Brush Creek Groundwater Plume, is divided into SWMUs 1 and 2 because the groundwater in the OU can flow into one of two different surface water drainages, which flow in different directions.

The soil SWMUs where concentrations of soil COCs were present on the ground surface at concentrations higher than worker protection levels were dealt with immediately via excavation and off-site disposal or engineered covers. Primarily, the selection of asphalt or concrete covers as interim measures for soil SWMUs was made to prevent or minimize disruption to continuing operations and/or structural integrity of buildings. Each interim action/interim corrective measure was planned and implemented with the explicit intent of having the interim measure fulfill the requirement of a remedial action for that SWMU. RAOs for soil SWMUs are: (1) where practical, restore soil at the site to unlimited use/unrestricted exposure via excavation, and proper off-site disposal of contaminated soil; or (2) prevent exposure to contaminants through engineering controls (covers), and/or LUCs where PCBs would remain in place. Each proposed interim measure was thoroughly described during RAB meetings, and questions and comments were solicited using a public participation process consistent with both CERCLA and RCRA Corrective Action requirements. The soil RAOs are being met by the interim actions/interim corrective measures that have been previously implemented. Because the ROD included the requirement for additional LUCs, Limited Action is the remedy selected for soils in the ROD.

The remedies proposed in the ROD for the groundwater OUs represent the final response action for the site. The impacted groundwater in each of the PJKS groundwater SWMUs is classified as “Domestic Use Quality” by the State of Colorado and has a federal classification of “Class II.A”. Based on data from the Fall 2011 groundwater monitoring event, the excess cancer risk for a

hypothetical person consuming PJKS groundwater at the maximum concentrations for NDMA and TCE may present a risk greater than the acceptable range in CERCLA, which is from one in one million to one in ten thousand. However, the actual current risks due to groundwater contamination are negligible because there are no pathways for exposure. Exposure is expected to be minimal in this industrial setting. PJKS impacted groundwater is not currently used as a private or public water supply and future use as a water supply will be prohibited via the PJKS Restrictive Notice. As noted above, concentrations of TCE and NDMA in the plumes are greater than state and federal drinking water standards, so a future risk may exist with a change in land use or groundwater use. No principal threat wastes, such as light non-aqueous phase liquids or dense non-aqueous phase liquids, were identified on this site.

Because of the complex geology and mixture of contaminants, there have been numerous phases of investigation and treatability studies or interim measures (interim actions) to ascertain groundwater conditions and evaluate treatment technologies. The results of these studies influenced the corrective measures/feasibility studies in that the studies could focus on the most promising technologies. In addition, these studies demonstrated that there was no practicable technology to meet CBSG in the bedrock aquifer for NDMA, thus a waiver for this particular ARAR was invoked in the ROD.

The interim actions performed at the groundwater SWMUs typically began as pilot tests of a particular remedial technology. If the results of the pilot testing showed that a remedial technology was promising, the pilot test was expanded to an interim measure for a larger area. This process allowed proven technologies for treatment of groundwater COCs to be quickly designed and installed.

The PJKS Restrictive Notice will be implemented at PJKS to restrict future land use to industrial use only and to maintain the integrity of limited covers and select SWMUs. The restrictive notice for these sites will remain in effect until a ROD addendum or other documentation is prepared based on the intent to change land use. The objectives of the PJKS Restrictive Notice are presented below. The current owner of the PJKS property, Lockheed Martin, has agreed to the industrial use cleanup level for the site (included in the quit claim deed) and has committed to allowing CDPHE to place a restrictive notice, pursuant to Section 25-15-320 of the Colorado Revised Statutes (the Colorado Environment Covenant Act), on the property. The PJKS Restrictive Notice will specify that all of the property that comprises the PJKS site will only be used for industrial purposes. CDPHE anticipates the restrictive notice will be in place by the end of December 2013. The objectives for the restrictions are specified below. The three groundwater SWMUs require the PJKS Restrictive Notice to restrict groundwater use. However, Lockheed Martin has determined that a non-residential land use restriction will be applied to the entire property that encompasses the PJKS site for ease of implementation of the restrictive notice.

Performance objectives for the PJKS Restrictive Notice being implemented as an integral part of the final remedy at PJKS are to restrict current and future land use to industrial use and to ensure long-term viability of the final remedy. Because PJKS Restrictive Notice will be placed on the entire property, the following performance objectives apply to all of PJKS groundwater:

- Place a restrictive notice on the property to limit PJKS to industrial use only.
- Protect human health by reducing rates of exposure to contaminated groundwater.
- Ensure that no wells are installed on the property or that the groundwater is in no other manner accessed or removed.
- Ensure that land use restrictions are maintained until the contaminants are reduced to levels that allow high-occupancy land use and the restrictive notice is no longer needed, or until the restrictive notice is no longer needed because site conditions have changed.
- Ensure that all future site users and environmental regulators are aware that contamination is present at the site at concentrations that may pose a risk under certain exposure scenarios.
- Ensure that all future site users and environmental regulators are aware that land use restrictions are imposed on the site to protect human health and the environment.
- Ensure that relevant records are maintained in the facility planning records and land use databases.

3.0 CHRONOLOGY OF EVENTS AND CONSTRUCTION ACTIVITIES

The soil SWMUs were addressed by containment and capping or the SWMUs were excavated and “clean closed” and verified with confirmation sampling. Section 1.2 above provides a chronological summary of the groundwater investigations and ICMs installed at the site. The infrastructure from the field scale studies is considered to be a complete design and the in situ parameters have been optimized and the optimized injection rates and contents constitute the remedial action work plan. **Table 4** below provides a chronology of events and construction activities at PJKS.

Table 4
Chronology of Events and Construction Activities

Activity Initiated (Report Issue Date)	Action/Report Title	Primary Focus	Applicable Solid Waste Management Units (SWMUs) included	Summary of Activity
1984 (JRB, 1984)	Installation Restoration program Phase I – Records Search, Final, Air Force Plant PJKS	Preliminary assessment of the PJKS facility.	SWMU 8, 9, 12, 13, 14, 29, 31, 42	In 1984, the Installation Restoration Program (IRP) preliminary assessment/records search for PJKS identified sites for further investigation.
1985 and 1986 (Parsons ES, 1986)	Installation Restoration Program, Phase II – Confirmation/Quantification (Stage I) for Air Force Plant PJKS	Determine the presence or absence of contamination at the sites identified during the Phase I.	SWMU 1, 8, 9, 12, 13, 14, 27, 29, 30, 31, 32, 42	An IRP Phase II, Stage 1 confirmation/quantification investigation was conducted in 1985 and 1986. The study confirmed the presence of contamination at the sites and identified specific requirements for additional work needed.
1987 and 1988 (Parsons ES, 1988 and 1989)	Installation Restoration Program, Phases II and IVA (Stage 2), Draft Final Remedial Investigation for Air Force Plant PJKS, and Installation Restoration Program, Phases II and IVA (Stage 2), Draft Final Supplemental Report for Air Force Plant PJKS	Determine the presence or absence of contamination at IRP sites.	SWMU 1, 2, 6, 7, 8, 9, 12, 13, 14, 25, 27, 29, 30, 31, 32, 33, 36, 41, 42, 43, 44, 45, 46, 49	This comprehensive IRP study, including additional Phase II work, was scoped as a remedial investigation/feasibility study (RI/FS) and work was conducted in 1987 and 1988. The study helped to determine the presence or absence of contamination at PJKS.
1992 (Parsons ES, 1996)	Supplemental Remedial Investigation/Feasibility Study Informal Technical Information Reports for Operable Units (OUs) 1, 4, and 6	Investigation of 3 OUs to fill data gaps identified during earlier studies.	SWMU 3, 4, 29, 30, 33, 36, 37, 38, 41	During the 1990s, a Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) RI/FS was conducted for 9 of the SWMUs at PJKS to fill data gaps identified during the earlier studies.
1993 (Parsons ES, 1995)	Supplemental Preliminary Assessment/Site Inspection, Areas of Concern 1, 2, 3, 4, 5, and 6	Investigation of 4 SWMUs to determine presence or absence of contamination.	SWMU 2, 14, 17, 34	A PA/SI was conducted for 6 Areas of Concern that are represented in 4 SWMUs at PJKS to identify presence or absence of contamination.

Activity Initiated (Report Issue Date)	Action/Report Title	Primary Focus	Applicable Solid Waste Management Units (SWMUs) included	Summary of Activity
1992 through 1996 (Parsons ES, 1998 and 1999)	Installation Restoration Program Supplemental Remedial Investigation Report for Air Force Plant PJKS	Remedial investigation of 37 IRP/SWMU sites in OUs 1 through 6.	SWMU 1 through 36, and 41	A comprehensive Supplemental RI (SRI) report was completed in May 1999. After reviewing the SRI Report, CDPHE identified 20 SWMUs that required additional soil characterization to address remaining data gaps.
1999 (Stone and Webster, 1999)	Engineering Evaluation/Cost Analysis, Operable Unit 5 – East Fork Brush Creek, Former Air Force Plant PJKS	Evaluate five potential remedies for TCE and N-Nitrosodimethylamine (NDMA) contamination in East Fork Brush Creek.	SWMU 1	The EE/CA was completed in October 1999 and evaluated five alternatives (No Action, Natural Attenuation with Institutional Controls, In Situ Zero-Valence Iron System, Remote Pump and Treat, and Onsite Pump and Treat) for remediation of TCE and NDMA in groundwater. The recommended alternative was In Situ Zero- Valence Iron System.
2000 (Stone and Webster, 2000)	Engineering Evaluation/Cost Analysis, Operable Unit 2 – Upper and Lower Volcano Areas, Former Air Force Plant PJKS	Evaluate four potential remedies for the Upper and Lower Volcano Areas.	SWMU 10 and 11	The EE/CA was completed in September 2000 and to evaluate four alternatives (No Action, Excavation and Offsite Disposal, Onsite Treatment of Soils by Thermal Desorption, and Onsite Treatment of Soils by Solvent Extraction) for remediation of soils. The selected remedy was Excavation and Offsite Disposal.
2000 and 2001 (Stone and Webster, 2001a)	Construction Completion Report, Early Action Phases I and II, Operable Unit 2 – Upper and Lower Volcano Areas, Former Air Force Plant PJKS	Document the early action activities completed for SWMU 10 and 11.	SWMU 10 and 11	In 2000 and 2001, an early action was performed at the Upper and Lower Volcano Areas. Phase I was completed in November 2000. Phase II was completed in March 2001. Approximately 2,351 cubic yards (cy) of polychlorinated biphenyls (PCB), pesticide, and metals-contaminated soils were removed from these areas. The construction complete report was completed in July 2001.
2001 (Stone and Webster, 2001b)	Addendum to the Construction Completion Report, Early Action Phase III, Operable Unit 2 – Lower Volcano Area, Former Air Force Plant PJKS	Document the early action activities completed for SWMU 10 and 11.	SWMU 10 and 11	In 2001, a continuation of the Phase I and II early action was performed at the Lower Volcano Area. Phase III was completed in August 2001. Approximately 2,308 cy of contaminated soils were removed from these areas. The construction complete report was completed in September 2001.
2002 (Stone and Webster, 2002)	Additional Investigation Report, OU4 – Lariat Gulch Groundwater Plume, Former Air Force Plant PJKS	Additional investigation of the Lariat Gulch Groundwater Plume.	SWMU 3	The additional investigation of SWMU 3, Lariat Gulch Groundwater Plume, was completed in May 2002, helped determine the groundwater contamination and also define nature and extent of soil contamination.

Activity Initiated (Report Issue Date)	Action/Report Title	Primary Focus	Applicable Solid Waste Management Units (SWMUs) included	Summary of Activity
2002 (Arcadis, 2002)	RCRA Facility Investigation Solid Waste Management Unit Group I	RFI to investigate SWMUs in Group I	SWMU 51 and 53	The investigations for the 2 SWMUs was completed in 2002 and determined nature and extent of soil contamination. NFA is warranted for the soils SWMUs.
2002 (Arcadis, 2003a)	RCRA Facility Investigation Solid Waste Management Unit Group H	RFI to investigate SWMUs in Group H	SWMU 42 and 47	The investigation for the 2 SWMUs was completed in 2002 and determined nature and extent of soil contamination. NFA is warranted for the soils SWMUs.
2003 (Shaw, 2003a)	Supplemental Remedial Investigation Addendum, OU5 – Brush Creek Groundwater Plume, Former Air Force Plant PJKS	Additional evaluation of the East Fork and West Fork Brush Creek Groundwater Plumes.	SWMU 1 and 2	The re-evaluation of remedial investigation results from SWMU 1 and 2, East Fork Brush Creek and West Fork Brush Creek Groundwater Plumes, completed in July 2003, helped determine the location of the groundwater contaminant source areas and the lateral extent of the groundwater contaminant plumes.
2003 (Arcadis, 2003b)	RCRA Facility Investigation Solid Waste Management Unit Group G	RFI to investigate SWMUs in Group G	SWMU 37 through 41	The investigation for the 5 SWMUs was completed in 2003 and determined nature and extent of soil contamination. NFA is warranted for the soils SWMUs.
2003 (Shaw, 2003b)	Evaluation of Alternatives, D-1 Landfill and T-31 Chemical Treatment Facility, Former Air Force Plant PJKS	Evaluate two potential remedies for the D-1 Landfill and the T-31 Chemical Treatment Facility.	SWMU 9 and 14	In September 2003, an Evaluation of Alternatives report was prepared to evaluate two potential remedies for the D-1 Landfill and the T-31 Chemical Treatment Facility. The two potential remedies (Excavation and Offsite Disposal and Installation of a Landfill Cover System) were determined to be technically feasible based on the additional investigation results. Based on the evaluation, Excavation and Offsite Disposal was selected as the most effective and preferred alternative.
2003 (Shaw, 2003c)	Additional Investigation Report, Systems and Components Areas, Former Air Force Plant PJKS	Present the results of field activities completed to collect data to address regulatory concerns.	SWMU 29, 30, and 36	The report was completed in December 2003 to document field activities for collection of data necessary to characterize and delineate soil contamination. The additional investigation also addressed the specific regulatory concerns provided in comments by CDPHE on the PJKS SRI Report.

Activity Initiated (Report Issue Date)	Action/Report Title	Primary Focus	Applicable Solid Waste Management Units (SWMUs) included	Summary of Activity
2002 (Shaw, 2003d)	Additional Investigation Report, D-1 Landfill and T-31 Chemical Treatment Facility, Former Air Force Plant PJKS	Additional investigation of the D-1 Landfill and T-31 Chemical Treatment Facilities to help determine the extent and quantity of waste.	SWMU 9 and 14	The additional investigations in the areas of the D-1 Landfill and T-31 Chemical Treatment Facilities was completed in 2002, identified wastes consisting primarily of paper, plastics, copper wire, food, wood, and some construction debris. During the utility repair activities, a small number of crushed drums were also found and removed.
2005 (Shaw, 2005b)	2004 Annual Groundwater Monitoring Report, Former Air Force Plant PJKS	Study the distribution and migration of TCE and NDMA in groundwater.	SWMU 1, 2, and 3	Groundwater sampling at PJKS has been conducted semi-annually since 2004 and is designed to refine the understanding of contaminant distribution in the groundwater systems to help select the appropriate remedy or remedies for groundwater treatment and to mitigate contaminant migration.
2003 through 2006 (Shaw, 2007c)	Summary and Evaluation Report, Brush Creek/Lariat Gulch Groundwater Plumes Pilot Study, Former Air Force Plant PJKS	Evaluate the effectiveness of anaerobic biodegradation of TCE and NDMA in Precambrian bedrock source areas.	SWMU 1, 2, and 3	The Pilot Study was implemented in 2004 and resulted in the chemical degradation of TCE in groundwater, including the production of all of the byproducts and the end-product, ethene. These results indicate that the source areas for groundwater are amenable to anaerobic bioremediation via in situ injection techniques. The Pilot Study evaluation of the NDMA anaerobic degradation did not show any evidence of a reduction in groundwater concentrations. Concentrations of NDMA in groundwater remained constant throughout the course of the Pilot Study. The report was completed in August 2007.
2003 through 2004 (Shaw, 2005c)	Combined Soils Additional Investigation Report, Combined Soils Units, Former Air Force Plant PJKS	Additional evaluation of 20 soil SWMU identified by CDPHE as requiring additional soil characterization to address remaining data gaps.	SWMU 12, 13, 15 through 26, 29, and 31 through 35	The Combined Soils Additional Investigation (CSI) Report was completed in August 2005. The study identified 13 soil SWMUs as not requiring any additional action and seven soil SWMUs (12, 13, 15, 17, 22, 29, and 31) as warranting ICMs because these SWMUs posed an unacceptable risk to human health from exposure to the soil medium.
2005 (Shaw, 2005d)	Interim Corrective Measures Study, Combined Soils Units, Former Air Force Plant PJKS	Evaluate alternatives for soil remediation in seven SWMUs identified in the CSI Report.	SWMU 12, 13, 15, 17, 22, 29, and 31	This study was completed in August 2005 to evaluate three alternatives (No Action, Limited Cover and Land Use Controls, and Limited Excavation and Offsite Disposal) for remediation of polycyclic aromatic hydrocarbon and PCBs in the seven soil SWMUs identified during the CSI Report. The selected ICM remedies included Limited Excavation, Offsite Disposal, and LUCs for four of the seven SWMUs. The selected ICM remedy for the remaining SWMUs included partial excavation with Limited Cover and LUCs.

Activity Initiated (Report Issue Date)	Action/Report Title	Primary Focus	Applicable Solid Waste Management Units (SWMUs) included	Summary of Activity
2005 (Shaw, 2005a)	Focused Engineering Evaluation/Cost Analysis, Groundwater Plumes, Interim Corrective Measure, Former Air Force Plant PJKS	Evaluation of alternatives for an ICM for remediation of TCE and NDMA in the groundwater plumes.	SWMU 1, 2 and 3	The focused EE/CA was completed in September 2005 and used a streamlining approach to implement the presumptive remedy at multiple locations at PJKS. The plug-in approach is a method of repetitively implementing a removal action for multiple groundwater source areas that are physically similar and have comparable contaminants. In situ bioremediation, in the form of ARD, coupled with bioaugmentation where warranted, was recommended as an ICM at the bedrock source areas; D-1, D-4, EPL, SCA, CSSA, OTL, and T-8A.
2005 (Shaw, 2005e)	Screening Ecological Risk Assessment for Avian Receptors, FS/CMS for Soils, Former Air Force Plant PJKS	Evaluate the risk to ecological receptors from contaminants of concern (COCs) at PJKS.	SWMU 1 through 3, 9, 12 through 26, 29, and 31 through 35	A screening ecological risk assessment for avian receptors was completed in October 2005 for the PJKS facility and concluded that adequate information exists to determine that the risk to avian receptors in soil/sediment is acceptable and does not warrant action.
2006 (Shaw, 2006a)	Action Memorandum, Groundwater Plumes, Interim Corrective Measure, Former Air Force Plant PJKS	Action Memorandum (AM) to document the recommendation of bioremediation as an ICM for PJKS groundwater.	SWMU 1, 2, and 3	In March 2008, an AM was prepared to document the proposed ICM activities at the groundwater source areas. Based on the results of the focused EE/CA, in situ biological treatment (or in-situ bioremediation) was proposed for implementation.
2006 (Shaw, 2006b)	2005 Annual Groundwater Report, Former Air Force Plant PJKS	Study the distribution and migration of TCE and NDMA in groundwater.	SWMU 1, 2, and 3	Annual groundwater sampling at the 3 SWMUs was conducted semi-annually to evaluate TCE and NDMA in groundwater.
2005 (Shaw, 2007a)	Interim Corrective Measures Remedial Construction Completion Report, Combined Soils Units, Former Air Force Plant PJKS	Document the ICM activities completed for SWMU 12, 13, 15, 17, 22, 29, and 31.	SWMU 12, 13, 15, 17, 22, 29, and 31	In 2005, 2,915 cy of contaminated soil was excavated from SWMUs 12, 13, 15, 17, 22, 29, and 31. Residual contamination was unable to be removed at SWMUs 12, 29, and 31. Four locations with limited covers were incorporated into an Operations and Maintenance Plan for restricted use. The construction complete report was completed in January 2007.
2006 (Shaw, 2007b)	Interim Corrective Measure, Construction Completion Technical Memorandum for CSA-1, CSA-2, and CSA-6 at D-1 Area, Former Air Force Plant PJKS	Document the limited ICM activities completed for SWMU 9 and 14.	SWMU 9 and 14	In 2006, a limited ICM was performed at contaminated soil areas (CSA)-1, CSA-2, and CSA-6. Approximately 420 cy of contaminated soils were removed from these areas. The construction complete report was completed in January 2007.

Activity Initiated (Report Issue Date)	Action/Report Title	Primary Focus	Applicable Solid Waste Management Units (SWMUs) included	Summary of Activity
2007 (Shaw 2007)	2006 Annual Groundwater Report, Former Air Force Plant PJKS	Study the distribution and migration of TCE and NDMA in groundwater.	SWMU 1, 2, and 3	Annual groundwater sampling at the 3 SWMUs was conducted semi-annually to evaluate TCE and NDMA in groundwater.
2006 (Shaw 2008)	Interim Corrective Measure, Remedial Construction Completion Report, D-1 Area Groundwater Plume, Former Air Force Plant PJKS	Summarize the ICM construction activities at the D-1 Area Groundwater Plume.	SWMU 1 and 2	The report was completed in January 2008 to document the ICM construction activities, which consisted of installing four groundwater injection/monitoring wells in the D-1 area in 2006. Additional work to be completed for the ICM, such as sodium lactate injections and groundwater sampling for performance monitoring is ongoing.
2006 (Shaw 2008)	Interim Corrective Measure, Remedial Construction Completion Report, D-4 Fuel Storage Area, Former Air Force Plant PJKS	Summarize the ICM well construction activities in the D-4 Fuel Storage Area (FSA).	SWMU 1 and 3	The report was completed in January 2008 to document the ICM well construction activities, which consisted of installing nine groundwater injection/monitoring wells in the D-4 FSA in 2006. Additional work to be completed for the ICM, such as sodium lactate injections and groundwater monitoring is on-going.
2006 and 2007 (Shaw 2008)	Groundwater Treatment Studies Report, N-Nitrosodimethylamine with Trichloroethene, Former Air Force Plant PJKS, Waterton, Colorado, Revision 1. Prepared for the Air Force Center for Engineering and the Environment. February 26.	Bench-scale tests and pilot tests completed to identify an effective treatment technology for remediation of NDMA in groundwater.	SWMU 1, 2, and 3	An in situ bench-scale study was conducted on PJKS groundwater to evaluate the feasibility of using in situ biodegradation for NDMA and TCE treatment. Results of the study indicated that bioremediation of NDMA was not successful; although TCE concentrations were reduced through aerobic and anaerobic treatments. In addition, a bench-scale study was conducted on PJKS groundwater to evaluate the feasibility of using an ex situ nickel catalyst system for NDMA and TCE treatment. The bench-scale study indicated that evaluation of the nickel catalyst technology in a field demonstration was warranted. From April 2006 to January 2007, an ex-situ pilot test was performed. While the nickel catalyst proved effective in treating commingled NDMA and TCE in groundwater, under field conditions, regular maintenance was required to reduce fouling and the presence of dissolved nickel in the effluent was problematic.
2008 (Shaw 2008)	Action Memorandum, Removal Action at Solid Waste Management Units 9 and 14, Former Air Force Plant PJKS	Document the proposed activities at the D-1 Landfill and T-31 Chemical Treatment Facility.	SWMU 9 and 14	In September 2008, an AM was prepared to document the proposed ICM activities at the D-1 Landfill and T-31 Chemical Treatment Facility. Based on the results of the Evaluation of Alternatives, Excavation and Offsite Disposal was proposed for implementation.
2008 (Shaw 2008)	2007 Annual Groundwater Report, Former Air Force Plant PJKS	Study the distribution and migration of TCE and NDMA in groundwater.	SWMU 1, 2, and 3	Annual groundwater sampling at the 3 SWMUs was conducted semi-annually to evaluate TCE and NDMA in groundwater.

4.0 PERFORMANCE STANDARDS AND CONSTRUCTION QA/QC

At PJKS, the remedy for soil and groundwater is effectively in place. Construction Quality Assurance (QA) and Quality Control (QC) protocols were followed for each investigation or treatability study. The investigations and treatability studies were completed consistent with design plans and specifications. Because of this, the USAF, CDPHE, and EPA agreed a formal Construction QA/QC Plan was not needed in this case.

An Interim Corrective Measures Study (Shaw, 2005c) was completed to address the contaminated soils at the seven SWMUs. Three alternatives (No Action, Limited Cover and Land Use Controls (LUCs), and Limited Excavation and Offsite Disposal) were evaluated in the study. The selected ICM remedies included Limited Excavation, Off-site Disposal, and LUCs for four of the seven SWMUs (SWMU 13, 15, 17, and 22). The four SWMUs were approved for Restricted Closure due to all remaining soils being above residential standards, but below industrial standards. The selected ICM remedy for the remaining SWMUs (SWMU 12, 29, and 31) included partial excavation with Limited Cover and LUCs. In 2005, a total of 2,915 cy of contaminated soil was excavated from the various SWMUs and disposed at a permitted RCRA Subtitle D landfill. The two SWMUs were approved for Restricted Closure with LUCs and Limited Covers because all remaining soils are above industrial standards.

The soil SWMUs where concentrations of soil COCs were present on the ground surface at concentrations higher than worker protection levels were dealt with immediately via excavation and off-site disposal or engineered covers. Primarily, the selection of asphalt or concrete covers as interim measures for soil SWMUs was made to prevent or minimize disruption to continuing operations and/or structural integrity of buildings. Each interim action/interim corrective measure was planned and implemented with the explicit intent of having the interim measure fulfill the requirement of a remedial action for that SWMU (see **Table 5**).

Table 5: Final Action for Solid Waste Management Unit (SWMU) Soil Sites

Unrestricted Closure	Restricted Closure with LUCs ⁽¹⁾	Restricted Closure with LUCs and Limited Cover ⁽²⁾
4, 5, 6, 7, 9, 10, 11, 14, 18, 23, 26, 27, 28, 30, 32, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56	13, 15, 16, 17, 19, 20, 21, 22, 24, 25, 33, 34	8, 12, 29, 31, and CSA-3

(1) soil values greater than the residential standard and less than industrial standard or

(2) soil values greater than the industrial standard and have a limited cover (either concrete or asphalt) in place.

The remaining two soil SWMUs (9 and 14) were addressed under a separate investigation. The D-1 Landfill (SWMU 9) is located in the south-central portion of PJKS, immediately north of the D-1 Test Stand. The T-31 Chemical Treatment Facility (SWMU 14) is located immediately north of the D-1 Landfill. In 2003, an Evaluation of Alternatives report was prepared to evaluate two potential remedies for the D-1 Landfill and the T-31 Chemical Treatment Facility (Shaw, 2003c). The two potential remedies (excavation and off-site disposal and installation of a landfill cover system) were determined to be technically feasible based on the additional investigation results. Based on the evaluation, excavation and off-site disposal was selected as the most effective and preferred alternative. Excavation activities began in September 2008 and resulted in 47,090 cy of non-hazardous waste, 600 cy of Toxic Substance Control Act waste, 306 cy of concrete, and 4,835 tons of scrap iron being removed from the area (Shaw, 2009b). The two SWMUs were approved for Unrestricted Closure because all remaining soils are below residential standards.

The interim remedial system for groundwater does not require any additional components, modifications, or extra infrastructure to continue as a full scale treatment system (Figure 2). Injections have been performed at the seven source areas; the EPL Area, the SCA (north and south), D-1 Area, D-4 Area, CSSA, OTL, and T-8A. The treatment chemicals consist of sodium lactate (typically 1 to 5 percent by volume solution) or EEO and a bioaugmentation culture known as DHC. The *Operations and Maintenance/Long-term Monitoring Plan for SMWU 1 (SS034), SWMU 2 (SS021), and SWMU 3 (SS022), (CDRL A001C)* (Shaw, 2013) provides a detailed description of the injection process information.

5.0 FINAL INSPECTIONS AND CERTIFICATIONS

The USAF or property owner will submit an annual report describing the results of annual inspection of covers that certifies to CDPHE and EPA that the PJKS Restrictive Notice is being complied with.

Monitoring of the environmental use restrictions and controls will be conducted annually by the USAF. The monitoring results will be included in a separate report or as a section of another environmental report, if appropriate, and provided to the EPA and CDPHE. The annual monitoring reports will be used in preparation of the Five-Year Review to evaluate the effectiveness of the remedy.

All inspection/construction activities will be in accordance with the Site Health and Safety Plan (January 5, 2012, Revision 6) located in Appendix B of the *Operations and Maintenance/Long-term Monitoring Plan for SMWU 1 (SS034), SWMU 2 (SS021), and SWMU 3 (SS022), (CDRL A001C)* (Shaw, 2013).

The remedy is operational and functional. At present, the existing well network is believed sufficient for injection and monitoring. Installing additional injection or monitoring wells in other areas of the plume(s) may be conducted as needed to improve the effectiveness of the remedy. Treatment mixtures will be delivered, if necessary, using permanently installed wells or temporary installed injection points. Injection techniques may include “biobarriers”, a three dimensional wall of injected materials.

6.0 OPERATIONS AND MAINTENANCE ACTIVITIES

Anticipated operations and maintenance activities are documented in the *Operations and Maintenance/Long-term Monitoring Plan for SMWU 1 (SS034), SWMU 2 (SS021), and SWMU 3 (SS022), (CDRL A001C)* (Shaw, 2013). This plan identifies the in situ bioremediation injection systems and the remedy performance groundwater monitoring activities. This plan is designed to collect the data necessary to evaluate the effectiveness of the selected groundwater remedy.

The groundwater remediation and monitoring activities at PJKS are focused on seven (7) source areas where groundwater contaminant plumes appear to have originated. The source areas identified are:

- the D-1 area (D-1) [TCE and NDMA source area],
- the D-4 Fuel Storage area (D-4) [TCE source area],
- the Engineering Propulsion Laboratory (EPL) area [TCE source area],
- the Systems and Components Area (SCA) [TCE and NDMA source area],
- the Central Support Storage area (CSSA) [TCE and NDMA source area],
- the Ordnance Testing Laboratory (OTL) area [TCE source area],
- and the T-8A Pump House (T-8A) area [TCE and NDMA source area].

The selected remedy for PJKS groundwater consists of the injection of sodium lactate, emulsified edible oil (EEO), nutrients, and dehalococoides (DHC) bacteria into the groundwater at the seven source areas via a total of ten (10) horizontal injection wells and eighteen (18) vertical injection wells. The timing of injections and the amount of treatment chemical delivered is different for each source area and each well within a source area. Decisions regarding the need for additional injections will be based on data collected as part of the remedy performance monitoring program.

The initial Long-term Monitoring Plan will consist of 45 monitoring wells that will be sampled on a semi-annual basis. The analytes of interest are VOCs, and NDMA. A select number of wells will also be analyzed for Dissolved Gases, Common Ions, and Total Organic Carbon, in addition to the VOCs and NDMA. Field tasks include taking water level measurements, monitoring well purging, groundwater sample collection, quality control sample procedures, and equipment decontamination.

The data from the Long-term Monitoring Program will be used to evaluate the continued effectiveness of the treatment chemical in each injection well at each source area. The primary requirement for successful bioremediation is to maintain reducing conditions within the groundwater aquifer system. Reducing conditions in PJKS source areas are considered optimum when the oxidation/reduction potential (ORP) is negative and the dissolved oxygen (DO) levels

are less than 1 milligrams per liter (mg/L). If the results of the groundwater monitoring program indicate that reducing conditions are not being achieved in one or more source areas, then additional injection of treatment chemicals is warranted. In general, the monitoring data evaluation process will lead to one of three conclusions regarding the effectiveness of the groundwater remedy in each area.

- Conditions are appropriate for continued reduction of contaminants via biodegradation, if groundwater contaminant levels appear to be decreasing and continued monitoring is appropriate,
- Conditions indicate that additional injections of treatment chemicals, and/or bioaugmentation culture are required to return conditions to those considered optimum to continued biodegradation of contaminants, or
- Conditions indicate that treatment endpoint criteria have been met for one or more source area(s) wells, and it is appropriate to cease active injections and begin a rebound study, or formally end treatment.

If conditions indicate that additional injection of treatment chemicals are required, then the treatment chemicals are mixed with water in 500 gallon portable tanks and taken to the injection well sites. The trailer containing the portable tank has a generator operated pump and hoses that connect the outlet of the pump to fixed piping that has been constructed at each injection well head. Valves are opened and the pump delivers the treatment chemical from the 500-gallon portable tank to the injection well piping. Some of the vertical wells use a gravity feed system from the portable tank.

The groundwater monitoring wells that constitute the injections wells are robust and do not require scheduled maintenance. However, over time the portions of wells exposed to the elements, such as protective casings, locks and concrete well pads, may deteriorate and require repair. Inspections will be performed on a regular basis and checklist completed. Any items in need of repair will be noted and the required repairs will be completed.

Operating the injection system requires a wide variety of standard construction and environmental equipment. Large items such as vehicles, generators and pumps will be maintained in accordance with the manufacturer's requirements. Other items such as containers, pipes, hoses and fittings will be inspected prior to, and during use for signs of leaks or other defects. These equipment items will be repaired or replaced on an as needed basis.

In addition to the source area treatment wells, two biobarriers were constructed in 2008 to provide a barrier to plume migration and to further deplete TCE contamination in the plume extending downgradient from the PJKS property. The biobarriers were constructed by injecting a mixture of EEO, sodium lactate solution, and DHC into direct-push boreholes. The biobarriers

are intended to create a treatment zone that will remain in place for a long time without maintenance. The Long-term Monitoring Program will also include sampling of wells to provide data to evaluate the effectiveness of the two biobarriers. However, the USAF and regulators have determined that the decision of whether or not to rejuvenate the biobarriers will be evaluated during the course of the first five-year review period.

The USAF may propose amendments to the plan as additional data becomes available, or if other alternative treatment technologies are presented as recognized in the PJKS ROD and Corrective Action Decision (CAD). A statutory review will be conducted within five years after initiation of remedial action to ensure that the remedy is, or will be, protective of human health and the environment. There are no identified potential problems of concerns with the operations and maintenance activities.

A final draft of the PJKS Restrictive Notice was prepared and the language agreed to by all parties with an interest in the PJKS remedy several months prior to the signing of the PJKS Record of Decision on August 7, 2013. However, the language of the restrictive notice could not be finalized until the PJKS final remedy was formalized with the signing of the ROD.

A requirement of the Colorado Environmental Covenant Law is that the USAF was required to conduct research to identify all persons with recorded, and unrecorded interest in the property where use restrictions were to be placed. These persons would include companies or individual holding easements or right-of-ways on the property, individuals or companies maintaining water or mineral rights and/or persons or individuals with contracts or permission to use the property for their activities (grazing, farming, etc.). This research was conducted for the USAF by LMSSC personnel.

As required by the Colorado Environmental Covenant Law, the USAF mailed a copy of the PJKS Restrictive Notice to all individuals or companies on the list of persons with recorded or unrecorded interest in the property on October 1, 2013. The individuals or companies with an interest in the property have 30-days from the time of receipt of the notice to provide comments to CDPHE regarding the proposed restrictions. The comment period for the PJKS Restrictive Notice ends on November 4, 2013. CDPHE will consider the comments received, and work with the USAF, LMSSC and EPA to change the proposed land use restrictions, if possible, to address the comments. Once the language of the PJKS Restrictive Notice has been approved by all parties, CDPHE will record the PJKS Restrictive Notice on the deed to the PJKS property. CDPHE anticipates that the PJKS Restrictive Notice will be recorded by the end of December 2013.

7.0 CONTACT INFORMATION

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8.0 SCHEDULE OF ACTIVITIES FOR COMPLETION

Because of uncertainties in the rates of reduction, the ROD estimates a 10 to 20 year time frame. As stated in Section 4.3.1 (page 4-4) of the Focused Feasibility Study (Shaw, 2010b) and the PJKS ROD, the active groundwater treatment operations of the selected final remedy for PJKS groundwater will continue until one of three conditions are achieved:

1. The concentration of TCE and its daughter products meet CBSGs/MCLs in a particular area.
2. It is determined that further treatment will not result in further reductions in TCE in the bedrock groundwater in a particular source area. This is generally agreed to be the time when TCE concentrations in bedrock groundwater over time reach an asymptotic concentration. Under these conditions the remedy may need to be reviewed. The asymptotic conditions will be proved and graphed using all groundwater monitoring performance data collected since active treatment started. Achievement of this asymptotic criteria will show source area degradation at the point where it is no longer feasible or practicable to continue treatment.
3. The concentrations of TCE and its daughter products in the source areas are low enough that they no longer cause an exceedance of CBSG in the alluvial groundwater at the PJKS site boundary.

As noted in Items 1 and 2 above, one of the shut-off criteria for active bedrock source area treatment is for TCE concentrations to reach asymptotic levels. To demonstrate that asymptotic conditions have been achieved at a particular source area, the performance monitoring data collected since the beginning of treatment in a particular area will be statistically evaluated. General procedures for evaluating completion are found in EPA's *Guidance for Evaluating Completion of Groundwater Restoration Remedial Actions*, (OSWER Dir. 9355.0-129, November 25, 2013). The evaluation will use statistical tests recommended per the EPA guidance document titled *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities – Unified Guidance* (EPA, 2009) (EPA 530/R-09-007), or the most recent EPA statistical guidance. The statistical test that may be most appropriate to employ for PJKS source areas is from Chapter 14.3.4, *Identifying Linear Trends Amidst Seasonality: Seasonal Mann-Kendall Test*.

Once asymptotic levels have occurred, the USAF may submit the relevant analytical and statistical results to the regulators, along with a request to stop active treatment in a particular source area. The request may be made in the annual report, or in a separate document. The EPA/CDPHE will be consulted if the remedy does not perform as expected or concentrations become asymptotic regardless of injection. The USAF is responsible for the implementation of completion activities.

A statutory review will be conducted within five years after initiation of remedial action to ensure that the remedy is, or will be, protective of human health and the environment. Such reviews must be performed every five years until such time as a site attains unrestricted use/unlimited exposure levels. The date of a finalized Five-Year Review will be five years from EPA's signature of the ROD and will be a statutory review (August 7, 2018).

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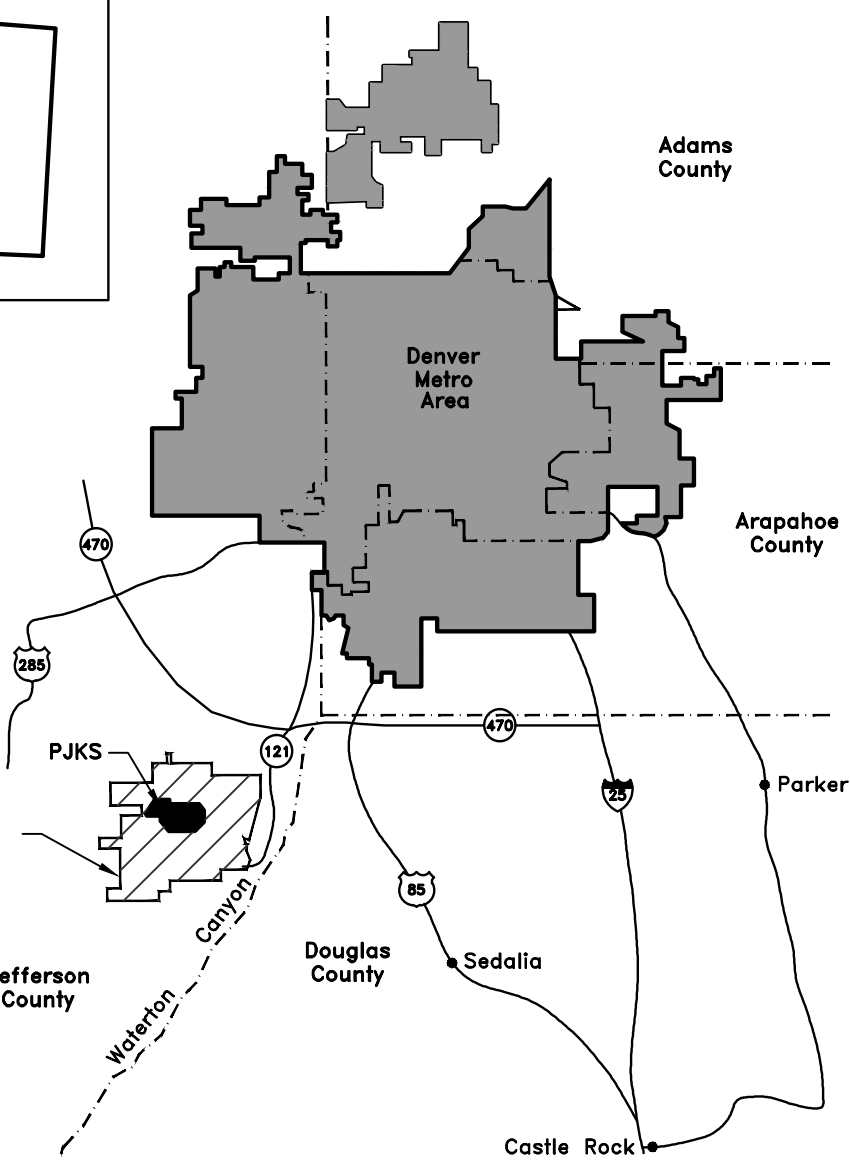
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

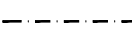
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FIGURES



LEGEND


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



 THE AIR FORCE CENTER FOR ENGINEERING AND THE ENVIRONMENT
BROOKS CITY-BASE, TEXAS

FORMER AIR FORCE PLANT PJKS

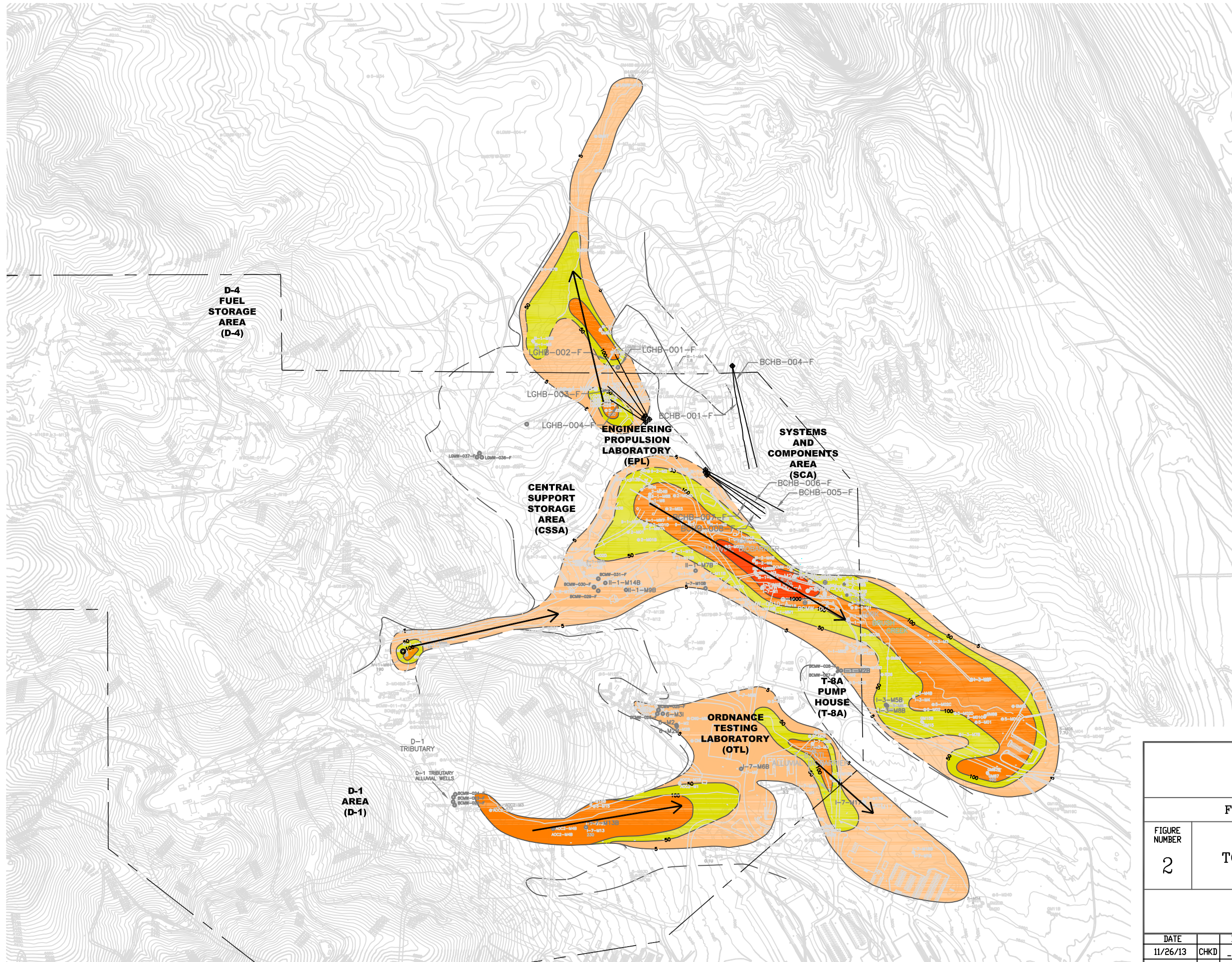
FIGURE NUMBER	PJKS LOCATION MAP
1	

 **Shaw** Environmental, Inc.

PROJECT NO.	REV.	FILE NAME
136328.0400	0	136328-01B

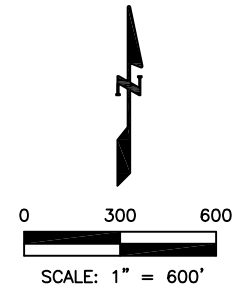
0	ISSUE TO PJKS TEAM						LWA	PSM	06/15/10		
REVISION	DESCRIPTION						CHKD	APPR	DATE		
	BY	DATE		BY	DATE		BY	DATE		BY	DATE
DSGN	LWA	08/29/06	DRAWN	MEC	08/29/06	CHKD	LWA	08/30/06	APPR	PSM	08/30/06

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- NOTE**
1. PLUMES BASED ON CURRENT AND HISTORICAL DATA
- LEGEND**
- 2-M100 WELLS NOT SAMPLED
 - ⊙ 5-M32 WELLS SAMPLED IN FALL 2010
 - 720 TCE CONCENTRATION IN µg/L
 - PJKS BOUNDARY
 - - - EXTENT OF SATURATED ALLUVIUM (DASHED WHERE INFERRED)
 - 5 — CONCENTRATION CONTOUR (DASHED WHERE INFERRED)
 - 5-50 µg/L
 - 50-100 µg/L
 - 100-1,000 µg/L
 - >1,000 µg/L
 - PLUME FLOW DIRECTION
 - ⊙ BCMW-031-F PERFORMANCE MONITORING WELLS
 - ⊕ IV-1-MW6 ALLUVIUM WELL
 - ⊙ BCMW-011-F FOUNTAIN WELL
 - ⊕ 3-M04B PRECAMBRIAN WELL
 - ↔ DIRECTIONAL INJECTION WELL CLUSTER

- DATA QUALIFIERS**
- F AN ESTIMATED VALUE - THE ANALYTE WAS POSITIVELY IDENTIFIED BUT THE ASSOCIATED NUMERICAL VALUE IS BELOW THE REPORTING LIMIT.
 - J AN ESTIMATED VALUE - AS WITH "F" QUALIFIER, THE ANALYTE WAS POSITIVELY IDENTIFIED BUT THE ASSOCIATED NUMERICAL VALUE IS BELOW THE REPORTING LIMIT.
 - JM ESTIMATED VALUE BECAUSE MATRIX SPIKE RECOVERY OUTSIDE QUALITY CONTROL LIMITS.
 - #U RESULT IS NON-DETECT WITH #=REPORTING LIMIT. DIFFERENCES IN THE REPORTING LIMIT VALUE ARE DUE TO THE DILUTION FACTOR.



THE AIR FORCE CIVIL ENGINEER CENTER BROOKS CITY-BASE, TEXAS						
FORMER AIR FORCE PLANT PJKS						
FIGURE NUMBER	PJKS SITE WITH TCE PLUME AND GROUNDWATER REMEDY SYSTEM					
2						
SHAW ENVIRONMENTAL, INC. A CB&I COMPANY						
DATE	BY	DATE	PROJECT NO.	REV.	FILE NAME	
11/26/13	CHKD	11/26/13	144932	0	144932_05000000_B1	
-	APPR	11/26/13				