Feasibility Study Addendum
for the
Dry Cleaning Facilities Area
(Operable Unit 003)
at
Main Post
Fort Riley, Kansas

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Prepared for

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Prepared by

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LIST OF ACRONYMS AND ABBREVIATIONS

ACL	Alternate Concentration Limits
AOC	Area of Concern
AR	Army Regulation
ARARs	Applicable or Relevant and Appropriate Requirements
β	Beta
BER	Bureau of Environmental Remediation
bgs	below ground surface
BMcD	Burns & McDonnell Engineering Company, Inc.
BTEX	Benzene, Toluene, Ethylbenzene, and Total Xylenes
$CaCO_3$	Calcium Carbonate
C/D	Construction/Demolition
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
Chemox	Chemical Oxidation
cis-1,2-DCE	cis-1,2-Dichloroethylene
CO_2	Carbon Dioxide
COPC	Chemicals of Potential Concern
COPEC	Chemicals of Potential Ecological Concern
Cy	Cubic Yards
DA	Department of the Army
DAA	Detailed Analysis of Alternatives
DCF Study Area	Dry Cleaning Facilities Study Area
DCFA	Dry Cleaning Facilities Area
DDC	Density Driven Convection
DES	Directorate of Environment and Safety
DO	Dissolved Oxygen
DSR	Data Summary Report
°C	Degree Celcius
°F	Degree Fahrenheit
EAB	Enhanced Anaerobic Bioremediation
ECORA	Ecological Risk Assessment
EWMC	Environmental Waste Management Center
Fe^0	Zero-Valent Iron
Fe^{+2}	Ferrous Iron
Fe^{+3}	Ferric Iron
FFA	Federal Facility Agreement
ft	feet
FS	Revised Feasibility Study
FSA	Feasibility Study Addendum

LIST OF ACRONYMS AND ABBREVIATIONS (continued)

g	gram
GCW	Groundwater Circulation Wells
GRA	General Response Action
H^+	Hydrogen Ion
H_2	Hydrogen gas
HCl	Hydrochloric Acid
HDPE	High Density Polypropylene
H_2O	Water
H_2O_2	Hydrogen Peroxide
HHBRA	Human Health Baseline Risk Assessment
IDW	Investigative Derived Waste
IRP	Installation Restoration Program
ISRM	In-Situ Redox Manipulation
J	Estimated
K.A.R.	Kansas Administrative Regulations
KDHE	Kansas Department of Health and Environment
$KMnO_4$	Potassium Permanganate
LBA	Louis Berger and Associates
LRC	Long-Range Component
MCL	Maximum Contaminant Level
MH	Manhole
MNA	Monitored Natural Attenuation
MnO_4^-	Permanganate
mg/L	milligrams per liter
μg/kg	micrograms per kilogram
μg/L	micrograms per liter
msl	Mean Seal Level
NA	Natural Attenuation
NAPL	Non-Aqueous Phase Liquid
$NA_2S_2O_4$	Sodium Dithianite
NCP	National Contingency Plan
NO_3^-	Nitrate
NOD	Natural Oxidant Demand
NOM	Natural Organic Matter
O_2	Oxygen
O_3	Ozone
OH^0	Hydroxyl Radical
O&M	Operation & Maintenance
ORP	Oxidation Reduction Potential

LIST OF ACRONYMS AND ABBREVIATIONS (continued)

OSHA	Occupational Safety and Health Administration
OU	Operational Unit
PCE	Tetrachloroethylene
PP	Proposed Plan
PRB	Permeable Reactive Barrier
PRG	Preliminary Remedial Goal
RAO	Remedial Action Objective
RCRA	Resource Conservation and Recovery Act
RI	Remedial Investigation
RIA	Remedial Investigation Addendum
RIAMER	Remedial Investigation Addendum Monitoring Expansion Report
RI/FS	Remedial Investigation/Feasibility Study
RME	Reasonable Maximum Exposure
RPMP	Real Property Master Plan
ROD	Record of Decision
ROI	Radius of Influence
RSK	Risk-Based Standards for Kansas
SARA	Superfund Amendments and Reauthorization Act
SDWA	Safe Drinking Water Act
SO_2	Sulfur Dioxide
SO_3^{-2}	Sulfite
SO_4^{-2}	Sulfate
SVE	Soil Vapor Extraction
TA2	Training Area 2
TBC	To Be Considered
TCE	Trichloroethylene
TCLP	Toxicity Characteristic Leaching Procedure
TDS	Total Dissolved Solids
TID	Technology Identification
TOC	Total Organic Carbon
trans-1,2-DCE	trans-1,2-Dichloroethylene
UCL	Upper Confidence Limit
UPRR	Union Pacific Railroad
USACE	United States Army Corps of Engineers
USC	United States Code
USDOE	United States Department of Energy
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
VC	Vinyl Chloride
VOCs	Volatile Organic Compounds
VVW	Vacuum Vaporizer Well

*****

1.0 INTRODUCTION

1.1 PURPOSE OF REPORT

The purpose of this Feasibility Study Addendum (FSA) is to present, develop, and evaluate remedial alternatives to allow selection of an appropriate remedy for contamination associated with the Dry Cleaning Facilities Study Area (DCF Study Area) (Operable Unit [OU] 003) on Main Post, Fort Riley, Kansas. This FSA was developed in support of the Fort Riley Directorate of Environment and Safety (DES) Installation Restoration Program (IRP). This FSA was also written to satisfy the requirements of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980, as amended by the Superfund Amendments and Reauthorization Act (SARA) of 1986. This FSA was prepared by Burns & McDonnell Engineering Company, Inc. (BMcD) under contract DACA41-96-D-8010 with the Kansas City District, United States Army Corps of Engineers (USACE), and represents Fort Riley's ongoing fulfillment of obligations to investigate and take appropriate actions at sites posing a potential threat to human health and the environment. This FSA replaces the Revised Feasibility Study (FS) report prepared by Louis Berger and Associates (LBA) in March of 1998 (LBA, 1998b).

1.2 REPORT ORGANIZATION

- Section 1.0, Introduction – Includes a brief overview of report organization, site description and history, nature and extent of contamination, contaminant fate and transport in groundwater, and a risk assessment summary.

- Section 2.0, Applicable or Relevant and Appropriate Requirements (ARARs) and To Be Considered (TBC) Information – A discussion of the preliminary ARAR/TBC identification.

- Section 3.0, Remedial Action Objectives (RAOs) and Preliminary Remediation Goals (PRGs) – This section provides a discussion of media of interest, exposure pathways, chemicals of concern, RAOs, and PRGs.

- Section 4.0, Identification and Screening of Technologies – This section (also referred to as the technology identification [TID]) will review all appropriate remedial technologies and provide an initial screening of potential technologies with reference to the DCF Study Area.

- Section 5.0, Detailed Analysis of Alternatives (DAA) – This section will provide a detailed review of remedial technologies appropriate for the DCF Study Area, with regard to effectiveness, implementability, and cost.

- Section 6.0, Comparative Evaluation of Alternatives – This section will provide a comparison of the alternatives described in Section 5.0.

- Section 7.0, References.

1.3 BACKGROUND INFORMATION

Detailed background on the DCF Study Area is provided in the following reports:

- *Remedial Investigation Report* (RI), *Dry Cleaning Facilities Area, Fort Riley, Kansas,* Louis Berger & Associates (LBA, 1995),

- *Remedial Investigation Addendum Monitoring Expansion Report* (RIAMER), *Dry Cleaning Facilities Area, Fort Riley, Kansas,* (LBA, 1998a),

- *Technical Memorandum Report, Potential Source Area and Sewer Line Field Screening, Dry Cleaning Facilities Area (OU 003), Fort Riley, Kansas,* (BMcD, 2002), and

- *Remedial Investigation Addendum* (RIA) *for the Dry Cleaning Facilities Area (OU 003) at Fort Riley, Kansas* (BMcD, 2003).

The information in the following sections was abstracted from these documents.

1.3.1 Site Description

<u>Overview</u>

The Fort Riley Military Reservation is located northeast of Junction City in the north-central portion of Kansas. The Reservation is over 100,000 acres in size and includes portions of Riley, Clay, and Geary Counties. The developed areas of Fort Riley are divided into six cantonment areas: Main Post, Camp Forsyth, Camp Funston, Camp Whitside, Marshall Army Airfield, and Custer Hill (see Figure 1-1).

The DCF Study Area is located within the Historic Main Post area of Fort Riley. The site location is east of the confluence of the Smoky Hill and Republican Rivers, which merge to form the Kansas River. Portions of the DCF Study Area are situated both north and south of the Kansas River and consist of five main investigative areas (Figure 1-2). These five areas are described as follows:

- The **Dry Cleaning Facilities Area (DCFA)** consists of two areas: the former Buildings 180/181 Area and the former Buildings 183/184 Area. Both of these areas are located on an alluvial terrace. The former Building 183 contained the more recent dry cleaning operations that consisted of dry cleaning (1983 to 2002) and laundry facilities (1941 to 2002). A steam generating plant was present at Building 184. Both of these buildings were located north of Custer Road. The former Buildings 180/181 Area consists of former Buildings 180/181 and 182, located south of Custer Road. Buildings 180/181 were the location of the original dry cleaning (1930 to 1983) and laundry (1915 to 1983) operations before these operations were transferred to Building 183. Building 182 was a storage building. The locations where Buildings 180/181, 182, 183, and 184 once stood are now empty grassy lots. Buildings 180/181 and 182, and the surrounding parking lots and sidewalks were demolished in the summer 2000. Buildings 183 and 184, and most surrounding structures were demolished in fall 2002.

- The **Transition Zone** separates the DCFA terraces from the Island and the Horse Corral. The Transition Zone is where the geology "transitions" from the upper terrace system beneath the DCFA to the point bars of the alluvial system of the Island and the Horse Corral. The Union Pacific Railroad (UPRR) tracks lie within the Transition Zone.

- The **Island** consists of a point bar formed by the Kansas River. This area is located between the DCFA and the Kansas River. The Island consists of approximately 40 heavily-wooded acres that are undeveloped and currently serve as a winter roosting area for bald eagles. The Island is a U.S. Fish and Wildlife Service designated critical habitat for bald eagles and is under the protection of federal and state endangered species law.

- The **Horse Corral** is the western portion of a point bar located downstream of the Island, and is located southeast of the DCFA. The Horse Corral is bounded by Henry Drive to the east, the Kansas River to the west and south, and the UPRR tracks to the north. The point bar is currently used for pasturing and training of Fort Riley's horses. Portions of the Horse Corral are also designated as a critical habitat for bald eagles and are under the protection of federal and state endangered species law.

- **Training Area 2 (TA2)** consists of the northern portion of a point bar located along the south side of the Kansas River directly across from the Island. TA2 is heavily wooded and is used by Fort Riley for military exercises. It is undeveloped and is also a winter roosting area for bald eagles. Portions of the TA2 area are also designated as a critical habitat for bald eagles and are under the protection of federal and state endangered species law.

Site Specifics

Alluvial terraces (DCFA), a Transition Zone, and river alluvium (the Island, Horse Corral, and TA2 Area) of the Kansas River dominate the topography across the DCF Study Area (Figure 1-3). The Kansas River flows across the DCF Study Area in a general west to east direction. There are two ephemeral streams within the DCF Study Area - Tributary A, which lies immediately east of former Buildings 180/181 and Tributary B, which is located on the Island.

The portion of the DCF Study Area located north of the UPRR grade (DCFA), is composed of two alluvial terraces, the Buck Creek Terrace and the Menoken Terrace (Dort, 1987). These terraced areas are composed of material deposited during flooding of the Kansas River, erosion of upland areas north of DCF Study Area, or placement of fill material (anthropogenic) along the western boundary of Tributary A. Inlets carved into the terrace walls are the results of flooding and intermittent stream erosion. The topography of the terrace in this area generally rises to the north. Elevations vary from about 1,062 feet (ft) above mean sea level (msl) along the UPRR grade in the Transition Zone to approximately 1,126 ft above msl north of former Building 183.

The Transition Zone is composed of Kansas River alluvium interspersed with erosional deposits from the upland and terrace areas. The topography of the Transition Zone rises abruptly from the alluvial point bars to the terrace areas in a north/south direction, but rises gradually along the UPRR grade from the east to west direction. Elevations vary in the north/south direction between 1,046 ft above msl at the base of the UPRR grade to approximately 1,066 ft above msl on the UPRR track. Elevations vary in the east/west direction between about 1,064 ft above msl at the UPRR tracks at Henry River Bridge, to 1069 ft above msl at the UPRR train trestle.

The Island, Horse Corral, and TA2 areas are underlain by Kansas River alluvium. The Kansas River alluvium is composed of Kansas River flood deposits and erosional deposits from the upland and terrace areas. The Island and the Horse Corral lie between the UPRR grade and the Kansas River, west of Henry Drive Bridge (Figure 1-3), while TA2 lies south of the Kansas River, west of Henry Drive bridge. All three areas are of low relief, with ground surface elevations generally between 1,046 ft above msl near the Kansas River to 1,060 ft above msl at TA2 and 1,065 ft above msl on the Island.

Geology

Geology of the alluvial terraces consists of clays, sands, and silts overlying Permian age sedimentary rock composed of alternating sequences of shale and limestone. A bedrock erosional channel underlies the eastern portion of former Building 180. The axis of the channel runs northeast/southwest and slopes to the southwest and extends through the Transition Zone into the Island. Sand is present within the bedrock erosional channel. The Transition Zone is composed of Kansas River alluvium interspersed with erosional deposits from the upland and terrace areas. Soil in the Transition Zone is composed primarily of alluvial sediment deposited by the Kansas River. The subsurface lithology within the Transition Zone consists of an upward-fining sequence of medium to coarse sand with traces of gravel present above the bedrock fining upwards into a fine sand with an upper layer of silty clay/clayey silt present in places. Soils beneath the Island, Horse Coral, and TA2 are also composed primarily of alluvial sediment deposited by the Kansas River. Subsurface lithologies in these areas also represent an upward-fining sequence typical of alluvial point bar and floodplain sediments.

Hydrogeology

The aquifers beneath the DCF Study Area consist of unconfined terrace aquifers, alluvial unconfined aquifers, and semi-confined bedrock aquifers. In general, the terrace aquifers are thin and lie immediately above bedrock, while the alluvium aquifers show a fining upward sequence typical of river alluvial sediments. The underlying Permian bedrock has a much lower porosity and permeability, although fractures and solution features may provide conduits for groundwater flow. Current groundwater flow conditions for 2003 at the DCFA (terrace area) show a south, southeast direction of flow toward the Kansas River with hydraulic conductivities ranging from 0.51 ft/day in silty sand to 0.0018 ft/day in lean clay (BMcD, 2003) based on geotechnical permeability tests. The hydraulic conductivity reported for the bedrock erosional channel based on slug tests was 69.31 ft/day. Groundwater flow within Island, Horse Coral, and TA2 (the alluvial valley) is controlled by the Kansas River and generally conforms to the direction of river flow. The hydraulic conductivity reported for the Kansas River alluvium is 737 ft/day based on aquifer test conducted by the USACE (BMcD, 2003). The terrace aquifer is not likely to ever be used as a source of drinking water due to the limited amount of groundwater present and the quantity of groundwater in nearby alluvial aquifers. It is also improbable, due to critical eagle habitat, that the alluvial aquifer on the Island would be used as a source for drinking water.

Facility Operations

The dry cleaning facility at former Buildings 180/181 operated as a laundry facility from 1915 to 1983 and as a dry cleaning facility from 1930 to 1983. From 1983 onward until demolition in the summer of 2000, former Buildings 180/181 were used for general storage. Former Building 183 was initially used as a laundry facility from construction in 1941 until 2001, and as a dry cleaning facility from 1983 to 2001. During dry cleaning operations, stoddard solvent, a petroleum distillate mixture, was used as the cleaning solution from 1944 until 1966. From 1966 until dry cleaning operations ceased, tetrachloroethylene (PCE) was used as the cleaning solution. Prior to 1993, spent PCE was emptied into floor drains that ran from the drains to the sanitary sewer. Sewer line investigations conducted in 1993 reported breaks, cracks, offsets, and root intrusions. Water and sediment samples collected from the sanitary and storm sewers showed concentrations of PCE, trichloroethylene (TCE), and cis-1,2-dichloroethylene (cis-1,2-DCE). Based on site investigation data, specific areas identified as possible source areas include the following:

- Former Building 180/181 Area and,
- Monitoring Well DCF-02-42 Area.

1.3.2 Previous Source Removal

A soil vapor extraction (SVE) pilot test was conducted in the vicinity of Manhole (MH) 363 from November 1994 through April 1995. The purpose of the pilot study was to evaluate the efficacy of SVE as a remedial technology for the cleanup of soils impacted by PCE. The groundwater extraction portion of the test was deleted based on poor groundwater yield and subsequent lack of hydraulic influence based on an aquifer test conducted in August 1994. The SVE test was conducted in two phases, the first phase was conducted in November/December 1994 and removed approximately 21 pounds of volatile organic compounds (VOCs). The second phase was conducted from March through April 1995 where an additional 3 pounds of VOCs were removed. The Radius of influence (ROI) was typically thirty feet for wells screened at approximately 15 ft below ground surface (bgs) however, significant subsurface heterogeneties resulted in preferred pathways during the SVE pilot test. This was attributed to prior construction efforts that included sewer lines and MHs as well as utility installations. The results of the

SVE pilot test concluded that approximately 50% of the contaminant mass had been removed using this technology.

1.3.3 Nature and Extent of Contamination

A number of field investigations have been conducted at the DCF Study Area. These investigations, beginning in 1992, included collection and chemical analysis of soil and groundwater-screening samples, soil gas samples, soil samples, and groundwater samples at the DCF Study Area. Monitoring wells were also installed and sampled at the DCF Study Area. Sample analytical results indicated that petroleum hydrocarbons and chlorinated solvents, including PCE, TCE, and cis-1,2-DCE, were present in the soil and groundwater at the DCF Study Area. Benzene, toluene, ethylbenzene, and xylenes (BTEX) have been detected in groundwater at the DCF Study Area, specifically at and downgradient of the DCFA. These detections have been below the United States Environmental Protection Agency (USEPA) maximum contaminant level (MCL). Petroleum based contamination will not be addressed in this document based on the following:

- CERCLA excludes petroleum, and
- BTEX and other petroleum related compounds found in the DCF Study Area were below their respective MCLs.

A brief summary of the solvent contamination detected at the DCF Study Area is as follows:

- **Former Building 183 Area** (DCFA) – No VOCs were detected in surface and subsurface soils. Groundwater was not present above the bedrock-overburden interface in this area. Based on the analytical results for the Former Building 183 Area, this area will be removed from further consideration in the FSA.

- **Former Buildings 180/181 Area** (DCFA) – PCE was detected in 10 of 39 surface soil samples collected from the ground surface to 0.5 ft below ground surface (bgs) ranging from 7.4 micrograms per kilogram (μg/kg), to 70.3 μg/kg. All of the detections were below the Kansas Department of Health and Environment (KDHE) Risk-Based Standards for Kansas (RSK) of 180 μg/kg for the soil to groundwater protection pathway (KDHE, 2003). No other VOCs were detected in the surface soil.

Subsurface soil samples contained concentrations of PCE, TCE, cis-1,2-DCE, and carbon disulfide. TCE, cis-1,2-DCE, and carbon disulfide were each detected once at low levels. Only PCE was detected in concentrations that exceeded the KDHE RSK of 180 μg/kg for the soil to groundwater protection pathway. PCE was detected in concentrations that exceeded the KDHE RSK in sixteen of the 304 subsurface soil samples with all of the exceedances being in the 1 to 12 ft bgs depth range. PCE subsurface soil concentrations ranged from 5.5 μg/kg to 513 μg/kg. PCE detections were generally highest near the surface and decreased with depth with some miscellaneous hits found near the top of groundwater. The main area of PCE detections in the subsurface soil were found in the area of former Buildings 180/181. These detections were found in the soil beneath the southwestern half of former Building 180 and the soil to the northeast of former Building 180 in the area of the sanitary sewer line and MH 363.

Groundwater samples collected from monitoring wells in this area during the April 2004 groundwater sampling round had detections of PCE, TCE, cis-1,2-DCE, and vinyl chloride (VC) above their respective USEPA MCLs (BMcD, 2004). Groundwater samples collected from monitoring wells and analyzed off site ranged from 1.6 micrograms per Liter (μg/L) to 47.3 μg/L for PCE, from 0.9 μg/L to 12.7 μg/L for TCE, from 1.8 μg/L to 18 μg/L for cis-1,2-DCE, and one detection of VC at 3.2 μg/L. No other VOCs were detected at levels above MCLs.

- **Island/Transition Zone** – Groundwater samples collected and analyzed on and off site during field investigations were found to contain PCE and TCE at concentrations that exceeded the USEPA MCL of 5 μg/L. Because the dry cleaning activities took place within the DCFA, no soil contamination was expected to be present in this area. Groundwater samples collected and analyzed on site during the recent field investigations conducted in the summer 2002 ranged from 0.3 estimated (J) μg/L to 44.8 J μg/L for PCE, from 0.5 J μg/L to 9.2 μg/L for TCE, and from 0.3 J μg/L to 33.0 J μg/L for cis-1,2-DCE. Groundwater samples collected from monitoring wells in April 2004 also had detections of PCE, TCE, and VC above their respective MCLs. Groundwater samples collected and analyzed off site ranged from 1.6 μg/L to 64.9 μg/L for PCE, from 0.5 J μg/L to 9.2 μg/L for TCE, and from 0.3 J μg/L to 33.0 J μg/L for cis-1,2-DCE. No other VOCs were detected at levels above MCLs.

- **Horse Corral** - Subsurface soil samples were collected along the sewer line which lies immediately north of the corral fence line. All soil samples were nondetect for PCE, TCE, and cis-1,2-DCE. Groundwater samples collected along the same field sample line showed analytical concentrations above the USEPA MCL for PCE and TCE. Groundwater samples collected and analyzed on site ranged from 0.2 J µg/L to 13.0 µg/L for PCE, from 0.2 J µg/L to10.4 µg/L for TCE, and from 0.1 J µg/L to 21.2 J µg/L for cis-1,2-DCE. No other VOCs were detected at levels above MCLs.

Groundwater samples collected from monitoring wells installed along the perimeter of the horse corral show analytical concentrations of PCE slightly above the 5 ug/L MCL. Groundwater samples collected and analyzed off site ranged from 1.7 µg/L to 11.8 µg/L for PCE, from 1.3 J µg/L to 1.8 µg/L for TCE, and from 0.5 µg/L to 1.2 µg/L for cis-1,2-DCE. No other VOCs were detected at levels above MCLs. No other VOCs were detected above their respective MCLs.

Groundwater contamination in the Horse Corral probably originates from the sewer line that lies north of the horse corral. This sewer line was formerly connected to the sewer lines that handled dry cleaning wastewater during operation of former Buildings 180/181 and 183. Since the Former Building 180/181 area has been identified as the source for solvent contamination at the DCF Study Area and since PCE is present only at low concentrations, the Horse Corral area will be removed from further consideration in the FSA. However, those monitoring wells with solvent concentrations above the KDHE RSK's and EPA MCL's will be included in the DCF Study Area groundwater monitoring program.

- **TA2** – During the March 2001 groundwater sampling event and the subsequent June 2001 confirmation sampling event, PCE was detected at Monitoring Well DCF96-36 at concentrations above the MCL. The groundwater samples collected and analyzed off site for this monitoring well contained during the initial chlorinated solvent detection was 14.7 µg/L for PCE, 2.5 µg/L for TCE, and 3.1 µg/L for cis- 1,2-DCE. No other VOCs were detected at levels above MCLs. The concentrations for the subsequent confirmation sampling event were less than the initial concentrations.

Based on these groundwater analytical results, two subsequent groundwater investigations were conducted. All groundwater samples collected in this area during these investigations, as well as numerous groundwater sampling events since the March 2001 detection, were nondetect for all VOCs with the exception of toluene, which was detected at 2.3 µg/L. This toluene concentration is below the USEPA MCL of 1,000 µg/L.

Since the dry cleaning activities took place in the DCFA, no soil contamination was expected to be present in the TA2. Therefore, no soil samples were collected from this area for VOC analysis.

Based on the groundwater analytical results for the TA2 Area, this area will be removed from further consideration in the FSA. However, selected monitoring wells in the TA2 area will be included in the DCF Study Area groundwater monitoring program.

1.3.4 Contaminant Fate and Transport in Groundwater

There are two solvent plumes that originate from the terrace within the DCFA Area. The eastern plume originates near the former Building 180/181 Area and enters the Kansas River alluvium through the bedrock erosional channel, which extends from beneath the location of the former Buildings 180/181 southwestward through the Transitional Zone into the Kansas River alluvium. Once the plume enters the Kansas River alluvium, the plume takes a more south/southeastern direction. Within the Island area, the fate and transport of contaminants appears to be dominated by the natural attenuation (NA) mechanisms dispersion and advection with biodegradation, diffusion, and adsorption playing secondary roles. The eastern plume appears to commingle with the western plume in the east central portion of the Island.

The western plume originates near Monitoring Well DCF02-42 and enters the Kansas River alluvium through the transition zone near Monitoring Well DCF96-25. From this point in the Kansas River alluvium, the plume resides in both the shallow and deep portions of the Kansas River alluvial aquifer and extends southeastward towards the Kansas River. Concentrations of PCE and TCE decreases to the southeast. The plume for cis-1,2-DCE is similar to the PCE plume, but is slightly longer in length. For the western plume, NA processes do not appear to be reducing the concentration of PCE and TCE to levels below the MCL before the plume reaches the monitoring wells installed along the northern bank of the Kansas River. As the western plume approaches the Kansas River, the solvent plume fronts for PCE and TCE concentrations above the MCL are approximately 1,400 and 800 feet wide, respectively. Summaries of the chlorinated solvent groundwater analytical concentrations are presented in the following paragraphs.

PCE - Concentrations of PCE exceeded the MCL of 5 μg/L at one bedrock monitoring well screened in the Upper Crouse Limestone Member (DCF92-02), three terrace monitoring wells (DCF92-05, DCF93-13, and DCF01-40), one bedrock erosional channel monitoring well (DCF02-41), one transition zone monitoring well (DCF02-42), and nine monitoring wells screened in the Kansas River alluvial aquifer (see Table 28-4, Data Summary Report [DSR], BMcD, 2004). PCE isoconcentration maps for April 2004 are presented on Figures 1-4 and 1-5. At Monitoring Wells DCF 01-40 and DCF02-41, concentrations of PCE have been decreasing over the past three years from 165 ug/L to 47.3 ug/L and 10.9 ug/L to ND, respectively. For the same time period, all other monitoring wells with PCE concentrations greater than 5 ug/L have been either slightly increasing, slightly decreasing, or have remained basically unchanged.

TCE – Concentrations of TCE exceeded the MCL of 5 μg/L at one bedrock monitoring well screened in the Lower Crouse Limestone Member (DCF93-20), one terrace monitoring well (DCF93-13), one bedrock erosional channel monitoring well (DCF02-41), one transition zone monitoring well (DCF02-42), and three monitoring wells screened in the Kansas River alluvial aquifer (see Table 28-4, DSR, BMcD, 2004). TCE isoconcentration maps for April 2004 are presented on Figures 1-6 and 1-7. In general, monitoring wells with TCE concentrations above the MCL have remained basically unchanged over the past three years with the exception of Monitoring Well DCF93-13, which has decreased from 256 ug/L to 10 ug/L.

cis-1,2-DCE – In April 2004, there were no monitoring wells with concentrations that exceed the 70 ug/L MCL. Current isoconcentration maps for cis-1,2-DCE are presented on Figures 1-8 and 1-9.

VC – Concentrations of VC in April 2004 exceeded the MCL of 2 μg/L at Monitoring Well DCF93-19, screened in the Lower Crouse Limestone Member. VC has also been intermittently detected in Monitoring Wells DCF96-27 and DCF02-45a (see Table 28-4, DSR, BMcD, 2004). A VC isoconcentration map for April 2004 is presented on Figure 1-10.

1.3.5 Risk Assessment Summaries

1.3.5.1 Human Health Risk Assessment

The potential for human health risk from exposure to chemicals at the DCF Study Area was considered for the soil, groundwater, and air media. The purpose of the risk assessment was to amend the baseline risk assessment completed as part of the RI Report (LBA, 1995) to reflect current site conditions in consideration of analytical data collected since the RI Report was completed. The risk assessment specifically addressed the following issues: potential exposures to PCE in surface soil, potential exposure to concentrations of PCE in subsurface soil; inhalation of chemical vapors migrating from groundwater, and potential exposures to groundwater as sediment pore water in the Kansas River.

Media evaluated include the following: surface soil, shallow subsurface soil, and groundwater from the Building 180/181 Area; groundwater from the Transition Zone/Island Area; and groundwater from monitoring wells located near the Kansas River. Groundwater data near the Kansas River was used as a surrogate for sediment pore water, which was not sampled directly. Because soil samples from the former

Building 183 area were nondetect, they were not included in the evaluation. Similarly, other than the small toluene concentration detected during a recent groundwater sampling event, no chemicals have been detected in the last two years at TA2, so this area was not separately evaluated. Only very low levels of site-related constituents have been detected in the Horse Corral, and the potential exposures are similar to those in the DCFA; therefore the Horse Corral was not individually evaluated. Chemicals of potential concern (COPCs) at the DCF Study Area include all chemicals detected in soil and groundwater samples from the site, with the primary constituents of concern being PCE and related compounds (TCE, cis-1,2-DCE, trans-1,2-dichloroethylene [trans-1,2-DCE], and VC).

Potential intakes of the COPCs were calculated using standard USEPA equations for intake from ingestion, dermal contact, and inhalation of contaminants. Cancer and noncancer risks were calculated for the following scenarios: current groundskeeper exposure to impacted soil and vapors from soil or groundwater while mowing; future utility worker exposure to impacted soil and vapors from soil or groundwater while excavating; and future youth trespasser exposure to impacted soil and vapors from soil or groundwater in the Building 180/181 Area, vapors from groundwater in the Transition Zone/Island Area, and potentially impacted sediment pore water. Exposure concentrations represented the lower of either the 95 percent upper confidence limit (UCL) or maximum detected concentration. Where impacted soil and groundwater were co-located, the higher of the two vapor concentrations was used in the vapor inhalation intake calculations.

The results of the risk characterization indicate that the excess cancer risks for all populations evaluated were below the USEPA's target levels. The hazard indices for the populations assessed were also below the USEPA's level of concern.

1.3.5.2 Ecological Risk Assessment

Preliminary chemicals of potential ecological concern (COPECs) identified included PCE in soils and groundwater and TCE and cis-1,2-DCE in groundwater. The impacts of the preliminary COPECs upon potential receptors were assessed qualitatively and by a quantitative screening when benchmarks were available. The preliminary screening did not provide any indications of adverse ecological effect to plants and animals from exposure to soil contamination. All other terrestrial receptors, including soil organisms, were qualitatively assessed and determined to exhibit minimal adverse effects. The qualitative risk characterization was based on the lack of any visible adverse effects within the plant and animal communities at the DCF Study Area. Based on the results of the semi-quantitative and qualitative evaluations of soil contaminants, ecological risk to terrestrial flora and fauna inhabiting the DCF Study

Area is expected to be insignificant. Additionally, protected species are unlikely to experience adverse effects due to incidental contact with contaminated soil or consumption of prey inhabiting the site of the former DCFA buildings. The future presence of any protected species in the contaminated areas in the vicinity of the DCFA buildings is likely to be transitory.

Potential for risk to benthic organisms inhabiting the Kansas River was assessed quantitatively. Existing chemical concentrations in groundwater near the Kansas River (as measured in samples collected from Island monitoring wells along the Kansas River) were compared to benchmark values for benthic organisms. The maximum detected concentrations of PCE, TCE, and cis-1,2-DCE in groundwater near the Kansas River were below the benchmarks used for this evaluation. Therefore, current concentration conditions at the groundwater interface with the Kansas River are unlikely to pose appreciable risk to benthic organisms in the Kansas River.

The critical habitat for the bald eagle, piping plover, and interior least tern occurs along the Kansas River at the southern edge of the Island and the northern edge of TA2. Only minimal exposure to PCE, TCE, and cis-1,2-DCE would be expected due to the short amount of time these species spend along the Kansas River at the DCF Study Area and the relatively low concentrations detected in the Island monitoring wells along the Kansas River. Secondary exposures may result from the bioaccumulation and bioconcentration of chemicals through the food chain. Considering also the exceedingly low concentrations in soils and groundwater along the Kansas River and the propensity of PCE, TCE, and cis-1,2-DCE to volatilize, it is unlikely that contaminants at the DCF Study Area present a significant exposure risk to bald eagles or other higher species in the food chain. Therefore, the risk to bald eagles, piping plovers, and interior least terns in the vicinity of the DCF Study Area is most likely insignificant. Risks to other state and federally listed species known to occur in Riley County are also likely to be insignificant.

1.4 DCF STUDY AREA SUMMARY

In summary, chlorinated solvent contamination is located mainly in the soils and groundwater at the former Buildings 180/181 Area; in groundwater in the western portion of the DCF Study Area near Monitoring Well DCF02-42, and groundwater beneath the Island. PCE is the main contaminant detected in the surface and subsurface soil. PCE is present in subsurface soils at levels exceeding the KDHE Residential RSK level for the soil to groundwater pathway. PCE, TCE, cis-1,2-DCE, and VC are the main contaminants detected in the groundwater of the DCFA (terrace aquifer) and the Island (alluvial aquifer). All have been detected in excess of USEPA MCLs, with PCE being detected the most frequently. The terrace aquifer is not likely to ever be used as a source of drinking water due to the limited amount of groundwater present and the quantity of groundwater in nearby alluvial aquifers. It is also improbable, due to critical eagle habitat, that the alluvial aquifer on the Island would be used as a source for drinking water.

Contaminants enter the alluvial aquifer from two sources. The eastern plume originating from the former Building 180/181 area appears to be effectively reduced to concentrations below the MCL for PCE, TCE, and cis-1,2-DCE before the plume intersects the Kansas River as the result of advection, dispersion, biodegradation, diffusion, and adsorption. This is not the case for the western plume originating from the area around Monitoring Well DCF02-42. Here, NA processes do not appear to be reducing the concentrations of PCE and TCE to below the MCL before the groundwater plume reaches the monitoring wells installed along the northern bank of the Kansas River. The results of the human health risk characterization indicate that the excess cancer risks were below the USEPA's target levels and that the hazard indices for the populations assessed were also below the USEPA's level of concern. The results of the ecological risk assessment indicate that there is minimal risk to ecological receptors at the DCF Study Area.

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2.0 APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS AND TO BE CONSIDERED INFORMATION

2.1 IDENTIFYING ARARS AND TBCS

2.1.1 Introduction

CERCLA requires the lead agency for a site to select remedial actions that are protective of human health and the environment, are cost-effective, and use permanent solutions and alternative technologies or resource recovery technologies to the maximum extent practicable. CERCLA itself does not contain any cleanup standards; however, one of the requirements of the FS process is to identify the federal and state environmental regulations associated with the remedial alternatives being considered. Specifically, Section 121(d) of CERCLA (42 United States Code [USC] § 9601 et. Seq.) and the National Contingency Plan (NCP) (40 Code of Federal Regulations [CFR] 300), require that the selected remedial action for a site meet the following requirements:

1. The remedial action must be protective of human health and the environment, and

2. The remedial action must comply with all federal and state ARARs, unless grounds for invoking a waiver of ARARs are provided. These ARARs are used in combination with the RAOs to assess remedial alternatives for the site.

These requirements make certain that remedial actions performed under CERCLA comply with all pertinent federal and Kansas environmental requirements. Effectively, the CERCLA process requires the lead and support agencies to use ARARs to select remedial standards.

2.1.2 ARAR Identification Process

The process of identifying ARARs and TBCs is specified in CERCLA Section 121 and the NCP. In addition to the above-mentioned statutory and regulatory requirements, the USEPA has published numerous guidance documents for identification of ARARs and TBCs.

The process of identification of ARARs is described and graphically depicted in Section 1.2.4 of the *CERCLA Compliance with Other Laws Manual: Part I* (USEPA, 1989a). In general, the identification process involves a two-part evaluation to determine if the promulgated environmental requirement is applicable or, if not applicable, relevant and appropriate. An ARAR may be either "applicable" or "relevant and appropriate."

An applicable requirement directly and fully addresses or regulates the hazardous substance, pollutant, contaminant, action being taken, or other circumstances at the site. To determine if the particular requirement is legally applicable, it is necessary to refer to the terms, definitions, and jurisdictional prerequisites of the statute or regulation. All pertinent jurisdictional prerequisites must be met for the requirement to be applicable. These jurisdictional prerequisites include:

- Who, as specified as in the statute or regulation, is subject to its authority;
- The types of substances or activities listed as falling under the authority of the statute or regulations;
- The time period for which the statute or regulation is in effect; and
- The type of activities the statute or regulations requires, limits, or prohibits.

These statutory or regulatory provisions must then be compared to the pertinent facts about the CERCLA site and the CERCLA response actions being considered. Other facts, such as the approximate date when substances were placed at a site, may also be needed to determine if the requirement applies. Different categories of information will be necessary to determine the jurisdictional prerequisites of different requirements, and not all categories will be pertinent in all cases.

If the requirement is not applicable, the next step is to decide if it is both relevant and appropriate. This is essentially a two-step process:

1. Determine if the requirement regulates or addresses problems or situations sufficiently similar to those at the site, and
2. Determine if the requirement is appropriate to the circumstances of the release or threatened release such that its use is well suited to the site.

The first step focuses on whether a requirement is relevant based on a comparison between the action, location, or chemicals covered by the requirement and related conditions of a site, the release, or the potential remedy. This step should be a screen that will determine the relevance to the potentially relevant and appropriate requirement under consideration. The second step determines whether the requirement is appropriate by further refining the comparison, focusing on the nature/characteristics of the substance(s), the characteristics of a site, the circumstances of the substance(s), the circumstances of the release, and the proposed remedial action. Determining if requirements are relevant and appropriate is site-specific and must be based on best professional judgment considering the characteristics of the remedial action, the hazardous substance(s) present at a site, and the physical circumstances of a site and of the release, as compared to the statutory or regulatory requirement.

The site-specific conditions must be compared to the statutory or regulatory requirements. The USEPA further clarifies that requirements determined to be relevant and appropriate do not need to be legally enforceable. This was clarified in the NCP Preamble which states, "USEPA disagrees [with the comment regarding changing the definition of relevant and appropriate to include 'while not applicable, sufficiently satisfies the jurisdictional prerequisites for legal enforceability'], because the jurisdictional prerequisites, while the key in the applicability determination, are not the basis for relevance and appropriateness."

The following eight factors, as identified in the NCP, are generally considered in determining if a requirement is relevant and appropriate:

- Purpose of requirement and purpose of CERCLA action;
- Medium regulated or affected by requirement and the medium contaminated or affected at the CERCLA site;
- Substances regulated by requirement and substances found at the CERCLA site;
- Actions or activities regulated by requirement and remedial actions contemplated at the CERCLA site;
- Variances, waivers, or exemptions of requirement and their availability for the circumstances at the CERCLA site;

- Type of place regulated and type of place affected by release or CERCLA action;

- Type and size of structure or facility affected by release or contemplated by the CERCLA action; and

- Consideration of use or potential use of affected resources in requirement and use or potential use of affected resource at the CERCLA site.

The pertinence of each of these factors depends in part on whether a requirement addresses a chemical-, location-, or action-specific ARAR.

The regulations and the USEPA guidelines state that the identification of ARARs is conducted on a site-specific basis for each remedial alternative under consideration. The rationale as to why a particular statutory or regulatory requirement is determined to be an ARAR should be documented for each remedial alternative being considered during the detailed analysis of alternatives. Because the preliminary chemical-specific ARARs will generally be the same for all alternatives, a single list of ARARs is sufficient for all alternatives and does not require repeating for each alternative.

2.1.3 TBC Identification Process

TBCs are to be used as guidance in assisting with the determination of remediation goals and/or developing remedies. TBCs can be used in determining the necessary level of cleanup for the protection of human health and the environment. The basic criterion to determine when a TBC should be used is to determine whether use of the TBC is helpful in aiding the protection of human health and the environment at the site. Those TBCs that may be useful in developing CERCLA remedies should be identified.

2.2 PRELIMINARY ARAR/TBC IDENTIFICATION

2.2.1 Introduction

In accordance with the Federal Facilities Agreement (FFA), the KDHE has provided a list of potential ARARs for the DCF Study Area early in the remedial process (KDHE, 1999). ARAR identification is an iterative process and possible ARARs are re-examined throughout the Remedial Investigation/Feasibility Study (RI/FS) process. The current lists of potential ARARs, as provided by KDHE, are depicted on Tables 2-1 through 2-3.

2.2.2 Evaluation of Potential ARARs

The KDHE list of potential ARARs was evaluated according to each statutory program and the regulations specific to each program, by considering the COPCs at the Site. The ARAR evaluation was conducted in accordance with *CERCLA Compliance with Other Laws Manual, Parts I and II* (USEPA, 1989a and USEPA, 1989b).

Following the ARAR evaluation process, preliminary chemical-, location-, and action-specific ARARs for the DCF Study Area were identified and are summarized in the following sections. The term "preliminary" is used at this stage of the FS process, until the final ARAR list is developed further in the CERCLA process (i.e. record of decision [ROD]). The list of ARARs for this Site will be updated as may be necessary throughout the CERCLA process.

2.2.2.1 Preliminary Chemical-Specific ARARs

The preliminary chemical-specific ARARs for this Site are:

- Kansas Surface Water Quality Standards (Kansas Administrative Regulation[KAR] § 28.16.28b),
- Kansas Water Pollution Control, Antidegradation Policy (KAR § 28.16.28c(a)),
- Safe Drinking Water Act (SDWA), National Primary Drinking Water Regulations (40 CFR § 141 and 142),
- Kansas Drinking Water Standards (KAR § 28.15),

2.2.2.2 Preliminary Location-Specific ARARs

The preliminary location-specific ARARs for this Site are:

- Archaeological and Historical Preservation Act of 1974 (16 USC § 469 et seq.),
- Endangered Species Act of 1973 (7 USC § 136 and 16 USC § 460 et seq.),
- Fish and Wildlife Conservation Act (16 USC § 2901 to 2911),

- Flood Control Act of 1944 16 (USC § 460 et seq.),
- Kansas Historic Preservation Act (KAR 118-3), and
- Non-Game, Threatened or Endangered Species (KAR 115-15).

2.2.2.3 Preliminary Action-Specific ARARs

The preliminary action-specific ARARs for this Site are:

- CERCLA of 1980 (42 USC § 9601 et seq. as amended by SARA of 1986),
- Clean Air Act (42 USC § 7401 et seq. as amended in 1977 and 1990),
- Clean Water Act (33 USC § 1251 et seq.),
- Emergency Planning and Right to Know Act of 1986 (42 USC § 11001 et seq.),
- Federal Hazardous Materials Transportation Law (49 USC § 5101 et seq.),
- Occupational Safety and Health Act (OSHA) of 1970 (29 USC § 651 et seq.). Includes both workplace standards (29 CFR 1910) and construction standards (29 CFR 1926).
- Resource Conservation and Recovery Act (RCRA) of 1976 (42 USC § 6901 et. seq.),
- Ambient Air Quality Standards and Air Pollution Control (KAR 28-19),
- Emergency Planning and Right to Know (KAR 28-65),
- Kansas Board of Technical Professions (KAR 66-6 through 66-14),
- Solid Waste Management (KAR 28-29), and
- Water Well Contractor's License, Water Well Construction and Abandonment (KAR 28-30).

- Spill Reporting (KAR 28-48).
- Underground Injection Control Regulations (KAR 28-46).
- Hazardous Waste Management Standards and Regulations (KAR 28-31).

2.2.3 Overview of Guidance and Policies

Guidances and policies (i.e., TBCs) do not carry the weight of statutory or regulatory requirements, but are considered during site evaluations and may be used as guidance in determining remediation goals and/or in developing remedies. The following section provides a list of major guidance materials considered during the preparation of the FS and the evaluation of remedial alternatives.

2.2.3.1 TBC Information

TBCs used to evaluate alternatives for this Site include:

- *Risk-Based Standards for Kansas* (RSK Manual – 3rd Version) (KDHE, 2003),
- *Land Use in the CERCLA Remedy Selection Process* (USEPA, 1995),
- *Groundwater Protection Strategy* (USEPA, 1984),
- *Monitored Natural Attenuation*, Bureau of Environmental Remediation Policy, (BER) Policy # BER-RS-042 (KDHE, 2001), and
- *Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites.* EPA-540-R-99-009 (USEPA, 1999).

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3.0 REMEDIAL ACTION OBJECTIVES AND PRELIMINARY REMEDIAL GOALS

3.1 INTRODUCTION

RAOs consist of medium-specific goals to address risks to human health and the environment posed by a site. RAOs should specify media of interest, contaminants of interest, and PRGs that permit a range of treatment and containment alternatives to be developed and evaluated. Acceptable contaminant levels or ranges of levels for each exposure route should be identified. RAOs are developed on the basis of preliminary chemical-specific ARARs and site-specific risk-related factors. RAOs should also consider current and anticipated future land and groundwater use.

3.2 MEDIA OF INTEREST AND EXPOSURE PATHWAYS

3.2.1 Soil

Potential exposure pathways from soil contamination (both surface and shallow subsurface) at the DCF Study Area include ingestion, dermal contact, inhalation of VOCs in vapors, and leaching to groundwater. The results of both the human health baseline risk assessment (HHBRA) and the ecological risk assessment (ECORA) concluded that risks for all populations were below the USEPA's allowable levels (BMcD, 2003).

The potential exists for leaching to groundwater from the shallow subsurface soil in the area of former Buildings 180/181. This area includes the soil beneath the southwestern half of former Building 180 and the soil to the northeast of former Building 180 in the area of the former sanitary sewer line near MH 363. Levels of PCE in this area exceeded the KDHE RSK of 180 μg/kg for the soil to groundwater protection pathway. Based on this analytical data, soil at the DCF Study Area is a media of interest. While PCE concentrations in groundwater samples collected from Monitoring Well DCF01-40, located within the subsurface soil contamination area, have gradually declined for the last 2.5 years, the subsurface soil in this area nonetheless will be included as one of the areas targeted for remedial action based on current soil concentrations in comparison to the KDHE RSK.

3.2.2 Groundwater

The only potentially completed exposure pathways for groundwater identified in the HHBRA was for the inhalation of VOCs in vapors and dermal contact. The risks for this scenario were below the USEPA allowable levels (BMcD, 2003). However, because the western chlorinated solvent plume impacts the

Kansas River alluvial aquifer at levels above the MCLs, the plume is reaching monitoring wells installed along the northern bank of the Kansas River, groundwater is the second medium of interest at the DCF Study Area.

3.2.3 Other Media

Surface water is not considered a medium of interest at the DCF Study Area. Surface water (other than the Kansas River) is not present except following significant precipitation events. The exception is Seep 1, which is located north of the UPRR trestle on the eastern bank of Tributary A. Samples collected from this seep resulted in no detections of any COPCs. Surface-water sampling of the Kansas River conducted by the United States Geological Survey (USGS) during 2000 and 2001 resulted in no detections of any COPCs (BMcD, 2000a, 2000b, and 2001).

3.3 CHEMICALS OF POTENTIAL CONCERN

The risk assessment concluded that COPCs in groundwater and soils did not pose significant risks to human health or the environment. However, some COPCs in soil and groundwater occur at levels above MCLs, the KDHE RSKs, and action levels. These are PCE for soil, and PCE, TCE, cis-1,2-DCE, VC, total dissolved solids (TDS), chloride, sulfate, nitrate, and orthophosphate for groundwater. Since TDS, chloride, sulfate, nitrate, and orthophosphate appear unrelated to the dry cleaning activities, only the organics listed above are addressed in this document.

Based on the results of the HHBRA, the ARAR analysis, and the COPCs currently present at concentrations above MCLs and the KDHE RSKs, the following are considered COPCs in soil and groundwater for the DCF Study Area:

Soil	Groundwater
PCE	PCE
	TCE
	cis-1,2-DCE
	VC

3.4 REMEDIAL ACTION OBJECTIVES

As identified in the USEPA guidance *Rules of Thumb for Superfund Remedy Selection* (USEPA, 1997), a remedial action is generally warranted if one or more of the following conditions apply:

1) Cumulative excess carcinogenic risk to an individual exceeds 10^{-4},
2) Non-carcinogenic hazard index is greater than one,
3) Site contaminants cause adverse environmental impacts, and/or
4) Chemical-specific standards (i.e., ARARs) or other measures that define acceptable levels are exceeded and exposure to contaminants above these levels is predicted for the reasonable maximum exposure (RME) identified in the risk assessment.

For the DCF Study Area, only item number (4) above applies, in that chemical-specific ARARs are being exceeded. The KDHE RSKs for PCE are exceeded in soil and the drinking water standards (i.e., MCL) for PCE, TCE, cis-1,2-DCE, and VC are exceeded in the groundwater, which is impacting the terrace and Kansas River alluvial aquifers.

RAOs provide a general description of what remedial action is anticipated to accomplish. RAOs are developed based on protection of human health and the environment including consideration of the goals of the CERCLA program. The current goal for soil cleanup at the DCF Study Area is based on the KDHE RSK for PCE of 180 ug/kg. The reduction of soil contamination to levels below the PCE RSK will reduce the amount of contaminant in the soil to groundwater pathway.

The current goal for long-term groundwater cleanup at the DCF Study Area is summarized in the NCP:

> "USEPA expects to return usable groundwaters to their beneficial uses wherever practicable, within a time frame that is reasonable given the particular circumstances of the site. When restoration of groundwater to beneficial uses is not technically practicable, USEPA expects to prevent further migration of the plume, prevent exposure to the contaminated groundwater, and evaluate further risk reduction."

RAOs are developed in this section considering the 1) current and future land use at the DCF Study Area; 2) beneficial use of groundwater at the DCF Study Area; 3) results of the risk assessment; and 4) anticipated fate and transport of contaminants beneath the DCF Study Area. Current land use, risk assessment (including media of interest, COPCs, and exposure pathways), and anticipated fate and transport are summarized in previous sections of this report with more details provided in the RIA Report

(BMcD, 2003). The following sections provide additional discussion of anticipated future land use and beneficial groundwater use at the DCF Study Area.

3.4.1 Land Use

3.4.1.1 General

Land use assumptions are an integral factor in the development of RAOs. These assumptions affect the exposure pathways that are evaluated. Future land use is important in estimating potential future exposure and associated risks, if any. Realistic land use assumptions allow the FS to be focused on developing practicable and cost-effective remedial alternatives.

The USEPA's directives on land use in the CERCLA remedy selection process (USEPA, 1995 and 2001) supports the formulation of realistic assumptions regarding future land use and clarifies how these assumptions influence the development of alternatives and the process of remedy selection. The key points of this directive which are relevant to the RAO and PRG selection process include the following:

- RAOs should reflect the reasonably anticipated future land use or uses.
- Future land use assumptions allow the HHBRA and the FS to be focused on developing practicable and cost-effective remedial alternatives. These alternatives should lead to site activities that are consistent with the reasonably anticipated future land use.
- Land uses that will be available following completion of remedial action are determined as part of the selection of RAOs and PRGs. During this process, the goal of realizing reasonably anticipated future land uses is considered along with other factors. Any combination of unrestricted uses, restricted uses, or use for long-term waste management may result.

Consistent with the USEPA guidance, an assessment of current and future land uses for the DCF Study Area was conducted, which considered the following factors:

- Current site conditions, such as acreage, zoning, and current land use;
- The zoning and character of the surrounding properties; and

- Potential future land uses for the DCF Study Area, including residential, recreational, conservation, commercial, and agricultural.

The intent of this land use evaluation is to identify feasible options for the development of the DCF Study Area as it pertains to the selection of RAOs and PRGs.

3.4.1.2 Anticipated Future Land Use

It is anticipated that the Army will retain operational control of the DCF Study Area and that future land use will be as described in the Fort Riley Real Property Master Plan (RPMP) (BMcD, 2003). This anticipated use consists of:

- Land use at the DCF Study Area is classified under the Fort Riley RPMP as an open area. Open areas have building restrictions and are used for safety areas, utility clearances and easements, conservation areas, and buffer zones. This area includes DCFA.

- The area south of the UPRR grade (the Island) will remain as forested open space. All of this area is within the active flood plain of the Kansas River. The RPMP restricts construction in the flood plain and future construction in this area is not anticipated.

- Portions of DCFA and all of the Island are located within a 100 meter buffer zone established by the U.S. Fish and Wildlife Service as a critical wildlife habitat for bald eagles. This area is under the protection of federal and state endangered species law. The RPMP restricts construction in this area and future construction is not anticipated.

These anticipated land uses should be considered in defining RAOs and evaluating remedial alternatives. It is anticipated that Fort Riley will continue to remain as an active U.S. Army post into the foreseeable future with no change in its basic mission. Land use for all areas within the DCF Study area should remain essentially as is. Based on projected land uses, the area that contains the contaminated subsurface soil (DCFA) will be classified as an open area with building restrictions that are anticipated to remain in place for the foreseeable future.

3.4.2 Groundwater Beneficial Use

RAOs and PRGs should reflect current and potential future groundwater uses and exposure scenarios that are consistent with those uses. As identified in the risk assessment, groundwater at the Site is not currently used as a drinking water source, nor is such use anticipated in the future. Fort Riley possesses sufficient excess capacity from the existing supply wells to provide potable water for any foreseeable expansion on the post. Additionally, the evaluation of environmental risk concluded that there is no detrimental exposure to environmental receptors at the Site.

The Kansas River reach flowing through Fort Riley is a major classified river under the Kansas State Water Plan. This reach of the river has multiple designated uses, one of which is domestic supply (KDHE, 2002). Because of this designated use, the Kansas River and its associated alluvial aquifer fall under the Kansas Antidegradation Policy. This policy applies in those situations where either an intentional or unintentional release of pollutants from a point source results in contamination or potential contamination of an alluvial aquifer that threatens to preclude attainment of the designated use of the alluvial aquifer or its associated surface water (KDHE, 1999).

Although there is virtually no prospect for supply wells to be installed within the Kansas River alluvial aquifer on the Island, groundwater here does discharge from the alluvial aquifer to the Kansas River along this reach. Therefore the beneficial use of the groundwater would be as a potential source of domestic supply once it discharges to and enters the surface water system. RAO and PRG development should reflect this.

Because of low transmissivities, the terrace aquifer is not considered to be a potential source for supply wells.

3.4.3 Defined RAOs

Based on the HHBRA and ECORA, the preliminary ARARs identified in Section 2.0, the media of interest, the COPCs in soil and groundwater at the DCF Study Area, and the anticipated land and beneficial groundwater use, the following soil and groundwater RAOs are presented:

- Prevent the migration of subsurface soil contaminants to groundwater at the DCFA,

- Prevent the potential for degradation of the surface waters of the Kansas River by preventing migration of contaminated groundwater from the terrace areas to the alluvial aquifer, and

- Reduce contaminant levels, to the extent practicable and appropriate, through natural and/or active remedial processes.

The RAOs are listed in the general sequence in which they should be addressed (USEPA, 1997). These RAOs will be used in the development and evaluation of remedial alternatives.

3.5 PRELIMINARY REMEDIAL GOALS

PRGs are the desired end point concentrations or risk levels, for each exposure route, that are believed to provide adequate protection of human health and the environment. PRGs are usually quantitative chemical-specific concentration targets for each individual COPC for each reasonable exposure scenario. When chemical-specific ARARs are not available or appropriate, risk-based PRG concentrations are often used to address contamination at environmental sites. PRGs are guidelines that establish chemical-specific or site-specific cleanup goals for soil and groundwater, and are formed from a compilation of MCLs, non-promulgated cleanup levels, and chemical, physical, and toxicological properties of the contaminants.

For soils, the PRG for PCE at the DCF Study Area is the KDHE RSK value of 180 ug/kg for the soil to groundwater pathway. For groundwater, drinking water standards are used although CERCLA Alternate Concentration Limits (ACLs) may also be used if the requirements of CERCLA Section 121 (d) (2) (B) (ii) are met. ACLs may be established in lieu of cleanup levels that would otherwise be ARARs. ACLs may be established where cleanup is not practicable or cost-effective (USEPA, 1989a) and where the circumstances fulfill the following conditions as identified in the NCP:

1) Contaminated groundwater discharges to surface water;

2) Such groundwater discharge does not lead to statistically significant increases of contaminants in surface water; and

3) Enforceable measures can be implemented to prevent human consumption of the contaminated groundwater.

In general, ACLs may be used where the preceding conditions are satisfied (as at the DCF Study Area), and where restoration of groundwater to beneficial use is found to be impracticable. In the context of determining whether ACLs could or should be used for a given site, practicability refers to an overall finding of the appropriateness of groundwater restoration. This is based on the analysis of remedial alternatives using the remedy selection criteria, especially the balancing criteria (long-term effectiveness and permanence; reduction of toxicity, mobility, or volume through treatment; short-term effectiveness; and cost) and modifying criteria (state and community acceptance). This is distinct from a finding of "technical impracticability from an engineering perspective", which refers specifically to an ARAR waiver and is based on the narrower grounds of engineering feasibility and reliability (with cost generally not a factor). When establishing an ACL, a detailed site-specific justification should be provided in the Administrative Record, which documents that the above three conditions for use of ACLs are met, and that restoration to ARAR or risk-based levels is not practicable.

Generally, drinking water standards are relevant and appropriate as PRGs for groundwater that is determined to be a current or potential future source of drinking water. As indicated in Section 3.4.2, groundwater at the DCF Study Area is considered to have a potential beneficial use as a drinking water source due to its hydraulic connection to the Kansas River; therefore, the PRGs are defined as the drinking water MCLs. The PRGs for the DCF Study Area including the DCFA, the Transition Zone, and the Island, are as follows:

- PCE 5 µg/L
- TCE 5 µg/L
- cis-1,2-DCE 70 µg/L
- VC 2 µg/L

As stated previously, the terrace aquifer yield is too low to be a potential source of and therefore may be subject to the Groundwater Quantity Standard B1 or B2 as set forth by BER-RS-045 of February 2004. This policy states that a groundwater bearing unit that is not capable of producing groundwater at a rate greater than 150 gallons per day or produces groundwater seasonably may be determined to be a non-potable source due to inadequate yield or unsustainable long-term yield.

The final remedial goals will be established during remedy selection. These goals can be changed at a later time if more appropriate standards are adopted by the regulatory community, if it is found that technical limitations preclude achieving the goals, if it is found that aquifer restoration is not practicable, or if ACLs are appropriate.

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4.0 IDENTIFICATION AND SCREENING OF TECHNOLOGIES

4.1 INTRODUCTION

The purpose of this section is to identify and evaluate potential remedial technologies for the DCF Study Area. There are three areas of specific concern that are present at the DCF Study Area and include the shallow subsurface soil at and beneath the building footprint of former Building 180, groundwater within the bedrock erosional channel near Monitoring Well DCF01-40, and the groundwater near Monitoring Well DCF02-42. The selection of potentially feasible technologies for the DCF Study Area comprises two steps:

1) Identification and initial screening of potential remedial technologies and process options, and

2) Evaluation of remedial technologies and process options.

Remedial technologies refer to general categories of technologies within each general response action (GRA) group. For example, biological treatment and physical/chemical treatment are technologies within the in-situ treatment GRA. Process options refer to specific processes within each technology type. For example, air sparging and in-situ chemical oxidation are process options under physical/chemical technologies. In subsequent chapters, selected technologies and process options are assembled into remedial alternatives capable of achieving the established RAOs. The GRAs selected for the DCF Study Area soil and groundwater remediation are presented below:

- No Action;
- Institutional Controls;
- Other Controls;
- Monitored Natural Attenuation (MNA);
- Containment;
- Ex-Situ Treatment; and
- In-Situ Treatment.

4.2 IDENTIFICATION AND INITIAL SCREENING OF POTENTIAL TECHNOLOGIES AND PROCESS OPTIONS

4.2.1 Identification of Potential Technologies and Process Options

The initial step taken in the technology evaluation process consists of the identification of potentially applicable technologies and process options, which may be used for the management, containment, treatment, and/or disposal of contaminated soil and groundwater. Technologies selected for preliminary screening represent a wide range of responses commonly used to address soil and groundwater contamination. Both fully-developed and emerging process options have been considered. A list of technologies and process options is presented in Table 4-1. Technologies are grouped into seven distinct subsets that correspond to the identified GRAs.

4.2.2 Initial Screening of Technologies and Process Options

Identified technologies are initially screened to eliminate technologies that cannot be effectively implemented at the DCF Study Area. Technologies are removed from further consideration if they are not technically feasible based on site-specific conditions such as the soil and aquifer characteristics, the volume of impacted soil and groundwater, and the chemical characteristics of compounds of interest. Table 4-2 presents a summary of this initial screening of technologies along with a brief description of each technology and the rationale for eliminating process options from further consideration.

4.3 EVALUATION OF TECHNOLOGIES

4.3.1 General

Following the initial technology screening, remaining potentially applicable technologies and process options are further evaluated to determine which are potentially feasible for implementation at the DCF Study Area. This section describes the evaluation and screening procedures and criteria which result in the selection of feasible remedial technology options.

Following USEPA guidelines (USEPA, 1988), the technology screening evaluation process considers the relative effectiveness, implementability, and cost of each process option for achieving RAOs. Specific technology processes are evaluated based on these three criteria as to whether they are effective (or have a low cost), have no advantage or disadvantage, or are ineffective (or have a high cost) relative to other processes within the same technology type.

The effectiveness of the process option focuses on: (1) the applicability of the process option for the given site characteristics and estimated areas and/or volumes of contaminated medium and its ability to meet the PRGs identified in the RAOs; (2) the potential impacts to human health and the environment during implementation of the process option; and (3) how proven and reliable the process option is for the given contaminants and site conditions.

Implementability considers the technical and administrative feasibility of using the technology at the site. Technical considerations include the ability to construct, maintain, and operate the technology and the ability to comply with regulations. Administrative considerations include the ability to obtain necessary approvals and the availability of equipment, materials, and services.

The relative cost evaluation of each process option focuses on a qualitative evaluation of the capital and operation and maintenance (O&M) costs to implement the technology as compared to other options in the same technology group. These costs will vary significantly from site to site and are used only as a preliminary indication of financial resources required to implement each technology. At this stage of the FS process, effectiveness and technical implementability evaluations of process options are more important than administrative implementability and cost analyses.

The evaluation of technologies and general comments regarding potential benefits or limitations of each process option are provided in Table 4-3 as part of the screening process. From the technology screening process, several process options are identified as potentially feasible options for soil and groundwater remediation at DCF Study Area based on relative potential effectiveness, implementability, and cost. The following sections evaluate process options, identify technologies selected for development of potential remedial alternatives, and provide the rationale for eliminating process options from further consideration. Technologies and process options are discussed by GRA, as identified above. Only technology and process options retained from the initial screening (Table 4-2) are discussed in the following sections.

4.3.2 No Action

Pursuant to Section 300.430(e)(6) of the revised NCP (March, 8 1990) and the USEPA's current guidance for conducting remedial investigations/feasibility investigations (RI/FS), the "no action" option must be developed and examined as a potential remedial action for all sites. Pursuant to the NCP, this action is retained for further consideration as a baseline for comparison with other remedial actions.

4.3.3 Institutional Controls

Institutional controls such as land used restrictions, water use restrictions, and alternative water supplies can be used to prevent or reduce exposure to soil and groundwater contaminants. Institutional controls are generally divided into two categories: governmental controls and proprietary controls. Governmental controls are usually implemented and enforced by state or local government and can include zoning restrictions, ordinances, statutes, building permits, or other provisions that restrict land or resource use at a site. Local governments have a variety of land use control measures available from simple use restrictions to more sophisticated measures such as planned unit development zoning districts and overlay zones (USEPA, 2000a). While governmental control of property also falls under state or local law, it does not present the same enforcement issues as private controls. Governmental controls remain effective so long as they are not repealed and are enforced. Proprietary controls include private land use restrictions that typically result by agreement with the landowner and an enforcing party that may be a neighboring landowner, a state environmental agency, or a local civic association. These controls are generally referred to as deed restrictions, since the restriction typically becomes placed within the chain-of-title to the restricted property. The benefit of these types of controls is that they can be binding on subsequent purchasers of the property (successors in title) and transferable, which may make them more reliable in the long-term than other types of institutional controls (USEPA, 2000b).

Since Fort Riley is a federal reservation, neither governmental controls nor proprietary controls are considered appropriate mechanisms for the application of institutional controls. Therefore, these types of institutional controls will not be discussed further.

4.3.3.1 Institutional Controls Through the Fort Riley Real Property Master Plan

Institutional controls could be applied through use of the Fort Riley RPMP. The RPMP ensures that compatibility of land uses are considered when planning for locations of functions or facilities. It is the equivalent of a city or county zoning plan. It also serves as a framework for maintenance and repair resource allocation and development activities. Army Regulation (AR) 210-20 "establishes a relationship between environmental planning and real property master planning to ensure that the environmental consequences of planning decisions are addressed." This is accomplished by the long-range component (LRC) in the RPMP. It consists of a variety of narratives and supporting graphics. One of these graphic representations is the Master Plan Environmental Overlay. This graphic reflects operational and environmental constraints.

The RPMP is the means the post authorities have to control and limit development and other activities on the post. This includes overall controls on land use, the issuing of excavation permits that could define and limit potential exposure for utility and grounds workers, and tactical dig permits that control potential exposure for soldiers.

In addition, the RPMP would be the appropriate planning mechanism for addressing the issue of water supply well locations. Fort Riley currently has a supply well field that is not operating near capacity. There is currently no reason to construct water supply wells at the DCF Study Area since the post has sufficient surplus supply to meet future contingencies (BMcD, 2003). A restriction on the construction of supply wells at the DCF Study Area could be incorporated into the RPMP as a remedial alternative (institutional control).

Institutional controls, through use of the RPMP, will be retained for inclusion as a potential component of remedial alternatives.

4.3.4 Other Controls

Other controls include monitoring rural water supply, new supply wells, and individual well treatment. Only monitoring will be addressed in this section. Rural water supply, new supply wells, and individual well treatment are not addressed since these were eliminated from consideration during the initial screening of technologies (Table 4-2).

4.3.4.1 Groundwater Monitoring

Groundwater monitoring can be used to evaluate contaminant concentration and migration, monitor NA, and evaluate remedial system performance. Monitoring results can indicate the need to take appropriate measures, and/or modify the operation of the remedial system, should contaminant concentrations indicate that contaminant migration from the terrace area to the Kansas River alluvial aquifer continues. A network of groundwater monitoring wells is currently in place at the DCF Study Area. If necessary, additional monitoring wells can be installed to evaluate specific remedial system requirements. Groundwater monitoring is an effective means of evaluating site conditions and is readily implemented at the DCF Study Area.

Groundwater monitoring is retained for inclusion as a potential component of remedial alternatives, since this option may be used in combination with other remedial technologies.

4.3.5 Monitored Natural Attenuation

MNA refers to the reliance on natural attenuation processes (within the context of a controlled and monitored site cleanup approach) to achieve site-specific remediation objectives within a time frame that is reasonable compared to those time frames offered by other more active methods (KDHE, 2001). MNA relies on natural subsurface processes to reduce contaminant concentrations. Some of these natural processes may be dilution, dispersion, volatilization, biodegradation, sorption, and chemical reactions with subsurface materials.

MNA is an active research topic and is becoming increasingly accepted as a remedial alternative. Mechanisms that result in natural attenuation are either destructive or nondestructive. Nondestructive mechanisms include dispersion, diffusion, dilution, volatilization, and sorption.

Dispersion, typically referred to as mechanical dispersion, is the process by which a contaminant plume spreads or disperses as it moves downgradient. Contaminated groundwater mixes with uncontaminated groundwater and produces a dilution of the plume along the leading edge (Fetter, 1993).

Diffusion is the process by which contaminants move from an area of greater concentration toward an area of lesser concentration (Fetter, 1993). Diffusion processes are more pronounced in groundwater systems with very slow flow velocities. The faster the flow velocity, the less likely there will be a noticeable effect due to diffusion processes.

Dilution is the process by which contaminant levels are reduced by introducing clean water into an area of contaminated groundwater. The clean water mixes with the contaminated water and reduces the contaminant concentrations through dilution.

Volatilization is the process by which groundwater concentrations of chlorinated solvents are reduced through mass transfer between liquid and gaseous phases. Contaminants that come in contact with air molecules may transfer from a liquid to gaseous phase and enter the air, thus decreasing the concentration in groundwater.

Adsorption is the process by which contaminants adhere to the solid surface of minerals or organic carbon present in the aquifer. These contaminants may later desorb from the solid surface and continue to flow along with the moving groundwater. This process of adsorption and desorption is generally referred to as sorption and is responsible for slowing the transport of contaminants relative to the transport of groundwater. Rebound of contaminant concentrations following treatment is often related to the adsorption and desorption process (USEPA, 1996). The effect of the desorption process also results in a tailing effect in groundwater concentrations. The sorption process is a reason why an ex-situ treatment technology such as pump and treat is less effective at a timely reduction in low contaminant levels when compared to a technology that effectively treats the sorbed phase more directly.

Destructive mechanisms include abiotic and biotic degradation processes. Abiotic degradation includes processes such as dechlorination of chlorinated aliphatic hydrocarbons through chemical reactions with ferrous iron. Biotic degradation includes degradation through mechanisms such as electron acceptor reactions, electron donor reactions, and co-metabolism. An important process of natural biodegradation of chlorinated solvents in groundwater is through reductive dechlorination (an electron acceptor reaction) (Wiedemeier and Chapelle, 1998). The reductive dechlorination pathway for PCE is as follows:

PCE → TCE → cis or trans-1,2-DCE → VC → Ethene → Carbon Dioxide (CO_2) + water (H_2O).

MNA is sometimes perceived as equivalent to "no action". However, MNA differs from the "no action" alternative in that the site is actively monitored and evaluated to reduce the risk of exposure and to evaluate potential further degradation of the aquifer. Typical performance parameters monitored for natural attenuation include: temperature, pH, methane, ethene/ethane, alkalinity, nitrate, sulfate/sulfide, chloride, total organic carbon (TOC), dissolved oxygen (DO), oxidation reduction potential (ORP), iron, and contaminant concentrations. System components of MNA are usually groundwater wells, soil borings, and/or soil vapor probes.

For MNA to be a considered a stand-alone remedial alternative for the DCF Study Area, the criteria outlined in the following guidance documents must be met: *Monitored Natural Attenuation, Bureau of Environmental Remediation/Remedial Section Policy*, BER Policy # BER-RS-042 (KDHE, 2001); and *Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites* (USEPA, 1999).

Consideration of this option as a sole remedy requires collection of groundwater quality information and evaluation of contaminant degradation rates and pathways. Site-specific analytical data collected at the DCF Study Area indicate that natural processes have reduced the chlorinated solvent contaminant concentrations below regulatory standards before potential exposure pathways are completed in the eastern plume. Additionally, the presence of petroleum hydrocarbon contamination (TPH and toluene) in groundwater samples collected from bedrock Monitoring Well DCF93-19 have enhanced NA by providing a carbon source. Site-specific analytical data collected from areas within the western plume indicate that natural processes have not reduced the chlorinated solvent contaminant concentrations below regulatory standards before potential exposure pathways are completed.

The eastern plume originates near Monitoring Well DCF01-40 and the western plume originates near Monitoring Well DCF02-42. Although some contaminant reduction does occur due to natural processes along the flowpath of the western plume, contaminant concentrations of PCE and TCE in monitoring wells installed along the north bank of the Kansas River are above MCLs. Site geochemical and contaminant concentrations, and results from USEPA reductive dechlorination screening protocol (USEPA, 1998) performed in the RIA, indicate there is limited evidence for reductive dechlorination (and thus natural attenuation) of chlorinated solvents within the western plume at the DCF Study Area. Therefore, MNA will only be retained as a potential component of an overall remedial alternative package and will not be considered as a sole remedy.

4.3.6 Containment

Containment involves the installation of vertical barriers, treatment walls, groundwater collection and extraction systems (pump and treat), or capping to control, arrest, or divert groundwater contaminant plumes. The type of containment method used depends upon site specific parameters such as soil type, depth to bedrock, type of contamination, contaminant concentration, and aquifer permeability.

4.3.6.1 Barrier Walls

Vertical barriers are typically used as containment walls that are installed to fully surround an area of contamination in order to arrest migration of contaminants. Horizontal barriers are low permeability barriers that prevent the leaching of contaminants to groundwater. Barriers can also be used as a means of focusing contaminant migration (funnel) toward a zone of treatment (gate) for either extraction and ex-situ treatment or in-situ treatment by reactants or amendments. Types of barrier walls include: slurry walls, sheet piling, and deep soil-mixed walls.

Slurry walls are low permeability vertical cutoff walls, which are constructed by installing a vertical barrier into the subsurface using the slurry trench method of construction. The resulting vertical barrier has a lower hydraulic conductivity than the associated formation. Slurries typically consist of lime, bentonite, cement, and/or a proprietary mixture. Sheet piling consists of steel sheets that are driven into the ground using vibratory or impact equipment to form a continuous cutoff wall. Deep soil mixing cutoff walls are installed using a crane-supported series of mixing paddles and augers that lift and mix the soil with a low permeability slurry as they penetrate through the subsurface.

Vertical and horizontal barriers are removed from further consideration because of the difficulty and cost of construction in aquifers at depths of approximately 42 feet near the Monitoring Well DCF01-40 area. For the Monitoring Well DCF02-42 area, less difficult options are available for consideration such as in-situ bioremediation and chemical oxidation (chemox).

4.3.6.2 Treatment Walls (Permeable Reactive Barriers)

Specialized treatment walls installed across a contaminant plume flow path are called Permeable Reactive Barriers (PRB). PRBs consist of permanent, semi-permanent, or replaceable media that react with the targeted contaminant. As contaminated groundwater moves through the PRB, the contaminants are removed by physical, chemical, and/or biological processes (Vidic, 2001). These processes include precipitation, sorption, oxidation/reduction, fixation, or degradation. The PRBs may contain metal-based catalyst such as zero-valent iron (Fe^0), nutrients, oxygen, or other reactants that chemically reacts with chlorinated solvents usually yielding non-toxic and non-chlorinated by-products. With Fe^0, iron and chlorinated organics undergo an oxidation/reduction reaction, which results in the dehalogenation of the contaminants. Fe^0 acts as an electron donor being oxidized into ferrous iron (Fe^{+2}), while carbon atoms act as electron acceptors being reduced to lower oxidation states. In this reduction process, the carbon atoms release chlorine atoms, which are replaced by hydrogen. As a result, the reductive elimination process usually renders non-toxic chlorine-free organic compounds.

Main parameters considered in the design of Fe^0 PRBs are the residence time in the reaction zone and the reaction zone size to provide an appropriate life span. Residence time in the PRB is of special importance in completing degradation of highly chlorinated solvents, such as PCE and TCE. If contaminants are not completely dehalogenated, intermediates, such as DCE and VC, may still be present in the effluent. The latter is more toxic than PCE itself. Fe^0 PRB design and residence time calculations are available from EnviroMetals Technologies Inc., who owns the patent on this technology.

This technology has several potential advantages and disadvantages when compared to other technologies. A major advantage is that PRBs do not require a continuous input of energy. However, a disadvantage of this technology is that it may require periodic replacement or rejuvenation of the reactive iron medium if its capacity is exhausted. The life of the iron medium mainly depends on contaminant concentrations and groundwater quality in the aquifer. Replacement of the iron medium would increase the cost of the technology based on multiple applications. Other advantages are that groundwater is conserved, contaminants are destroyed (not just transferred to other media), and no above-ground structures are required. Therefore, the land surface can be returned to other useful purposes. This technology is ideal for large-scale application but is cost prohibitive for small-scale sites.

PRB is not retained for further evaluation because of the difficulty of implementation, high capital cost, and low solvent concentration of the groundwater plume.

4.3.6.3 Groundwater Collection and Extraction System

Extraction of contaminated groundwater can be accomplished through use of vertical and directional wells equipped with pumps that extract contaminated groundwater for treatment and disposal. The design of recovery wells depends on the type of aquifer that has been contaminated and the recovery rate that is required. The recovery rate determines the size and type of pump and, consequently, determines the diameter of the casing and screen.

Vertical pumping wells are a proven technology for hydraulic containment of groundwater plumes, however the limitations of this technology in reducing contaminant concentrations to MCL (within a reasonable duration) have been well documented (USEPA, 1996). Directional or horizontal pumping wells are an emerging technology, which is finding increased applications to ground water remediation. Horizontal collection wells can have an advantage over vertical wells because of the ability of a single horizontal well to contact a large horizontal area, and because horizontal aquifer transmissivity is generally greater than vertical transmissivity (Domenico and Schwartz, 1990). This provides an advantage in plumes that are laterally extensive, but vertically restricted. Horizontal wells are more expensive to install per well than vertical wells, but usually fewer are required to accomplish the same results.

Typically, pumping well systems (generally referred to as "pump and treat" systems) have been successful in reducing high (milligrams per liter [mg/L]) concentrations to much lower levels (i.e., µg/L), but not to MCLs. Reduction to concentrations below MCLs are usually achieved by "polishing" using an additional alternative more appropriate to low level concentrations.

Because pumping well systems typically do not reduce contaminant concentrations to levels below the target MCLs and require the installation and operation of an additional alternative to reduce the contaminant concentrations to levels below the MCL, collection/extraction systems (i.e., pump and treat) is not retained as a viable remedial alternative.

4.3.6.4 Surface Capping

Capping is the most common form of remediation because it is generally less expensive than other treatment technologies and effectively manages the human and ecological risk associated with remediation of a site (FRTR, 2004). In general, capping eliminates or minimizes surface exposure and prevents vertical infiltration of precipitation and overland runoff. Capping is most effective when most of the contamination is above the water table. Components of a cap can range from complex, using a multitude of layers consisting of soil barrier layers, geomembrane layers, drainage layers, and protection layers to simple, but effective single-layer caps composed of concrete or bituminous asphalt.

Capping does have limitations, which reduces its potential as a component of remedial alternatives. Capping does not lessen the toxicity, mobility, or volume of the contaminant in groundwater, although it does mitigate migration through the subsurface soil in the vadose zone. Additionally, a cap will not prevent the horizontal flow of groundwater through the bedrock erosional channel from areas of upgradient recharge and from Tributary A bank recharge (losing stream effect). Based on these limitations, capping is not retained for inclusion as a potential component of remedial alternatives.

4.3.7 Ex-Situ Soil Removal and Treatment

Ex-situ soil removal involves excavation of contaminated soil at the source area that contains PCE concentrations above the KDHE RSK value for the soil to groundwater protection pathway of 180 μg/kg. Excavated soil would be removed and transported to a newly constructed landfarm, an existing landfarm, or off site for ex-situ thermal treatment and disposal.

4.3.7.1 Soil Excavation and Backfill

Subsurface soil with concentrations of PCE above the KDHE RSK value of 180 μg/kg are currently found within the building footprint of former Building 180 and between former Building 180 and Manhole 363. More detail for this area is provided in Section 5.3.2.1. Subsurface soil contamination in these locations extends from approximately one to twelve ft bgs. The soil in these areas would be excavated using a backhoe and placed in lined end-dump trucks for removal off site. Following soil removal, clean soil with a high clay content would be transported to the site and used as backfill in the excavations.

4.3.7.2 Landfarming

Following excavation, the extracted soil would be transported to a landfarm treatment unit. Landfarming is an effective above-ground remediation technology that reduces VOC contaminant concentrations. A landfarm treatment unit is a lined, bermed area that would contain the excavated soil. Installation of a leachate collection system would also be required to handle water that accumulates within the bermed area due to precipitation events. Excavated soil placed within the bermed area would be spread out in windrows and periodically disked. Solar radiation, wind, and periodic disking of the soil would promote volatilization and biodegradation of the VOCs. The excavated soil could be placed in a newly constructed landfarm at a designated area at Fort Riley or the soil could be added to the conceptual landfarm currently being considered for excavated soil from the Building 354 Site.

4.3.7.3 Thermal Treatment and Disposal

Following excavation, the extracted soil would be transported off site for thermal treatment (incineration) at an approved facility. Excavated soil would be loaded into end-dump trucks equipped with a new bed liner placed before loading. The soil would then be transported to the nearest incineration facility (Kimball, Nebraska). Following incineration, the soil would be used as landfill cover. Incineration operates at high temperatures between 800 to 1,200 degrees Celsius (°C) or 1,400 to 1,600 degrees Fahrenheit (°F). At these temperatures, VOCs would volatilize and combust. The destruction and removal efficiency for properly operated incinerators exceeds the 99.9 % requirement for hazardous waste. Although this potential component would effectively remove the contaminated subsurface soil from the former Building 180 area, the cost would be high.

Based on the effectiveness of soil excavation with disposal at a landfarm treatment unit or soil excavation with off site thermal treatment and disposal, both of these ex-situ treatment technologies are retained for further consideration as potential components of remedial alternatives.

4.3.8 In-Situ Treatment

4.3.8.1 Enhanced Anaerobic Bioremediation

Common electron acceptors used by microorganisms to degrade organic compounds under aerobic (oxygen [O_2]) or anoxic (nitrate [NO_3^-], sulfate [SO_4^{-2}]) conditions become depleted in anaerobic environments. Therefore, under these conditions, chlorinated solvents have been shown to serve as terminal electron acceptors through reduction reactions. Reduction reactions may be of an abiotic or a biotic nature. Through reduction reactions, chlorinated solvents are dehalogenated (i.e., chlorine atoms are replaced by protons) and the carbon atoms are reduced to a lower oxidation state.

Anaerobic conditions can be produced or enhanced in the subsurface by introducing a primary carbon source, such as glucose, molasses, acetate, organic oils, or lactate; and/or mineral nutrients, such as nitrogen and phosphorous. When proper anaerobic conditions are attained, the introduced carbon source acts as an electron donor and the target contaminants are reduced. For example, PCE is dechlorinated to TCE, and TCE is dechlorinated to DCE and VC. Since the carbon atoms in the resulting intermediate products of the dehalogenation process (e.g., DCE) have a lower oxidation state, these intermediates are more susceptible to subsequent aerobic biological oxidation.

Enhanced anaerobic bioremediation (EAB) systems can be designed to function as an injection/recovery well system, or injection only well system. Systems consisting of horizontal and/or vertical wells have been used to inject gaseous or liquid additions into groundwater aquifers. EAB systems are generally more applicable to medium- to coarse-grained aquifers where compounds and nutrients can be easily delivered to the aquifer. EAB is very site specific and typically requires extensive pilot testing to determine which system design and/or nutrient option is the most applicable to the site.

Vegetable oil has been used recently by the United States Air Force for EAB. The vegetable oil is composed of triacylglycerols consisting of molecules of carboxylic acids. Microbes breakdown the carboxylic acid in a process called beta-oxidation, thus providing a slow-release carbon source and electron donor to support long-term anaerobic biodegradation (AFCEE, 2004). One of the benefits of organic oils is the partitioning of the contaminants in the oil rather than on the subsurface structure or groundwater, thus reducing the amount of dissolved contaminant and the risk to downgradient receptors. This ultimately results in a combined containment and treatment technology.

A common carbon source is polylactate ester specially formulated for slow release of lactic acid upon hydration. Water soluble formulations represent another class of injectable electron donors. Sodium lactate and molasses solutions are examples of water soluble electron donor products. Water soluble formulations must be injected more frequently (i.e., about every 2-5 weeks), than slow-release electron donor products (i.e., about every 6-12 months). The polylactate is applied to the subsurface via direct-push injection or within dedicated wells. The polylactate is then left in place where it passively works to stimulate contaminant degradation (Regenesis, 2003). The process by which polylactate operates is a complex series of chemical and biologically mediated reactions. Initially, when in contact with subsurface moisture, the polylactate slowly releases lactic acid. Indigenous anaerobic microbes (such as acetogens) metabolize the lactic acid, producing low concentrations of dissolved hydrogen. The resulting hydrogen is then used by other subsurface microbes (reductive dehalogenators) to replace the chloride atoms with hydrogen atoms and allows for further biological degradation. When in the subsurface, the lactate continues to operate for a period of approximately one year, degrading a wide range of chlorinated aliphatic hydrocarbons including PCE and TCE, as well as their daughter products (Regenesis, 2003).

The polylactate formulation includes a time-release mechanism to facilitate controlled hydrogen production, to help optimize reductive dechlorination. This controlled release of hydrogen from lactate has been documented in field applications to generate the desired conditions for dechlorination (2-8 nanomolar) resulting in contaminant degradation and site restoration (Regenesis, 2003).

EAB is retained for inclusion as a potential component in remedial alternatives due to the potential for enhancing reductive dechlorination of chlorinated solvents at the DCF Study Area.

4.3.8.2 Air Sparging

Air sparging is an in-situ physical treatment process used to remove volatile chemicals from groundwater. During air sparging, air is discharged into the aquifer through sparging wells. This creates a radial flow of air horizontally and vertically through the saturated soil column. The air flow enhances chemical volatilization. The air bubbles produced during sparging carry the volatilized contaminants to the unsaturated soil layer where they may require removal by SVE wells. Air sparging is applicable to the treatment of chlorinated and non-chlorinated VOCs and fuels.

Air sparging systems have traditionally been designed and implemented using a series of vertical injection wells. One of the major disadvantages of this method is that a close spacing of wells, and thus a large number of wells, is typically required. More recently, horizontal wells have been successfully used in air sparging systems. This method has been shown to be effective and requires fewer wells than a typical vertical well system.

At the DCF Study Area, specifically around Monitoring Well DCF01-40, the terrace aquifer is thin and the subsurface soil is not uniform. Aquifer heterogeneties significantly reduce the effectiveness of this technology in this area. In the area around Monitoring Well DCF02-42, the terrace aquifer is thin (less than 2 ft of saturated thickness), and has been dry on occasion, but the soil in the vadose zone is relatively uniform.

The overall effectiveness of this technology is limited at the DCF Study Area based on aquifer thickness and soil heterogeneity. Additionally, the overall effectiveness may also be reduced because air flow from sparging has been shown to flow primarily in discrete air channels, limiting the amount of saturated zone contacted by the air and producing only minimal mixing. These deficiencies results in limited, slow, diffusion and will probably only reduce, not prevent the migration of PCE from the terrace to the Kansas River alluvial aquifer.

Based of the reduced effectiveness of this technology due to soil heterogeneity and aquifer thickness, air sparging is removed from inclusion as a potential component in remedial alternatives.

4.3.8.3 C-Sparger™

C-Sparger™ systems are patented systems that combine in-situ air stripping with in-situ chemical oxidation to remove and destroy chlorinated solvents in the subsurface. In this system, an air/ozone mixture is injected below and into the VOC plume in the form of fine bubbles with a high surface to volume ratio. The gas bubbles extract the volatile contaminants from the contaminated groundwater and the ozone (O_3) contained within the bubbles reacts in the gaseous phase to decompose the solvents into CO_2, H_2O, and hydrochloric acid (HCl).

The system consists of a two-screen well, two air/ O_3 points of injection, one below the well casing and the other at the bottom screen, and a submersible pump. Pulsed injection of air/ O_3 through the bottom diffuser introduces bubbles near the bottom of the plume region, which move upward through the contaminated water. Within the central core area of the plume, a second air/ O_3 diffusion point, combined with the intermittent operation of a submersible pump at the bottom screen of the well, displaces the vertically-moving bubbles laterally to maximize dispersion and contact. By pulsing the pump operation, groundwater enters the well through the top screen and is forced into the aquifer through the bottom screen. Therefore, groundwater is externally circulated from the bottom to the top of the well, causing circulation of groundwater in the aquifer adjacent to the well and improving the treatment area of the VOC-impacted saturated zone.

With this technology, a vapor recovery system in the vadose zone is not necessary because by the time the gas bubbles reach the unsaturated zone, the contaminants are oxidized by the O_3. One potential concern with this approach may be the O_3, which is an air pollutant itself. The quantity of ozone fed to the system needs to be carefully evaluated based on contaminant concentrations in the groundwater. In theory, the amount of O_3 needed could be calculated from the chemical oxidation reaction by stoichiometry; however, there may be other organic materials competing with the contaminants of concern, which would increase the required dose.

C-Sparging™ is removed from further consideration because it is has no distinct advantage over competing technologies, is not very effective on low concentration VOC plumes, has similar limitations to pump and treat systems, and requires extensive O&M.

4.3.8.4 Groundwater Circulation Wells

The technology of groundwater circulation wells (GCW) provides volatilization of VOCs within the well casing. In this system, the well has two screened intervals within the same saturated zone. The lower screen is placed at or near the bottom of the contaminated aquifer and the upper screen is installed across or above the water table. By introducing compressed air into the well casing through an open-ended bubbler pipe, groundwater is lifted within the well casing due to the density gradient created between the aerated water and the non-aerated water. As groundwater moves upward and is discharged through the upper screened interval, contaminated groundwater enters the well from the aquifer through the lower screen, creating a circulation cell around the well. A mass transfer of VOCs from the aqueous to the gaseous phase occurs within the well as the air and water mixture rises to the surface.

The three main types of GCW systems that have been used for in-situ VOCs removal are:

- NoVOCs™ patented by Stanford University and purchased in 1994 by EG&G Environmental;
- Vacuum vaporizer well (VVW) system developed in Germany and patented by IEG Technologies Corp.; and,
- Density Driven Convection (DDC) system, developed and patented by Wasatch Environmental, Inc.

With all of the systems, the treatment of VOCs is enhanced by using an SVE system to transfer the vapor to a VOC treatment system. In the VVW system, the upper and lower screens of the well casing are separated by a packer or divider and a support pump is used to improve water circulation.

The main criteria that needs to be considered in designing a GCW system are vapor pressures of the contaminants and subsurface geologic conditions. Optimum conditions for this technology are high contaminant vapor pressures, and coarse and homogeneous subsurface soils. For deep aquifers (> 50 ft), the use of a submersible pump (i.e., VVW) may be necessary to assist the air-lift effect. Potential problems associated with GCW systems may be excessive biological growth and precipitation of soluble metals around injection points. Furthermore, calcium may precipitate as insoluble calcium carbonate ($CaCO_3$) in the presence of carbon dioxide (CO_2) (or highly alkaline waters) and aquifer anisotropy can present serious problems in the design of a successful GCW system. Additional problems include upper screen interval retardation due to the presence of finer grained subsurface soils. The installation of a course-grained infiltration gallery surrounding the upper well screen area would be required to enhance the groundwater circulation characteristics for this remedial system.

Chlorinated VOCs, the main contaminants at the DCF Study Area, have high vapor pressures and are likely to be effectively volatilized by this technology. However, aquifers within the DCF Study Area present marginal hydrogeological conditions at best. Due to inherent anisotropy present within virtually all aquifers, vertical hydraulic conductivity would probably be two orders of magnitude less than horizontal hydraulic conductivity. The only practical way to overcome this is to design a significant hydraulic head difference within the GCW system. Due to the thin nature of the terrace aquifer, it would be very difficult to design a system to this constraint.

GCW are removed from further consideration because they have no distinct advantage over competing technologies, are not very effective on low concentration VOC plumes, and have the design limitations outlined in the previous paragraphs.

4.3.8.5 Soil Vapor Extraction

SVE is an in-situ unsaturated (vadose) zone soil remediation technology in which a vacuum is applied to the soil to induce the controlled flow of air and remove volatile and some semivolatile contaminants from the soil. The VOCs are removed from the vadose zone as a negative pressure (vacuum) is exerted by a vacuum pump blower. The blower is connected to vapor collection lines/manifold connected to each extraction well. The applied vacuum results in soil gas and air flow towards the extraction well, while also concurrently causing mass transfer from the water phase, which is then subsequently extracted from the subsurface soils (Marley, 1991). The mass transfer is dependent upon many factors, the most important being the volatility of the target contaminants. A contaminant's volatility is directly related to the degree to which it will partition into the vapor phase (vapor pressure).

The SVE technology supplies continuous soil airflow within the radius of influence, which in turn provides oxygen for aerobic biological degradation of contaminants. The effectiveness of SVE is controlled by the permeability and homogeneity of the soil. SVE technology works best for coarse-grained soils while fine-grained soils will limit the effectiveness of the technology.

The soil vapor removed from the soil may need to be treated to recover or destroy the contaminants, depending on local and state air discharge regulations. Vertical extraction wells are typically used at depths of five ft or greater and have been successfully applied as deep as 300 ft. Horizontal extraction wells (installed in trenches or horizontal borings) can be used as warranted by contaminant zone geometry, drill rig access, or other site-specific factors. For the soil surface, geomembrane covers are often placed over the soil surface to limit or prevent short-circuiting and to increase the radius of influence of the wells.

Subsurface soils in the areas around Monitoring Wells DCF02-41 and DCF02-42 range from homogeneous to heterogeneous. Soil contamination in the area of former Building 180 is present above the KDHE RSK value of 180 μg/kg for PCE in the upper 12 ft only (see Table 4-2 RIA), although minor PCE concentrations are detected at greater depths. Setting SVE screens close to the surface increases the likelihood for short circuiting. Additionally, the upper soil zones are composed mainly of fine-grained soils that limit the effectiveness of the system and reduces the ROI.

Based on shallow soil permeability, soil heterogeneity, depth of PCE concentrations above the KDHE RSK PCE value of 180 μg/kg, and no distinct advantage over competing technologies, SVE is removed from consideration as a potential component in remedial alternatives.

4.3.8.6 Chemical Oxidation

Chemical oxidants, such as hydrogen peroxide (H_2O_2), permanganate (MnO_4), or O_3 can be used to oxidize organic contaminants in-situ. This approach may be used to address groundwater and/or soil contamination and non-aqueous phase liquids (NAPLs). An injection method is designed for the specific site and can be either an injection well array, direct-push points, or groundwater injection galleries, depending on the media of concern. For groundwater, a concentrated oxidant solution is injected into the wells or galleries and reacts with organic material present, yielding mainly CO_2 and water (H_2O), both of which are inert and nontoxic. Larger quantities of oxidants may be required if a high organic carbon content is present in aquifer materials. An array of groundwater recovery wells may also be installed downstream of the contaminated plume to provide hydraulic containment. In this latter case, recovered groundwater would be mixed with the oxidant and reinjected into the aquifer creating a circulation cell.

When H_2O_2 is used as the oxidant in the process, Fe^{+2} may also be added as a catalyst. The combination of H_2O_2 with Fe^{+2}, known as Fenton's Reagent, has been successfully used for chemical oxidation of contaminants. Fe^{+2} enhances the production of hydroxyl radicals, which are very strong oxidants. The addition of H_2O_2 may also increase DO levels in the aquifer, which may promote aerobic degradation. Highly chlorinated VOCs are not readily biodegraded aerobically, but some of the transformation products, such as DCE, dichloroethane, and VC have been shown to be metabolized under aerobic conditions.

Permanganate is commercially available as two salts, either potassium or sodium, which differ primarily in solubility. The active oxidant is the permanganate ion; the cation (potassium or sodium) associated with the permanganate does not affect the oxidation potential of the permanganate ion, thus the selection of which salt to use depends upon evaluation of site factors and design considerations. Following selection of the permanganate salt, a treatability bench study will be conducted to determine the natural oxidant demand (NOD) of the soil. Natural organic matter (NOM) and reduced metal species in the subsurface can exert a significant oxidant demand that competes with the COPCs for the available permanganate, and may directly affect permanganate's persistence and transport in the subsurface and lead to incomplete chemical oxidation of the target compound(s). The results from the NOD treatability bench study are used to determine the mass of permanganate required for complete in-situ chemical oxidation. At most sites, the NOD of the soil is several orders of magnitude greater than the demand expressed by the COPCs. The mass of permanganate required to satisfy the contaminant demand is determined based on an assessment of the contaminant mass, phase, and distribution as well as the permanganate/contaminant stoichiometric relationships.

The evaluation of permanganate consumption will be conducted by monitoring the decay of MnO_4, thus allowing for a direct determination of the NOD on a mass/mass basis [gram (g) MnO_4^-/g soil]. This will determine the approximate volume of permanganate required in order to treat the COPCs, as well as overcome the NOD presented by the native soils.

A liquid limit test will also be conducted to provide information on the moisture content of the soil. The liquid limit is defined as the moisture content (expressed as a percentage of the mass of oven-dried soil) at the boundary between the liquid and plastic states. This information will also be used by the remediation subcontractor to calculate a more accurate total for permanganate demand and estimate total water requirements as a part of the remedial design.

The by-products of oxidation of permanganate and chlorinated VOCs include CO_2, potassium, hydrogen, chloride, and insoluble manganese dioxide. If precipitation of manganese dioxide in the soil is excessive, it can reduce the permeability of the soil. Although manganese dioxide is insoluble in water, dissolved divalent manganese may form under low pH and redox conditions, thus elevated concentrations of dissolved manganese may develop. Additionally, commercially available permanganate may have heavy metal impurities that may include chromium. Because the DCF Study Area is located adjacent to the Kansas River alluvial aquifer, background measurements of manganese for soil and groundwater need to be established prior to application (ITRC, 2000).

This technology works better in coarse and homogeneous soils, so that uniform distribution of the oxidant throughout the soil matrix can be achieved. However, large quantities of oxidants may be required to effectively reduce contaminant concentrations. In low permeability or highly heterogeneous soils, non-uniform distribution of the reagents may result in poor cleanup results. Technical considerations do not significantly limit the implementability of this technology.

In-situ chemical oxidation is retained as a remedial technology that could be applied to the relatively localized groundwater hot spots at the Monitoring Well DCF01-40 and/or DCF02-42 areas.

4.3.8.7 Redox Manipulation

In-situ redox manipulation (ISRM) is a new, innovative technology that is based upon the in-situ manipulation of natural processes to change the mobility or form of contaminants in the subsurface. ISRM was developed to remediate groundwater that contains chemically reducible metallic and organic contaminants. ISRM creates a permeable treatment zone by injection of chemical reagents and/or microbial nutrients into the subsurface. The type of reagent is selected according to its ability to alter the oxidation/reduction state of the groundwater, thereby destroying or immobilizing specific contaminants. Because unconfined aquifers are usually oxidizing environments, and many of the contaminants in these aquifers are mobile under oxidizing conditions, appropriate manipulation of the redox potential can result in the immobilization of redox-sensitive inorganic contaminants and the destruction of organic contaminants. This concept requires the presence of natural iron (i.e., ferric iron [Fe^{+3}] state), which can be reduced from its oxidized state in the aquifer sediments to serve as a long-term reducing agent [United States Department of Energy (USDOE, 2000)].

A chemical reducing agent such as sodium dithionite ($Na_2S_2O_4$) is injected into the aquifer through a conventional groundwater well. The reducing agent reacts with iron (i.e., Fe^{+3} state) naturally present in the aquifer sediments in the form of various minerals (clays, oxides, etc.). During the injection phase, the reagent is injected into the aquifer through injection/withdrawal wells at the rate and duration required to treat the desired volume of aquifer sediments. This treatment volume plus the quantity of available iron in the sediments determines the amount of reductive capacity generated in the barrier and, ultimately, the barrier's duration. During the residence phase (24 to 36 hours), the reagent is allowed to react with the aquifer sediments. The reductant reacts with the iron in the sediments by the following reaction: sulfur dioxide (SO_2)+ Fe^{+3} + H_2O = sulfite (SO_3^{-2})+ Fe^{+2} +2 hydrogen (H^+). Buffers are added to balance the groundwater pH, which decreases with the addition of $Na_2S_2O_4$.

During the withdrawal phase, unreacted reagent, buffers, reaction products, and mobilized trace metals are withdrawn through the injection/withdrawal wells and disposed. Once Fe^{+3} in the aquifer has been reduced to Fe^{+2}, reductive degradation of chlorinated solvents is initiated. Redox sensitive contaminants that migrate through the reduced zone in the aquifer become immobilized (metals) or destroyed (organic solvents). The major pathway for reductive degradation of chlorinated solvents is by reductive elimination. TCE, for example, is reduced to chloroacetylene, then to acetylene, and finally to ethene by reductive elimination. The minor pathway, hydrogenolysis, is also possible within the reactive zone, but less likely than reductive elimination. In this pathway, TCE is reductively reduced to cis-1,2-DCE, then to VC, and finally to ethene.

ISRM is a passive barrier technique, with no pumping or above-ground treatment required once the treatment zone is installed. For this reason, the O&M costs after installation are very low. The treatment zone remains active in the subsurface, where it is available to treat contaminants that seep slowly from less permeable zones. The barrier is renewable if the original emplacement does not meet performance standards.

Although ISRM has been demonstrated to treat TCE contamination at a Fort Lewis, Washington site in 1998, this technology was only moderately successful due to high permeabilities and inadequate treatment or contact time with the groundwater plume. Battelle Pacific Northwest National Laboratory is currently working with commercial partners to deploy the technology.

Because ISRM is a relatively new innovative technology, extensive pilot testing would likely be required before a full-scale system could be implemented. ISRM is removed from consideration as a potential component in remedial alternatives.

4.3.8.8 Fluid Delivery Systems

Fluids such as nutrients, oxidants, and other chemical compounds can be added to the subsurface through use of vertical or horizontal wells, borings, and direct-push delivery systems. Vertical wells and direct-push injections have typically been used to disperse and inject chemicals, oxidants, and additives into subsurface soil and groundwater aquifers. The advantage of this method is that chemicals can be continuously applied or reapplied as necessary.

Recently, direct-push technology has been used to disperse chemicals and additives into groundwater aquifers. This method has been used in bioremediation to apply lactate, and in chemical oxidation to apply oxidants to the subsurface. The advantage of this method is that multiple injection points at various depths can be used at a cost much less than that of conventional wells.

Horizontal wells have also been used to disperse chemicals and additives into the subsurface. The advantage of this method is that fewer wells are typically required to achieve the desired coverage, compared to vertical wells. In addition, fluids can be dispersed at specific depths if required, and applied continuously or reapplied as necessary.

Technical considerations do not significantly limit the implementability of these delivery systems. Vertical and horizontal fluid delivery systems are retained for inclusion as a potential component in remedial alternatives because these systems may be used in conjunction with other remedial technologies.

4.4 REMEDIAL ALTERNATIVES

Previous site investigation activities have identified three areas of concern (AOCs) and two different types of media (soil and groundwater) that need to be addressed by this FS Report. The three AOCs are the following:

- The shallow subsurface soil located around and beneath the building footprint of former Building 180.
- The groundwater in the bedrock erosional channel in the vicinity of Monitoring Well DCF01-40. Portions of this channel lie beneath the former Building 180 location. Monitoring Well DCF01-40 is screened in this channel.
- The groundwater around Monitoring Well DCF02-42. This area is located in the western portion of DCFA and is the approximate point where the western plume enters the Kansas River alluvium.

The Site presents a complex challenge for identifying and comparing alternatives to address each of the three AOCs. An alternative, which might be appropriate for one AOC and/or media, may not be applicable at another AOC. For example, an ex-situ soil removal option would be appropriate for addressing shallow soil contamination, but would not be useful for remediating groundwater contamination at depth. Similarly, a chemox injection curtain alternative for groundwater would not be applicable for shallow subsurface soil contamination. Therefore, different remedial alternatives were selected for evaluation at each of the three AOCs. For each AOC, a best option will be selected in the future as a result of the DAA. The final remedial option for the DCF Study Area will consist of three remedial technologies, one selected alternative for each of the three AOCs, plus the addition of MNA and institutional controls. For AOC 1, MNA will not be reviewed as part of the remedial alternatives for this area since MNA is also being considered for the other AOCs.

Based on the results from the screening procedure previously presented, the following remedial alternatives will be considered for each of the following AOCs:

AOC 1 (Shallow subsurface soil at former Building 180)

- No Action
- Excavation and landfarming at pre-existing 354 treatment cell and institutional controls
- Excavation and landfarming at new treatment cell and institutional controls
- Excavation and off-site incineration and institutional controls

AOC 2 (Groundwater in subsurface bedrock channel near Monitoring Well DCF01-40)

- No Action
- EAB, MNA, and institutional controls
- Chemox, MNA, and institutional controls

AOC 3 (Groundwater near Monitoring Well DCF02-42)

- No Action
- EAB, MNA, and institutional controls
- Chemox, MNA, and institutional controls

* * * * * *

5.0 DETAILED ANALYSIS OF ALTERNATIVES

5.1 INTRODUCTION

This discussion of alternatives consists of the analysis and comparison of remedial alternatives and allows decision-makers to select a site remedy. During the detailed analysis, each alternative is assessed against the evaluation criteria described in Section 5.2. The results of this assessment are summarized to compare the alternatives and identify the key tradeoffs in Section 6.0 of this report. This approach to analyzing alternatives is designed to provide decision-makers with sufficient information to adequately compare the alternatives, select an appropriate remedy for a site, and demonstrate satisfaction of the CERCLA remedy selection requirements (USEPA, 1988).

5.2 EVALUATION CRITERIA

To address the CERCLA requirements adequately, nine evaluation criteria have been developed by the USEPA (USEPA, 1988). The first two criteria are the "threshold" factors. Any alternative that does not satisfy both of the following criteria is dropped from further consideration in the remedy selection process:

1. Protection of human health and the environment, and

2. Compliance with ARARs.

Five "primary balancing" criteria are then used to make comparisons and to identify the major trade-offs between the remedial alternatives. Alternatives that satisfy the threshold criteria are evaluated using the following balancing criteria:

3. Long-term effectiveness and permanence,

4. Reduction of toxicity, mobility, or volume,

5. Short-term effectiveness,

6. Implementability, and

7. Cost.

The remaining two criteria are "modifying" factors and are to be evaluated in the final ROD. The evaluation of these two factors can only be completed after the CERCLA Proposed Plan (PP) is published for comment and the public comment period is completed. These modifying factors are:

8. State (or support agency) acceptance, and

9. Community acceptance.

A more detailed discussion of the nine evaluation criteria is presented below. Each remedial alternative is evaluated in Section 5.3 with respect to the first seven criteria.

5.2.1 Protection of Human Health and the Environment

Remedial actions must be protective of human health and the environment. If the alternative is not considered to be protective of human health and the environment, then it cannot be selected. This analysis is a final check to assess whether each alternative provides adequate protection of human health and the environment. Each alternative is evaluated on its potential to limit exposure risk to humans and the environment during and after implementation of the remedial action. Alternatives posing the least short- and long-term risk to human health and the environment are the most desirable. Risks associated with construction and management of wastes generated during remedial actions are also considered in the evaluation.

5.2.2 Compliance with ARARs

The NCP indicates that the lead agency will identify ARARs based upon an objective determination of whether the requirement specifically addresses a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance found at a CERCLA site (40 CFR 300.400(g)). The identification and selection of potential ARARs and TBCs are intended to assist in evaluation of potential remedial alternatives. Alternatives must be compliant with ARARs or they cannot be considered for remedy selection unless an ARAR waiver is justifiable (as defined under 40 CFR 300.430 (f)). Preliminary ARARs and TBCs potentially applicable at the DCF Study Area are presented in Section 2.0 of this report. Table 5-1 presents a matrix indicating which of the ARARs have been identified as preliminary ARARs for each of the remedial alternatives presented herein.

5.2.3 Long-Term Effectiveness and Permanence

The long-term effectiveness and permanence criterion evaluates the ability of an alternative to prevent or minimize risk to public health and the environment after RAOs have been met. Components considered when evaluating the long-term effectiveness and permanence of an alternative include examining the magnitude of residual risk and the adequacy and long-term reliability of controls that may be required to manage this residual risk (USEPA, 1988). Residual risk, for example, may be the risk posed by treatment residuals and/or untreated wastes or areas. The demonstrated long-term effectiveness and permanence of equivalent alternatives(s) (under similar site conditions) at other sites can be considered in evaluating whether the alternative can be used effectively.

5.2.4 Reduction of Toxicity, Mobility, or Volume

This evaluation criterion addresses the statutory preference for selecting remedial actions that employ treatment technologies that permanently and significantly reduce toxicity, mobility, or volume of the hazardous substances as their principal element (USEPA, 1988). The fundamental objective of reducing the toxicity of a hazardous chemical is the protection of human health and the environment. This can be accomplished by reducing the contamination levels (thus, the risk of human exposure) and by limiting or preventing contaminants from reaching unimpacted areas. Mobility refers to the contaminant's ability to migrate to unimpacted areas or media. Volume reduction can be evaluated by assessing the amount of hazardous material destroyed or treated, the proportion of the contaminant plume that is remediated, and the amount remaining on site. In addition, the degree to which the treatment is reversible needs to be evaluated. Thus, based on these considerations, the effectiveness of each alternative in reducing toxicity, mobility, and volume is evaluated in this document by assessing its ability to: (1) reduce risk for human exposure, (2) prevent leaching of contaminants from the vadose zone to the underlying aquifer, (3) prevent further degradation of the aquifer or migration of contaminants to the Kansas River alluvial aquifer, and (4) reduce the volume of the impacted terrace and alluvial aquifers.

5.2.5 Short-Term Effectiveness

Short-term effectiveness evaluates alternatives with respect to their effects on human health and the environment during implementation of the remedial action. The estimated time frame required to achieve the RAOs, the short-term reliability of the technology, and protection of the community and workers during remediation also are considered under this criterion. Furthermore, the ability of an alternative to be protective of potential receptors during the failure of any one technology or uncontrollable changes at the site is considered.

5.2.6 Implementability

Implementability is used as a measure of both the technical and administrative feasibility of constructing, operating, and maintaining a remedial action alternative (USEPA, 1988). Technical feasibility refers to the following factors:

- Ability to reliably construct, operate, and maintain the components of the alternative during remediation and after completion, as well as the ability to meet applicable technical regulatory requirements;
- Likelihood that technical problems associated with implementation will lead to schedule delays;
- Ability of remedial equipment to undertake additional remedial actions (e.g., increased flows or volumes), and/or phase in other interim remedial actions, if necessary; and
- Ability to monitor the effectiveness of the implemented remedies.

Administrative feasibility includes the following criteria:

- Ability to get permits and approvals from the appropriate agencies to implement the alternative;
- Availability of support services for the treatment, storage, and disposal of generated wastes; and,
- Availability of specialized equipment or technical experts to support the remedial actions.

5.2.7 Cost

Both capital and O&M costs are evaluated for each alternative. Capital costs include design costs, equipment costs, construction costs, and other relevant short-term expenditures associated with the installation of the remedial action components. O&M costs include the expenses associated with equipment maintenance and repair, site and equipment monitoring, power, chemicals, disposal of residues, and any other periodic costs associated with the remedial action operation throughout the project life.

Cost is mainly used to eliminate alternatives that are significantly more expensive than others without proportional benefits or to choose among several alternatives offering similar protection to human health and the environment. The main components of each alternative were sized prior to developing the cost estimates. Sizing was based on general guidelines found in technical literature, past experience, and general professional judgment. For the cost estimation process, data were gathered from cost proposals provided by subcontractors for each remedial alternative, prior expenses, and professional judgement.

The level of detail was kept very similar in all of the alternatives to avoid comparing estimates having different levels of accuracies.

For comparison purposes, capital costs are assumed to be expended in year zero (0), even though some alternatives may take longer to implement than others. Because expenditures occur over different periods of time in some of the alternatives, O&M and periodic costs are discounted to a common base year (i.e., year zero) and added to the capital costs to obtain the total present worth of each alternative. With present worth analysis, alternatives can be compared on the basis of a single value. Following USEPA guidelines (USEPA, 1993 and 2000a), a discount rate of 3.2 percent is appropriate to use for federal facilities. This discount rate is based on the 'difference' between the return rate on an annuity investment 'less' the inflation rate. For this cost analysis, the rate of return was based on the 30-year treasury bill of 5.2 percent and an inflation rate of two percent. This resulted in a discount rate equal to 1 – 1.052/1.02, or 3.14 percent. This was rounded up to 3.2 percent.

In accordance with 40 CFR 300.430 (f)(1)(ii)(D), cost-effectiveness is determined by first evaluating overall effectiveness based on the three balancing criteria of long-term effectiveness and permanence; reduction of toxicity, mobility, or volume through treatment; and short-term effectiveness. Overall effectiveness of an alternative is then compared to its cost to determine if its costs are proportional to its overall effectiveness. Cost estimates are intended to provide a basis for alternative evaluation and comparison purposes only and should not be used for future budgeting, bidding, or construction purposes. Detailed cost analysis tables are presented in Appendix 5A.

5.2.8 State Acceptance

This assessment is to be performed as part of the ROD development and public comment process and incorporates the state's technical and administrative agency input regarding each of the remedial alternatives. At the DCF Study Area, the state is represented by KDHE and USEPA Region VII, along with the lead agency (the Department of the Army [DA]). The factors to be evaluated include features of the actions that the state supports, has reservations about, or opposes.

5.2.9 Community Acceptance

This assessment is to be performed as part of the PP and ROD development and public comment process, and incorporates public input into the analysis of the remedial alternatives. Factors of community acceptance to be discussed include features of the support, reservations, and opposition of the community.

Fort Riley has an existing community relations plan (per the Fort Riley Restoration Advisory Board) and conformance with this plan will be a component of the assessment of this criterion.

5.3 ANALYSIS OF REMEDIAL ALTERNATIVES

In this section, the remedial alternatives identified in Section 4.4 are evaluated using the first seven criteria described above in Section 5.2. Evaluations of the last two criteria (i.e., state and community acceptance) are deferred to the ROD following receipt of state and public comments from the PP process.

As stated previously in Section 4.4, previous site investigation activities have identified three AOCs and two different types of media (soil and groundwater). The three AOCs are the following:

- The shallow subsurface soil located around and beneath the building footprint of former Building 180.
- Groundwater in the bedrock erosional channel in the vicinity of Monitoring Well DCF01-40.
- Groundwater in the vicinity of Monitoring Well DCF02-42.

Different remedial alternatives were selected for evaluation at each of the three AOCs. For each AOC, a best option will be selected as a result of the DAA. The final remedial option for the DCF Study Area will consist of three remedial technologies (one for each of the three AOCs), plus the addition of MNA and institutional controls. As stated previously, MNA will not be reviewed as part of the remedial alternatives for AOC 1 because MNA is also being considered for both AOC 2 and AOC 3. The following remedial alternatives will be considered for each of the following AOCs:

AOC 1 (Shallow subsurface soil at former Building 180)

- Alternative 1 - No Action
- Alternative 2 - Excavation and landfarming at pre-existing 354 treatment cell with institutional controls
- Alternative 3 - Excavation and landfarming at new treatment cell with institutional controls
- Alternative 4 - Excavation and off-site incineration with institutional controls

AOC 2 (Groundwater in the bedrock erosional channel near Monitoring Well DCF01-40)

- Alternative 1 - No Action
- Alternative 2 – Chemox, MNA, and institutional controls
- Alternative 3 – EAB, MNA, and institutional controls

AOC 3 (Groundwater in the vicinity of Monitoring Well DCF02-42)

- Alternative 1 - No Action
- Alternative 2 – Chemox, MNA, and institutional controls
- Alternative 3 – EAB, MNA, and institutional controls

In addition to the screening criteria evaluation, this detailed analysis of alternatives presents advantages and disadvantages of each alternative. These are included to provide information that may influence the selection of a remedial alternative. This list includes information obtained from technology vendors, technology reports and articles, and other related publications. With the exception of the no action alternative, institutional controls are considered components of each remedial alternative being evaluated in this FS. MNA is considered a component of each remedial alternative being evaluated in AOC 2 and AOC 3.

5.3.1 AOC 1 (Shallow Subsurface Soil - Former Building 180 Area)

5.3.1.1 Alternative 1 - No Action

5.3.1.1.1 Description

This alternative is the "no action" alternative, a requirement of the NCP, which provides a baseline for the comparison of active remedial alternatives developed for the DCF Study Area. Under the "no action" alternative, institutional controls are not implemented, and remediation and monitoring of the groundwater contamination are not conducted.

This AOC is classified by the RPMP as a designated open area. Open areas have building restrictions and are used for safety areas, utility clearances and easements, conservation areas, and buffer zones. It is anticipated that land use activities within the DCF Study Area will remain unchanged into the foreseeable future based on these building restrictions.

By definition, this alternative requires that the current monitoring program be discontinued. At a minimum, CERCLA requires administrative reassessments every five years, if the DCF Study Area is not open for unrestricted use, whenever contaminants are left in place.

Because the "no action" alternative is an idealized baseline, even though institutional controls are in place due to the location of the site on a military base, the "no action" alternative does not acknowledge these controls. Similarly, the "no action" alternative also does not acknowledge the migration of contaminants from the vadose zone to the groundwater.

5.3.1.1.2 Evaluation

Protection of Human Health and the Environment

Based on the risk assessments (human health and ecological) performed in the RIA Report (BMcD, 2003), this alternative is protective of human health and the environment because the risk estimates for current and future RME scenarios do not exceed the USEPA accepted risk levels. However, because this alternative does not include institutional controls, there is no control of future use. Therefore, an unforeseen exposure scenario (not characterized in the RIA Report baseline risk assessment, BMcD, 2003) is possible when no institutional controls are acknowledged for the property. Based on this, plus the fact that the No Action Alternative functions as a baseline for the comparison of all remedial alternatives, no action will be considered not protective of human health and the environment.

Compliance with ARARs

Preliminary chemical-specific ARARs for this alternative are presented in Table 5-1. Location- and action-specific ARARs do not apply to this alternative, since no active measures will be taken at DCF Study Area under this alternative.

Soil sampling results (see Table 5-2) indicate that the KDHE RSK value of 180 ug/kg were exceeded for PCE down to 12 ft bgs at two soil hotspots located near the former Building 180 location. Under the "no action" alternative, there is no monitoring to determine if migration of contaminants from the vadose zone to the underlying groundwater is occurring. Therefore, under the "no action" alternative, the evaluation assumes the contaminant concentration levels remain "as-is". Because the KDHE RSK value is exceeded, it is assumed under the "no action" alternative that the KDHE RSK value will continue to be exceeded. Additionally, no credit would be given for future ex-situ treatment of shallow soil hot spots at the Building 180 area.

Long-Term Effectiveness and Permanence

Although the risk assessment (BMcD, 2003) concluded that the magnitude of risk to human health and the environment for soil is within the USEPA accepted limits at the DCF Study Area Site, the No Action Alternative would not treat the suspected shallow soil hot spots located at the former Building 180 location. The No Action Alternative would not prevent or reduce the potential for leaching of PCE contamination through the vadose zone to the groundwater. Therefore, it is anticipated that contamination levels will continue to be above the KDHE RSKs value for soil under this alternative.

Institutional controls are not acknowledged with this alternative; therefore, there is a hypothetical possibility that an unforeseen exposure scenario could occur under the "no action" alternative.

Reduction of Toxicity, Mobility, or Volume

The No Action Alternative will not prevent or reduce the mobility of the solvent contamination in the soil from leaching to groundwater, although reductions in contaminant concentration may be is occurring through natural attenuation of the soil.

Under the No Action Alternative, there is no monitoring and interpretation of monitoring results to verify natural attenuation processes are operating. Therefore, when comparing the No Action Alternative to other more comprehensive alternatives, the reduction of toxicity, mobility, or volume is not reconciled until the first mandated 5-year review in accordance with CERCLA 121(c). The limitation of a discrete 5-year review is that it is not as comprehensive as a set of measurements collected over time to corroborate that the sampling event results are consistent and reproducible.

Short-Term Effectiveness

Because no quantitative modeling was performed at the DCF Study Area, it is difficult to predict how long it will take to achieve RAOs across this AOC. Currently, RAOs are not being met for the two soil hot spots at the former Building 180 location; however, the No Action Alternative would pose no additional detrimental effects to human health or the environment as a result of implementation.

Implementability

There are no implementability concerns posed by this remedy because no action would be taken.

Cost Evaluation

The present worth cost of this alternative is estimated to be $410,000, with total periodic costs totaling $610,000, and a total project cost of $610,000 (undiscounted). The only costs are for five-year reviews, groundwater monitoring for the reviews, and the closure report. Detailed cost analysis tables are presented in Appendix 5A (Tables 5A-1 and 5A -2).

5.3.1.1.3 Additional Criteria

Advantages

- Low cost.
- No additional risk to the community or environment.

Limitations and Considerations

- Without an annual groundwater monitoring program, changes in the site and/or contaminant conditions would only be assessed during the five-year reviews.
- Does not prevent leaching of contaminants from the soil hot spots in the shallow vadose zone to the underlying groundwater.
- Does not prevent the migration of contaminated groundwater from the terrace to the Kansas River alluvial aquifer.

5.3.1.2 Alternative 2 –Excavation and Landfarming - Pre-existing Treatment Cell and Institutional Controls

5.3.1.2.1 Description

Site Specific Description

This alternative includes excavation of shallow subsurface soil with PCE concentrations above the KDHE RSK value for PCE of 180 ug/kg for landfarming at a pre-existing treatment cell. The shallow subsurface soil above the KDHE RSK is located in two hot spots in the area around former Building 180 (See Figure 5-1). Soil hotspot #1 is located in the central to southwestern portion of the former Building 180 footprint. In this area, all of the soil with PCE concentrations above the KDHE RSK of 180 μg/kg is concentrated in the upper shallow soil from one to eight ft bgs (see Table 5-2). This amounts to approximately 620 cubic yards (cy) of soil. Hot spot #2 is located around former Manhole 363. In this area, all of the soil with PCE concentrations above the KDHE RSK of 180 μg/kg are concentrated in the upper shallow soil from one to twelve ft bgs (see Table 5-2), which is approximately 930 cy of soil. Total soil that would need to be excavated is approximately 1,550 cy prior to excavation or 2,015 cy after excavation (1.3 fluff factor). The abandoned-in-place sanitary sewer lines around and including Manhole 363 and 364 will also be removed during excavation.

During soil excavation at AOC 1, the utility corridor running parallel to Custer Road from MH 363 to Monitoring Well DCF02-42 will also be exposed to confirm the presence or absence of chlorinated solvent contamination within the specific utility trenches. This field action will be undertaken because utility corridors can be conduits for contaminant transport. The utilities exposed during AOC 1 soil excavation may include the sanitary sewer, the storm sewer, and the abandoned high-pressure gas line.

Excavation of the utility corridor will be accomplished in two stages. The first stage would involve the actual removal of soil from the utility trenches following location of all utilities by locating personnel. Additionally, a magnetometer survey would be conducted to aid in the location of all utility lines. Following utility location, the soil would be removed carefully using a backhoe. Because the soil removal will be in close proximity to buried utility lines, manual excavation will also be required. All soil that is removed would be field screened using a PID. Soils that present detections during field screening will be removed and transported to the selected soil treatment site. Soil with no detections will be stockpiled on site and returned to the trench as backfill. Once the utility line in question has been exposed, the bedding material within the utility trench will be sampled and analyzed on site with a field GC for PCE, TCE, and cis1,2-DCE. Soil samples would also be sent to an off-site laboratory for analytical confirmation for the same analytes.

The second stage of the utility corridor confirmation process would be to spread or inject a chemical oxidant or EAB treatment into the utility trench before backfilling. The addition of a chemical oxidant or EAB would address the possibility of the presence of chlorinated solvents within the utility trench and would serve as a deterrent for contaminant transport through the corridor. Following treatment, the utility trench would be backfilled with silty soil in six-inch lifts and tamped. Following backfilling, the area would be returned to pre-excavation conditions. This two-stage utility corridor confirmation process would most likely extend from the abandoned-in-place sanitary sewer lines around Manhole 363 and 364 westward toward Monitoring Well DCF02-42.

For the soil excavation around former Building 180, following the location of all utilities in the proposed excavation area, the soil would be excavated using backhoes or other similar-type excavation equipment. Once excavated, the soil would be loaded into lined dump trucks for transportation to the preexisting treatment cell. Each dump truck would be covered during transport. OSHA requirements are anticipated to be met during implementation of this alternative.

Because the soil was contaminated from PCE that leaked from the sanitary sewer line, and was not a waste generated by a facility, the excavated soil is not an F-listed waste as defined by 40 CFR 261.31 (Standards Applicable to Generators of Hazardous Waste), and is excluded from regulation as a hazardous waste as defined under 40 CFR 261.4(b)(1). Therefore, transportation of the soil on public highways does not require manifesting under 40 CFR 262.20. However, to confirm that hazardous constituents in excavated soil are not being improperly transported from the site to the treatment cell at Camp Funston, one soil sample will be collected from each soil hotspot as defined in Section 5.3.1.2.1 to be analyzed for VOCs using USEPA Method 1311/8260 for toxicity characteristic leaching procedure (TCLP).

Following excavation, borrow material of a high clay content would be placed and compacted in the excavation, and the area would be returned to its original condition. The landfarming treatment option may be required to meet the substantive requirements as presented in the KDHE Landfarm Application information for a remedial design plan. These requirements are as follows:

- Groundwater depth must be greater than 10 ft bgs.
- Sufficient native soils (not sand) must be available to create a two ft berm to surround the landfarmed soils and prevent runoff and runon.
- The treatment cell must be at least 500 ft from homes, schools, public water supply wells, domestic wells, and surface waters.
- Fencing will be required for any landfarm within 0.5 miles of homes, parks, schools, and other places where children may play.

The proposed treatment cell for the 354 Site would be constructed at a designated area adjacent to the Environmental Waste Management Center (EWMC) located at Camp Funston (see Figure 5-2). The size of the treatment cell would be approximately 150 by 250 ft; although, this may be adjusted to better fit the designated area. Based on the size of this treatment cell, approximately 1,400 cy of soil could be treated at one time. At a minimum, approximately 2,015 cy of soil from the two hotspots at the DCF Study Area would need be treated at the same time. With this amount of excavated soil, a phased excavation and treatment approach would be used. For the phased approach, soil from hotspot #1 would be excavated and landfarmed first. Following treatment of soil from hotspot #1, soil from hotspot #2 would be then be excavated and landfarmed for treatment. To treat the entire amount of soil from both hotspots at the same time, the size of the preexisting landfarm treatment cell would need to be increased in size.

The preexisting treatment cell would contain a two ft high earthen berm, which would form the perimeter of the treatment cell (see Figure 5-3). The berm and the treatment cell would be covered with a 30-mil high density polypropylene (HDPE) sheeting. The seams of the sheeting would be sealed to preclude leakage from the treatment cell. Approximately six inches of sand would then be placed on top of the liner to protect the liner from damage during the disking of the soil. A sump would be constructed to collect any runoff and/or leachate from the treatment cell. This sump would be excavated and lined with HDPE sheeting. A holding tank would be located adjacent to the sump pit. Runoff and/or leachate which collects in the sump during soil treatment would be pumped from the sump into the holding tank for temporary storage prior to disposal. This transfer will be accomplished using a sump pump with an auto-float switch. A secondary option would be to transfer the runoff from the sump directly to the sewer line. This option is presented for consideration because the current standard operational procedure for disposal of IDW water collected during periodic groundwater sampling events is to dispose of the IDW into designated sanitary sewer disposal points. Runoff from the treatment cell would either have comparable concentrations of contaminants as the monitoring wells or would be less due to dilution.

Although this option utilizes a preexisting treatment cell, the following points would have to be considered:

- The preexisting landfarm treatment cell would be handling contaminated soil from two different sites at two different times.

- Following soil treatment of Building 354 soil, the condition of the treatment liner will have to be carefully monitored and inspected. Removal of the treated soil without damaging the liner may not be possible. Therefore, with this option, the liner may have to be replaced three separate times using the phased approach.

For this option, the excavated soil spread within the treatment cell would remain in the cell for a period of approximately eight weeks. During weeks two, four, and six, the soil would be disked as needed to improve the volatilization of the soil. This disking would be a one-day operation in each case. Precautions would be taken by the contractor to ensure that excessive dust was controlled. The contractor would also use these opportunities to remove any runoff and/or leachate that may have collected in the frac tank or sump, and to conduct routine inspection and maintenance of the treatment cell.

Confirmation soil samples would be collected approximately eight weeks after the soil is placed within the treatment cell. The purpose of the confirmation soil sampling is to evaluate the effectiveness of the land farming. The target concentrations for PCE, TCE, and cis-1,2-DCE are 180, 200, and 800 μg/kg, respectively. These are the KDHE RSK standards for the soil to groundwater protection pathway (residential scenario).

Following confirmation that the soil in the treatment cell is below the KDHE RSK values, the soil would be removed and transported to the Construction Demolition (C/D) Landfill on Campbell Hill for use as cover. Once all of the soil has been treated, the treatment cell would be dismantled. The sand within the treatment cell would be loaded and transported to the CD landfill. Once the sand has been removed, the HDPE liner would be cut up and removed. The liner would be disposed by the excavation subcontractor. Following removal of the liner, the area would be graded, including filling in the sump. The excavation subcontractor would then seed the area with broome grass.

Institutional Controls

The inclusion of institutional controls, such as restrictions on new building construction, land use, and groundwater use, reduces the potential for human ingestion, inhalation, or direct contact with contaminated soil and groundwater at the DCF Study Area. The USEPA guidance on institutional controls suggests that controls should by "layered" to enhance the effectiveness and protectiveness of the remedy (USEPA, 2000b). Layering refers to using different types of institutional controls together or in series to enhance their effect. The variety of institutional controls available at the DCF Study Area is limited, because the site is on an active military reservation. Tools such as zoning and easements generally apply to private property. However, post authorities could apply controls, such as prohibiting the new building construction, soil excavation, or the installation of water supply wells within the DCF Study Area (as examples). The purpose of institutional controls is to limit exposure to contaminants in the soil and groundwater. Details of any institutional controls to be implemented under this alternative and how their implementation affects contaminant pathways will be provided as part of the PP.

5.3.1.2.2 Evaluation

Protection of Human Health and the Environment

Based on the risk assessments (human health and ecological) performed as part of the RIA report (BMcD, 2003), this alternative is protective of human health and the environment because the risk estimates for current and future RME scenarios do not exceed USEPA accepted risk levels. It is anticipated that the potential future risk to human health or the environment would decrease because excavation and removal of the shallow soil hotspots located at the former Building 180 area would result in lower amounts of VOCs being released to the dissolved plume. Additionally, institutional controls would be in place to limit or prevent exposure to contaminated groundwater and natural degradation within the aquifer would further reduce the concentrations of contaminants.

Compliance with ARARs

This alternative is anticipated to meet the preliminary TBC standard for soils (i.e., KDHE RSKs) by excavation and removal of all soils with PCE concentrations above the KDHE RSK of 180 ug/kg, and the chemical-specific ARARs for groundwater (i.e., MCLs) by reducing the volume of PCE being released to the dissolved plume. A list of preliminary ARARs and TBCs for the DCF Study Area is presented in Section 2.2.2.

Preliminary location-specific ARARs for this alternative is mainly concerned with endangered species, and archaeological and historical preservation. Location-specific ARARs will be met by coordinating remedial activities with Fort Riley Conservation Division personnel to minimize or eliminate adverse impacts on either wildlife, archaeological sites, or historical structures.

Preliminary action-specific ARARs include but are not limited to portions of CERCLA, OSHA, RCRA, and selected State of Kansas ARARs. It is anticipated that there would be no difficulties complying with all of these. Table 5-1 presents a matrix indicating the ARARs that have been identified as preliminary ARARs for this remedial alternative.

Long-Term Effectiveness and Permanence

Excavation and removal of shallow soil with PCE concentrations above the KDHE RSK 180 ug/kg value would achieve the soil RAOs for the DCF Study Area. Removal of the shallow contaminated soil would also decrease the potential for leaching of PCE from the vadose zone to the underlying groundwater. This would reduce the amount of contamination migrating with groundwater from the terrace to the Kansas River alluvial aquifer. Therefore, the magnitude of risk to human health and the environment is anticipated to be less than current risk conditions, which are already within the USEPA accepted risk limits at the DCF Study Area (BMcD, 2003). However, contaminants sorbed to the aquifer matrix may leach low levels of COPCs after remediation is completed. Additionally, current groundwater concentrations of PCE and TCE are above their respective MCLs. Therefore, periodic groundwater collection and analysis will be required to ensure that the remedy continues to provide adequate protection of human health and the environment.

Reduction of Toxicity, Mobility, or Volume

Reduction in contaminant volume is anticipated to be achieved with this alternative primarily through shallow soil excavation and removal of the two hot spot areas located near the location of former Building 180. Removal of contaminated soil above the KDHE RSK of 180 ug/kg for PCE and backfilling with high clay content borrow would also reduce the mobility of the contaminants by reducing the amount of leaching of PCE from the vadose zone to the underlying groundwater. Additionally, soil excavation would reduce the amount of contaminates in groundwater migrating from the terrace to the Kansas River alluvial aquifer. Based upon the results of periodic groundwater sampling events, NA processes in the Kansas River alluvial aquifer, which are primarily physical attenuation processes, will also act to further reduce contaminant concentrations and should continue to reduce concentrations of the COPCs, thereby reducing the risk of exposure to both human and environmental receptors.

Short-Term Effectiveness

A groundwater monitoring program and institutional controls addresses short-term reliability in the event that the remedial technology used in this alternative does not reduce the contaminant levels at the DCF Study Area. Institutional controls address potential receptors during remedial actions by limiting or preventing exposure to contaminated soil and groundwater. Therefore, risks of adverse effects to human health during the remedial phase are low. A health and safety plan would address any short-term risks associated with implementation of this alternative.

Implementability

There are no anticipated technical difficulties implementing this alternative. The current groundwater monitoring well network is anticipated to provide adequate coverage for evaluating the effectiveness of this technology and monitoring any changes in the nature and extent of contamination at the DCF Study Area. Because this is an active government installation, it is also anticipated that there will be no problems with implementing a program of institutional controls through the post RPMP (see Section 4.3.3.1).

Cost Evaluation

The present worth cost of this alternative is estimated to be $260,000, with a capital cost of $180,000, periodic costs totaling $130,000, and a total project cost of $310,000. Detailed cost analysis tables are presented in Appendix 5A (Tables 5A-3 and 5A-5). An estimated additional $160,000 would also be required for the utility corridor confirmation field effort. While cost estimates are sound, unexpected costs could occur during implementation of this alternative.

5.3.1.2.3 Additional Criteria

Advantages

- Reduces the potential for human ingestion, inhalation, or direct contact with contaminated soil and groundwater at the DCF Study Area.
- No additional risk to the community or environment.
- A groundwater monitoring program is currently in place to assess future changes in site and/or contaminant conditions.

Limitations and Considerations

- May require rehabilitation of an existing soil treatment cell
- Would require O&M and monitoring during treatment stage for landfill options.
- May produce leachate due to runoff from precipitation events for landfill options.

5.3.1.3 Alternative 3 – Excavation and Landfarming - New Treatment Cell and Institutional Controls

5.3.1.3.1 Description

Following excavation activities described in Section 5.3.1.2.1, a new treatment cell could also be constructed to handle the soil removed from the two shallow soil hotspots. The newly constructed treatment cell would be located at the former Building 183 area (see Figure 5-1), which would require less transportation cost than the first excavation and treatment option. Since this area has recently been graded following demolition of former Buildings 183/184, it is anticipated that minimal ground preparation would be required. As with the preexisting landfarm treatment cell, utilities would be located prior to the start of excavation. The new treatment cell would also require the excavation subcontractor to construct a two ft high earthen berm covered with 30-mil HDPE liner (see Figure 5-3). The size of the treatment cell would be approximately 375 ft by 125 ft. Treatment cell construction would be the same as the pre-existing treatment cell outlined in Section 5.3.1.2.1. Soil removed from the excavation would not be classified as an F-listed waste, is excluded from regulations as a hazardous waste, and would not require manifesting during transportation to the new treatment cell. Construction of the new treatment cell would also be conducted according to the KDHE substantive requirements listed in the landfarm application for a remedial design plan.

For this treatment option, the excavated soil spread within the treatment cell would remain in the cell for a period of approximately eight weeks. During weeks two, four, and six, the soil would be disked as needed to improve the volatilization of the soil. This disking would be a one-day operation in each case. Precautions would be taken by the contractor to ensure that excessive dust was controlled. The contractor would also use these opportunities to remove any runoff and/or leachate that may have collected in the frac tank or sump, and to conduct routine inspection and maintenance of the treatment cell.

Confirmation soil samples would be collected approximately eight weeks after the soil is placed within the treatment cell. The purpose of the confirmation soil sampling is to evaluate the effectiveness of the land farming. The target concentrations for PCE, TCE, and cis-1,2-DCE are 180, 200, and 800 µg/kg, respectively. These are the KDHE RSK standards for the soil to groundwater protection pathway (residential scenario).

Following confirmation that the soil in the treatment cell is below the KDHE RSK values, the soil would be removed and the treatment cell dismantled. All treated soil and sand within the treatment cell will be loaded and transported to the C/D Landfill on Campbell Hill for use as cover. Once this material has been removed, the HDPE liner would be cut up and removed. The liner would be disposed by the excavation subcontractor. Following removal of the liner, the area would be graded, including filling in the sump. The excavation subcontractor would then seed the area with broome grass.

Institutional Controls

The inclusion of institutional controls for this alternative is the same as those listed for the pre-existing treatment cell and include restrictions on new building construction, land use, and groundwater use. This restriction reduces the potential for human ingestion, inhalation, or direct contact with contaminated soil and groundwater at the DCF Study Area. This alternative also uses a "layered" approach to enhance the effectiveness and protectiveness of the remedy (USEPA, 2000b). Layering refers to using different types of institutional controls together or in series to enhance their effect. Details of any institutional controls to be implemented under this alternative and how their implementation affects contaminant pathways will be provided as part of the PP.

5.3.1.3.2 Evaluation

Protection of Human Health and the Environment

Based on the risk assessments (human health and ecological) performed as part of the RIA report (BMcD, 2003), this alternative is protective of human health and the environment because the risk estimates for current and future RME scenarios do not exceed USEPA accepted risk levels. It is anticipated that the potential future risk to human health or the environment would decrease because excavation and removal of the shallow soil hotspots located at the former Building 180 area would result in lower amounts of VOCs being released to the dissolved plume. Additionally, institutional controls would be in place to limit or prevent exposure to contaminated groundwater and natural degradation within the aquifer would further reduce the concentrations of contaminants.

Compliance with ARARs

This alternative is anticipated to meet the preliminary TBC standard for soils (i.e., KDHE RSKs) by excavation and removal of all soils with PCE concentrations above the KDHE RSK of 180 ug/kg, and the chemical-specific ARARs for groundwater (i.e., MCLs) by reducing the volume of PCE being released to the dissolved plume. A list of preliminary ARARs and TBCs for the DCF Study Area is presented in Section 2.2.2.

Preliminary location-specific ARARs for this alternative is mainly concerned with endangered species, and archaeological and historical preservation. Location-specific ARARs will be met by coordinating remedial activities with Fort Riley Conservation Division personnel to minimize or eliminate adverse impacts on either wildlife, archaeological sites, or historical structures.

Preliminary action-specific ARARs include but are not limited to portions of CERCLA, OSHA, RCRA, and selected State of Kansas ARARs. It is anticipated that there would be no difficulties complying with all of these. Table 5-1 presents a matrix indicating the ARARs that have been identified as preliminary ARARs for this remedial alternative.

Long-Term Effectiveness and Permanence

Excavation and removal of shallow soil with PCE concentrations above the KDHE RSK 180 ug/kg value would achieve the soil RAOs for the DCF Study Area. Removal of the shallow contaminated soil would also decrease the potential for leaching of PCE from the vadose zone to the underlying groundwater. This, combined with NA, would reduce the amount of contamination migrating with groundwater from the terrace to the Kansas River alluvial aquifer. Therefore, the magnitude of risk to human health and the environment is anticipated to be less than current risk conditions, which are already within the USEPA accepted risk limits at the DCF Study Area (BMcD, 2003). However, contaminants sorbed to the aquifer matrix may leach low levels of COPCs after remediation is completed. Additionally, current groundwater concentrations of PCE and TCE are above their respective MCLs. Therefore, periodic groundwater collection and analysis will be required to ensure that the remedy continues to provide adequate protection of human health and the environment.

Reduction of Toxicity, Mobility, or Volume

Reduction in contaminant volume is anticipated to be achieved with this alternative primarily through shallow soil excavation and removal of the two hot spot areas located near the location of former Building 180. Removal of contaminated soil above the KDHE RSK of 180 ug/kg for PCE and backfilling with high clay content borrow would also reduce the mobility of the contaminants by reducing the amount of leaching of PCE from the vadose zone to the underlying groundwater. Additionally, soil excavation would reduce the amount of contaminates in groundwater migrating from the terrace to the Kansas River alluvial aquifer. Based upon the results of periodic groundwater sampling events, NA processes in the Kansas River alluvial aquifer, which are primarily physical attenuation processes, will also act to further reduce contaminant concentrations and should continue to reduce concentrations of COPCs, thereby reducing the risk of exposure to both human and environmental receptors.

Short-Term Effectiveness

A groundwater monitoring program and institutional controls addresses short-term reliability in the event that the remedial technology used in this alternative does not reduce the contaminant levels at the DCF Study Area. Institutional controls address potential receptors during remedial actions by limiting or preventing exposure to contaminated soil and groundwater. Therefore, risks of adverse effects to human health during the remedial phase are low. A health and safety plan would address any short-term risks associated with implementation of this alternative.

Implementability

There are no anticipated technical difficulties implementing this alternative. The current groundwater monitoring well network is anticipated to provide adequate coverage for evaluating the effectiveness of this technology and monitoring any changes in the nature and extent of contamination at the DCF Study Area. Because this is an active government installation, it is also anticipated that there will be no problems with implementing a program of institutional controls through the post RPMP (see Section 4.3.3.1).

Cost Evaluation

The present worth cost of this alternative is estimated to be $290,000, with a capital cost of $200,000, periodic costs totaling $130,000, and a total project cost of $335,000. Detailed cost analysis tables are presented in Appendix 5A (Tables 5A-6 and 5A-8). An estimated additional $160,000 would also be required for the utility corridor confirmation field effort. While cost estimates are sound, unexpected costs could occur during implementation of this alternative.

5.3.1.3.3 Additional Criteria

Advantages

- Reduces the potential for human ingestion, inhalation, or direct contact with contaminated soil and groundwater at the DCF Study Area.
- No additional risk to the community or environment.
- A groundwater monitoring program is currently in place to assess future changes in site and/or contaminant conditions.

Limitations and Considerations

- Will require construction of a new treatment cell.
- Treatment cell would be located within the Historic Main Post.
- Treatment cell would be located neat post housing.
- Will require O&M and monitoring during treatment stage for landfill options.
- May produce leachate due to runoff from precipitation events for landfill options.

5.3.1.4 Alternative 4 – Excavation, Incineration, and Institutional Controls

5.3.1.4.1 Description

Following excavation activities described in Section 5.3.1.2.1, the excavated soil would be transported to an off-site incinerator for incineration and disposal. During excavation activities, the contaminated soil would be loaded into dump trucks equipped with bed liners. The soil would then be transported to an incinerator located in Kimball, Nebraska. This facility is operated by Clean Harbors Environmental Services. The soil would be offloaded at this facility and incinerated. Following incineration, the soil would be used for on-site landfill cover at the Kimball Facility.

Soil removed from the excavation would not be classified as an F-listed waste, is excluded from regulations as a hazardous waste, and would not require manifesting during transportation to the Clean

Harbors Facility. However, to confirm that hazardous constituents in excavated soil are not being improperly transported from the site to the treatment cell at Camp Funston, one soil sample will be collected from each soil hotspot as defined in Section 5.3.1.2.1 to be analyzed for VOCs using USEPA Method 1311/8260 for TCLP.

Institutional Controls

The inclusion of institutional controls for this alternative is the same as those listed for the previous two soil removal alternatives and include restrictions on new building construction, land use, and groundwater use. This restriction reduces the potential for human ingestion, inhalation, or direct contact with contaminated soil and groundwater at the DCF Study Area. This alternative also uses a "layered" approach to enhance the effectiveness and protectiveness of the remedy (USEPA, 2000b). Layering refers to using different types of institutional controls together or in series to enhance their effect. Details of any institutional controls to be implemented under this alternative and how their implementation affects contaminant pathways will be provided as part of the PP.

5.3.1.4.2 Evaluation

Protection of Human Health and the Environment

Based on the risk assessments (human health and ecological) performed as part of the RIA report (BMcD, 2003), this alternative is protective of human health and the environment because the risk estimates for current and future RME scenarios do not exceed USEPA accepted risk levels. It is anticipated that the potential future risk to human health or the environment would decrease because excavation and removal of the shallow soil hotspots located at the former Building 180 area would result in lower amounts of VOCs being released to the dissolved plume. Additionally, institutional controls would be in place to limit or prevent exposure to contaminated groundwater and natural degradation within the aquifer would further reduce the concentrations of contaminants.

Compliance with ARARs

This alternative is anticipated to meet the preliminary TBC standard for soils (i.e., KDHE RSKs) by excavation and removal of all soils with PCE concentrations above the KDHE RSK of 180 ug/kg, and the chemical-specific ARARs for groundwater (i.e., MCLs) by reducing the volume of PCE being released to the dissolved plume. A list of preliminary ARARs and TBCs for the DCF Study Area is presented in Section 2.2.2.

Preliminary location-specific ARARs for this alternative is mainly concerned with endangered species, and archaeological and historical preservation. Location-specific ARARs will be met by coordinating remedial activities with Fort Riley Conservation Division personnel to minimize or eliminate adverse impacts on either wildlife, archaeological sites, or historical structures.

Preliminary action-specific ARARs include but are not limited to portions of CERCLA, OSHA, RCRA, and selected State of Kansas ARARs. It is anticipated that there would be no difficulties complying with all of these. Table 5-1 presents a matrix indicating the ARARs that have been identified as preliminary ARARs for this remedial alternative.

Long-Term Effectiveness and Permanence

Excavation and removal of shallow soil with PCE concentrations above the KDHE RSK 180 ug/kg value would achieve the soil RAOs for the DCF Study Area. Removal of the shallow contaminated soil would also decrease the potential for leaching of PCE from the vadose zone to the underlying groundwater. This would reduce the amount of contamination migrating with groundwater from the terrace to the Kansas River alluvial aquifer. Therefore, the magnitude of risk to human health and the environment is anticipated to be less than current risk conditions, which are already within the USEPA accepted risk limits at the DCF Study Area (BMcD, 2003). However, contaminants sorbed to the aquifer matrix may leach low levels of COPCs after remediation is completed. Additionally, current groundwater concentrations of PCE and TCE are above their respective MCLs. Therefore, periodic groundwater collection and analysis would be required to ensure that the remedy continues to provide adequate protection of human health and the environment.

Reduction of Toxicity, Mobility, or Volume

Reduction in contaminant volume is anticipated to be achieved with this alternative primarily through shallow soil excavation and removal of the two hot spot areas located near the location of former Building 180. Removal of contaminated soil above the KDHE RSK of 180 ug/kg for PCE and backfilling with high clay content borrow would also reduce the mobility of the contaminants by reducing the amount of leaching of PCE from the vadose zone to the underlying groundwater. Additionally, soil excavation would reduce the amount of contaminates in groundwater migrating from the terrace to the Kansas River alluvial aquifer. Based upon the results of periodic groundwater sampling events, NA processes in the Kansas River alluvial aquifer, which are primarily physical attenuation processes, will also act to further reduce contaminant concentrations and should continue to reduce concentrations of COPCs, thereby reducing the risk of exposure to both human and environmental receptors.

Short-Term Effectiveness

A groundwater monitoring program and institutional controls addresses short-term reliability in the event that the remedial technology used in this alternative does not reduce the contaminant levels at the DCF Study Area. Institutional controls address potential receptors during remedial actions by limiting or preventing exposure to contaminated soil and groundwater. Therefore, risks of adverse effects to human health during the remedial phase are low. A health and safety plan would address any short-term risks associated with implementation of this alternative.

Implementability

There are no anticipated technical difficulties implementing this alternative. The current groundwater monitoring well network is anticipated to provide adequate coverage for evaluating the effectiveness of this technology and monitoring any changes in the nature and extent of contamination at the DCF Study Area. Because this is an active government installation, it is also anticipated that there will be no problems with implementing a program of institutional controls through the post RPMP (see Section 4.3.3.1).

Cost Evaluation

The present worth cost of this alternative is estimated to be $1,800,000, with a capital cost of $1,700,000, periodic costs totaling $130,000, and a total project cost of $1,850,000. Detailed cost analysis tables are presented in Appendix 5A (Tables 5A-9 and 5A-11). An estimated additional $160,000 would also be required for the utility corridor confirmation field effort. While cost estimates are sound, unexpected costs could occur during implementation of this alternative.

5.3.1.4.3 Additional Criteria

Advantages

- Reduces the potential for human ingestion, inhalation, or direct contact with contaminated soil and groundwater at the DCF Study Area.
- No additional risk to the community or environment.
- Includes a groundwater monitoring program to assess future changes in site and/or contaminant conditions.

Limitations and Considerations

- Would require transportation of soil off site.
- Cost.

5.3.2 AOC 2 (Groundwater at Monitoring Well DCF01-40 Area)

5.3.2.1 Alternative 1 - No Action

5.3.2.1.1 Description

This alternative is the "no action" alternative, a requirement of the NCP, which provides a baseline for the comparison of active remedial alternatives developed for the DCF Study Area. Under the "no action" alternative, institutional controls are not implemented, and remediation and monitoring of the groundwater contamination are not conducted.

The area where former Buildings 180/181 was located is classified by the RPMP as a designated open area. Open areas have building restrictions and are used for safety areas, utility clearances and easements, conservation areas, and buffer zones. There are no supply wells within the area impacted by the chlorinated solvent plume. It is anticipated that land use activities within the DCF Study Area will remain unchanged into the foreseeable future based on these building restrictions.

By definition, this alternative requires that the current monitoring program be discontinued. At a minimum, CERCLA requires administrative reassessments every five years, if the DCF Study Area is not open for unrestricted use, whenever contaminants are left in place.

Because the "no action" alternative is an idealized baseline, even though institutional controls are in place due to the location of the site on a military base, the "no action" alternative does not acknowledge these controls. Similarly, the "no action" alternative also does not acknowledge the migration of the solvent plumes from the terrace area to the Kansas River alluvial aquifer, nor does it address that natural processes are indicated to be operating to further attenuate these plumes.

5.3.2.1.2 Evaluation

Protection of Human Health and the Environment

Based on the risk assessments (human health and ecological) performed in the RIA Report (BMcD, 2003), this alternative is protective of human health and the environment because the risk estimates for current and future RME scenarios do not exceed the USEPA accepted risk levels. However, because this alternative does not include institutional controls, there is no control of future use. Therefore, an unforeseen exposure scenario (not characterized in the RIA Report baseline risk assessment, BMcD, 2003) is possible when no institutional controls are acknowledged for the property.

Compliance with ARARs

Preliminary chemical-specific ARARs for this alternative are presented in Table 5-1. Location- and action-specific ARARs do not apply to this alternative, since no active measures will be taken at DCF Study Area.

Groundwater sampling results, up to and including the April 2004 sampling round, indicate that preliminary chemical-specific ARARs (i.e., MCLs) were exceeded for three of the four COPCs at the DCF Study Area (PCE, TCE, and VC) (BMcD, 2004). For the April 2004 groundwater sampling event, concentrations of cis-1,2-DCE did not exceed the 70 ug/L MCL.

Under the "no action" alternative there is no groundwater monitoring to determine concentration trends in the plume. Therefore, under the "no action" alternative the evaluation assumes the groundwater levels remain "as-is". Because MCLs are exceeded, it is assumed under the "no action" alternative that MCLs will continue to be exceeded. Additionally, no credit would be given for future ex-situ treatment of shallow soil hot spots at the Building 180 area and natural attenuation of the solvent plumes.

Long-Term Effectiveness and Permanence

Although the risk assessment (BMcD 2003) concluded that the magnitude of risk to human health and the environment for groundwater is within the USEPA accepted limits at the DCF Study Area Site, the No Action Alternative would not treat the groundwater beneath the former building 180 location and would continue to allow the migration of contaminated groundwater from the terrace to the Kansas River alluvial aquifer. Therefore, it is anticipated that contamination levels will continue to be above the MCLs for groundwater under this alternative.

Institutional controls are not acknowledged with this alternative; therefore, there is a hypothetical possibility that an unforeseen exposure scenario could occur under the "no action" alternative.

Reduction of Toxicity, Mobility, or Volume

Because the distal portion of the western PCE, TCE, and cis-1,2-DCE contaminant plumes terminate at the Kansas River, it is apparent that the No Action Alternative will not restrict or prevent the migration contaminant laden groundwater from the terrace to the Kansas River alluvial aquifer. Although reductions in contaminant volume are probably taking place based upon the documented reductions in contaminant concentrations at monitoring wells located within the bedrock erosional trench, the transition zone, and in the Kansas River alluvial aquifer, PCE concentrations above the MCL are currently found in those monitoring wells installed along the Kansas River.

Reductions in contaminant concentration is occurring through natural attenuation, but appears to be dominated by biological processes in the bedrock erosional channel and possibly the Lower Crouse Limestone Member, and by the physical processes of advection and dispersion in the Kansas River alluvial aquifer. NA parameters measured for the April 2004 groundwater sampling event are presented on Figure 5-4. Based upon the results of periodic groundwater sampling events, the effects of natural attenuation within the bedrock erosional channel and the Kansas River alluvial aquifer should continue to reduce concentrations of COPCs and reduce the risk of exposure to both human and environmental receptors.

Under the No Action Alternative, there is no monitoring and interpretation of monitoring results to verify natural attenuation processes are operating. Therefore, when comparing the No Action Alternative to other more comprehensive alternatives, the reduction of toxicity, mobility, or volume is not reconciled until the first mandated 5-year review in accordance with CERCLA 121(c). The limitation of a discrete 5-year review is that it is not as comprehensive as a set of measurements collected over time to corroborate that the sampling event results are consistent and reproducible.

Short-Term Effectiveness

Because no quantitative modeling was performed at the DCF Study Area, it is difficult to predict how long it will take to achieve RAOs across the entire site. The No Action Alternative would pose no additional detrimental effects to human health or the environment as a result of implementation.

Implementability

There are no implementability concerns posed by this remedy because no action would be taken.

Cost Evaluation

The present worth cost of this alternative is estimated to be $410,000, with total periodic costs totaling $610,000, and a total project cost of $610,000 (undiscounted). The only costs are for five-year reviews, groundwater monitoring for the reviews, and the closure report. Detailed cost analysis tables are presented in Appendix 5A (Tables 5A-1 and 5A -2).

5.3.2.1.3 Additional Criteria

Advantages

- Low cost.
- No additional risk to the community or environment.

Limitations and Considerations

- Without an annual groundwater monitoring program, changes in the site and/or contaminant conditions would only be assessed during the five-year reviews.
- Does not prevent the migration of contaminated groundwater from the terrace to the Kansas River alluvial aquifer.

5.3.2.2 Alternative 2 – In-Situ Chemical Oxidation, MNA, and Institutional Controls

5.3.2.2.1 Description

General Technology Description

Chemical oxidation converts hazardous contaminants to non-hazardous or less toxic compounds that are more stable, less mobile, and/or inert. The oxidizing agents most commonly used are O_3, H_2O_2, and permanganate (MnO_4^-). O_3 gas can oxidize contaminants directly or through the formation of hydroxyl radicals ($OH^\bullet$). A liquid H_2O_2 solution, in the presence of native or supplemental Fe^{2+}, produces Fenton's Reagent, which yields various reactive free radicals including $OH^\bullet$. Both O_3 and H_2O_2 are most effective in systems with an acidic pH. MnO_4^- (typically provided as either sodium or potassium salts) can destroy contaminants by either direct electron transfer or free radical advanced oxidation. MnO_4^- treatment is effective over a pH ranging from acidic to alkaline (3.5 to 12). MnO_4^- is a selective oxidant in that it has the potential to be less reactive with some of the natural organics and can persist longer in the subsurface than Fenton's reagent or ozone. MnO_4^- is generally effective in treating chlorinated ethenes (i.e., PCE, TCE, and cis-1,2-DCE).

For the purposes of conceptual design, cost estimation, and applicability evaluation, the $KMnO_4$ technology and vertical injection points will be used as a representative option. Other oxidant options may be evaluated in detail in the PP.

Site-Specific Description

Alternative 2 consists of in-situ treatment of contaminated groundwater within the terrace aquifer located in the vicinity of Monitoring Well DCF01-40 (see Figure 5-5). Alternative 2 is designed to treat groundwater within the bedrock erosional channel, which exhibits concentrations of COPCs in excess of MCLs. Although, groundwater monitoring indicates that the plume poses minimal adverse risk to human health and the environment, by discovering and treating additional groundwater with contaminant levels above MCLs, it may be possible to reach site closure in a shorter time and possibly reduce the cost of long-term monitoring. This alternative focuses on treating the saturated zone above bedrock which has an approximate thickness of 8.0 ft (BMcD, 2004).

Depending on bench scale treatability and the distribution of potential deep contamination, $KMnO_4$ can be injected into the subsurface by the following methods:

- Injection of concentrated (dense) $KMnO_4$ solution in one or multiple layers or "pancakes" with density flow of $KMnO_4$ to distribute $KMnO_4$ as curtains within the saturated zone. Injection in discrete layers is intended to limit the displacement of contaminated groundwater outside the treatment zone.

- Injection of $KMnO_4$ slurry in layer(s) via pressure injection or fracturing. $KMnO_4$ acts as a long-term supply of oxidant to treat residual contamination.

- Injection and circulation of lower concentration $KMnO_4$ solution for gradual treatment of groundwater contamination.

For the purpose of this FS, injection of a $KMnO_4$ slurry is the assumed injection method. This method is the preferred injection method at the site because it eliminates O&M and water supply issues associated with the solution injection, circulation, and recovery system, and it still provides long-term treatment in the source area.

Alternative 2 includes bench-scale testing of groundwater and an aquifer matrix treatability study to evaluate the NOD at the site. The NOD is primarily a function of natural organic content, oxidizable minerals/mineral surfaces, and oxidizable material dissolved or suspended in the groundwater. Although bench-scale studies have been performed for similar soils, the aquifer matrix at depth combined with groundwater may exert a different NOD than the soils that have been previously tested.

Alternative 2 also includes a pilot test to determine injection spacing, application mass/volume, and other design parameters. For cost estimating purposes, it is assumed that six injection points/fractures will be installed on 20-ft spacing along the orientation of the bedrock erosional channel. The injection will be implemented under pressure using direct-push technology with an injection pump and mixing equipment at the ground surface. Approximately 1,000 pounds of $KMnO_4$ will be injected at each injection point as a slurry with approximately 100 gallons of a 3% bentonite/water solution. The pilot test will be conducted to evaluate the application mechanics, including direct-push ease, injectability, and to estimate effective injection radius, prior to full-scale implementation. The sampling of Monitoring Well DCF01-40) plus two temporary wells, will occur bi-monthly for twelve months to estimate the movement of injected $KMnO_4$. It should be noted that Monitoring Well DCF01-40 may have to be abandoned during the soil excavation and removal activities presented for AOC 1. This monitoring well will be replaced prior to initiation of the chemical oxidation pilot test.

For full-scale design, it is assumed that enough oxidant will need to be delivered to treat a 50-ft x 150-ft area in the vicinity of Monitoring Well DCF01-40. Based on typical NOD for similar soils, the amount of oxidant needed to treat this area is approximately 30,000 pounds of $KMnO_4$. The actual amount needed would be determined from the bench-scale testing performed as part of this alternative. The oxidant will be delivered via injection points/fractures, with 1,000 pounds per location. The actual number and spacing of injection points will be determined by the pilot test results.

Natural Attenuation

MNA refers to the periodic sampling and monitoring of geochemical and contaminant conditions at the DCF Study Area. Contaminant concentrations and NA parameters will be monitored periodically to evaluate if the NA processes are continuing to reduce contaminant concentrations. NA parameters may include the following: temperature, pH, conductivity, methane, ethane, ethene, alkalinity, nitrate, sulfate, sulfide, chloride, TOC, DO, ORP, and ferrous iron. These parameters were used in the RIA Report (BMcD, 2003) to demonstrate that some NA is occurring at the DCF Study Area; however, not all of these parameters are needed to demonstrate that NA is continuing during MNA. MNA would be performed using the currently available monitoring wells to assess ongoing NA at the DCF Study Area. For cost estimating purposes, it is assumed approximately 22 existing wells would be used for long-term monitoring.

The inclusion of institutional controls and monitoring with this alternative reduces the potential for human ingestion, inhalation, or dermal contact with contaminated groundwater at the DCFA Site.

Institutional controls include restrictions on new building construction, land use, and groundwater use. These restrictions reduce the potential for human ingestion, inhalation, or direct contact with contaminated soil and groundwater at the DCF Study Area. At a minimum, CERCLA requires administrative reassessments every five years whenever contaminants are left in place, if the site is not open for unrestricted use. If justified by this review, additional remedial actions could be implemented if unexpected monitoring results (e.g., increases in contaminant levels) or land use changes indicate that such action is warranted.

5.3.2.2.2 Evaluation

Protection of Human Health and the Environment

Based on the risk assessments performed in the RIA Report (BMcD, 2003), this alternative is protective of human health and the environment because the risk estimate does not exceed the USEPA accepted risk levels. The potential for future risk to human health or the environment is anticipated to decrease because institutional controls would be in place to limit or prevent exposure to contaminated groundwater and remediation of contaminants would further reduce contaminant concentrations.

Compliance with ARARs

This alternative is anticipated to control exposure to the contaminated groundwater through governmental controls and proprietary controls. Therefore, the use of groundwater during the time when levels are decreasing would be restricted by this alternative. This alternative potentially could accelerate meeting preliminary chemical-specific ARARs (i.e., MCLs) in the terrace and alluvial aquifers by reducing contaminant mass that contributes to the dissolved plume. A list of preliminary ARARs for the DCF Study Area is presented in Section 2.2.2.

Preliminary action-specific ARARs are anticipated to be met by this alternative as follows. An underground injection permit will not likely be required to inject chemical oxidants into the subsurface, because CERCLA sites are exempt. However, the functional equivalent of a permit may be necessary for KDHE concurrence because the substantive requirements of a permit typically must be satisfied (K.S.A 65-164, 65-165, and 65-171d). OSHA requirements are anticipated to be met during implementation of this alternative. All action-specific RCRA-related ARARs are anticipated to be met.

Preliminary location-specific ARARs for this alternative is mainly concerned with endangered species, and archaeological and historical preservation. Location-specific ARARs will be met by coordinating remedial activities with Fort Riley Conservation Division personnel to minimize or eliminate adverse impacts on either wildlife, archaeological sites, or historical structures. Table 5-1 presents a matrix indicating the ARARs that have been identified as preliminary ARARs for this remedial alternative.

Long-Term Effectiveness and Permanence

Once groundwater RAOs are achieved at the DCF Study Area, groundwater contaminant levels can be expected to remain low because there are no ongoing industrial activities to increase the groundwater concentrations of the COPCs. Therefore, the magnitude of risk to human health and the environment is anticipated to be less than current risk conditions, which are already within the USEPA accepted limits at this site (BMcD, 2003). However, contaminants sorbed to the aquifer matrix may continue to leach COPCs after remediation has been completed.

Since the source areas for groundwater contamination are not open for unrestricted use, a review of groundwater contamination at the DCF Study Area would be required every five years to verify that the remedy continues to provide adequate protection of human health and the environment in accordance with CERCLA 121(c). Institutional controls are anticipated to limit exposure to present and future users of the groundwater, if necessary.

Reduction of Toxicity, Mobility, or Volume

Reduction in contaminant volume is anticipated to be achieved with this alternative primarily through chemical oxidation of groundwater contamination near Monitoring Well DCF01-40. Reduction of concentrations would be anticipated to lower dissolved concentrations in the terrace aquifer portion of the plume and further reduce the concentrations of VOCs in the aquifer. NA processes would also act to further reduce contaminant concentrations.

$KMnO_4$ treatment is not expected to interfere with NA processes that are presently operating. Specifically, $KMnO_4$ has limited mobility and oxidizing conditions would be limited to the immediate treatment area. Any excess $KMnO_4$ would be consumed by the NOD in the vicinity of the chemox injection point.

Short-Term Effectiveness

The inclusion of a groundwater monitoring program and institutional controls addresses short-term reliability in the event that the remedial technology used in this alternative does not reduce the contaminant levels at the DCF Study Area. Institutional controls address potential receptors during remedial actions by limiting or preventing exposure to contaminated groundwater. Therefore, risks of adverse effects to human health during the remedial phase are low. A health and safety plan would address any short-term risks associated with implementation.

Implementability

There are no anticipated technical difficulties in implementing this alternative. The current groundwater monitoring well network will provide adequate coverage for evaluating the effectiveness of this technology and monitoring any changes in the nature and extent of contamination at the DCF Study Area.

Cost Evaluation

The capital cost for this alternative is $510,000 with O&M cost totaling $2,000,000, periodic costs totaling $260,000, a total project cost of $2,800,000, and a present value cost of $2,200,000. Detailed cost analysis tables are presented in Appendix 5A (Tables 5A-12 and 5A-13). While cost estimates are sound, unexpected costs could occur during implementation of this alternative.

5.3.2.2.3 Additional Criteria

Advantages

- Reduces the potential for human ingestion, inhalation, or dermal contact with contaminated groundwater at the DCF Study Area.
- Includes a groundwater monitoring program to assess future changes in site and/or contaminant conditions.
- Minimizes human exposure to contaminants during remediation because neither contaminated groundwater nor aquifer materials are brought to the ground surface.
- Destroys contaminants in-situ, rather than transferring them to another medium.
- Can be injected using direct-push methods.
- Low disruption to surface.
- No permanent surface structures/facilities.
- Following injections, there are no O&M issues or costs (not including semiannual groundwater monitoring).

Limitations and Considerations

- Re-injections may be required if contaminant levels do not decrease as predicted.
- NA is active in this area and is reducing the concentrations of PCE and TCE to levels below the MCL.

5.3.2.3 Alternative 3 – Enhanced Anaerobic Bioremediation, MNA, and Institutional Controls

5.3.2.3.1 Description

General Technology Description

Carbon sources such as lactate, vegetable oil, molasses, and others can be added to aquifer materials to enhance anaerobic bioremediation via reductive dechlorination. Lactate is a compound that slowly releases lactic acid, which breaks down to release hydrogen, and stimulates degradation of chlorinated solvents. Vegetable oil and molasses are other potential carbon additions for promoting increased biodegradation. When applied at a slow continuous rate, these products provide a constant carbon source for the anaerobic degrading of microbes. Various combinations of methane, nitrogen, and phosphorous have also been used to promote increased biodegradation.

Although several biodegradation options are available, for conceptual design, cost estimation, and applicability evaluation, the vegetable oil based substrate technology will be used as a representative option. Other carbon source options may be evaluated in detail in the PP. Vegetable oil based substrates are comprised of triacylglycerols, which consist of long-chain fatty acids and glycerol. The fatty acids, which consist of large hydrogen-rich molecules, are digested by microorganisms via beta (β) oxidation. A series of β oxidation cycles reduces the fatty acids to produce molecules of acetic acid and hydrogen gas (H_2). The resulting hydrogen can be used by reductive dehalogenators that are capable of dechlorinating PCE and associated chlorinated solvents.

Site Specific Description

To remediate the chlorinated solvent plume at the DCFA Site, treatment of the groundwater plume in the bedrock erosional channel is proposed using a vegetable oil based substrate. Additionally, portions of the sanitary sewer line that fed wastewater from former Building 183 to Manhole 363 may also be treated because the sanitary sewer utility corridor may have been a potential contamination migration pathway during past drycleaning operations (see Figure 5-1).

Attenuation of contamination is occurring in the bedrock erosional channel, but monitoring indicates that biological processes may not be significant compared to physical attenuation mechanisms such as adsorption, dilution, and dispersion. Injection of a vegetable oil based substrate will be used as biostimulation in this area. No biostimulation is proposed for the downgradient portion of the plume because the natural attenuation rates appear adequate to polish any residual dissolved contamination that may escape an upgradient treatment zone in the terrace aquifer.

A typical injection system for a contaminated site of this scale (approximately 225-ft by 75-ft area) would be an injection grid (see Figure 5-6). The actual spacing distance between injection points is determined by the level of contamination in the groundwater, amount of substrate mass needed at each injection point, and the hydrogeologic conditions of the site. The substrate is injected into the aquifer using standard direct-push equipment through probe rods to the base of the aquifer. Since vegetable oil has a specific gravity (approximately 0.92) slightly less than water, the injected vegetable oil creates a "smear" zone within the saturated portion of the aquifer to provide sufficient vertical distribution. The vegetable oil does not require emulsification prior to injection.

Alternative 3 includes bench-scale testing of groundwater and an aquifer matrix treatability study to evaluate design parameters. Also, site-specific data will be collected via a pilot test to evaluate the application mechanics including direct-push ease, injectability, and estimate effective injection radius, prior to full-scale implementation. Due to the relatively steep hydraulic gradient (average 0.01), possible heterogeneity of the terrace aquifer, and infiltration of relatively oxidizing precipitation and rapid recharge of potentially oxidizing groundwater from up gradient locations, the feasibility of achieving reducing conditions in the potential higher velocity channel is not known.

For the pilot study, a partial curtain within the treatment area would be used consisting of ten injection points spaced on 10 ft centers, 100 ft wide, with an assumed vegetable oil substrate application amount of 15 pounds per vertical ft and a 10 ft saturated thickness. Sampling will occur at two existing monitoring wells, DCF93-13 and DCF02-41, twice in the first month after application, then monthly thereafter for six months to estimate movement and performance of injected vegetable oil substrate. It should be noted that Monitoring Well DCF01-40 may have to be abandoned during the soil excavation and removal activities presented for AOC 1. This monitoring well will be replaced prior to initiation of the EAB pilot test.

Conceptual full-scale design of this alternative makes use of an injection grid applied over a 75-ft by 225-ft area spaced on 15-ft centers. Injection will be performed using direct-push equipment within the saturated portion of the bedrock erosional channel from the top of bedrock to the top of groundwater, which is approximately 8-ft thick. A conservative estimate of 10 ft will be used for design purposes to adjust for upward groundwater fluctuation. This design is consistent with the horizontal and vertical extent of the contaminant plume at the DCFA Site. For cost estimating, it is assumed that the vegetable oil substrate will be applied at a rate of 15 pounds per vertical ft., with a total of approximately 11,250 pounds of vegetable oil substrate injected. The actual number of injection points and the injection rate will be determined from the pilot test.

Natural Attenuation

MNA refers to the periodic sampling and monitoring of geochemical and contaminant conditions at the DCF Study Area. Contaminant concentrations and NA parameters will be monitored periodically to evaluate if the NA processes are continuing to reduce contaminant concentrations. NA parameters may include the following: temperature, pH, conductivity, methane, ethane, ethene, alkalinity, nitrate, sulfate, sulfide, chloride, TOC, DO, ORP, and ferrous iron. These parameters were used in the RIA Report (BMcD, 2003) to demonstrate that NA is occurring at the DCF Study Area; however, not all of these parameters are needed to demonstrate that NA is continuing during MNA. MNA would be performed using the currently available monitoring wells to assess ongoing NA at the DCF Study Area. For cost estimating purposes, it is assumed approximately 22 existing wells would be used for long-term monitoring.

The inclusion of institutional controls and monitoring with this alternative reduces the potential for human ingestion, inhalation, or dermal contact with contaminated groundwater at the DCF Study Area. Institutional controls include restrictions on new building construction, land use, and groundwater use. These restrictions reduce the potential for human ingestion, inhalation, or direct contact with contaminated soil and groundwater at the DCF Study Area. At a minimum, CERCLA requires administrative reassessments every five years whenever contaminants are left in place, if the site is not open for unrestricted use. If justified by this review, additional remedial actions could be implemented if unexpected monitoring results (e.g., increases in contaminant levels) or land use changes indicate that such action is warranted.

5.3.2.3.2 Evaluation

Protection of Human Health and the Environment

Based on the risk assessments performed in the RIA Report (BMcD, 2003), this alternative is protective of human health and the environment because the risk estimates do not exceed the USEPA accepted risk levels. The potential for future risk to human health or the environment is anticipated to decrease because institutional controls would be in place to limit or prevent exposure to contaminated groundwater and remediation of contaminants would further reduce concentrations.

Compliance with ARARs

This alternative is anticipated to control exposure to the contaminated groundwater through governmental controls and proprietary controls. Therefore, the use of groundwater during the time when levels are decreasing to MCLs is restricted by this alternative. This alternative potentially could meet preliminary chemical-specific ARARs (i.e., MCLs) in the terrace aquifer by stimulating microbes and accelerating natural biological processes that are operating within the bedrock erosional channel at the DCF Study Area. A list of preliminary ARARs for the DCF Study Area is presented in Section 2.2.2.

Preliminary action-specific ARARs are anticipated to be met by this alternative as follows. An underground injection permit would not likely be required to inject vegetable oil substrate into the subsurface, because CERCLA sites are exempt. However, the functional equivalent of a permit may be necessary for KDHE concurrence because the substantive requirements of a permit typically must be satisfied (K.S.A 65-164, 65-165, and 65-171d). OSHA requirements are anticipated to be met during implementation of this alternative. All action-specific RCRA-related ARARs are anticipated to be met.

Preliminary location-specific ARARs for this alternative is mainly concerned with endangered species, and archaeological and historical preservation. Location-specific ARARs will be met by coordinating remedial activities with Fort Riley Conservation Division personnel to minimize or eliminate adverse impacts on either wildlife, archaeological sites, or historical structures. Table 5-1 presents a matrix indicating the ARARs that have been identified as preliminary ARARs for this remedial alternative.

Long-Term Effectiveness and Permanence

Once groundwater RAOs are achieved at the DCF Study Area, groundwater contaminant levels are expected to remain low because there are no ongoing industrial activities to renew the shallow soil hot spots near the former Building 180 area. Therefore, the magnitude of risk to human health and the environment is anticipated to be less than current risk conditions, which are already within the USEPA accepted limits at the DCF Study Area (BMcD 2003). However contaminants sorbed to the aquifer matrix may leach low levels of COPCs after remediation is completed.

A review of groundwater contamination at the DCF Study Area would be required every five years, if the site is not open for unrestricted use, to verify that the remedy continues to provide adequate protection of human health and the environment in accordance with CERCLA 121(c). Institutional controls are anticipated to limit exposure to present and future users of the groundwater, if necessary.

Reduction of Toxicity, Mobility, or Volume

Reduction in contaminant volume is anticipated to be achieved with this alternative primarily through EAB. The injection of the vegetable oil substrate will enhance the NA processes in the area. NA processes will then work to further reduce contaminant concentrations downgradient of the treatment area.

Short-Term Effectiveness

The inclusion of a groundwater monitoring program and institutional controls addresses short-term reliability in the event that the remedial technology used in this alternative does not reduce the contaminant levels at the DCF Study Area. Institutional controls address potential receptors during remedial actions by limiting or preventing exposure to contaminated groundwater. Therefore, risks of adverse effects to human health during the remedial phase are low. A health and safety plan would address any short-term risks associated with implementation.

Implementability

There are no anticipated technical difficulties in implementing this alternative. The current groundwater monitoring well network is anticipated to provide adequate coverage for evaluating the effectiveness of this technology and monitoring any changes in the nature and extent of contamination at the DCF Study Area.

Cost Evaluation

The capital cost for this alternative is $310,000 with O&M cost totaling $2,000,000, periodic costs totaling $260,000, a total project cost of $2,600,000, and a present value cost of $2,000,000. Detailed cost analysis tables are presented in Appendix 5A (Tables 5A-14 and 5A-15). While cost estimates are sound, unexpected costs could occur during implementation of this alternative.

5.3.2.3.3 Additional Criteria

Advantages

- Reduces the potential for human ingestion, inhalation, or dermal contact with contaminated groundwater at the DCF Study Area.
- Includes a groundwater monitoring program to assess future changes in site and/or contaminant conditions.
- Minimizes human exposure to contaminants during remediation because neither contaminated groundwater nor aquifer materials are brought to the ground surface.
- Destroys contaminants in-situ, rather than transferring them to another medium.
- Can be injected using direct-push methods.
- Low disruption to surface.

- No permanent surface structures/facilities.
- Following injection, there are no O&M issues with the EAB treatment.

Limitations and Considerations

- Possibility for VC to accumulate, although unlikely due to low level concentrations of contaminants at the DCF Study Area.
- Re-injections may be required if contaminant levels do not decrease as predicted.
- Success is dependent on site-specific aquifer conditions and the microbial population.

5.3.3 AOC 3 (Groundwater at Monitoring Well DCF02-42 Area)

5.3.3.1 Alternative 1 - No Action

5.3.3.1.1 Description

This alternative is the "no action" alternative, a requirement of the NCP, which provides a baseline for the comparison of active remedial alternatives developed for the DCF Study Area. Under the "no action" alternative, institutional controls are not implemented, and remediation and monitoring of the groundwater contamination are not conducted.

The area around Monitoring Well DCF02-42 is classified by the RPMP as a designated open area. Open areas have building restrictions and are used for safety areas, utility clearances and easements, conservation areas, and buffer zones. There are no supply wells within the area impacted by the chlorinated solvent plume. It is anticipated that land use activities within the DCF Study Area will remain unchanged into the foreseeable future based on these building restrictions.
By definition, this alternative requires that the current monitoring program be discontinued. At a minimum, CERCLA requires administrative reassessments every five years, if the DCF Study Area is not open for unrestricted use, whenever contaminants are left in place.

Because the "no action" alternative is an idealized baseline, even though institutional controls are in place due to the location of the site on a military base, the "no action" alternative does not acknowledge these controls. Similarly, the "no action" alternative also does not acknowledge the migration of the solvent plumes from the terrace area to the Kansas River alluvial aquifer, nor does it address that natural processes are indicated to be operating to further attenuate these plumes.

5.3.3.1.2 Evaluation

Protection of Human Health and the Environment

Based on the risk assessments (human health and ecological) performed in the RIA Report (BMcD, 2003), this alternative is protective of human health and the environment because the risk estimates for current and future RME scenarios do not exceed the USEPA accepted risk levels. However, because this alternative does not include institutional controls, there is no control of future use. Therefore, an unforeseen exposure scenario (not characterized in the RI Report baseline risk assessment, BMcD, 2003) is possible when no institutional controls are acknowledged for the property.

Compliance with ARARs

Preliminary chemical-specific ARARs for this alternative are presented in Table 5-1. Location- and action-specific ARARs do not apply to this alternative, since no active measures will be taken at DCF Study Area.

Groundwater sampling results, up to and including the April 2004 sampling round, indicate that preliminary chemical-specific ARARs (i.e., MCLs) were exceeded for three of the four COPCs at the DCF Study Area (PCE, TCE, and VC) (BMcD, 2004). For the April 2004 groundwater sampling event, concentrations of cis-1,2-DCE did not exceed the 70 ug/L MCL.

Under the "no action" alternative there is no groundwater monitoring to determine concentration trends in the plume. Therefore, under the "no action" alternative the evaluation assumes the groundwater levels remain "as-is". Because MCLs are exceeded, it is assumed under the "no action" alternative that MCLs will continue to be exceeded. Additionally, no credit would be given for natural attenuation of the solvent plume.

Long-Term Effectiveness and Permanence

Although the risk assessment (BMcD 2003) concluded that the magnitude of risk to human health and the environment for groundwater is within the USEPA accepted limits at the DCF Study Area Site, the No Action Alternative would not treat the groundwater near Monitoring Well DCF02-42 and would continue to allow the migration of contaminated groundwater from the terrace to the Kansas River alluvial aquifer. Therefore, it is anticipated that contamination levels will continue to be above the MCLs for groundwater under this alternative.

Institutional controls are not acknowledged with this alternative; therefore, there is a hypothetical possibility that an unforeseen exposure scenario could occur under the "no action" alternative.

Reduction of Toxicity, Mobility, or Volume

Because the distal portion of the western PCE, TCE, and cis-1,2-DCE contaminant plumes terminate at the Kansas River, it is apparent that the No Action Alternative will not restrict or prevent the migration of contaminant laden groundwater from the terrace to the Kansas River alluvial aquifer. Some reductions in contaminant concentration are occurring through natural attenuation processes such as advection and dispersion in the Kansas River alluvial aquifer. NA parameters measured for the April 2004 groundwater sampling event are presented on Figure 5-4. The effects of natural attenuation in the Kansas River alluvial aquifer should continue to reduce concentrations of COPCs and reduce the risk of exposure to both human and environmental receptors. However, PCE concentrations above the MCL are currently found in those monitoring wells installed along the Kansas River.

Under the No Action Alternative, there is no monitoring and interpretation of monitoring results to verify natural attenuation processes are operating. Therefore, when comparing the No Action Alternative to other more comprehensive alternatives, the reduction of toxicity, mobility, or volume is not reconciled until the first mandated 5-year review in accordance with CERCLA 121(c). The limitation of a discrete 5-year review is that it is not as comprehensive as a set of measurements collected over time to corroborate that the sampling event results are consistent and reproducible.

Short-Term Effectiveness

Because no quantitative modeling was performed at the DCF Study Area, it is difficult to predict how long it will take to achieve RAOs across the entire site. Currently, RAOs are not being met for the western PCE and TCE plume originating from the DCF02-42 Area; however, the No Action Alternative would pose no additional detrimental effects to human health or the environment as a result of implementation.

Implementability

There are no implementability concerns posed by this remedy because no action would be taken.

Cost Evaluation

The present worth cost of this alternative is estimated to be $410,000, with total periodic costs totaling $610,000, and a total project cost of $610,000 (undiscounted). The only costs are for five-year reviews, groundwater monitoring for the reviews, and the closure report. Detailed cost analysis tables are presented in Appendix 5A (Tables 5A-1 and 5A -2).

5.3.3.1.3 Additional Criteria

Advantages

- Low cost.
- No additional risk to the community or environment.

Limitations and Considerations

- Without an annual groundwater monitoring program, changes in the site and/or contaminant conditions would only be assessed during the five-year reviews.
- Does not prevent the migration of contaminated groundwater from the terrace to the Kansas River alluvial aquifer.

5.3.3.2 Alternative 2 – In-Situ Chemical Oxidation, MNA, and Institutional Controls

5.3.3.2.1 Description

General Technology Description

As stated in Section 5.3.2.2.1, chemical oxidation converts hazardous contaminants to non-hazardous or less toxic compounds that are more stable, less mobile, and/or inert. The oxidizing agents most commonly used are O_3, H_2O_2, and MnO_4^-. O_3 gas can oxidize contaminants directly or through the formation of $OH^\bullet$. A liquid H_2O_2 solution, in the presence of native or supplemental Fe^{2+}, produces Fenton's Reagent, which yields various reactive free radicals including $OH^\bullet$. MnO_4^- can destroy contaminants by either direct electron transfer or free radical advanced oxidation, and is a selective oxidant in that it has the potential to be less reactive with some of the natural organics and can persist longer in the subsurface than Fenton's reagent or ozone. MnO_4^- is generally effective in treating chlorinated ethenes (i.e., PCE, TCE, and cis-1,2-DCE).

For the purposes of conceptual design, cost estimation, and applicability evaluation, the $KMnO_4$ technology and vertical injection points will be used as a representative option. Other oxidant options may be evaluated in detail in the PP.

Site-Specific Description

Alternative 2 consists of in-situ treatment of contaminated groundwater within the terrace aquifer located in the vicinity of Monitoring Well DCF02-42 (see Figure 5-7). Alternative 2 is designed to treat groundwater in the vicinity of Monitoring Well DCF02-42, which exhibits concentrations of COPCs in excess of MCLs. Although, groundwater monitoring indicates that the plume poses minimal adverse risk to human health and the environment, by discovering and treating additional groundwater with contaminant levels above MCLs, it may be possible to reach site closure in a shorter time and possibly reduce the cost of long-term monitoring. This alternative focuses on treating the saturated zone above bedrock which has an approximate thickness of 1.0 ft (BMcD, 2004).

Depending on bench scale treatability and the distribution of contamination, $KMnO_4$ can be injected into the subsurface by the following methods:

- Injection of concentrated (dense) $KMnO_4$ solution in one or multiple layers or "pancakes" with density flow of $KMnO_4$ to distribute $KMnO_4$ as curtains within the saturated zone. Injection in discrete layers is intended to limit the displacement of contaminated groundwater outside the treatment zone.
- Injection of $KMnO_4$ slurry in layer(s) via pressure injection or fracturing. $KMnO_4$ acts as a long-term supply of oxidant to treat residual contamination.

- Injection and circulation of lower concentration $KMnO_4$ solution for gradual treatment of groundwater contamination.

For the purpose of this FS, injection of a $KMnO_4$ slurry is the assumed injection method. This method is the preferred injection method at the site because it eliminates O&M and water supply issues associated with the solution injection, circulation, and recovery system, and it still provides long-term treatment in the source area.

Alternative 2 includes bench-scale testing of groundwater and an aquifer matrix treatability study to evaluate the NOD. The NOD is primarily a function of natural organic content, oxidizable minerals/mineral surfaces, and oxidizable material dissolved or suspended in the groundwater. Although bench-scale studies have been performed for similar soils, the aquifer matrix at depth combined with groundwater may exert a different NOD than the soils that have been previously tested.

Alternative 2 also includes a pilot test to determine injection spacing, application mass/volume, and other design parameters. For cost estimating purposes, it is assumed that three injection points/fractures will be installed on 20-ft spacing along the orientation of the bedrock erosional channel. The injection will be implemented under pressure using direct-push technology with an injection pump and mixing equipment at the ground surface. Approximately 1,000 pounds of $KMnO_4$ will be injected at each injection point as a slurry with approximately 100 gallons of a 3% bentonite/water solution. The pilot test will be conducted to evaluate the application mechanics, including direct-push ease, injectability, and to estimate effective injection radius, prior to full-scale implementation. The sampling of Monitoring Well DCF02-42) plus two temporary wells, will occur bi-monthly for twelve months to estimate the movement of injected $KMnO_4$.

For full-scale design, it is assumed that enough oxidant will need to be delivered to treat a 30-ft x 200-ft area in the vicinity of Monitoring Well DCF02-42. Based on typical NOD for similar soils, the amount of oxidant needed to treat this area is approximately 25,000 pounds of $KMnO_4^-$. The actual amount needed would be determined from the bench-scale testing performed as part of this alternative. The oxidant will be delivered via injection points/fractures, with 1,000 pounds per location. The spacing of injection points will be determined by the pilot test results, and may involve injection points south of the UPRR tracks between Monitoring Wells DCF02-42 and DCF96-25, based upon approval of the DES Conservation Office, DES project manager, and the USACE.

Natural Attenuation

MNA refers to the periodic sampling and monitoring of geochemical and contaminant conditions at the DCF Study Area. Contaminant concentrations and NA parameters will be monitored periodically to evaluate if the NA processes are continuing to reduce contaminant concentrations. NA parameters may include the following: temperature, pH, conductivity, methane, ethane, ethene, alkalinity, nitrate, sulfate, sulfide, chloride, TOC, DO, ORP, and ferrous iron. These parameters were used in the RIA Report (BMcD, 2003) to demonstrate that NA is occurring at the DCF Study Area; however, not all of these parameters are needed to demonstrate that NA is continuing during MNA. MNA would be performed using the currently available monitoring wells to assess ongoing NA at the DCF Study Area. For cost estimating purposes, it is assumed approximately 22 existing wells would be used for long-term monitoring.

The inclusion of institutional controls and monitoring with this alternative reduces the potential for human ingestion, inhalation, or dermal contact with contaminated groundwater at the DCFA Site.

Institutional controls include restrictions on new building construction, land use, and groundwater use. These restrictions reduce the potential for human ingestion, inhalation, or direct contact with contaminated soil and groundwater at the DCF Study Area. At a minimum, CERCLA requires administrative reassessments every five years whenever contaminants are left in place, if the site is not open for unrestricted use. If justified by this review, additional remedial actions could be implemented if unexpected monitoring results (e.g., increases in contaminant levels) or land use changes indicate that such action is warranted.

5.3.3.2.2 Evaluation

Protection of Human Health and the Environment

Based on the risk assessments performed in the RIA Report (BMcD, 2003), this alternative is protective of human health and the environment because the risk estimate does not exceed the USEPA accepted risk levels. The potential for future risk to human health or the environment is anticipated to decrease because institutional controls would be in place to limit or prevent exposure to contaminated groundwater and remediation of contaminants would further reduce contaminant concentrations.

Compliance with ARARs

This alternative is anticipated to control exposure to the contaminated groundwater through governmental controls and proprietary controls. Therefore, the use of groundwater during the time when levels are decreasing would be restricted by this alternative. This alternative potentially could accelerate meeting preliminary chemical-specific ARARs (i.e., MCLs) in the terrace and alluvial aquifers by reducing contaminant mass that contributes to the dissolved plume. A list of preliminary ARARs for the DCF Study Area is presented in Section 2.2.2.

Preliminary action-specific ARARs are anticipated to be met by this alternative as follows. An underground injection permit will not likely be required to inject chemical oxidants into the subsurface, because CERCLA sites are exempt. However, the functional equivalent of a permit may be necessary for KDHE concurrence because the substantive requirements of a permit typically must be satisfied (K.S.A 65-164, 65-165, and 65-171d). OSHA requirements are anticipated to be met during implementation of this alternative. All action-specific RCRA-related ARARs are anticipated to be met.

Preliminary location-specific ARARs for this alternative is mainly concerned with endangered species, and archaeological and historical preservation. Location-specific ARARs will be met by coordinating remedial activities with Fort Riley Conservation Division personnel to minimize or eliminate adverse impacts on either wildlife, archaeological sites, or historical structures. Table 5-1 presents a matrix indicating the ARARs that have been identified as preliminary ARARs for this remedial alternative.

Long-Term Effectiveness and Permanence

Once groundwater RAOs are achieved at the DCF Study Area, groundwater contaminant levels can be expected to remain low because there are no ongoing industrial activities to increase the groundwater concentrations of the COPCs. Therefore, the magnitude of risk to human health and the environment is anticipated to be less than current risk conditions, which are already within the USEPA accepted limits at this site (BMcD, 2003). However, contaminants sorbed to the aquifer matrix may continue to leach COPCs after remediation has been completed.

Since the source areas for groundwater contamination are not open for unrestricted use, a review of groundwater contamination at the DCF Study Area would be required every five years to verify that the remedy continues to provide adequate protection of human health and the environment in accordance with CERCLA 121(c). Institutional controls are anticipated to limit exposure to present and future users of the groundwater, if necessary.

Reduction of Toxicity, Mobility, or Volume

Reduction in contaminant volume is anticipated to be achieved with this alternative primarily through chemical oxidation of groundwater contamination near Monitoring Well DCF02-42. Reduction of concentrations would be anticipated to lower dissolved concentrations in the terrace aquifer portion of the plume and further reduce the concentrations of VOCs in the aquifer. NA processes would also act to further reduce contaminant concentrations.

$KMnO_4$ treatment is not expected to interfere with NA processes that are presently operating. Specifically, $KMnO_4$ has limited mobility and oxidizing conditions would be limited to the immediate treatment area. Any excess $KMnO_4$ would be consumed by the NOD at the location of chemical oxidation injection.

Short-Term Effectiveness

The inclusion of a groundwater monitoring program and institutional controls addresses short-term reliability in the event that the remedial technology used in this alternative does not reduce the contaminant levels at the DCF Study Area. Institutional controls address potential receptors during remedial actions by limiting or preventing exposure to contaminated groundwater. Therefore, risks of adverse effects to human health during the remedial phase are low. A health and safety plan would address any short-term risks associated with implementation.

Implementability

There are no anticipated technical difficulties in implementing this alternative. The current groundwater monitoring well network will provide adequate coverage for evaluating the effectiveness of this technology and monitoring any changes in the nature and extent of contamination at the DCF Study Area.

Cost Evaluation

The capital cost for this alternative is $490,000 with O&M cost totaling $2,000,000, periodic costs totaling $260,000, a total project cost of $2,800,000, and a present value cost of $2,200,000. Detailed cost analysis tables are presented in Appendix 5A (Tables 5A-16 and 5A-17). While cost estimates are sound, unexpected costs could occur during implementation of this alternative.

5.3.3.2.3 Additional Criteria

Advantages

- Reduces the potential for human ingestion, inhalation, or dermal contact with contaminated groundwater at the DCF Study Area.
- Includes a groundwater monitoring program to assess future changes in site and/or contaminant conditions.
- Minimizes human exposure to contaminants during remediation because neither contaminated groundwater nor aquifer materials are brought to the ground surface.
- Destroys contaminants in-situ, rather than transferring them to another medium.
- Can be injected using direct-push methods.
- Low disruption to surface.
- No permanent surface structures/facilities.
- Following injections, there are no O&M issues or costs (not including semiannual groundwater monitoring).

Limitations and Considerations

- Re-injections may be required if contaminant levels do not decrease as predicted.
- Injections may be required on the Island within the eagle protective area to insure adequate coverage.

5.3.3.3 Alternative 3 – Enhanced Anaerobic Bioremediation, MNA, and Institutional Controls

5.3.3.3.1 Description

General Technology Description

As stated previously, carbon sources such as lactate, vegetable oil, molasses, and others can be added to aquifer materials to enhance anaerobic bioremediation via reductive dechlorination. When applied at a slow continuous rate, these products provide a constant carbon source for the anaerobic degrading of microbes. For conceptual design, cost estimation, and applicability evaluation, the vegetable oil based substrate technology will be used as a representative option.

Vegetable oil based substrates are comprised of triacylglycerols, which consist of long-chain fatty acids and glycerol. A series of β oxidation cycles reduces the fatty acids to produce molecules of acetic acid and H_2. The resulting hydrogen can be used by reductive dehalogenators that are capable of dechlorinating PCE and associated chlorinated solvents.

Site Specific Description

To remediate the chlorinated solvent plume at the DCFA Site, treatment of the groundwater plume in the vicinity of Monitoring Well DCF02-42 is proposed using a vegetable oil based substrate. Since there is little evidence of NA in this area, injection of a vegetable oil based substrate would be used as biostimulation in this area. Additional areas located downgradient between Monitoring Wells DCF02-42 and DCF96-25 would also be injected to stimulate bioremediation based on prior approval from the Fort Riley DES, DES Conservation Office, and the USACE.

A typical injection system for a contaminated site of this scale (approximately 30-ft by 200-ft area) would be an injection grid (see Figure 5-8). The actual spacing distance between injection points is determined by the level of contamination in the groundwater, amount of substrate mass needed at each injection point, and the hydrogeologic conditions of the site. The substrate is injected into the aquifer using standard direct-push equipment through probe rods to the base of the aquifer. Since vegetable oil has a specific gravity (approximately 0.92) slightly less than water, the injected vegetable oil creates a "smear" zone within the saturated portion of the aquifer to provide sufficient vertical distribution. The vegetable oil does not require emulsification prior to injection.

Alternative 3 includes bench-scale testing of groundwater and an aquifer matrix treatability study to evaluate design parameters. Also, site-specific data will be collected via a pilot test to evaluate the application mechanics including direct-push ease, injectability, and estimate effective injection radius, prior to full-scale implementation. Due to the possible heterogeneity of the terrace aquifer, infiltration of relatively oxidizing precipitation, and rapid recharge of potentially oxidizing groundwater from up gradient locations, the feasibility of achieving reducing conditions at the injection area is not known.

For the pilot study, a partial curtain within the treatment area would be used consisting of five injection points spaced on five ft centers, approximately 30 ft wide, with an assumed vegetable oil substrate application amount of 15 pounds per vertical ft and a two ft saturated thickness. Sampling will occur at two existing monitoring wells, DCF96-26 and DCF02-42, twice in the first month after application, then monthly thereafter for six months to estimate movement and performance of injected vegetable oil substrate.

Conceptual full-scale design of this alternative makes use of an injection grid applied over an approximate 50-ft by 200-ft area spaced on 15-ft centers. Injection will be performed using direct-push equipment within the saturated portion of the aquifer from the top of bedrock to the top of groundwater (approximately 1 to 8-ft thick, depending on location). For cost estimation purposes, an aquifer with an 8-ft thick saturation zone will be used. This design is consistent with the horizontal and vertical extent of the contaminant plume at the DCFA Site. For cost estimating, it is assumed that the vegetable oil substrate will be applied at a rate of 15 pounds per vertical ft., with a total of 9,000 pounds of vegetable oil substrate injected. The actual number of locations and the injection rate will be determined from the pilot test.

Natural Attenuation

MNA refers to the periodic sampling and monitoring of geochemical and contaminant conditions at the DCF Study Area. Contaminant concentrations and NA parameters will be monitored periodically to evaluate if the NA processes are continuing to reduce contaminant concentrations. NA parameters may include the following: temperature, pH, conductivity, methane, ethane, ethene, alkalinity, nitrate, sulfate, sulfide, chloride, TOC, DO, ORP, and ferrous iron. These parameters were used in the RIA Report (BMcD, 2003) to demonstrate that NA is occurring at the DCF Study Area; however, not all of these parameters are needed to demonstrate that NA is continuing during MNA. MNA would be performed using the currently available monitoring wells to assess ongoing NA at the DCF Study Area. For cost estimating purposes, it is assumed approximately 22 existing wells would be used for long-term monitoring.

The inclusion of institutional controls and monitoring with this alternative reduces the potential for human ingestion, inhalation, or dermal contact with contaminated groundwater at the DCF Study Area. Institutional controls include restrictions on new building construction, land use, and groundwater use. These restrictions reduce the potential for human ingestion, inhalation, or direct contact with contaminated soil and groundwater at the DCF Study Area. At a minimum, CERCLA requires administrative reassessments every five years whenever contaminants are left in place, if the site is not open for unrestricted use. If justified by this review, additional remedial actions could be implemented if unexpected monitoring results (e.g., increases in contaminant levels) or land use changes indicate that such action is warranted.

5.3.3.3.2 Evaluation

Protection of Human Health and the Environment

Based on the risk assessments performed in the RIA Report (BMcD, 2003), this alternative is protective of human health and the environment because the risk estimates do not exceed the USEPA accepted risk levels. The potential for future risk to human health or the environment is anticipated to decrease because institutional controls would be in place to limit or prevent exposure to contaminated groundwater and remediation of contaminants would further reduce concentrations.

Compliance with ARARs

This alternative is anticipated to control exposure to the contaminated groundwater through governmental controls and proprietary controls. Therefore, the use of groundwater during the time when levels are decreasing to MCLs is restricted by this alternative. This alternative potentially could meet preliminary chemical-specific ARARs (i.e., MCLs) in the terrace aquifer by stimulating microbes and accelerating natural biological processes that are operating in the area of Monitoring Well DCF02-42. A list of preliminary ARARs for the DCF Study Area is presented in Section 2.2.2.

Preliminary action-specific ARARs are anticipated to be met by this alternative as follows. An underground injection permit would not likely be required to inject vegetable oil substrate into the subsurface, because CERCLA sites are exempt. However, the functional equivalent of a permit may be necessary for KDHE concurrence because the substantive requirements of a permit typically must be satisfied (K.S.A 65-164, 65-165, and 65-171d). OSHA requirements are anticipated to be met during implementation of this alternative. All action-specific RCRA-related ARARs are anticipated to be met.

Preliminary location-specific ARARs for this alternative is mainly concerned with endangered species, and archaeological and historical preservation. Location-specific ARARs will be met by coordinating remedial activities with Fort Riley Conservation Division personnel to minimize or eliminate adverse impacts on either wildlife, archaeological sites, or historical structures. Table 5-1 presents a matrix indicating the ARARs that have been identified as preliminary ARARs for this remedial alternative.

Long-Term Effectiveness and Permanence

Once groundwater RAOs are achieved at the DCF Study Area, groundwater contaminant levels are expected to remain low because there are no ongoing industrial activities to renew the shallow soil hot spots near the former Building 180 area. Therefore, the magnitude of risk to human health and the environment is anticipated to be less than current risk conditions, which are already within the USEPA accepted limits at the DCF Study Area (BMcD 2003). However contaminants sorbed to the aquifer matrix may leach low levels of COPCs after remediation is completed.

A review of groundwater contamination at the DCF Study Area would be required every five years, if the site is not open for unrestricted use, to verify that the remedy continues to provide adequate protection of human health and the environment in accordance with CERCLA 121(c). Institutional controls are anticipated to limit exposure to present and future users of the groundwater, if necessary.

Reduction of Toxicity, Mobility, or Volume

Reduction in contaminant volume is anticipated to be achieved with this alternative primarily through EAB. The injection of the vegetable oil substrate will enhance the NA processes in the area. NA processes will then work to further reduce contaminant concentrations downgradient of the treatment area.

Short-Term Effectiveness

The inclusion of a groundwater monitoring program and institutional controls addresses short-term reliability in the event that the remedial technology used in this alternative does not reduce the contaminant levels at the DCF Study Area. Institutional controls address potential receptors during remedial actions by limiting or preventing exposure to contaminated groundwater. Therefore, risks of adverse effects to human health during the remedial phase are low. A health and safety plan would address any short-term risks associated with implementation.

Implementability

There are no anticipated technical difficulties in implementing this alternative. The current groundwater monitoring well network is anticipated to provide adequate coverage for evaluating the effectiveness of this technology and monitoring any changes in the nature and extent of contamination at the DCF Study Area.

Cost Evaluation

The capital cost for this alternative is $300,000 with O&M cost totaling $2,000,000, periodic costs totaling $250,000, a total project cost of $2,500,000, and a present value cost of $2,000,000. Detailed cost analysis tables are presented in Appendix 5A (Tables 5A-18 and 5A-19). While cost estimates are sound, unexpected costs could occur during implementation of this alternative.

5.3.3.3.3 Additional Criteria

Advantages

- Reduces the potential for human ingestion, inhalation, or dermal contact with contaminated groundwater at the DCF Study Area.
- Includes a groundwater monitoring program to assess future changes in site and/or contaminant conditions.
- Minimizes human exposure to contaminants during remediation because neither contaminated groundwater nor aquifer materials are brought to the ground surface.
- Destroys contaminants in-situ, rather than transferring them to another medium.
- Can be injected using direct-push methods.
- Low disruption to surface.
- No permanent surface structures/facilities.
- Following injection, there are no O&M issues with the EAB treatment (excluding monitoring well network).

Limitations and Considerations

- Possibility for VC to accumulate, although unlikely due to low level concentrations of contaminants at the DCF Study Area.
- Re-injections may be required if contaminant levels do not decrease as predicted.
- Success is dependent on site-specific aquifer conditions and the microbial population.

- Injections may be required on the Island with the eagle protective area to insure adequate coverage.

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6.0 COMPARATIVE EVALUATION OF ALTERNATIVES

6.1 INTRODUCTION

In this section, remedial options are assessed relative to one another for the two threshold criteria and five balancing criteria. The final two criteria, state acceptance and community acceptance, were not considered in this evaluation, but will be evaluated after publication of the PP as part of the development of the ROD. The purpose of this analysis is to identify and discuss the relative advantages or disadvantages of each alternative to aid in the decision-making process.

6.2 EVALUATION METHOD

The alternatives were scored on a pass/fail basis for the two threshold criteria (protection of human health and environment, and compliance with ARARs). Those alternatives passing the threshold criteria were then evaluated for the five balancing criteria on the basis of incremental differences between alternatives. For this FS, there are three AOCs and two media's which include soil and groundwater. The first AOC is the shallow subsurface soil around and beneath the building footprint of former Building 180. The second AOC is groundwater in the bedrock erosional channel, and the third AOC is groundwater in the vicinity of Monitoring Well DCF02-42. Each set of alternatives for each AOC will be evaluated for each of the balancing criteria.

An evaluation and semi-quantitative comparison was performed to facilitate a rating of the alternatives evaluated in the detailed analysis for each AOC. Evaluations were based on vendor information, published reports, past experiences, and professional judgment (see Section 7.0 for references). Equal rating was given if it was not possible to differentiate performance for the given criteria. The range was on a scale of 1 to 10. Any alternative that completely fails the criteria was given a 10. Other alternatives were placed appropriately within the range based on their expected performance relative to the other alternatives and in accordance with the following further justification for specific ratings.

1 Most favorable alternative

3 Good, generally favorable

5 Fair, potentially unfavorable

7 Poor, unfavorable

10 Completely fails the criteria

Ratings of 2, 4, 6, 8, and 9 were used to differentiate between alternatives with similar qualifications where one slightly outperformed the other (e.g., two alternatives were considered "fair" but one was slightly more favorable). This method was employed for each of the five balancing criteria (see Sections 6.3.3 through 6.3.7).

6.3 COMPARATIVE ANALYSIS

6.3.1 Overall Protection of Human Health and the Environment

This is a pass/fail criterion. Based on the risk assessments (human health and ecological) performed in the RIA Report (BMcD, 2003), all of the alternatives are protective of human health and the environment because the risk estimates for current and future RME scenarios do not exceed the USEPA accepted risk levels.

6.3.2 Compliance with ARARs

This is a pass/fail criterion. All of the remedial alternatives with the exception of Alternative 1 (No Action) in each AOC, are anticipated to comply with preliminary chemical-specific ARARs. Additionally, it appears that possible location- and action-specific ARARs will not be a factor. This assumes that all treatment alternatives will be conducted between March 15th and October 15th, which is the window of operation within or adjacent to the bald eagle buffer zone. Alternative 1 for each AOC does not comply with chemical-specific ARARs (i.e., MCLs) because contaminant levels are currently above the MCLs for groundwater in the terrace and Kansas River alluvial aquifers and this alternative takes no action to address the ARAR. Additionally, soil concentrations are also currently above the KDHE RSK PCE value of 180 μg/kg. Although Alternative 1 (No Action) does not meet one of the threshold criteria (i.e., either Overall Protection of Human Health and the Environment; or Compliance with ARARs), it is offered for evaluation in each AOC.

6.3.3 Long-Term Effectiveness and Permanence

6.3.3.1 AOC 1 Shallow Subsurface Soils – Former Building 180 Area

The treatment of shallow subsurface soils at the former Building 180 Area involves three different alternatives for this AOC. While each alternative involves the excavation of shallow subsurface soil to approximately 12 ft bgs for soil with PCE concentrations above the KDHE RSK value of 180 μg/kg, the treatment of the excavated soil is different for each alternative. Each alternative would involve excavation of two areas of concern followed by backfilling with high clay content soil to reduce future infiltration. Soil hotspot #1 is located in the central to southwestern portion of the former Building 180 footprint, while soil hot spot #2 is located around former Manhole 363. The removal of the soil would result in lower amounts of VOCs being released to the dissolved plume. Additionally, institutional controls are anticipated to be in place to limit or prevent exposure to contaminated soil and groundwater and natural degradation within the aquifer will further reduce the concentrations of contaminants. Each option would minimize the risk to public health and the environment.

The difference for each option is the transportation and treatment of the excavated soil. Alternative 2 considers transporting the excavated soil to a preexisting treatment cell, Alternative 3 involves transporting the excavated soil to a newly constructed treatment cell at the former Building 183 area, and Alternative 4 is the transportation of excavated soil off-site for incineration. All of these options satisfy the criteria for long-term effectiveness and permanence. The ratings for long-term effectiveness and permanence for the three different soil excavation alternatives are assigned as follows:

Alternative 2 (Excavation using preexisting treatment cell)	1
Alternative 3 (Excavation using new treatment cell)	1
Alternative 4 (Excavation using off-site incineration)	1

6.3.3.2 AOC 2 Groundwater - Monitoring Well DCF01-40 Area

Alternative 2 (Chemical Oxidation) and Alternative 3 (EAB) were considered for this AOC. Both of these alternatives would effectively treat groundwater that contains concentrations of chlorinated solvents. However, based on past as well as current NA parameters measured during groundwater sampling events, some NA of the groundwater is occurring within the bedrock erosional channel. Therefore, Alternative 3 (EAB) would seem to be more favorable for the treatment of groundwater in this area. Treatment with Alternative 3 (EAB) would enhance and promote the NA that is occurring within this area. MNA would effectively manage the adequacy and long-term reliability of this alternative. Both Alternative 2 and Alternative 3 would minimize the risk to public health and the environment. The ratings for long-term effectiveness and permanence for the this area are assigned as follows:

Alternative 2 (Chemical Oxidation)	5
Alternative 3 (EAB)	4

6.3.3.3 AOC 3 Groundwater - Monitoring Well DCF02-42 Area

Alternative 2 (Chemical Oxidation) and Alternative 3 (EAB) were considered for this area. Both of these alternatives would effectively treat groundwater that contains concentrations of chlorinated solvents. Both alternatives would address the residual risk at the site, and with MNA and institutional controls, would effectively manage the adequacy and long-term reliability of this alternative. Each alternative would minimize the risk to public health and the environment. Treatment with Alternative 3 (EAB) would enhance and promote NA within this area. The ratings for long-term effectiveness and permanence for this area are assigned as follows:

Alternative 2 (Chemical Oxidation)	5
Alternative 3 (EAB)	4

6.3.4 Reduction of Toxicity, Mobility, or Volume

6.3.4.1 AOC 1 Shallow Subsurface Soils – Former Building 180 Area

Alternatives 2 through Alternative 4 are anticipated to provide similar levels of reduction in toxicity, mobility, and volume of contaminants in the shallow subsurface soil. Each alternative would reduce the toxicity, mobility, and volume of contaminants in the shallow subsurface soil, protect the human health and the environment, and would also prevent further degradation of the underlying aquifer. Additionally, institutional controls would be in place to limit or prevent exposure to contaminated soil and groundwater and natural degradation within the aquifer will further reduce the concentrations of contaminants. The ratings for reduction in toxicity, mobility, and volume are assigned as follows:

Alternative 2 (Excavation using preexisting treatment cell)	1
Alternative 3 (Excavation using new treatment cell)	1
Alternative 4 (Excavation using offsite incineration)	1

6.3.4.2 AOC 2 Groundwater - Monitoring Well DCF01-40 Area

Alternatives 2 (Chemical Oxidation) and Alternative 3 (EAB) were considered for this area. Both Alternative 2 and Alternative 3 would effectively treat groundwater that contains concentrations of chlorinated solvents, would reduce the toxicity, mobility, and volume of contaminants in the aquifer, protect the human health and the environment, and would also prevent further degradation of the aquifer. Institutional controls are anticipated to be in place to limit or prevent exposure to contaminated groundwater and natural degradation within the aquifer would further reduce the concentrations of contaminants. The ratings for reduction in toxicity, mobility, and volume are assigned as follows:

Alternative 2 (Chemical Oxidation)	5
Alternative 3 (EAB)	4

6.3.4.3 AOC 3 Groundwater - Monitoring Well DCF02-42 Area

Alternative 2 (Chemical Oxidation) and Alternative 3 (EAB) were also considered for this area. In the Monitoring Well DCF02-42 area, both Alternative 2 and Alternative 3 would effectively treat groundwater that contains concentrations of chlorinated solvents. Both alternatives would reduce the toxicity, mobility, and volume of contaminants in the aquifer, would protect the human health and the environment, and would also prevent further degradation of the aquifer. Institutional controls are anticipated to be in place to limit or prevent exposure to contaminated soil and groundwater and natural degradation within the aquifer would further reduce the concentrations of contaminants. The ratings for reduction in toxicity, mobility, and volume are assigned as follows:

Alternative 2 (Chemical Oxidation)	5
Alternative 3 (EAB)	4

6.3.5 Short-Term Effectiveness

Because no quantitative modeling was performed at the DCF Study Area, only a qualitative estimate can be made on the length of time required to achieve RAOs. This was achieved by a comparative ranking of the time required to achieve the RAO for each alternative at each AOC. This evaluation criterion also measures each alternative with respect to their effect on human health and the environment.

6.3.5.1 AOC 1 Shallow Subsurface Soils – Former Building 180 Area

Alternative 2 through Alternative 4 are anticipated to provide similar levels of short-term effectiveness during the soil excavation stage. The differences between each alternative are expressed in the time required to treat the soil following excavation. Alternative 2 (preexisting treatment cell) and Alternative 3 (new treatment cell) are similar, but reusing a preexisting treatment cell would require less front-end construction time and administrative requirements than construction of a new treatment cell. Both Alternative 2 and Alternative 3 would require more treatment time than Alternative 4 (off-site incineration). Alternative 2 (preexisting treatment cell) and Alternative 3 (new treatment cell) would require an estimated three to six month treatment time while Alternative 4 (offsite incineration) would require considerably less time for treatment. For Alternative 4, removal and transportation of the contaminated soil from the site to the incinerator would basically represent the treatment time.

Institutional controls address potential receptors during remedial actions by limiting or preventing exposure to contaminated soil. For each of the three alternatives, there are construction and/or operation hazards associated with excavation. These include risks involved with working with heavy machinery, including trenching, hauling, and erection equipment. A site-specific safety and health plan will minimize hazards associated with construction and/or operation. The ratings for short-term effectiveness are assigned as follows:

Alternative 2 (Excavation using preexisting treatment cell)	2
Alternative 3 (Excavation using new treatment cell)	3
Alternative 4 (Excavation using offsite incineration)	1

6.3.5.2 AOC 2 Groundwater - Monitoring Well DCF01-40 Area

Both Alternative 2 (Chemical Oxidation) and Alternative 3 (EAB) are similar with respect to achieving the RAO within a general time frame. Institutional controls address potential receptors during remedial actions by limiting or preventing exposure to contaminated groundwater. Both alternatives involve the treatment of the groundwater in-situ, which limits the potential for direct contact with contaminated media.

There are construction and/or operation hazards associated with Alternatives 2 (Chemical Oxidation) and Alternative 3 (EAB). These include risks involved with working with heavy machinery, including direct-push probing, drilling, and trenching. A site-specific safety and health plan will minimize hazards associated with construction and/or operation. Reliability of the alternatives are similar. Alternatives 2 and 3 do not require any O&M following the initial injection; however, it is possible that re-injection of an oxidant or reagent might be required in the event contaminant levels do not decrease as predicted. The inclusion of a groundwater monitoring program and institutional controls address short-term reliability in the event the selected remedial alternative does not reduce contaminant levels at the Site. The ratings for short-term effectiveness are assigned as follows:

Alternative 2 (Chemical Oxidation)	5
Alternative 3 (EAB)	4

6.3.5.3 AOC 3 Groundwater - Monitoring Well DCF02-42 Area

In this area, both Alternative 2 (Chemical Oxidation) and Alternative 3 (EAB) are similar with respect to achieving the RAO within a general time frame. Institutional controls address potential receptors during remedial actions by limiting or preventing exposure to contaminated groundwater. Both alternatives involve the treatment of the groundwater in-situ, which limits the potential for direct contact with contaminated media.

The construction and/or operation hazards associated with Alternative 2 (Chemical Oxidation) and Alternative 3 (EAB) are similar to those stated for the Monitoring Well DCF01-40 area and include risks involved with working with heavy machinery. A site-specific safety and health plan will minimize hazards associated with construction and/or operation. Reliability of the alternatives are similar, and both alternatives do not require any O&M following the initial injection. However, it is possible additional injections might be required in the event contaminant levels do not decrease as predicted. The inclusion of a groundwater monitoring program and institutional controls address short-term reliability in the event the selected remedial alternative does not reduce contaminant levels at the Site. The ratings for short-term effectiveness are assigned as follows:

Alternative 2 (Chemical Oxidation)	5
Alternative 3 (EAB)	4

6.3.6 Implementability

6.3.6.1 AOC 1 Shallow Subsurface Soils – Former Building 180 Area

Implementation of excavation for each alternative would be of a similar nature. The differences for the options occur in the transportation and treatment of excavated soil. Although slightly different, the transportation and treatment phase of Alternative 2 (preexisting treatment cell) and Alternative 3 (new treatment cell) are similar, but both differ substantially from Alternative 4 (off-site incineration). Of the three soil treatment alternatives, Alternative 4 would be the simplest option to implement because there are no landfarm treatment activities associated with this option at Fort Riley following transportation off-site.

Alternatives 2 and 3 would require the reconditioning or construction of a landfarm treatment cell, soil distribution and spreading, periodic turning over of the soil by tilling, leachate collection and disposal, and soil sampling and analysis. Following contaminant reduction in the soils to concentrations below the KDHE RSK value of 180 μg/kg, the soil would require removal to the Campbell C/D landfill on Post and removal and disposal of the landfarm treatment cell. Administrative implementability would also require more effort for Alternative 2 and 3 than for Alternative 4. The ratings for implementability are assigned as follows:

Alternative 2 (Excavation with preexisting treatment cell)	3
Alternative 3 (Excavation with new treatment cell)	4
Alternative 4 (Excavation with offsite incineration)	2

6.3.6.2 AOC 2 Groundwater-Monitoring Well DCF01-40 Area

Alternatives 2 and 3 (Chemical oxidation and EAB) would be fairly simple to implement since both require the use of trenching, drilling, and direct-push equipment to inject treatment fluids into the aquifer. No permanent support infrastructure on the surface is required; however, in the case of multiple injections, above ground or flush mounted injection points may be left in place. Administrative implementability of the institutional controls associated with these two alternatives would be the same. Additionally, institutional controls are anticipated to be in place to limit or prevent exposure to contaminated groundwater and natural degradation within the aquifer will further reduce the concentrations of contaminants. The ratings for implementability are assigned as follow:

Alternative 2 (Chemical Oxidation)	1
Alternative 3 (EAB)	1

6.3.6.3 AOC 3 Groundwater-Monitoring Well DCF02-42 Area

Implementation of Alternatives 2 and 3 (Chemical oxidation and EAB) would be similar to the Monitoring Well DCF01-40 area. Both treatment alternatives require injection by direct-push equipment. Permanent surface support infrastructure is not required. However, in the case of multiple injections, above ground or flush mounted injection points may be left in place. Administrative implementability of the institutional controls associated with these two alternatives would be the same and are anticipated to be in place to limit or prevent exposure to contaminated groundwater. Natural degradation within the aquifer will further reduce the concentrations of contaminants. The ratings for implementability are assigned as follow:

Alternative 2 (Chemical Oxidation)	1
Alternative 3 (EAB)	1

6.3.7 Cost Evaluation

A summary of the cost evaluation is provided in Table 6-1. Details of the cost estimates are provided in Appendix 5A. While cost estimates are sound, unexpected costs could occur during implementation of each of the alternatives. With the exception of AOC 1 and the No Action Alternative for each AOC, each alternative cost also includes expenses for MNA and institutional controls. Including MNA with each alternative, together with institutional controls, offers a more reliable remediation package. Each alternative includes cost for administrative task, treatment, and post treatment monitoring to ensure the effectiveness of the selected remedial alternative.

6.3.7.1 AOC 1 Shallow Subsurface Soils – Former Building 180 Area

Alternative 2 (existing treatment cell) uses an area already set aside for the treatment of soil and is less costly than Alternative 3 (newly constructed treatment cell). Both Alternative 2 and Alternative 3 are less expensive than Alternative 4 (offsite incineration), but Alternative 4 effectively treats the soil in less time and insures complete destruction of the contaminant. The rating for cost are assigned as follows:

Alternative 2 (Excavation with preexisting treatment cell)	3
Alternative 3 (Excavation with new treatment cell)	3
Alternative 4 (Excavation with offsite incineration)	8

6.3.7.2 AOC 2 Groundwater-Monitoring Well DCF01-40 Area

The cost for Alternatives 2 (Chemical Oxidation) and 3 (EAB) are similar and are presented as follows:

Alternative 3 (Chemical Oxidation)	4
Alternative 4 (EAB)	4

6.3.7.3 AOC 3 Groundwater-Monitoring Well DCF02-42 Area

The cost for Alternatives 2 (Chemical Oxidation) and 3 (EAB) are similar and are presented as follows:

Alternative 3 (Chemical Oxidation)	4
Alternative 4 (EAB)	4

6.4 SUMMARY

The alternatives were first evaluated as either compliant or non-compliant with the threshold criteria (Protection of Human Health and the Environment, and Compliance with ARARs). The no action alternative was the only alternative that does not comply with the threshold criteria (non-compliant with ARARs) in each of the three AOCs. Each alternative that met the threshold criteria was then comparatively evaluated using the five balancing criteria. Because there are three AOCs; the shallow subsurface soil beneath and around the foundation footprint of former Building 180; the groundwater in the bedrock erosional channel near Monitoring Well DCF01-41; and the groundwater near Monitoring Well DCF02-42, which is located west of former Building 180, each AOC was evaluated separately. For AOC 1, the alternative with the most favorable ranking was Alternative 2 (preexisting treatment cell). In AOC 2 and AOC 3, the alternative with the most favorable ranking was Alternative 3 (EAB). Discussions of the results are presented below, and a semi-quantitative summary of the rankings is presented in Table 6-2.

The shallow subsurface soil was addressed in AOC 1 by comparing the "No Action " alternative and three soil excavation and removal alternatives. Following the comparative evaluation of all four alternatives using the five balancing criteria, the alternative with the most favorable ranking for soil treatment at the former Building 180 area is Alternative 2 (preexisting treatment cell). For shallow subsurface soil treatment, the favorable rating for Alternative 2 was due to the administrative network that would already exist for the preexisting treatment cell. The preexisting treatment cell would be located at Camp Funston adjacent to the HWMC. Alternative 3 would require construction of a new treatment cell at the historic Main Post, construction near a family housing unit, would contain undesirable esthetic qualities in a heavily trafficked area, and would require new or additional administrative support and implementation.

For AOCs 2 and 3, both injection alternatives for groundwater are similar in ease of implementability (direct push application), favorable cleanup time, no permanent structures, reliability, and cost effectiveness. Alternative 3 (EAB) was selected as the best groundwater treatment alternative for both AOCs. This selection was based on the stimulation of subsurface microbial activity due to the injection of an organic substrate, thereby increasing the NA of the chlorinated solvents, and the propensity for chemical injection to mobilize the contaminants during the treatment phase.

This evaluation of alternatives utilized the two threshold criteria and the five balancing criteria to rank the remedial alternatives for the DCF Study Area. The ranking was an evaluation, not a selection, of the alternatives considered at the DCF Study Area. The final two criteria, state and community acceptance, were not considered in this evaluation, but will be evaluated after publication of the PP as part of the development of the ROD.

* * * * * *

7.0 REFERENCES

Air Force Center for Environmental Excellence (AFCEE) 2004, *AFCEE Protocol for Enhanced Anaerobic Bioremediation Using Edible Oils,* Robert C. Borden, et. al, Paper presented at the Remediation of Chlorinated and Recalcitrant Compounds, Monterey, California, May 2004.

Burns & McDonnell Engineering Company, Inc (BMcD), 2000a, *Quality Control Technical Memorandum, March 2000 USGS River Sampling Event at the Fort Riley, Kansas,* May 2000.

BMcD, 2000b, *Quality Control Summary Report, July 2000 USGS River Sampling Event at the Fort Riley, Kansas,* September 2000.

BMcD, 2001, *Quality Control Summary Report, July 2001 USGS River Sampling Event for the Dry Cleaning Facilities Area, 354 Area Solvent Detections, Marshall Army Airfield, and Southwest Funston Landfill, Fort Riley, Kansas,* September 2001.

BMcD, 2002, *Technical Memorandum Report, Potential Source Area and Sewer Line Field Screening, Dry Cleaning Facilities Area (Operable Unit 003) at Fort Riley, Kansas,* April 2002.

BMcD, 2003, *Remedial Investigation Addendum* (RIA) *for the Dry Cleaning Facilities Area (OU 003) at Fort Riley, Kansas.*

BMcD, 2004, *Data Summary Report, Dry Cleaning Facilities Area at, Fort Riley, Kansas* (DSR), April 2004.

Domenico, P. A. and F. W. Schwartz, 1990, *Physical and Chemical Hydrogeology*. John Wiley & Sons, Inc. 824 p.

Dort, Wakefield, 1987, *Type Descriptions for Kansas River Terraces* in *Quaternary Environments of Kansas* (W. C. Johnson, ed.), Kansas Geological Survey Guidebook Series 5, p. 103 – 107.

Fetter, C. W., 1993, *Contaminant Hydrogeology*. Prentice-Hall, Inc. 458 p.

Federal Remediation Technologies Roundtable (FRTR), *Remediation Technologies Screening Matrix and Reference Guide, Version 4.0,* 2004.

Kansas Department of Health and Environment (KDHE), 1999, Letter correspondence from Cynthia Randall outlining ARARs for the DCF Study Area.

Kansas Surface Water Quality Criteria (KSWQC), 1999. KS/Article 28-16-28e. July 30.

KDHE, 2001, *Monitored Natural Attenuation*, Bureau of Environmental Remediation: BER-RS-042.

KDHE, 2002, *Kansas Surface Water Register*, Bureau of Environmental Field Services

KDHE, 2003, *Risk-Based Standards for Kansas* (RSK Manual – 3rd Version), Division of Environment, Bureau of Environmental Remediation.

Louis Berger & Associates, Inc. (LBA), 1995, *Remedial Investigation Report, Dry Cleaning Facilities Area, Fort Riley, Kansas*, March 1995.

LBA, 1998a, *Remedial Investigation Addendum Monitoring Expansion Report, Dry Cleaning Facilities Study Area, Fort Riley, Kansas*, March 1998.

LBA, 1998b, *Revised Feasibility Study for the Dry Cleaning Facilities Study Area, Fort Riley, Kansas*, March 1998.

Marley, M.C., 1991, *Air Sparging in Conjunction with Vapor Extraction for Source Removal at VOC Spill Sites*, May, 1991.

Regenesis, 2003. HRC information obtained from the Regenesis web site (www.regenesis.com).

United States Department of Energy (USDOE), 2000, *In-Situ Redox Manipulation*. Innovative Technology Summary Report DOE/EM-0499. Office of Environmental Management.

United States Environmental Protection Agency (USEPA), 1984, *A Groundwater Protection Strategy for the Environmental Protection Agency.*

USEPA, 1988, *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA, Interim Final.* Office of Emergency and Remedial Response. EPA/540/G-89/004. OSWER Directive 9355.3-01.

USEPA, 1989a, *CERCLA Compliance with Other Laws Manual: Part I. Clean Air Act and Other Environmental Statutes and State Requirements*. EPA/540/G89/006.

USEPA, 1989b, *CERCLA Compliance with Other Laws Manual: Part II. Clean Air Act and Other Environmental Statutes and State Requirements*. EPA/540/G89/009.

USEPA, 1993. *Memorandum: M-03-08, 2003 Discount Rates for OMB Circular No. A-94*, (http://www.whitehouse.gov/OMB/circulars/a094/094_appx-c.html)

USEPA, 1995, *Land Use in the CERCLA Remedy Selection Process*. OSWER Directive 9355.7-04.

USEPA, 1996, *Pump-and-Treat Ground-Water Remediation. A Guide for Decision Makers and Practitioners*. Office of Research and Development. EPA/625/R-95.

USEPA, 1997, *Rules of Thumb for Superfund Remedy Selection*. EPA/540/R97/013.

USEPA, 1998, *Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Ground Water*. EPA/600/R98/128.

USEPA, 1999, *Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites*. OSWER Directive 9200.4-17.

USEPA, 2000a, *A Guide to Developing and Documenting Cost Estimates During the Feasibility Study*. EPA 540-R-00-002, OSWER 9355.0-75. www.epa.gov/superfund.

USEPA, 2000b, *Institutional Controls: A Site Manager's Guide to Identifying, Evaluating and Selecting Institutional Controls at Superfund and RCRA Corrective Action Cleanups.* EPA 540-F-00-005, OSWER 9355.0-75FS-P.

USEPA, 2001, *Reuse Assessments: A Tool To Implement The Superfund Land Use.* EPA OSWER Directive 9355.7-06P.

Vidic, R.D., 2001, *Premeable Reactive Barriers: Case Study Review,* Department of Civil and Environmental Engineering, University of Pittsburg, November 2001.

Wiedemeier, T. H. and F. H. Chapelle, 1998, *Technical Guidelines for Evaluating Monitored Natural Attenuation of Petroleum Hydrocarbons and Chlorinated Solvents in Ground Water at Naval and Marine Corps Facilities,* Naval Facilities Engineering Command.

Tables

Table 2-1
List of Potentially Applicable Relevant And Appropriate Requirements (ARARs)
Chemical-Specific
Feasibility Study Addendum
DCF Study Area

Potentially Applicable Relevant and Appropriate Requirements	Description	Comment
Clean Water Act (CWA) of 1977 33 U.S.C. § 1251et seq. as amended in 1987	Implements a system to impose effluent limitations on, or otherwise prevent, discharges of pollutants into any waters of the United States from any point source.	Will be applicable if discharges to streams, rivers, or lakes occur from a site.
National Pollutant Discharge Elimination System (NPDES) (40 CFR 122)	Regulates discharges of pollutants from any point source into waters of the United States	Will be applicable if water from the site will be discharged onto land or into streams, rivers, or lakes.
Storm Water Discharge Requirements NPDES (40 CFR 122.26)	Provide requirements to obtain a permit to discharge to the storm water sewer system under the NPDES program	Will be applicable if the site has storm water that comes in contact with construction or industrial activity or if the selected remedy involves discharge of treated water to surface waters.
Federal Water Quality Standards (40 CFR 131)	Establishes methods and requirements for states in the development of ambient water quality criteria for the protection of aquatic organisms and/or the protection of human health.	May be indirectly applicable to surface water remediation and is directly applicable to surface water discharges.
General Pre-treatment Regulations for Existing and New Sources of Pollution for Publically Owned Treatment Works (POTW) (40 CFR 403)	Provides effluent limitations and guidelines for existing sources, standards of performance for new sources, and pre-treatment standards for new and existing sources.	Will be applicable if wastewater from a site is discharged to a POTW.
Wetlands Protection (40 CFR 22, 40 CFR 230 to 233, and 33 CFR 320 to 330)	Allows for permitting of discharge of dredged or fill material to the waters of the United States if no practicable alternatives exists that are less damaging to the aquatic environment. Applicants must demonstrate that the impact to wetlands is minimized.	Will be applicable if designated wetlands are impacted by a remedy.

Table 2-1 (continued)
List of Potentially Applicable Relevant And Appropriate Requirements (ARARs)
Chemical-Specific
Feasibility Study Addendum
DCF Study Area

Potentially Applicable Relevant and Appropriate Requirements	Description	Comment
Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) of 1980 42 U.S.C. § 9601 et seq. as amended by the Superfund Amendments and Reauthorization Act (SARA) of 1986	Enacted to provide Federal authority to respond directly to releases or threatened releases of hazardous substances that may endanger public health and the environment. Established a trust fund (i.e., Superfund) to provide for cleanup when no responsible party is identified. Provides for liability of persons responsible for releases of hazardous substances. Established prohibitions and requirements concerning closed and abandoned hazardous waste sites.	Will be applicable if the site is on the EPA National Priorities List (NPL). May be applicable for any site where a release of hazardous substances has occurred.
National Oil and Hazardous Substances Pollution Contingency Plan (NCP) (40 CFR 300)	Federal government's blueprint for responding to spills or releases of oil and hazardous substances.	
Safe Drinking Water Act (SDWA) of 1974 42 U.S.C. § 300f et seq. as amended in 1986	Established to protect the quality of drinking water in the Unites States. Focuses on all waters actually or potentially designed for drinking use, whether from above ground or underground sources. The Act authorized EPA to establish safe standards of purity and required all owners or operators of public water supply systems to comply with primary (health-related) standards.	May be applicable, relevant or appropriate at sites where waters that are used or may potentially be used as drinking water supplies are impacted or threatened.
National Primary Drinking Water Regulations and Implementation (40 CFR 141 and 142)	Establishes maximum contaminant levels (MCLs) which are health risk based standards for public water systems.	Will be applicable at the distribution point (i.e., at the tap). Will be relevant and appropriate for groundwater cleanup at sites where potential drinking water sources (aquifers) are impacted.
National Secondary Drinking Water Standards (40 CFR 143)	Establishes welfare-based secondary standards for public water systems.	Will be applicable at the distribution point (i.e., at the tap).
Underground Injection Control Program (40 CFR 144 to 148)	Assures that Underground Injection will not endanger drinking water sources. Provides regulations governing the use of underground injection wells including: identification of the classifications of injection wells; and the permitting, construction, operation, monitoring, testing, and reporting requirements. Also provides requirements for plugging of injection wells.	Will be applicable if underground injection of liquids or air is conducted as part of a site remedy.

Table 2-1 (continued)
List of Potentially Applicable Relevant And Appropriate Requirements (ARARs)
Chemical-Specific
Feasibility Study Addendum
DCF Study Area

Potentially Applicable Relevant and Appropriate Requirements	Description	Comment
Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) of 1972 7 U.S.C. § 136 et seq.	Provides Federal control of pesticide distribution, sale and use. Allows EPA to study the consequences of pesticide use. Requires users of pesticides to take exams for certification as applicators of pesticides. Pesticide users must register purchases of these materials.	May be applicable if pesticides were distributed, sold or used at a site.
Toxic Substances Control Act (TSCA) of 1976 15 U.S.C. § 2601 et seq.	Enacted to give EPA the ability to track industrial chemicals currently produced or imported into the United States. EPA screens these chemicals and may require reporting or testing of those that pose an environmental or human-health hazard. EPA may ban the manufacture and import of those chemicals that pose an unreasonable risk.	Will be applicable if site activities involve handling of toxic substances such as polychlorinated biphenyls (PCBs) or remediation of these substances.
Asbestos Control K.A.R 28-50	Established the requirements for licensing of businesses and examination and certification of asbestos workers. Established requirement for notification of asbestos projects. Establishes work practices for asbestos projects. Establishes rules for disposal of asbestos containing materials.	Will be applicable if asbestos is handled or removed from a site or encapsulated.
Hazardous Waste Management Standards and Regulations K.A.R 28-31	Identifies the characteristics and listing of hazardous waste. Prohibits underground burial of hazardous waste except as granted by EPA or KDHE. Establishes restrictions on land disposal. Establishes standards for generators or transporters of hazardous waste. Establishes standards for hazardous waste storage, treatment and disposal facilities.	Will be applicable if hazardous wastes are present at a site.
Hydrocarbon Storage Wells and Well Systems K.A.R 28-45	Establishes a system for permitting of hydrocarbon storage wells. Establishes requirements for construction, operation and monitoring, and plugging of hydrocarbon storage wells.	Will be applicable if hydrocarbon storage wells are present at a site.
Kansas Drinking Water Standards K.A.R 28-15	The State of Kansas has promulgated drinking water regulations designed to protect human health from the potential adverse effects of drinking water contaminants. The regulation establishes water quality standards and MCLs.	Will be applicable if groundwater is currently or could potentially be used in the future as a drinking water source.

Table 2-1 (continued)
List of Potentially Applicable Relevant And Appropriate Requirements (ARARs)
Chemical-Specific
Feasibility Study Addendum
DCF Study Area

Potentially Applicable Relevant and Appropriate Requirements (Federal)	Description	Comment
Kansas Drycleaner Environmental Response Act K.A.R 28-68	Enacted to provide funds to assist with assessment and corrective action of former and existing drycleaner facilities. Requires registration of drycleaning facilities and compliance with waste management measures.	May be applicable if a drycleaner operated onsite.
Pesticides K.A.R. 4-13	Requires licensing of pesticide businesses and certification of persons that apply pesticides.	Will be applicable if pesticides are present at a site or application of pesticides occurs.
Petroleum Products Storage Tanks K.A.R 28-44	Provides requirements for permitting of the installation and operation of underground storage tanks (USTs). Provides requirements for design and construction of storage tanks. Provides a system for licensing contractors who install and test USTs. Requires implementation of methods for detecting releases and reporting releases from USTs.	Will be applicable if petroleum storage tanks are or were present at a site.
Radiation K.A.R 28-35	Regulations require registration of radiation producing devices and licensing of sources of radiation. Provides standards for protection against radiation. Provides requirements for industrial radiographic operations and wireline and subsurface tracer studies.	Will be applicable if radiation producing devices or sources of radiation are present or are used at a site.
PCB Facility Construction Permit Standards and Regulations K.A.R 28-55	Establishes the requirement for permitting of facilities constructed for the treatment, storage, and disposal of materials containing polychlorinated buphenyls (PCBs). Establishes standards for PCB facilities.	Will be applicable if treatment, storage, or disposal of materials containing PCB's occurs.
Spill Reporting K.A.R 28-48	Requires reporting of unpermitted discharges or accidental spills. Requires that containment and immediate environmental response measures are implemented. Also provides for technical assistance for mercury-related spills.	Will be applicable if unpermitted discharges or accidental spills occur at a site.

Table 2-2
List of Potentially Applicable Relevant And Appropriate Requirements (ARARs) Location-Specific Feasibility Study Addendum DCF Study Area

Potentially Applicable Relevant and Appropriate Requirements	Description	Comment
Archaeological and Historic Preservation Act of 1974 16 U.S.C. § 469 et seq.	Provides for the preservation of historical or archaeological data which might be destroyed or lost as the result of 1) flooding, building of access roads, relocation of railroads and highways, and other alterations of terrain caused by the construction of a dam by government or persons, or 2) alteration of terrain caused by Federal construction projects or federally licensed activity or program.	Will be applicable if construction projects or alteration of terrain at a site have the potential to destroy historical or archaeological materials.
Endangered Species Act of 1973 7 U.S.C. § 136; 16 U.S.C. § 460 et seq.	Provides a program for conservation of threatened and endangered plants and animals and the habitats in which they are found.	Will be applicable if threatened or endangered species, or their habitats are present at or near a site.
Fish and Wildlife Conservation Act 16 U.S.C. § 2901 to 2911	Action to conserve fish and wildlife, particularly those species which are indigenous to the state.	Will be applicable if significant populations are present at a site or they are affected by site activities.
Fish and Wildlife Coordination Act 16 U.S.C. § 661-667e	The Act allows the Departments of Agriculture and Commerce to assist Federal and State agencies to study the effects of domestic sewage, trade wastes, and other polluting substances on wildlife.	Will be applicable if significant populations are present at a site or they are affected by site activities.
Flood Control Act of 1944 16 U.S.C. § 460	Provides the public with knowledge of flood hazards and promotes prudent use and management of flood plains.	Will be applicable if a site is located on a designated flood plain.
National Historic Preservation Act of 1966 16 U.S.C. § 470 et seq.	Establishes a national registry of historic sites. Provides for preservation of historic or prehistoric resources.	Will be applicable if a site is listed on, or is potentially eligible for listing on, the National Register and if activities requiring permitting are initiated at a site.
Kansas Historic Preservation Act K.A.R. 118-3	Provides for the protection and preservation of sites and buildings listed on state or federal historic registries.	Will be applicable if a site or building is listed on the state or federal historic registry and if activities requiring permitting are initiated at a site.
Non-Game, Threatened or Endangered Species K.A.R. 115-15	Identifies Threatened and Endangered Species	Will be applicable if any of the identified species are present at a site.

Table 2-3
List of Potentially Applicable Relevant And Appropriate Requirements (ARARs) Action-Specific Feasibility Study Addendum DCF Study Area

Potentially Applicable Relevant and Appropriate Requirements	Description	Comment
Clean Air Act (CAA) 42 U.S.C. § 7401 et seq. as amended in 1977 and 1990	Regulates air emissions from area, stationary, and mobile sources. Authorizes EPA to establish National Ambient Air Quality Standards.	May be applicable if remedial actions result in emissions of contaminants to the air.
Standards of Performance for New Stationary Sources (40 CFR 60)	Identifies standards of performance for new stationary sources of air emissions. Provides emission guidelines and compliance times.	Will be applicable for new stationary sources of air emissions.
National Emission Standards for Hazardous Air Pollutants (40 CFR 61)	Identifies emission standards for specific hazardous air pollutants.	Will be applicable if the identified hazardous air pollutants are emitted from a site.
National Emission Standards for Hazardous Air Pollutants for Source Categories (40 CFR 63)	Identifies emission standards for hazardous air pollutants that originate from specific categories of sources.	Will be applicable if the identified hazardous air pollutants are emitted from a specific source category that has been identified.
Emergency Planning and Community Right-to-Know Act (EPCRA) of 1986 42 U.S.C. § 11001 et seq.	Designated to help local communities protect public health, safety and the environment from chemical hazards. Enables states and communities to prepare to respond to unplanned releases of hazardous substances. Requires facilities at which hazardous substances are present to report the presence of these materials to emergency responders. Requires companies to report the release of hazardous substances.	Will be applicable if hazardous chemicals are stored or used at a facility.
Explosives 18 U.S.C. § 847	Regulates commerce in explosives. Requires licensing and permitting, record keeping and reporting for purchase and use of explosives. Provides standards for storage of explosive materials.	Will be applicable if explosives are purchased, stored or used at a site.
Federal Hazardous Materials Transportation Law 49 U.S.C. § 5101 et seq.	Regulates the transportation of hazardous wastes and hazardous substances by aircraft, railcars, vessels, and motor vehicles. Requires employers to train, test and maintain training records for all hazmat employees.	Will be applicable if hazardous materials are transported to or from a site.

Table 2-3 (continued)
List of Potentially Applicable Relevant And Appropriate Requirements (ARARs) Action-Specific Feasibility Study Addendum DCF Study Area

Potentially Applicable Relevant and Appropriate Requirements	Description	Comment
Resource Conservation and Recovery Act (RCRA) of 1976 42 U.S.C. § 6901 et seq. as amended by the Hazardous and Solid Waste Amendments of 1984 (HSWA) and 1986, the Federal Facilities Compliance Act of 1992, and the Land Disposal Program Flexibility Act of 1996.	Enacted to provide control of hazardous waste by imposing management requirements on generators and transporters of hazardous waste and upon owners and operators of treatment, storage and disposal (TSD) facilities. Also set forth a framework for management of non-hazardous waste. Focuses only on active or future facilities. HSWA requires phasing out land disposal of hazardous waste.	Applies to active hazardous and solid waste operations including facilities that treat, store and dispose of these materials as well as generators and transporters of hazardous wastes.
Solid Waste Disposal Facility Criteria (40 CFR 257 - 258)	Regulations apply to owners and operators of facilities that treat, store or dispose of solid wastes	Will be applicable if site activities are analogous to solid waste facility activities.
Standards for Identification and Listing of Hazardous Waste (40 CFR 261)	Provides criteria for identification of hazardous and solid wastes.	Will be applicable for identifying hazardous wastes.
Standards Applicable to Generators of Hazardous Waste (40 CFR 262)	Regulates the manifesting, pre-transport requirements, and record keeping and reporting for hazardous waste generators.	Will be applicable if hazardous waste is generated at a site.
Standards Applicable to Transporters of Hazardous Waste (40 CFR 263)	Establishes standards which apply to persons transporting hazardous waste within the United States if the transportation requires a manifest under RCRA.	Will be applicable if hazardous waste is disposed off site.
Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities (40 CFR 264)	Regulations apply to owners and operators of facilities that treat, store, or dispose of hazardous waste through the use of surface impoundments, waste piles, incinerators, land treatment units, and landfills.	Will be applicable if site activities are analogous to hazardous waste facility activities.
Manifesting, Record Keeping, and Reporting Requirements (40 CFR 264.70 to 264.77)	These standards apply to owners and operators of all facilities which treat, store or dispose of hazardous wastes	Will be applicable if site activities are analogous to hazardous waste facility activities.
Releases from Solid Waste Management Units (40 CFR 264.90 to 264.101)	Regulations apply to owners or operators of hazardous waste treatment, storage or disposal facilities.	Will be applicable if solid waste is stored at a site.
Closure and Post Closure Requirements (40 CFR 264.110 to 264.120)	Facility owner or operator must close a hazardous waste facility in a way that minimizes the need for further maintenance and maximizes the protection of human health and the environment.	Will be applicable upon the closure and post closure of a hazardous waste facility.

Table 2-3 (continued)
List of Potentially Applicable Relevant And Appropriate Requirements (ARARs) Action-Specific Feasibility Study Addendum DCF Study Area

Potentially Applicable Relevant and Appropriate Requirements	Description	Comment
Resource Conservation and Recovery Act (RCRA)		
Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage and Disposal Facilities (40 CFR 265)	Regulations apply to owners and operators of facilities that treat, store, or dispose of hazardous waste.	Will be applicable if site activities are analogous to hazardous waste facility activities.
Land Disposal Restrictions (40 CFR 268)	Identifies hazardous wastes that are restricted from land disposal and defines those limited circumstances under which an otherwise prohibited waste may continue to be land disposed.	Will be applicable depending on the type of waste generated at the site.
Technical Standards and Corrective Action Requirements for Owners and Operators of Underground Storage Tanks (40 CFR 280)	Establishes regulations relating to underground storage tanks.	Will be applicable if underground storage tanks are present at a site
Occupational Safety and Health Act (OSHA) of 1970 29 U.S.C. § 651 et seq.	Enacted to ensure worker and workplace safety. Employers are required to provide workers a place of employment that is free from recognized hazards to safety and health.	Applies to workers and workplaces.
Occupational Safety and Health Standards (29 CFR 1910)	Provides standards for workers and the workplace including: working surfaces; means of egress; ventilation; noise; hazardous materials; personal protective equipment; sanitation; medical services and first aid; fire protection, detection, and suppression; materials handling and storage; machinery and machinery guards; power tools; and welding and electrical equipment. Also requires training for workers.	Will be applicable to workers and workplaces including hazardous waste sites.
Safety and Health Regulations for Construction (29 CFR 1926)	Provides standards for construction activities including: work practices; safety equipment; scaffolding and ladders; fall protection; heavy equipment; excavations; concrete and masonry construction; steel erection; tunnels and shafts; demolition; use of explosives; power transmission and distribution; and overhead protection.	Will be applicable to workers and workplaces where construction activities take place.

Table 2-3 (continued)
List of Potentially Applicable Relevant And Appropriate Requirements (ARARs)
Action-Specific
Feasibility Study Addendum
DCF Study Area

Potentially Applicable Relevant and Appropriate Requirements	Description	Comment
Ambient Air Quality Standards and Air Pollution Control K.A.R 28-19	Regulates air emissions from processing operations, indirect heating equipment, and incinerators. Establishes requirements for Attainment and Non-Attainment Areas. Establishes requirements for Stack Heights. Restricts open burning.	Will be applicable if a remedy results in the release of contaminants to the air.
Agricultural Chemicals, Commercial Fertilizers, Anhydrous Ammonia, and Chemigation K.A.R. 4-1, 4-4, 4-10 and 4-20	Requires labeling and registration of agricultural chemicals. Provides regulations for storage and secondary containment, transportation and record keeping for commercial fertilizers and anhydrous ammonia. Requires permitting and certification of operators of chemigation equipment.	Will be applicable if agricultural chemicals, commercial fertilizers or anhydrous ammonia are used at site. Will be applicable if chemicals or animal wastes are applied by chemigation.
Construction, Operation, Monitoring and Abandonment of Salt Solution Mining Wells K.A.R 28-43	Regulates the construction, operation, monitoring, testing and abandonment of salt solution mining wells.	Will be applicable if salt solution mining wells are present.
Emergency Planning and Right-to-Know K.A.R 28-65	Designated to help local communities protect public health, safety and the environment from chemical hazards. Enables communities to prepare to respond to unplanned releases of hazardous substances. Requires facilities at which hazardous substances are present to report the presence of these materials to emergency responders. Requires companies to report the release of hazardous substances.	Will be applicable if hazardous chemicals are stored or used at a site.
Explosive Materials K.A.R. 22-4	Requires all contractors to obtain explosive storage site permits before moving, storing or using any explosives or blasting agents at any job site with the state.	Will be applicable if explosives or blasting agents are used or stored at a site.
Kansas Board of Technical Professions K.A.R. 66-6 through 66-14	Establishes the requirements for licensing of engineers, land surveyors, geologists and architects.	Will be applicable if the services of a geologist, engineer or land surveyor are required for site investigations or remediation.
Kansas Water Appropriations Act K.A.R. 5-1 through 5-10 and 5-50	Establishes the requirements for obtaining and maintaining and transferring water appropriations.	Will be applicable if water appropriations are required for groundwater remediation.
Mined Land Reclamation K.A.R. 47-16	Allows for the reclamation of mined land and associated waters.	Will be applicable if mined land or associated waters are to be reclaimed.

Table 2-3 (continued)
List of Potentially Applicable Relevant And Appropriate Requirements (ARARs)
Action-Specific
Feasibility Study Addendum
DCF Study Area

Potentially Applicable Relevant and Appropriate Requirements	Description	Comment
Solid Waste Management K.A.R 28-29	Provides standards for management of solid wastes. Establishes administrative procedures. Establishes the requirement for development and submittal of Solid Waste Management Plans.	Will be applicable if solid waste is generated, stored or disposed at a site.
Underground Injection Control Regulations K.A.R 28-46	Provides regulations governing the use of underground injection wells including: identification of the classifications of injection wells; and the permitting, construction, operation, monitoring, testing, and reporting requirements. Also provides requirements for plugging of injection wells.	Will be applicable if the remedy involves the injection of fluids or air into the subsurface.
Underground Storage, Disposal Wells and Surface Ponds K.A.R. 28-13	Regulates the construction and use of underground storage reservoirs, disposal wells and surface ponds for the confinement, storage and disposal of industrial fluids including but not limited to brine. Also pertains to removal of material from surface ponds upon abandonment. Does not include regulations pertaining to oil field activities.	Will be applicable if underground reservoirs, disposal wells or surface ponds are used for storage or disposal of industrial fluids at a site. Will be applicable if use of a surface pond is discontinued.
Voluntary Cleanup and Property Redevelopment Program K.A.R 28-71	Provides a mechanism for property owners, facility operators, prospective purchasers, and local governments to voluntarily address contaminated properties with technical and regulatory guidance from KDHE.	May be applicable if a site meets the criteria for acceptance into the Voluntary Cleanup Program
Water Pollution Control K.A.R 28-16	Provides regulation of sewage discharge. Establishes pre-treatment standards for industry. Designates uses of rivers and streams. Establishes River Basin Quality Criteria and Surface Water Quality Criteria. Provides for the establishment of Critical Water Quality Management Areas.	Will be applicable if water is to be discharged to state waterways.
Water Well Contractor's License; Water Well Construction and Abandonment K.A.R 28-30	Establishes the requirements for licensing of drillers. Regulates drilling activities including the construction of wells.	Will be applicable if drilling and/or well construction or abandonment is conducted at a site.

Table 4-1
Technologies and Process Options for Soil and Groundwater Remediation
Feasibility Study Addendum
DCF Study Area

General Response Actions	Technologies	Process Options
No Action	No Action	No Action
Institutional Controls	Governmental Controls	Zoning Ordinance Amendment County Resolution
	Proprietary Controls	Negative Easements and Restrictive Covenants Affirmative Easements
	Other Institutional Controls	Real Property Master Plan (RPMP)
Other Controls	Monitoring	Groundwater Monitoring
	Alternative Water Supply	Rural Water Supply New Supply Wells
	Individual Well Treatment	Low Profile Air Stripping Activated Carbon Adsorption UV Oxidation
Monitored Natural Attenuation	Monitored Natural Attenuation	Monitored Natural Attenuation
Containment	Low Permeabilty Barrier	Vertical Barriers Horizontal Barriers
	Permeable Reactive Barrier	Zero Valent Iron In-Situ Air Stripping In-Situ Adsorption
	Groundwater Collection and Extraction	Pumping Wells: Vertical Pumping Wells: Horizontal Interceptor Trenches
	Surface Capping	Surface Capping
Ex-Situ Physical Treatment	Excavation and Off-site Removal	Soil Excavation and Backfill Landfarming: Newly Constructed Treatment Cell Landfarming: Existing Treatment Cell Offsite Thermal Incineration
	Excavation and Treatment	Chemical Extraction Chemical Reduction/Oxidation Dehalogenation Contaminant Seperation Solidification and Stabilization Soil Washing
Ex-Situ Biological Treatment	Biological Treatment	Slurry Treatment in Bioreactor Solid Phase Biopiles

Table 4-1 (continued)
Technologies and Process Options for Soil and Groundwater Remediation
Feasibility Study Addendum
DCF Study Area

General Response Actions	Technologies	Process Options
In-Situ Treatment	Biological Treatment	Biosparging Aerobic Bioremediation with Lab-Isolated Solvent-Degrading Bacteria Cometabolic Aerobic Bioremediation Enhanced Anaerobic Bioremediation Nitrate Enhanced Bioremediation Hydrogen Peroxide Enhanced Bioremediation Electric Induced Redox Barriers Oxygen Release Compound® (ORC) In-Situ Biofilters
	Physical/Chemical Treatment	Air Sparging C-Sparger™ Groundwater Circulation Wells Soil Vapor Extraction (SVE) In-Situ Chemical Oxidation Permeable Reactive Barrier: Zero Valent Iron Permeable Reactive Barrier: In-Situ Air Stripping Permeable Reactive Barrier: In-Situ Adsorption In-Situ Redox Manipulation Bimetallic Nanoscale Particles In-Situ Chemical Flushing Electrical Separation In-Situ Radio Frequency Heating Steam Injection Dynamic Underground Stripping (DUS) Hydrous Pyrolysis/Oxidation (HPO) Six-Phase Soil Heating
	Components - Fluid Delivery Systems	Vertical Wells Horizontal Wells Direct-Push Injection Points

Table 4-2
Initial Screening of Potential Technologies for Soil and Groundwater Remediation
Feasibility Study Addendum
DCF Study Area

Process Options	Description	Retain*	Screening Comments
No Action			
No Action	No Action	Yes	Consideration of no action alternative is required by NCP and provides baseline to compare other alternatives.
Institutional Controls			
Governmental Controls			
Zoning Ordinance Amendment	Amendment to the county zoning ordinance creating a groundwater restriction overlay district.	No	Not applicable. Property is on U.S. military reservation and outside jurisdiction of Geary County.
County Resolution	Enactment of a county resolution designed to restrict contaminated groundwater use.	No	Not applicable. Property is on U.S. military reservation and outside jurisdiction of Geary County.
Proprietary Controls			
Negative Easements and Restrictive Covenants	A negative easement acts as a land use restriction and imposes limits on how the landowner can use his or her property.	No	Not applicable. Property is on U.S. military reservation.
Affirmative Easements	An affirmative easement allows the holder of the easement to enter upon or use another's property for a particular purpose (e.g. an access easement).	No	Not applicable. Property is on U.S. military reservation.
Other Institutional Controls			
Real Property Master Plan (RPMP)	The RPMP is the means for codifying land use controls, including the location of water supply wells, on the post.	Yes	Applicable. Use the RPMP to apply institutional controls on the post.
Other Controls			
Monitoring			
Groundwater Monitoring	Periodic sampling and analysis of groundwater from monitoring wells.	Yes	Groundwater monitoring is currently in place at the Site.
Alternative Water Supply			
Rural Water Supply	Extension of municipal water distribution system to serve residents in the area of influence.	No	There are no water supply wells within the area of influence.
New Supply Wells	New uncontaminated wells to serve residents in the area of influence.	No	There are no water supply wells within the area of influence.
Individual Well Treatment			
Low Profile Air Stripping	Volatilization of contaminants from water by either passing air through water or water through air.	No	There are no water supply wells within the area of influence.
Activated Carbon Adsorption	Adsorption of contaminants onto activated carbon by passing water through carbon column.	No	There are no water supply wells within the area of influence.
UV Oxidation	Oxidation of organic contaminants by addition of H_2O_2 and/or O_3 and catalyzed by ultraviolet (UV) light.	No	There are no water supply wells within the area of influence.
Monitored Natural Attenuation			
Monitored Natural Attenuation	Natural subsurface processes such as dispersion, volatilization, biodegradation, adsorption, and chemical reactions combine to reduce contaminant levels over time.	Yes	Applicable. Data indicates that natural attenuation processes are acting to reduce contaminant concentrations at the DCF Study Area.

Table 4-2 (continued)
Initial Screening of Potential Technologies for Soil and Groundwater Remediation
Feasibility Study Addendum
DCF Study Area

Process Options	Description	Retain*	Screening Comments
Containment			
Low Permeabilty Barrier			
Vertical Barriers	Low permeability wall made of soil-bentonite, reinforced concrete, chemical grout, or steel sheets.	Yes	Potentially applicable.
Horizontal Barriers	Low permeability barrier typically used to prevent leaching of contaminants to groundwater.	Yes	Potentially applicable.
Permeable Reactive Barrier			
Zero Valent Iron	Permeable zero-valent iron reactive wall is installed across the flow path of contaminant plume, which moves through the wall under natural gradient. Iron chemically reacts (reductive dehalogenation) with chlorinated organics, removing chlorine.	Yes	Potentially applicable.
In-Situ Air Stripping	Permeable reaction trench is installed across flow path of contaminant plume, which moves through the treatment zone under natural gradient. Air is injected into the trench to volatilize contaminants. Contaminated air is collected at the surface.	No	Technology is more applicable to materials with low hydraulic conductivity where aquifer air sparging is limited. Thickness of aquifer will limit effectiveness of technology.
In-Situ Adsorption	Surfactants are injected as an aqueous solution into the subsoil to create organoclays. Organoclays attract and hold toxic organic contaminants. The clay then can be disposed of or may be bioremediated on site.	No	Feasible in low permeability (clay) aquifers. Not applicable in high permeability media, even if commercial organoclay is used, since groundwater would bypass the wall.
Groundwater Collection and Extraction			
Pumping Wells: Vertical	Series of vertical wells with water pumps to extract contaminated groundwater.	Yes	Potentially applicable.
Pumping Wells: Directional	Series of horizontal or inclined wells with water pumps to extract contaminated groundwater.	Yes	Potentially applicable.
Interceptor Trenches	Perforated pipe in trenches backfilled with porous media to collect contaminated water for further treatment or disposal.	No	Trenches are more applicable to low-yield clay aquifers.
Surface Capping			
Surface Capping	Surface is covered with impermeable materials to prevent leaching of contaminants to groundwater.	Yes	Potentially applicable.
Ex-Situ Physical Treatment			
Excavation and Off-Site Removal			
Soil Excavation and Backfill	Soil with PCE concentrations above 180 ug/kg are removed and clean soil is used for backfill.	Yes	Potentially applicable
Landfarming - New Constructed Treatment Cell	Excavated soil transported to newly constructed treatment cell.	Yes	Potentially applicable
Landfarming - Existing Treatment Cell	Excavated soil transported to existing treatment cell (B354).	Yes	Potentially applicable
Off-Site Thermal Incineration	Excavated soil transported off site for incineration.	Yes	Potentially applicable

Table 4-2 (continued)
Initial Screening of Potential Technologies for Soil and Groundwater Remediation
Feasibility Study Addendum
DCF Study Area

Process Options	Description	Retain*	Screening Comments
Excavation and Treatment			
Chemical Extraction	Separates hazardous contaminants from soil using chemical extractor to reduce volume of hazardous waste to be treated.	No	Higher clay content may reduce extraction efficiency. High capital costs. System appropriate for use on heavily contaminated media.
Chemical Reduction/Oxidation	Reduction/oxidation reactions chemically convert hazardous contaminants to nonhazardous or less toxic compounds.	No	Ineffective for VOCs.
Dehalogenation	Contaminated soil is screened, processed, and mixed with reagents. The mixture is then heated in a reactor causing either the replacment of the halogen molecules or the decomposition and partial volatilization of the contaminants.	No	Can be used to treat halogented VOCs but is generally more expensive that other technologies. High clay and mositure will increase treatment costs further.
Contaminant Seperation	Seperation using gravity or seiving/physical seperation to remove contaminated concentrates from soils leaving a relatively uncontaminated fraction.	No	Can only be used on selected VOCs. High clay and moisture increase treatment cost.
Solidification and Stabilization	Contaimants are physically bound or enclosed within a stabilized mass by a variety of processes.	No	Organics are generally not immobilized. Long term effectiveness has not been demonstrated for many contamiant/process conbinations.
Soil Washing	Removes contaminants from soil by dissolving or suspending in the wash solution, then seperating into the aqueous stream.	No	Difficult to remove organics absorbed onto clay. Aqueous stream requires treatment.
Ex-Situ Biological Treatment			
Biological Treatment			
Slurry Treatment in Bioreactor	Slurry-phase bioreactors containing cometabolites and specially adapted microorganisms are used to treat the excavated soil.	No	Nonhomogeneous soils and clayey soils can create serious materials handling problems.
Solid Phase Biopiles	Excavated soil is mixed with soil admendments and placed in above ground enclosures. System typically includes leachate collection and aeration systems.	No	Questionable effectiveness for halogenated hydrocarbons.
In-Situ Treatment			
Biological Treatment			
Biosparging	Uses low flow air sparging to stimulate aerobic biodegradation of contaminants by delivering oxygen to the saturated zone in permeable aquifers.	No	Some chlorinated solvents present at this Site are not readily biodegradable under aerobic conditions.
Aerobic Bioremediation with Lab-Isolated Solvent-Degrading Bacteria	Bacteria capable of biodegrading chlorinated aliphatics is isolated and used at the site for in-situ aerobic bioremediation.	No	Not feasible in large-scale bioremediation applications. However, it could be applicable using in-situ biofilters (see below).
Cometabolic Aerobic Bioremediation	Chlorinated VOCs are transformed as secondary substrate by methanotrophic bacteria (methane degraders). For this to occur, methane and O_2 must be provided in an injection-recovery well system.	No	Some chlorinated solvents present at this Site are not readily biodegradable under aerobic conditions.

Table 4-2 (continued)
Initial Screening of Potential Technologies for Soil and Groundwater Remediation
Feasibility Study Addendum
DCF Study Area

Process Options	Description	Retain*	Screening Comments
In-Situ Treatment (continued)			
Enhanced Anaerobic Bioremediation	Technology designed to treat chlorinated solvents using anaerobic conditions. Oxygen depletors, such as acetate, methanol, and sodium lactate are used to consume dissolved O_2 and to act as electron donors in anaerobic reactions. Nutrients such as nitrogen, phosphorus, and carbon sources are added to promote the growth of anaerobic microbes. The patented method, Hydrogen Release Compound (HRC™), consists of injecting time-release lactic acid which is metabolized by anaerobic microbes and releases hydrogen. The resulting hydrogen is then used by other microbes to stimulate rapid degradation of chlorinated solvents. Other carbon sources such as molasses and vegetable oil may also be used to enhance anaerobic degradation.	Yes	Potentially applicable.
Nitrate Enhanced Bioremediation	Solubilized nitrate is circulated throughout contaminated zone to provide electron acceptors for biological degradation.	No	Some chlorinated solvents present at the Site are not readily biodegradable under aerobic (presence of electron acceptors) conditions.
H_2O_2 Enhanced Bioremediation	A dilute solution of H_2O_2, which breaks down into O_2 and water, is circulated throughout contaminated zone to increase O_2 content of groundwater and promote aerobic degradation.	No	Some chlorinated solvents present at the Site are not readily biodegradable under aerobic conditions.
Electric Induced Redox Barriers	Electric current is used to produce hydrogen from water. The resulting hydrogen is utilized by microbes to stimulate reductive dechlorination of chlorinated organics.	No	Technology is still in a development phase, has only been tested in a laboratory setting, and limited information is available. Developers indicate that small-scale field tests and more rigorous laboratory studies are required before the effectiveness of the technology can be fully evaluated.
Oxygen Release Compound® (ORC)	ORC formulation is placed in passive wells. Groundwater hydrates the ORC, which slowly releases molecular oxygen. O_2 is then used by microorganisms to degrade contaminants aerobically.	No	Some chlorinated solvents present at the Site (TCE and PCE) are not readily biodegradable under aerobic conditions. ORC may inhibit the natural anaerobic biodegradation that is occurring at the Site. May require regulatory approval to inject ORC into the aquifer.
In-Situ Biofilters	Sand-filled trench that intercepts contaminated plume is inoculated with non-indigenous methanotrophic bacteria. Chlorinated VOCs are degraded by resting-state microorganisms with intermittent provision of methane.	No	Issues with the longevity of non-indigenous bacteria are limitations of this technology. More applicable to low permeability aquifers.
Physical/Chemical Treatment			
Air Sparging	Air is injected into the saturated zone which forms bubbles that volatilize contaminants and carry them to the surface. Vacuum extraction wells in the unsaturated zone capture volatilized contaminants.	Yes	Potentially applicable.

Table 4-2 (continued)
Initial Screening of Potential Technologies for Soil and Groundwater Remediation
Feasibility Study Addendum
DCF Study Area

Process Options	Description	Retain*	Screening Comments
Physical/Chemical Treatment (Continued)			
C-Sparger™	An air/ozone mixture is injected into saturated zone to chemically oxidize contaminants in-situ. An in-well water pump is provided to help disperse oxidant through formation.	Yes	Potentially applicable.
Groundwater Circulation Wells	Air is introduced into screened well to promote air stripping within the well. Less dense, aerated water is lifted creating a circulation pattern. Mass transfer of VOCs occurs as air/water mixture rises and contaminated air is extracted by a blower or discharged into the vadose for treatment by biodegradation.	Yes	Potentially applicable.
Soil Vapor Extraction (SVE)	A vacuum is applied to wells screened in the vadose zone to promote increased volatilization of VOCs. Vapors are collected for treatment and disposal if necessary.	Yes	Potentially applicable to remove contaminants that are volatilized during the groundwater remediation. May be used in combination with other technologies.
In-Situ Chemical Oxidation	Solubilized oxidant (H_2O_2, $KMnO_4$, or O_3), and sometimes catalysts, are circulated throughout contaminated zone to chemically oxidize organic contaminants.	Yes	Potentially applicable.
Permeable Reactive Barrier: Zero Valent Iron	Permeable zero-valent iron reactive wall is installed across the flow path of contaminant plume, which moves through the wall under natural gradient. Iron chemically reacts (reductive dehalogenation) with chlorinated organics, removing chlorine.	Yes	Potentially applicable.
Permeable Reactive Barrier: In-Situ Air Stripping	Permeable reaction trench is installed across flow path of contaminant plume, which moves through the treatment zone under natural gradient. Air is injected into the trench to volatilize contaminants. Contaminated air is collected at the surface.	No	Technology is more applicable to materials with low hydraulic conductivity where aquifer air sparging is limited. Thickness of aquifer will limit effectiveness of technology.
Permeable Reactive Barrier: In-Situ Adsorption	Surfactants are injected as an aqueous solution into the subsoil to create organoclays. Organoclays attract and hold toxic organic contaminants. The clay then can be disposed of or may be bioremediated on site.	No	Feasible in low permeability (clay) aquifers. Not applicable in high permeability media, even if commercial organoclay is used, since groundwater would bypass the wall.
In-Situ Redox Manipulation	Sodium dithionite, potassium carbonate, and potassium bicarbonate are injected into the aquifer to chemically reduce the ferric iron in sediments to ferrous iron. The ferrous iron chemically reacts (reductive dehalogenation) with chlorinated organics, removing chlorine.	Yes	Potentially applicable.
Bimetallic Nanoscale Particles	Submicron ($<10^{-6}$ meters) particles of zero-valent iron coated with palladium (Pd) are mixed in a slurry and injected into the aquifer. The iron particles chemically react (reductive dehalogenation) with chlorinated organics, removing chlorine.	No	Bench scale technology that has not been extensively field tested.
In-Situ Chemical Flushing	Surfactants and/or cosolvents (e.g., alcohol) added to injection wells can mobilize and/or solubilize nonaqueous phase liquids and/or sorbed contaminants.	No	Concentrations of contaminants are generally below solubility limit, so free-phase product is not likely to exist. In the dissolved phase, contaminants are fairly mobile, so mobility enhancement does not appear to be necessary.
Electrical Separation	Two series of electrodes (anode and cathode) are placed in boreholes and current is applied across the electrodes. This process promotes migration of specific contaminants or chemical reagents.	No	More applicable to low hydraulic conductivity materials. Has mainly been used to remove metals and organic ions.

Table 4-2 (continued)
Initial Screening of Potential Technologies for Soil and Groundwater Remediation
Feasibility Study Addendum
DCF Study Area

Process Options	Description	Retain*	Screening Comments
Physical/Chemical Treatment (Continued)			
In-Situ Radio Frequency Heating	Heat is applied to the subsurface through electromagnetic radiation. Raises the soil temperature to enhance soil vapor extraction, air sparging, or product recovery methods.	No	More applicable to vadose zone remediation.
Steam Injection	Steam is forced into the aquifer through injection wells to vaporize volatile and semivolatile contaminants. Vaporized components are then removed by vacuum extraction.	No	More applicable to vadose zone remediation.
Dynamic Underground Stripping (DUS)	Uses steam injection to heat permeable layers and electric current to heat impermeable layers. Vaporized volatile and semivolatile components are then removed by soil vapor extraction.	No	Has been used mainly to remediate sites with high contaminant concentrations (mg/L). Requires extensive above-ground support infrastructure.
Hydrous Pyrolysis/Oxidation (HPO)	Used in combination with DUS (above), or similar heating technology,where oxygen is injected into the pre-heated subsurface to rapidly oxidize VOCs.	No	More applicable to sites with high VOC concentrations.
Six-Phase Soil Heating	Electricity is used to heat aquifer materials to enhance the volatilization of VOCs. Volatilized VOCs are collected by soil vapor extraction.	No	Has been used mainly to remediate sites with high contaminant concentrations (mg/L). Requires extensive above-ground support infrastructure.
Components - Fluid Delivery Systems			
Vertical Wells	Permanent wells used to distribute chemicals or other fluids (i.e., air, nutrients, etc.) into the aquifer.	Yes	Potentially applicable.
Horizontal Wells	Horizontally placed wells used to distribute chemicals or other fluids (i.e., air, nutrients, etc.) into the aquifer.	Yes	Potentially applicable.
Direct-Push Injection Points	Temporary wells (installed using direct-push technology) used to distribute chemicals or other fluids (i.e., air, nutrients, etc.) into the aquifer.	Yes	Potentially applicable.

NOTES:
- Retain for further consideration as an applicable technology that may be considered as a part of a remedial alternative.

[shaded] Technology eliminated from further consideration based on technical implementability.

Table 4-3
Evaluation of Technologies for Soil and Groundwater Remediation
Feasibility Study Addendum
DCF Study Area

Process Options	Description	Effectiveness	Implementability	Relative Cost	Retain*	Screening Comments
No Action						
No Action	No Action	o	o	o	Yes	Consideration of no action alternative is required by NCP and provides baseline to compare other alternatives.
Institutional Controls						
Other Institutional Controls						
Real Property Master Plan (RPMP)	The RPMP is the mechanism by which the post codifies land use controls.	+	+	+	Yes	The RPMP is used to formalize land use controls on the post. The RPMP could be used to establish areas where supply wells could not be installed; for example, within the DCF Study Area. It could be used to codify other types of restrictions as well.
Other Controls						
Monitoring						
Groundwater Monitoring	Periodic sampling and analysis of groundwater from monitoring wells.	o	+	-	Yes	Groundwater monitoring is currently in place at the DCF Study Area.
Monitored Natural Attenuation						
Monitored Natural Attenuation	Natural subsurface processes such as dispersion, volatilization, biodegradation, adsorption, and chemical reactions combine to reduce contaminant levels over time.	o	o	o	Yes	Data indicates that some natural attenuation processes are acting to reduce contaminant concentrations at the DCF Study Area. MNA could be used as a component of a remedial alternative package
Containment						
Low Permeability Barrier: Vertical Barriers	Low permeability wall made of soil-bentonite, reinforced concrete, chemical grout, or steel sheets.	o	-	-	No	Removed from consideration due to difficulty and cost of construction.
Low Permeability Barrier: Horizontal Barriers	Low permeability barrier typically used to prevent leaching of contaminants to groundwater.	o	-	-	No	Removed from consideration due to difficulty and cost of construction.
Permeable Reactive Barrier: Zero Valent Iron	Permeable zero-valent iron reactive wall is installed across the flow path of contaminant plume, which moves through the wall under natural gradient. Iron chemically reacts (reductive dehalogenation) with chlorinated organics, removing chlorine.	-	+	-	No	Difficult installation and high capital cost for the amount of solvent contamination being treated. Difficulty in shoring up side walls at depth due to subsurface soil type.
Pumping Wells: Vertical	Series of vertical wells with water pumps to extract contaminated groundwater.	o	o	o	No	Groundwater extraction (i.e., "Pump and Treat") is ineffective in reducing concentrations to MCLs and has rebounding effects.

\+ Relatively Effective, Easily Implementable, or Low Cost
o No Relative Advantage/Disadvantage
\- Relatively Ineffective, Difficult to Implement, or High Cost
? Unknown

Table 4-3 (Continued)
Evaluation of Technologies for Soil and Groundwater Remediation
Feasibility Study Addendum
DCF Study Area

Process Options	Description	Effectiveness	Implementability	Relative Cost	Retain*	Screening Comments
Containment (Continued)						
Pumping Wells: Directional	Series of horizontal or inclined wells with water pumps to extract contaminated groundwater.	o	o	o	No	Groundwater extraction (i.e., "Pump and Treat") is ineffective in reducing concentrations to MCLs and has rebounding effects.
Surface Capping	Surface is covered with impermeable materials to prevent leaching of contaminants to groundwater.	-	o	+	No	Will not reduce toxicity, mobility, or volume of contaminant. Will not prevent horizontal flow of groundwater.
Ex-Situ Soil Removal and Treatment						
Excavation and Backfill	Soil with PCE concentrations above 180 ug/kg are removed and clean soil is used for backfill.	+	+	+	Yes	Will remove subsurface soil source and high clay content backfill will retard precipitation infiltration.
Landfarming - New Cell	Excavated soil will be transported to newly constructed treatment cell.	+	o	o	Yes	Will remove subsurface soil source. Soil will be disked in treatment cell until VOCs are at or below RAOs. Soil would then be used as landfill cover.
Landfarming - Existing Cell	Excavated soil will be transported to existing treatment cell.	+	+	+	Yes	Will remove subsurface soil source. Soil will be disked in treatment cell until VOCs are at or below RAOs. Soil would then be used as landfill cover.
Off-site Thermal Incineration	Excavated soil will be transported off site for incineration.	+	o	-	Yes	Will remove subsurface soil source. Soil will be transported to thermal treatment unit and immediately incinerated. Soil would then be used as landfill cover.

+ Relatively Effective, Easily Implementable, or Low Cost
o No Relative Advantage/Disadvantage
- Relatively Ineffective, Difficult to Implement, or High Cost
? Unknown

Table 4-3 (Continued)
Evaluation of Technologies for Soil and Groundwater Remediation
Feasibility Study Addendum
DCF Study Area

Process Options	Description	Effectiveness	Implementability	Relative Cost	Retain*	Screening Comments
In-Situ Treatment						
Biological Treatment						
Enhanced Anaerobic Bioremediation	Technology designed to treat chlorinated solvents using anaerobic conditions. Oxygen depletors, such as acetate, methanol, or sodium lactate are used to consume dissolved O_2 and to act as electron donors in anaerobic reactions. Nutrients such as nitrogen, phosphorus, and carbon sources are added to promote the growth of anaerobic microbes. The patented method, Hydrogen Release Compound (HRC™), consists of injecting time-release lactic acid which is metabolized by anaerobic microbes and releases hydrogen. The resulting hydrogen is then used by other microbes to stimulate rapid degradation of chlorinated solvents. Other carbon sources such as molasses and vegetable oil may also be used to enhance anaerobic degradation.	o	+	?	Yes	This technology may be appropriate to enhance remediation within the terrace aquifer (the high concentration area of the plume). May require regulatory approval to inject chemicals into the aquifer.
Physical/Chemical Treatment						
Air Sparging	Air is injected into the saturated zone and then forms bubbles that volatilize contaminants and carry them to the surface. Vacuum extraction wells in the unsaturated zone capture volatilized contaminants.	-	o	o	No	Not effective on low concentrations of VOCs. No distinct advantage over other competing technologies.
C-Sparger™	An air/ozone mixture is injected into saturated zone to chemically oxidize contaminants in-situ. An in-well water pump is provided to help disperse oxidant through formation.	-	o	-	No	Not effective on low concentrations of VOCs. Similar limitations to pump and treat. No distinct advantage over other competing technologies
Groundwater Circulation Wells	Air is introduced into screened well to promote air stripping within the well. Less dense, aerated water is lifted creating a circulation pattern. Mass transfer of VOCs occurs as air/water mixture rises and contaminated air is extracted by a blower or discharged into the vadose for treatment by biodegradation.	-	o	-	No	Not effective on low concentrations of VOCs. Similar limitations to pump and treat. No distinct advantage over other competing technologies

\+ Relatively Effective, Easily Implementable, or Low Cost
o No Relative Advantage/Disadvantage
\- Relatively Ineffective, Difficult to Implement, or High Cost
? Unknown

Table 4-3 (Continued)
Evaluation of Technologies for Soil and Groundwater Remediation
Feasibility Study Addendum
DCF Study Area

Process Options	Description	Effectiveness	Implementability	Relative Cost	Retain*	Screening Comments
In-Situ Treatment (Continued)						
Soil Vapor Extraction (SVE)	A vacuum is applied to wells screened in the vadose zone to promote increased volatilization of VOCs. Vapors are collected for treatment and disposal if necessary.	-	+	+	No	Not effective in shallow, fine grained, or heterogeneous soils. No distinct advantage over other soil technologies.
In-Situ Chemical Oxidation	Solubilized oxidant (H_2O_2, $KMnO_4$, or O_3), and sometimes catalysts, are circulated throughout contaminated zone to chemically oxidize organic contaminants.	o	+	o	Yes	This technology is mainly applicable to small source zone type settings.
In-Situ Redox Manipulation	Sodium dithionite, potassium carbonate, and potassium bicarbonate are injected into the aquifer to chemically reduce the ferric iron in sediments to ferrous iron. The ferrous iron chemically reacts (reductive dehalogenation) with chlorinated organics, removing chlorine.	?	o	-	No	Technology is still in the testing phase. May require regulatory approval to inject chemicals into the aquifer.
Components - Fluid Delivery Systems						
Vertical Wells	Permanent wells used to distribute chemicals or other fluids (i.e., air, nutrients, etc.) into the aquifer.	o	o	+	Yes	May require large number of wells to distribute chemicals or other fluids into the subsurface soil or aquifer.
Horizontal Wells	Horizontally placed wells used to distribute chemicals or other fluids (i.e., air, nutrients, etc.) into the aquifer.	o	o	-	Yes	Will likely require fewer wells than traditional vertical well applications, but at a higher relative cost.
Direct-Push Injection Points	Temporary wells (installed using direct-push technology) used to distribute chemicals or other fluids (i.e., air, nutrients, etc.) into the aquifer.	o	+	+	Yes	May require large number of wells to distribute chemicals or other fluids into the subsurface soil or aquifer.

\+ Relatively Effective or Low Cost
o No Relative Advantage/Disadvantage
\- Relatively Ineffective, Difficult to Implement, or High Cost
? Unknown
* - MNA will be evaluated as part of a total remedial alternative package for each of the selected alternatives except no action.

NOTES:
* Retain for further consideration as an applicable technology that may be considered as a part of a remedial alternative.
- Evaluation parameters are relative to each general response action group and not to entire list of technologies.
- Effectiveness focuses on: (1) the applicability of the process for the given site characteristics and its ability to meet the remediation goals identified in the RAOs; (2) the potential impacts to human health and the environment during the implementation of the technology; and (3) how proven and reliable the process is for the given contaminants and site conditions.
- Implementability considers the technical and primarily the administrative feasibility of implementing the process option at the site.
- Relative cost focuses on a qualitative evaluation of the capital and O&M costs to implement the technology. Costs will vary significantly from site to site and are used only as a preliminary indication.

- Technology eliminated from further consideration

Table 5-1
Preliminary ARARs Matrix
All Areas of Concern
Feasibility Study Report
DCF Study Area

	No Action	Soil Excavation with 354 Cell	Soil Excavation with New Cell	Soil Excavation with Offsite Disposal	Chemox	EAB
Chemical-Specific ARARs[1]						
Kansas Surface Water Quality Standards	X	X	X	X	X	X
Kansas Water Pollution Control, Antidegradation Policy	X	X	X	X	X	X
Safe Drinking Water Act (SDWA), National Primary Drinking Water Regulations	X	X	X	X	X	X
Kansas Drinking Water Standards	X	X	X	X	X	X
KDHE Risk Based Standards for Soils[2]	X	X	X	X	X	X
Location-Specific ARARs[1]						
Archaeological and Historic Preservation Act of 1974						
Endangered Species Act of 1973		X	X	X	X	X
Fish and Wildlife Conservation Act		X	X	X	X	X
Flood Control Act of 1944					X	X
Kansas Historic Preservation Act						
Non-Game, Threatened, or Endangered Species (State of Kansas)		X	X	X	X	X
Action-Specific ARARs[1]						
CERCLA		X	X	X	X	X
Clean Air Act		X	X	X		
Clean Water Act						
Emergency Planning and Right to Know		X	X	X	X	X
Federal Hazardous Materials Transportation Law		X	X	X		
OSHA (workplace standards)		X	X	X	X	X
OSHA (construction standards)		X	X	X		
Resource Conservation and Recovery Act		X	X	X		
Ambient Air Quality Standards and Air Pollution Control (State of Kansas)		X	X	X		
Kansas Board of Technical Professions		X	X	X	X	X
Solid Waste Management		X	X	X		
Underground Injection Control Regulations (State of Kansas)					X	X
Spill Reporting		X	X	X	X	X
Hazardous Waste Management Standards and Regulations		X	X	X		
Water Well Contractor License; Water Well Construction and Abandonment		X	X	X	X	X

Notes:

1. See Section 2.2.2 and Table 2-1 for a detailed description of these ARARs
2. This is actually a To Be Considered (TBC) but is listed here as a guide for soils.

Chemox - Chemical Oxidation
EAB - Enhanced Anaerobic Bioremediation
MNA - Monitored Natural Attenuation
P&T - Pump & Treat
KDHE - Kansas Department of Health and Environment

Table 5-2
Subsurface Soil PCE Results - Former Buildings 180/181 Area
Feasibilty Study Addendum
DCF Study Area

		Sample Number/Sample Interval Depth Range (Results in ug/kg)										
Borehole Number	Date Samples Collected	SB01 1 to 4 ft bgs	SB02 4 to 8 ft bgs	SB03 8 to 12 ft bgs	SB04 12 to 16 ft bgs	SB05 16 to 20 ft bgs	SB06 20 to 24 ft bgs	SB07 24 to 28 ft bgs	SB08 28 to 32 ft bgs	SB09 32 to 36 ft bgs	SB10 36 to 40 ft bgs	SB11 40 to 44 ft bgs
401	06/03/02	11	15.6	5.4U	5.6U	6U	9.7	8.1				
402	06/03/02	298	43.8	14.2	5.6U	7.7	5.6U	5.6U	5.1U			
403	06/04/02	201	5.5U	16	5.7U	5.5U	5.5U	5.2U		Not Sampled		
404	06/04/02	5.5U	5.4U	5.7	5.9U	5.7U	5.7U	10.0				
405	06/05/02	5.5	5.3U	5.6U	5.8U	5.9U	5.6U	14.6	8.1	5.3U		
406	06/05/02	68.6	5.2U	28.6	18.1	5.9U	5.6U	5.6U	5.9U			
407	06/06/02	487	215	78.9	5.6U	14.9	5.8U	5.7U	28.8	5.1U		
408	07/16/02	149	227	7.4	8.2	5.3U	5.2U	22.6	5.5U	5.5U	5.6U	
412	07/16/02	71.2	214	150	5.5U	5.6U	5.6U	38.3	32.8	17.9	5.9U	
415	06/06/02	122	16.5	17.5	5.5U	6U	5.6U	5.8U				
416	06/07/02	55.7	5.3U	78.4	5.4U	6U	5.2U	7.2	5.1U		Not Sampled	
417	06/07/02	5.6U	19.5	5.5U	5.6U	5.5U	5.5U	6.4U				
418	07/10/02	440	53.7	8	5.5U	5.3U	5.4U	5.9U	5.3U	6.3U	106	
419	07/11/02	5.3U	5.3U	56	5.6U	5.7U	5.7U	6U	5.4U	5.1U	11	
420	07/11/02	11	5.4U	47.7	16.3	13.7	5.7U	5.3U	5.4U	5.5U	5.5U	
421	07/11/02	12.8	24.6	11	31.1	6.6	5.6U	6.6U	5.9U	5.4U	5.6U	
423	07/15/02	25.1	32.9	181	34.4	5.6U	6.2U	12	5.8UJ	5.2U	6.3	
424	07/15/02	5.2U	84.2	7	5.2U	140						
430	07/17/02	230	324	25.4	5.9U	5.6U	5.4U	5.3U	6.1U	6U		
431	07/17/02	208	437	16.1	7.5	5.3U	5.5U	5.4U	5.1U	5.8U		
432	07/17/02	260	513	78R	11	18	31.4	5.3U	5.2U	5.9U		
433	07/18/02	431	321	17.4	30.6	15.2	11	5.1U	5.2U	5.3U	Not Sampled	
434	07/18/02	23.2	5.4U	68.7	14.5	6.1U	5.7U	5.8U	5.7U	5.2U		
435	07/18/02	142	12.6	11.9	9.7	5.1U	5.2U	5.6U	6.1U	5.9U		
436	07/10/02	5.5U	5.4U									
441	07/08/02	175	33	6U	32	5.8U	5.3U	5.2U	5.3U	5.2U		
442	07/09/02	5.7U	119R	39	5.6U	5.6U	8.2	5.1U	6.2U	5.3U	6.7U	
443	07/10/02	6U	17.2	5.3U	5.8U	6.2U	5.2U	5.2U	6.3U	6U	11.3	5.3U

Table 5-2 (continued)
Subsurface Soil PCE Results - Former Buildings 180/181 Area
FS Addendum
DCF Study Area

Borehole Number	Date Samples Collected	Sample Number/Sample Interval Depth Range (Results in ug/kg)										
		SB01 1 to 4 ft bgs	SB02 4 to 8 ft bgs	SB03 8 to 12 ft bgs	SB04 12 to 16 ft bgs	SB05 16 to 20 ft bgs	SB06 20 to 24 ft bgs	SB07 24 to 28 ft bgs	SB08 28 to 32 ft bgs	SB09 32 to 36 ft bgs	SB10 36 to 40 ft bgs	SB11 40 to 44 ft bgs
444	05/22/02	6.1U	5.5U	5.7U	5.7U	6.9U	5.5U	5.4U	6.1UR	5.4UR		
445	07/08/02	5.7U	5.6U	5.4U	5.9U	5.7U	5.7U	5.4U	6.2U	5.7U		
446	07/23/02	**38.9**	**17.6**	5.6U	5.6U	**7.4**	**27.1**	5.8U	5.3U	5.8U		
447	07/23/02	**21.5**	**36**	5.6U	5.5U	5.7U	**13.4**	5.8U	5.8U			
448	07/24/02	**54.9**	**10.9**	5.7U	5.7U	**8.7**	5.5U	5.9U	5.7U			
449	07/24/02	**69.4**	**12**	5.5U	5.5U	5.5U	**11.7**	6U	5.1U		Not Sampled	
450	07/25/02	**56.1**	5.5U	5.4U	5.2U	5.6U	5.8U	5.7U				
451	07/25/02	5.1U	5.3U	5.2U	5.5U							
452	07/25/02	5.6U	5.2U	5.2U	5.2U							

ug/kg = micrograms per kilogram
PCE = Tetrachloroethylene
U = Compound not detected above detection limit.
213 = Detected
R = Result was rejected during QC evaluation.
J = Estimated
431 = Result above the Kansas Department of Health and Environment RSK level of 180 ug/L for the soil to groundwater protection pathway.

Table 6-1
Cost Summary
Feasibility Study Addendum
DCF Study Area

AOC	Alternative		Total Capital Costs[1]	Total O&M Costs[2]	Total Periodic Costs[3]	Total Project Cost[4]	Total Present Value Cost at 3.2%[5]
1	1	No Action	$ -	$ -	$ 612,000	$ 612,000	$ 413,754
	2	Soil Removal - Preexisting Cell	$ 177,000	$ -	$ 132,000	$ 309,000	$ 261,937
	3	Soil Removal -New Cell	$ 202,500	$ -	$ 132,000	$ 334,500	$ 287,437
	4	Soil Removal - Offsite	$ 1,715,880	$ -	$ 132,000	$ 1,847,880	$ 1,800,817
2	1	No Action	$ -	$ -	$ 612,000	$ 612,000	$ 413,754
	2	Chemical Oxidation	$ 503,520	$ 1,989,600	$ 257,000	$ 2,750,120	$ 2,158,837
	3	Enhanced Bioremediation[6]	$ 306,900	$ 1,989,600	$ 252,050	$ 2,548,550	$ 1,957,569
3	1	No Action	$ -	$ -	$ 612,000	$ 612,000	$ 413,754
	2	Chemical Oxidation	$ 489,120	$ 1,989,600	$ 257,000	$ 2,735,720	$ 2,144,437
	3	Enhanced Bioremediation	$ 302,580	$ 1,989,600	$ 252,050	$ 2,544,230	$ 1,953,249

Notes:

1. Includes costs for design, bench and pilot testing (if necessary), equipment/chemical costs, construction and implementation, and institutional controls.
2. Includes costs for groundwater monitoring, reporting (when necessary), electricity (when necessary), periodic maintenance (when necessary), and periodic parts (when necessary).
3. Includes costs for five-year reviews and closure reporting.
4. Total Capital Costs + Total O&M Costs + Total Periodic Costs = Total Project Cost
5. Present value cost using a 3.2 percent discount rate (EPA, 1993). For this analysis, the rate of return was based on the 30-year treasury bill of 5.2 percent an an inflation rate of 2 percent (formula = 1-1.052/1.02), which yields a value of 3.14 percent, rounded up to 3.2 percent.
6. Injection into the sewerline and utility corridor confirmation will add an additional cost of $160,000.

MNA - Monitored Natural Attenuation
O&M - Operation & Maintenance
AOC - Area of Concern

Table 6-2
Comparative Evaluation Summary
Feasibilty Study Addendum
DCF Study Area

AOC	AOC - 1				AOC - 2			AOC - 3		
Alternative	**1***	**2**	**3**	**4**	**1***	**2**	**3**	**1***	**2**	**3**
Media	**Shallow Subsurface Soil**				**Groundwater DCF01-40 Area**			**Groundwater DCF02-42 Area**		
Protection of Human Health and the Environment	No	Yes	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Compliance with ARARs	No	Yes	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Long-term Effectiveness and Permanence	0	1	1	1	0	5	4	0	5	4
Reduction of Toxicity, Mobility, or Volume	0	1	1	1	0	5	4	0	5	4
Short-term Effectiveness	0	2	3	1	0	5	4	0	5	4
Implementability	0	3	4	2	0	1	1	0	1	1
Cost	0	3	3	8	0	4	4	0	4	4
Total of Rankings	**0**	**10**	**12**	**13**	**0**	**20**	**17**	**0**	**20**	**17**
Overall Rank	**4**	**1**	**2**	**3**	**3**	**2**	**1**	**3**	**2**	**1**

Notes

Ranking
- 1 Most favorable alternative
- 3 Good, generally favorable
- 5 Fair, potentially unfavorable
- 7 Poor, unfavorable
- 10 Completely fails the criteria

Alt Alternative
AOC - 1 Alt. 1= No Action, Alt. 2 = Preexisting cell, Alt. 3 = New Cell, Alt. 4 = Offsite.
AOC - 2 Alt. 1= No Action, Alt. 2 = Chemox, Alt. 3 = EAB.
AOC - 3 Alt. 1= No Action, Alt. 2 = Chemox, Alt. 3 = EAB.
Yes Meets the requirements of the threshold criteria.
No Does not meet the requirements of the threshold criteria.
ARAR - Applicable or Relevant and Appropriate Requirements
Chemox - Chemical Oxidation
EAB - Enhanced Anaerobic Bioremediation
* - Does not include MNA and instititional controls.

Figures

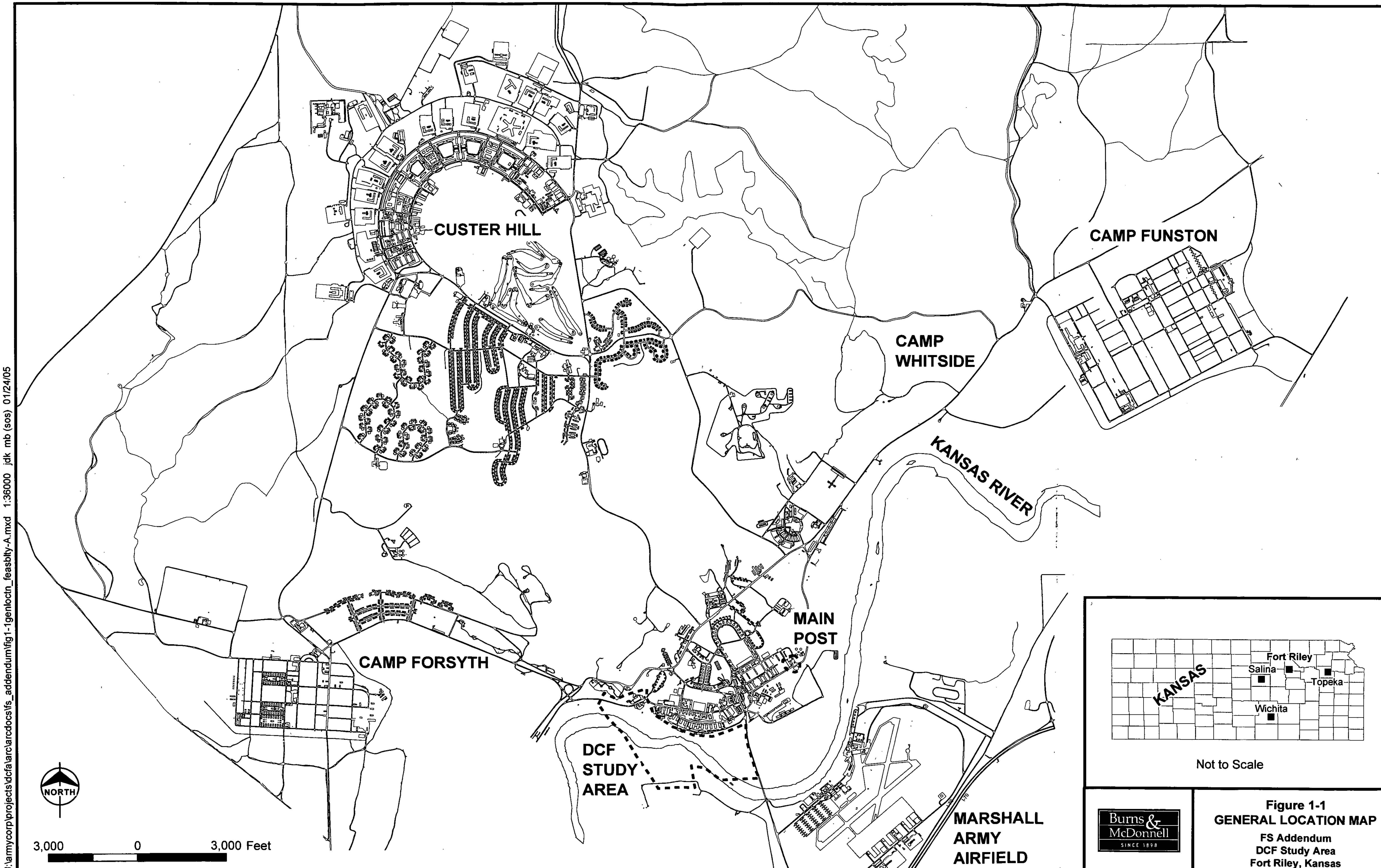

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Figure 1-1
GENERAL LOCATION MAP

FS Addendum
DCF Study Area
Fort Riley, Kansas

Figure 1-2
MAIN INVESTIGATIVE AREAS
FS Report Addendum
DCF Study Area
Fort Riley, Kansas

Figure 1-3
SITE TOPOGRAPHY
FS Addendum
DCF Study Area
Fort Riley, Kansas

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Tetrachloroethylene (ug/L)		
Sample Point:	July-03	October-03
DCF92-01	NS	NS
DCF92-02	***9.2***	***12.5***
DCF92-03	NS	NS
DCF92-05	***17.7***	***12.6***
DCF92-06	NS	NS
DCF93-09	***1.9***	***2.7***
DCF93-10	NS	***1.6***
DCF93-13	***63.2***	***30.9***
DCF93-19	1.1 U	1.1 U
DCF93-20	***1.5***	1.1 U
DCF96-25	***65.7***	***74.3***
DCF96-26	***4.9***	***5.2***
DCF96-27	***1.8***	***1.2***
DCF00-34b	1.1 U	1.1 U
DCF99-37b	***2.2***	1.3 U
DCF99-38b	1.1 U	1.1 U
DCF01-40	***113.0***	***96.8***
DCF02-41	1.1 U	***1.5***
DCF02-42	***77.0***	***75.1***
DCF02-44a	***57.4***	***50.6***
DCF02-45a	1.1 U	1.1 U
DCF02-46a	***2.6***	***1.5***
DCF02-47a	***5.3***	***4.1***
DCF02-48a	***5.8***	***3.0***
DCF02-49a	1.1 U	1.1 U
DCF03-50a	1.1 U	1.1 U
B354-99-11	NS	NS

NS = Not Sampled

LEGEND

- Monitoring Well (Sampled)
- Monitoring Well (Not Sampled)
- Piezometer (Sampled)
- Piezometer (Not Sampled)
- -5- PCE Isoconcentration Contour (ug/L)
- Study Boundary
- Roads with Parking Lots
- Tributaries
- Railroad
- Current Buildings
- Former Building Location

200 0 200 Feet

NOTES:

1. All concentrations reported in micrograms per liter (ug/L).
2. PCE detection limit = 1.1 ug/L.
3. Figure presents data for wells screened on the terrace and the shallow alluvial aquifer.
4. Contours represent isoconcentration of 5 ug/L (the MCL for PCE), 50 ug/L, and ND.
5. Contours are approximate and dashed where data is insufficient for interpolation between monitoring wells.
6. River bank based on aerial photography collected on February 8, 1998.
7. Gaps in charts indicate data was not collected.
8. The scale of horizontal (time) and vertical (PCE values) axes are variable between graphs.
9. ND - Not detected above laboratory detection limit.

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Figure 1-4
PCE RESULTS
TERRACE/SHALLOW ALLUVIAL AQUIFER
APRIL 2004
FS Addendum
DCF Study Area
Fort Riley, Kansas

Tetrachloroethylene (ug/L)		
Sample Point:	**July-03**	**October-03**
DCF92-01	NS	NS
DCF92-03	NS	NS
DCF92-06	NS	NS
DCF96-23	***17.0***	***10.7***
DCF96-24	***4.3***	6.8 U
DCF00-34c	1.1 U	1.1 U
DCF96-35	1.1 U	1.1 U
DCF96-36	1.1 U	1.1 U
DCF99-37c	***8.3***	***4.4***
DCF99-38c	1.1 U	1.1 U
DCF02-43	1.1 U	1.1 U
DCF02-44c	***66.1***	***39.3***
DCF02-45c	1.1 U	9.0
DCF02-46c	1.1 U	1.1 U
DCF02-47c	***4.0***	***3.1***
DCF02-48c	***17.1***	***10.8***
DCF02-49c	***13.3***	***12.6***
DCF03-50c	***1.1 U***	***1.1 U***
B354-99-11c	NS	NS
NS = Not Sampled		

LEGEND

- Monitoring Well (Sampled)
- Monitoring Well (Not Sampled)
- -ND- PCE Isoconcentration Contour
- Study Boundary
- Roads with Parking Lots
- Tributaries
- Railroad
- Current Buildings
- Former Building Location

NORTH

200 0 200 Feet

NOTES:

1. All concentrations reported in micrograms per liter (ug/L).
2. PCE detection limit = 1.1 ug/L.
3. Figure presents data for wells screened within the deep alluvial aquifer.
4. Contours represent isoconcentration of 5 ug/L (the MCL for PCE) and ND.
5. Contours are approximate and dashed where data is insufficient for interpolation between monitoring wells.
6. River bank based on aerial photography collected on February 8, 1998.
7. Gaps in charts indicate data was not collected.
8. ND - Not detected above laboratory detection limit.

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Figure 1-5
PCE RESULTS
DEEP ALLUVIAL AQUIFER
APRIL 2004

FS Addendum
DCF Study Area
Fort Riley, Kansas

Trichloroethylene (ug/L)		
Sample Point:	July-03	October-03
DCF92-01	NS	NS
DCF92-02	0.6 U	0.6 U
DCF92-03	NS	NS
DCF92-05	***1.0***	***0.6 J***
DCF92-06	***NS***	***NS***
DCF93-09	0.6 U	***0.8***
DCF93-10	NS	***3.8***
DCF93-13	***76.1***	***10.0***
DCF93-19	0.6 U	0.6 U
DCF93-20	***6.7***	***2.8***
DCF96-25	***9.3***	***8.3***
DCF96-26	***7.8***	***7.0***
DCF96-27	0.6 U	0.6 U
DCF00-34b	0.6 U	0.6 U
DCF99-37b	0.6 U	0.6 U
DCF99-38b	0.6 U	0.6 U
DCF01-40	0.6 U	0.6 U
DCF02-41	***22.1***	***24.4***
DCF02-42	***5.4***	***5.5***
DCF02-44a	***6.7***	***8.1***
DCF02-45a	0.6 U	0.6 U
DCF02-46a	***1.2***	***0.7***
DCF02-47a	***3.2***	***3.4***
DCF02-48a	***3.0***	***4.1***
DCF02-49a	0.6 U	0.6 U
DCF03-50a	0.6 U	0.6 U
B354-99-11	NS	NS

NS = Not sampled

NOTES:

1. All concentrations reported in micrograms per liter (ug/L).
2. TCE detection limit = 0.6 ug/L.
3. Figure presents data for wells screened on the terrace and the shallow alluvial aquifer.
4. Contours represent isoconcentration of 5 ug/L (the MCL for TCE) and ND.
5. Contours are approximate and dashed where data is insufficient for interpolation between monitoring wells.
6. River bank based on aerial photography collected on February 8, 1998.
7. ND - Not detected above laboratory detection limit.

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Figure 1-6
TCE RESULTS
TERRACE/SHALLOW ALLUVIAL AQUIFER
APRIL 2004
FS Addendum
DCF Study Area
Fort Riley, Kansas

Trichloroethylene (ug/L)		
Sample Point:	July-03	October-03
DCF92-01	NS	NS
DCF92-03	NS	NS
DCF92-06	NS	NS
DCF96-23	***3.3***	***1.9***
DCF96-24	***1.1***	***1.4***
DCF00-34c	***0.9***	***1.0***
DCF96-35	0.6 U	0.6 U
DCF96-36	0.6 U	0.6 U
DCF99-37c	***2.5***	***2.2***
DCF99-38c	0.6 U	0.6 U
DCF02-43	0.6 U	0.6 U
DCF02-44c	***7.4***	***5.5***
DCF02-45c	***0.6***	***1.8***
DCF02-46c	0.6 U	0.6 U
DCF02-47c	0.6 U	0.6 U
DCF02-48c	***2.2***	***1.4***
DCF02-49c	***2.9***	***2.9***
DCF03-50c	***0.6 U***	***0.6 U***
B354-99-11c	NS	NS
NS = Not sampled		

LEGEND

- Monitoring Well (Sampled)
- Monitoring Well (Not Sampled)
- —5— TCE Isoconcentration Contour (ug/L)
- Study Boundary
- Roads with Parking Lots
- Tributaries
- Railroad
- Current Buildings
- Former Building Location

200 0 200 Feet

NOTES:

1. All concentrations reported in micrograms per liter (ug/L).
2. TCE detection limit = 0.6 ug/L.
3. Figure presents data for wells screened within the deep alluvial aquifer.
4. Contours represent isoconcentration of 5 ug/L (the MCL for TCE) and ND.
5. Contours are approximate and dashed where data is insufficient for interpolation between monitoring wells.
6. River bank based on aerial photography collected on February 8, 1998.
7. ND - Not detected above laboratory detection limit.

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Burns & McDonnell

Figure 1-7
TCE RESULTS
DEEP ALLUVIAL AQUIFER
APRIL 2004
FS Addendum
DCF Study Area
Fort Riley, Kansas

cis-1,2-Dichloroethylene (ug/L)		
Sample Point:	**July-03**	**October-03**
DCF92-01	NS	NS
DCF92-02	0.5 U	0.5 U
DCF92-03	NS	NS
DCF92-05	0.5 U	***0.7 J***
DCF92-06	NS	NS
DCF93-09	***1.2***	***2.4***
DCF93-10	NS	***3.3***
DCF93-13	***19.7***	***9.9***
DCF93-19	***2.8***	***3.1***
DCF93-20	***13.6***	***11.7***
DCF96-25	***12.9***	***10.7***
DCF96-26	***23.9***	***13.4***
DCF96-27	***2.9***	***8.1***
DCF00-34b	0.5 U	0.5 U
DCF99-37b	0.5 U	0.5 U
DCF99-38b	0.5 U	0.5 U
DCF01-40	0.5 U	0.5 U
DCF02-41	***57.6***	***73.9***
DCF02-42	***4.0***	***4.9***
DCF02-44a	***6.0***	***7.2***
DCF02-45a	***11.0***	***8.2***
DCF02-46a	***0.7***	***0.7***
DCF02-47a	***31.5***	***20.7***
DCF02-48a	***10.2***	***14.7***
DCF02-49a	***2.5***	***1.5***
DCF03-50a	***0.5 U***	***0.5 U***
B354-99-11	NS	NS

NS = Not sampled

NOTES:

1. All concentrations reported in micrograms per liter (ug/L).
2. cis-1,2-DCE detection limit = 0.5 ug/L.
3. Figure presents data for wells screened on the terrace and the shallow alluvial aquifer.
4. Contours are approximate and dashed where data is insufficient for interpolation between monitoring wells.
5. River bank based on aerial photography collected on February 8, 1998.
6. ND - Not detected above laboratory detection limit.
7. J - Qualified as estimated during quality control evaluation.

Burns & McDonnell

Figure 1-8
cis-1,2-DCE RESULTS
TERRACE/SHALLOW ALLUVIAL AQUIFER
APRIL 2004

FS Addendum
DCF Study Area
Fort Riley, Kansas

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cis-1,2-Dichloroethylene (ug/L)		
Sample Point:	July-03	October-03
DCF92-01	NS	NS
DCF92-03	NS	NS
DCF92-06	NS	NS
DCF96-23	***4.0***	***1.9***
DCF96-24	***5.9***	***3.0***
DCF00-34c	***2.1***	***2.3***
DCF96-35	0.5 U	0.5 U
DCF96-36	0.5 U	0.5 U
DCF99-37c	***2.2***	***7.5***
DCF99-38c	***2.9***	***2.9***
DCF02-43	0.5 U	0.5 U
DCF02-44c	***6.8***	***4.6***
DCF02-45c	***2.1***	***1.9***
DCF02-46c	0.5 U	0.5 U
DCF02-47c	0.5 U	0.5 U
DCF02-48c	***1.5***	***1.6 J***
DCF02-49c	***3.7***	***4.1***
DCF03-50c	***0.5 U***	***0.5 U***
B354-99-11c	NS	NS

NS = Not sampled

LEGEND

- Monitoring Well (Sampled)
- Monitoring Well (Not Sampled)
- -ND- DCE Isoconcentration Contour
- Study Boundary
- Roads with Parking Lots
- Tributaries
- Railroad
- Current Buildings
- Former Building Location

200 0 200 Feet

NOTES:

1. All concentrations reported in micrograms per liter (ug/L).
2. cis-1,2-DCE detection limit = 0.5 ug/L.
3. Figure presents data for wells screened within the deep alluvial aquifer.
4. Contours are approximate and dashed where data is insufficient for interpolation between monitoring wells.
5. River bank based on aerial photography collected on February 8, 1998.
6. ND - Not detected above laboratory detection limit.

Burns & McDonnell

Figure 1-9
cis-1,2-DCE RESULTS
DEEP ALLUVIAL AQUIFER
APRIL 2004

FS Addendum
DCF Study Area
Fort Riley, Kansas

Vinyl Chloride (ug/L)		
Sample Point:	July-03	October-03
DCF92-01	NS	NS
DCF92-02	0.8 U	0.8 U
DCF92-03	NS	NS
DCF92-05	0.8 U	0.8 U
DCF92-06	NS	NS
DCF93-09	0.8 U	0.8 U
DCF93-10	NS	0.8 U
DCF93-13	0.8 U	0.8 U
DCF93-19	***1.0***	***1.3***
DCF93-20	0.8 U	0.8 U
DCF96-25	0.8 U	0.8 U
DCF96-26	0.8 U	0.8 U
DCF96-27	0.8 U	***1.5***
DCF00-34b	0.8 U	0.8 U
DCF99-37b	0.8 U	0.8 U
DCF99-38b	0.8 U	0.8 U
DCF01-40	0.8 U	0.8 U
DCF02-41	0.8 U	0.8 U
DCF02-42	0.8 U	0.8 U
DCF02-44a	0.8 U	0.8 U
DCF02-45a	***1.6***	0.8 U
DCF02-46a	0.8 U	0.8 U
DCF02-47a	0.8 U	0.8 U
DCF02-48a	0.8 U	0.8 U
DCF02-49a	0.8 U	0.8 U
DCF03-50a	0.8 U	0.8 U
B354-99-11	NS	NS

NS = Not sampled

LEGEND

- Monitoring Well (Sampled)
- Monitoring Well (Not Sampled)
- Piezometer (Sampled)
- Piezometer (Not Sampled)
- -ND- Vinyl Chloride Isoconcentration Contour (ug/L)
- Study Boundary
- Roads with Parking Lots
- Tributaries
- Railroad
- Current Buildings
- Former Building Location

NORTH

210 0 210 Feet

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NOTES:

1. All concentrations reported in micrograms per liter (ug/L).
2. Vinyl chloride detection limit = 0.8 ug/L.
3. Figure presents data for wells screened on the terrace and the shallow alluvial aquifer.
4. All results for the deep alluvial aquifer were non detect.
5. Contours are approximate and dashed where data is insufficient for interpolation between monitoring wells.
6. ND - Not detected above laboratory detection limit.
7. River bank based on aerial photography collected on February 8, 1998.

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Figure 1-10
VINYL CHLORIDE RESULTS
TERRACE/SHALLOW ALLUVIAL AQUIFER
APRIL 2004
FS Addendum
DCF Study Area
Fort Riley, Kansas

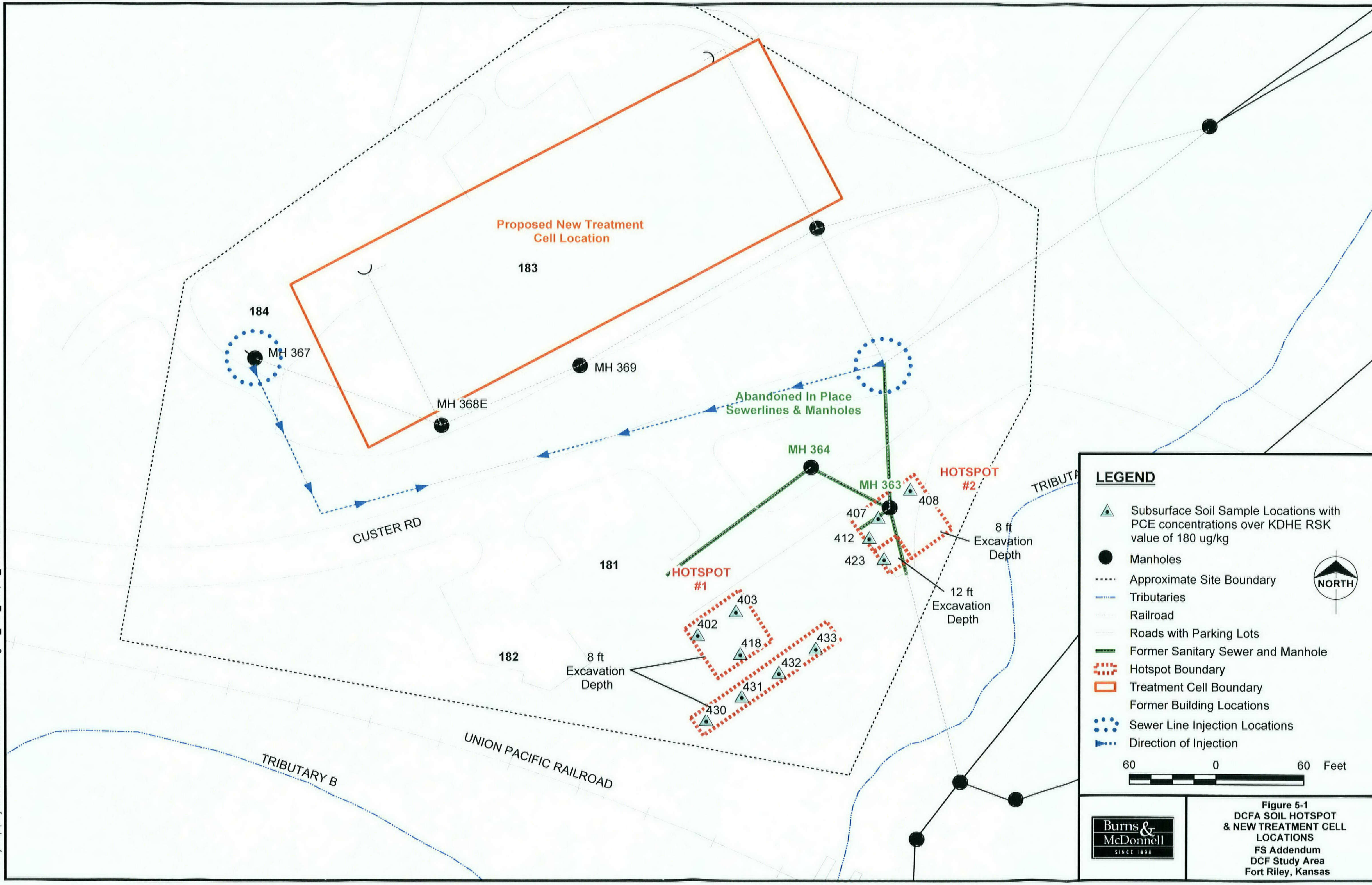

Figure 5-1
DCFA SOIL HOTSPOT
& NEW TREATMENT CELL
LOCATIONS
FS Addendum
DCF Study Area
Fort Riley, Kansas

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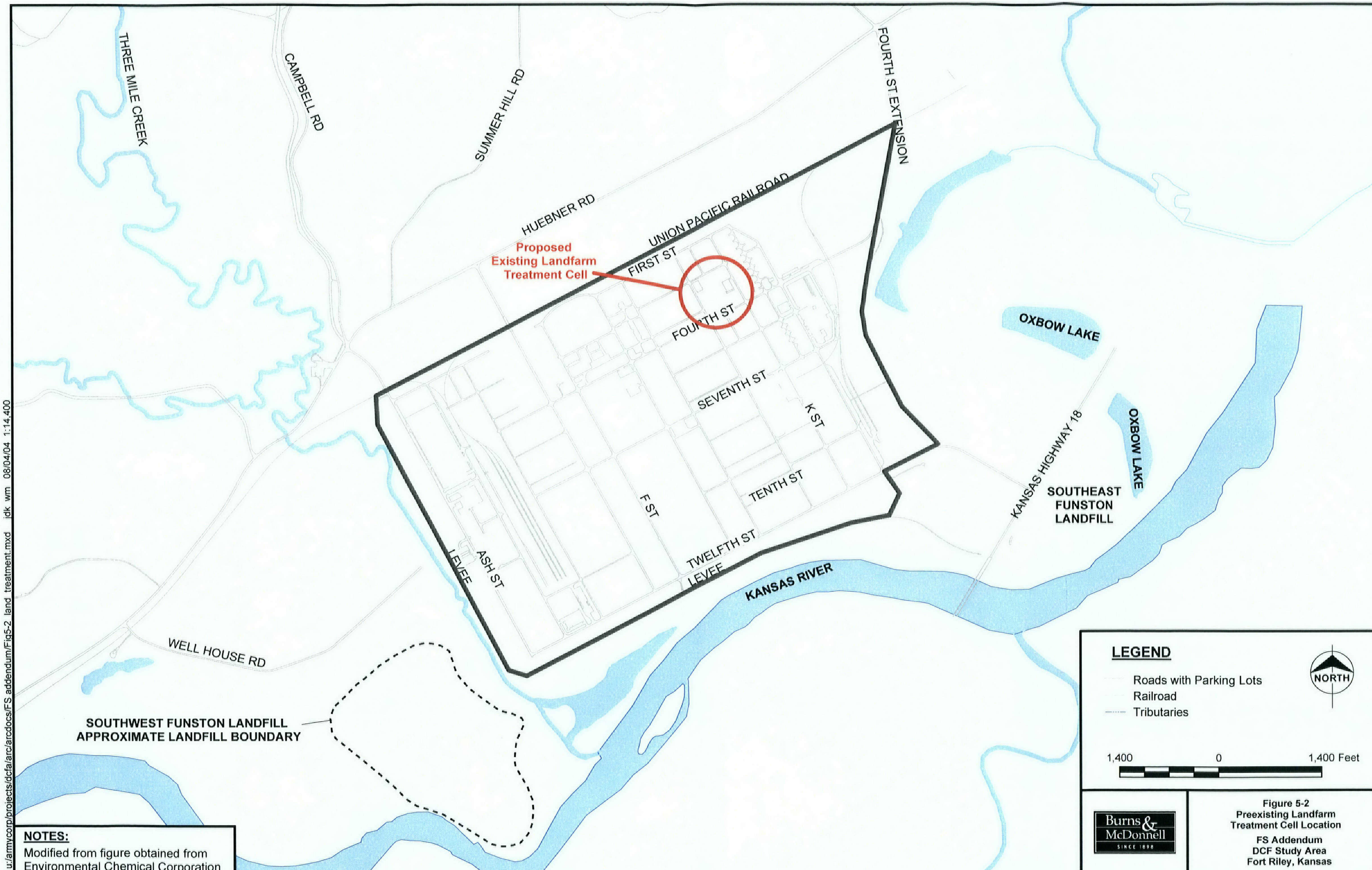

NOTES:

Modified from figure obtained from Environmental Chemical Corporation

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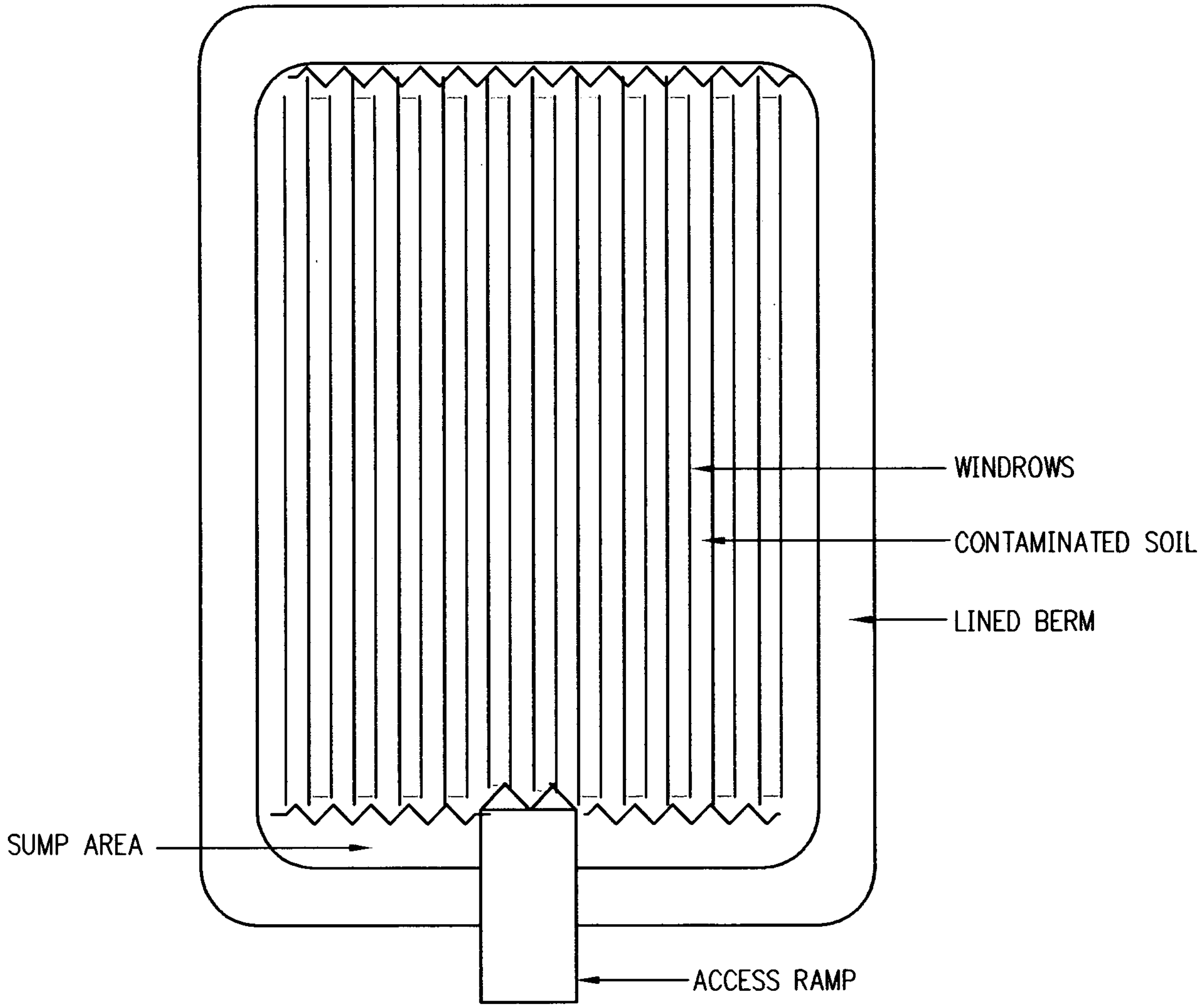
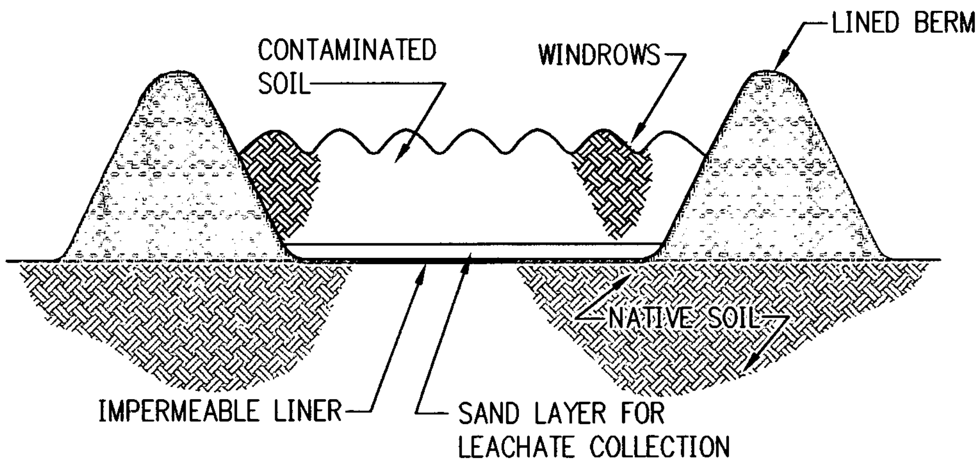
Figure 5-2
Preexisting Landfarm Treatment Cell Location

FS Addendum
DCF Study Area
Fort Riley, Kansas



PLAN VIEW
NOT TO SCALE



CROSS SECTION
NOT TO SCALE

FIGURE FOR ALTERNATIVE COMPARISON PURPOSES ONLY, NOT FOR DESIGN.

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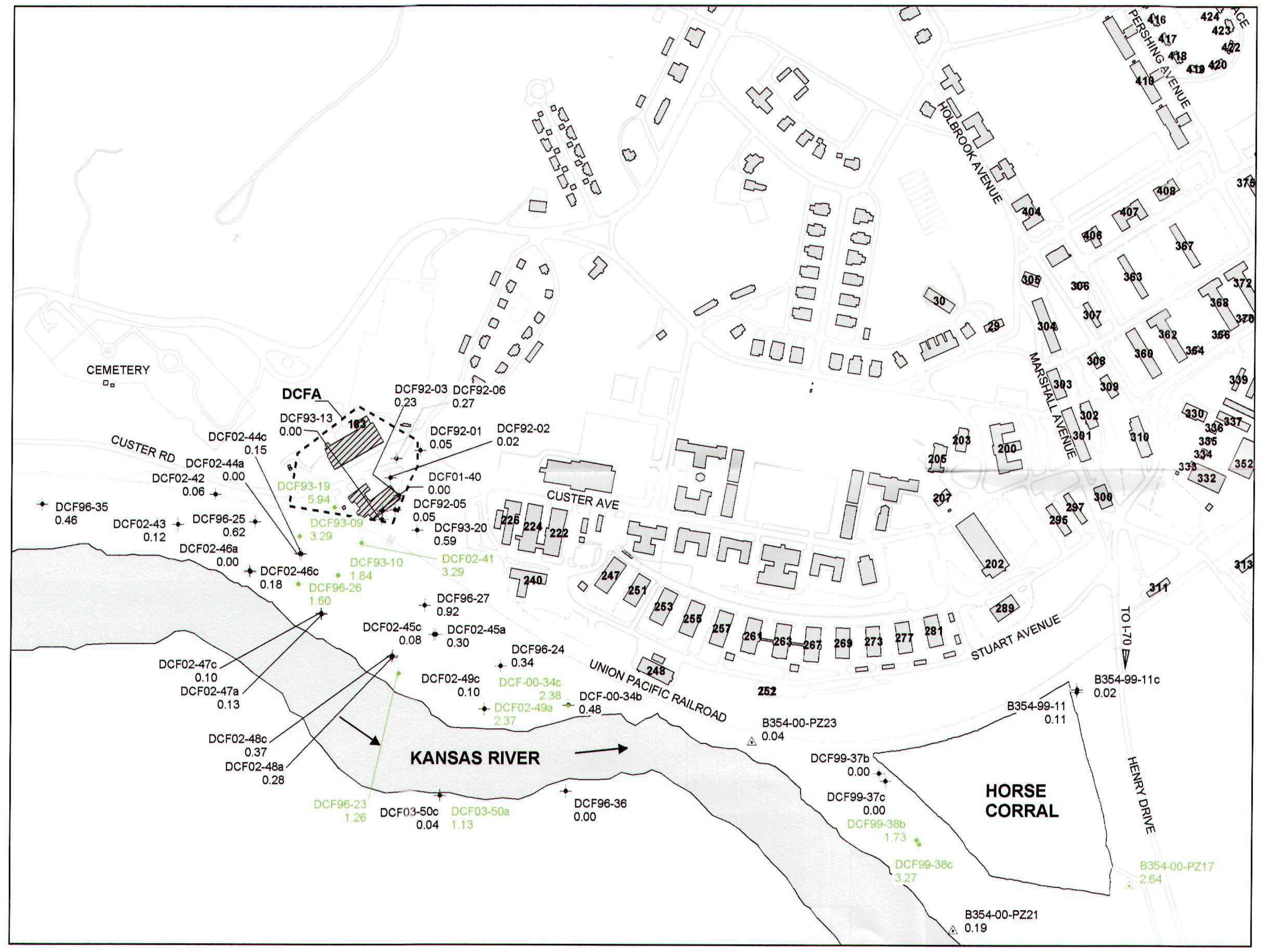
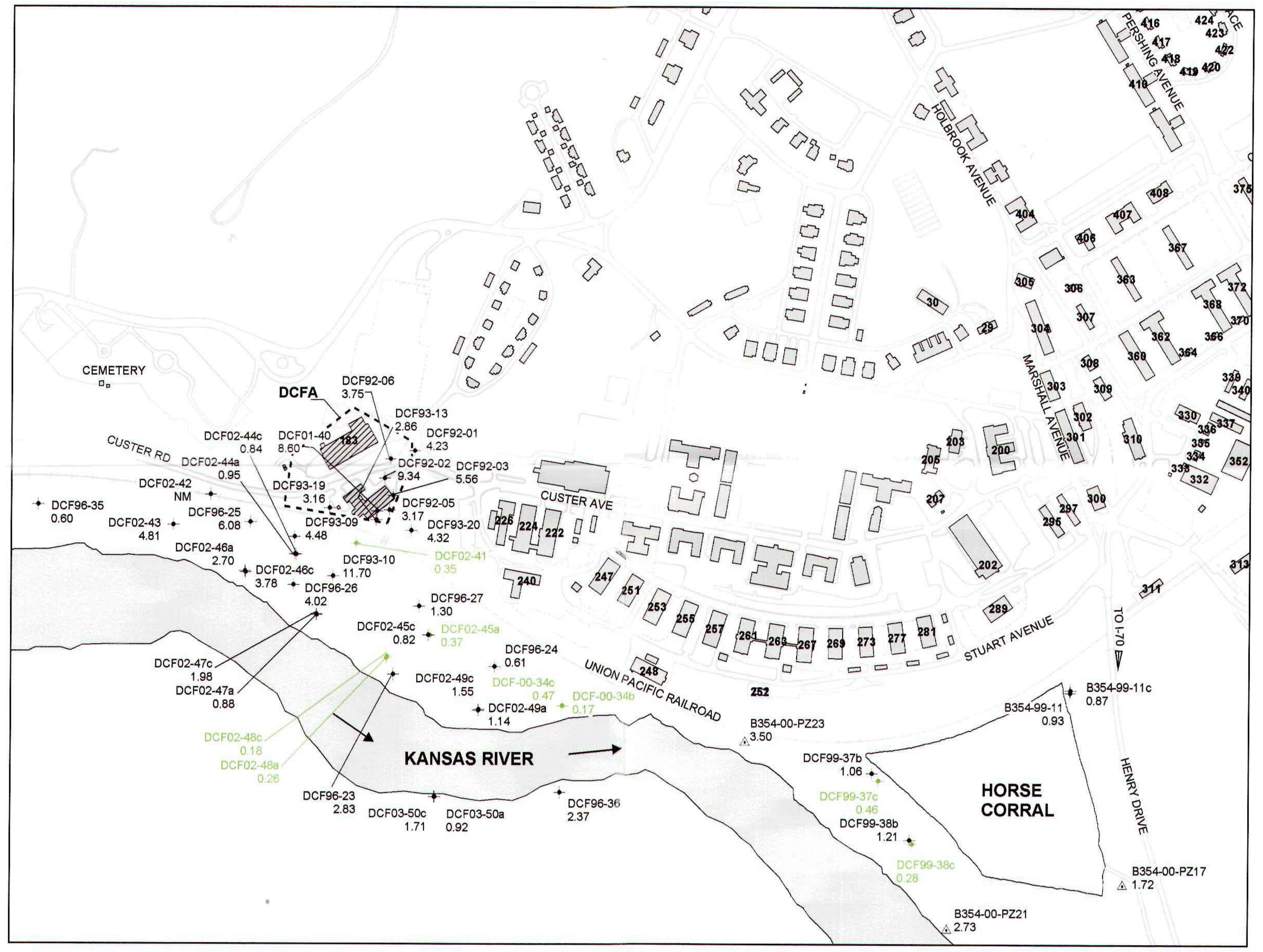
SINCE 1898

Figure 5–3

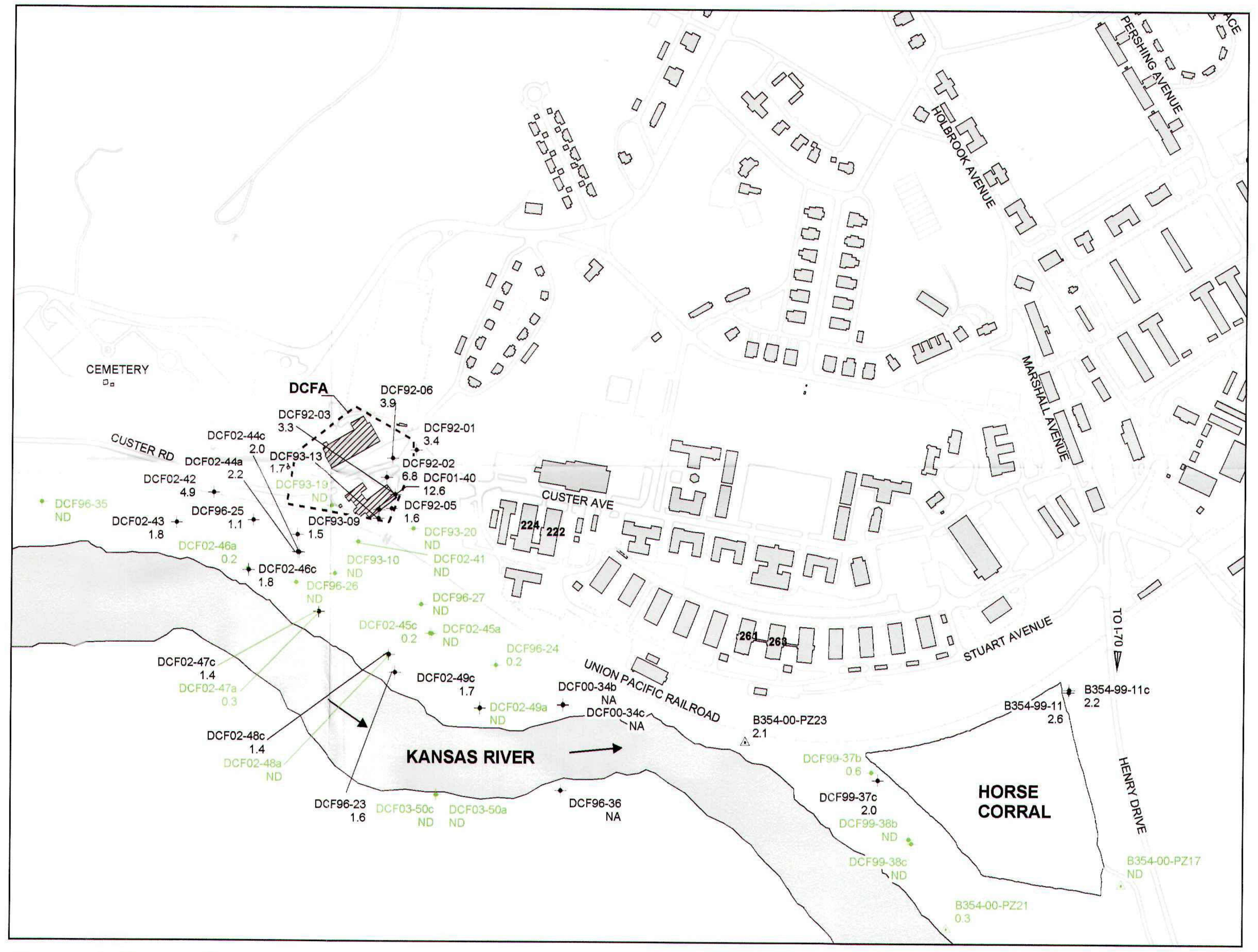
TYPICAL LANDFARM
TREATMENT CELL
FS ADDENDUM
DCF STUDY AREA



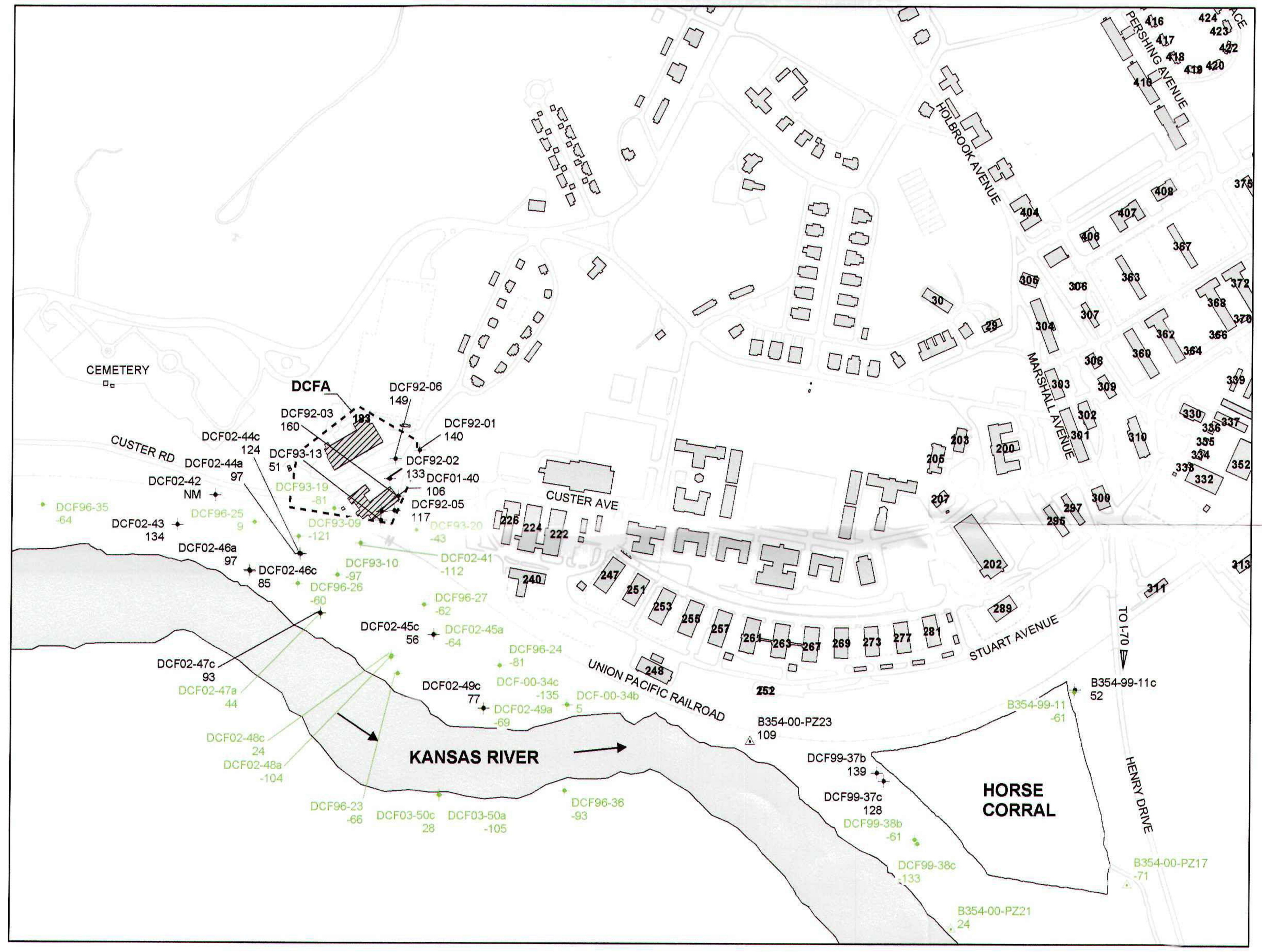
Ferrous Iron (Favorable Geochemical Condition > 1 mg/L)



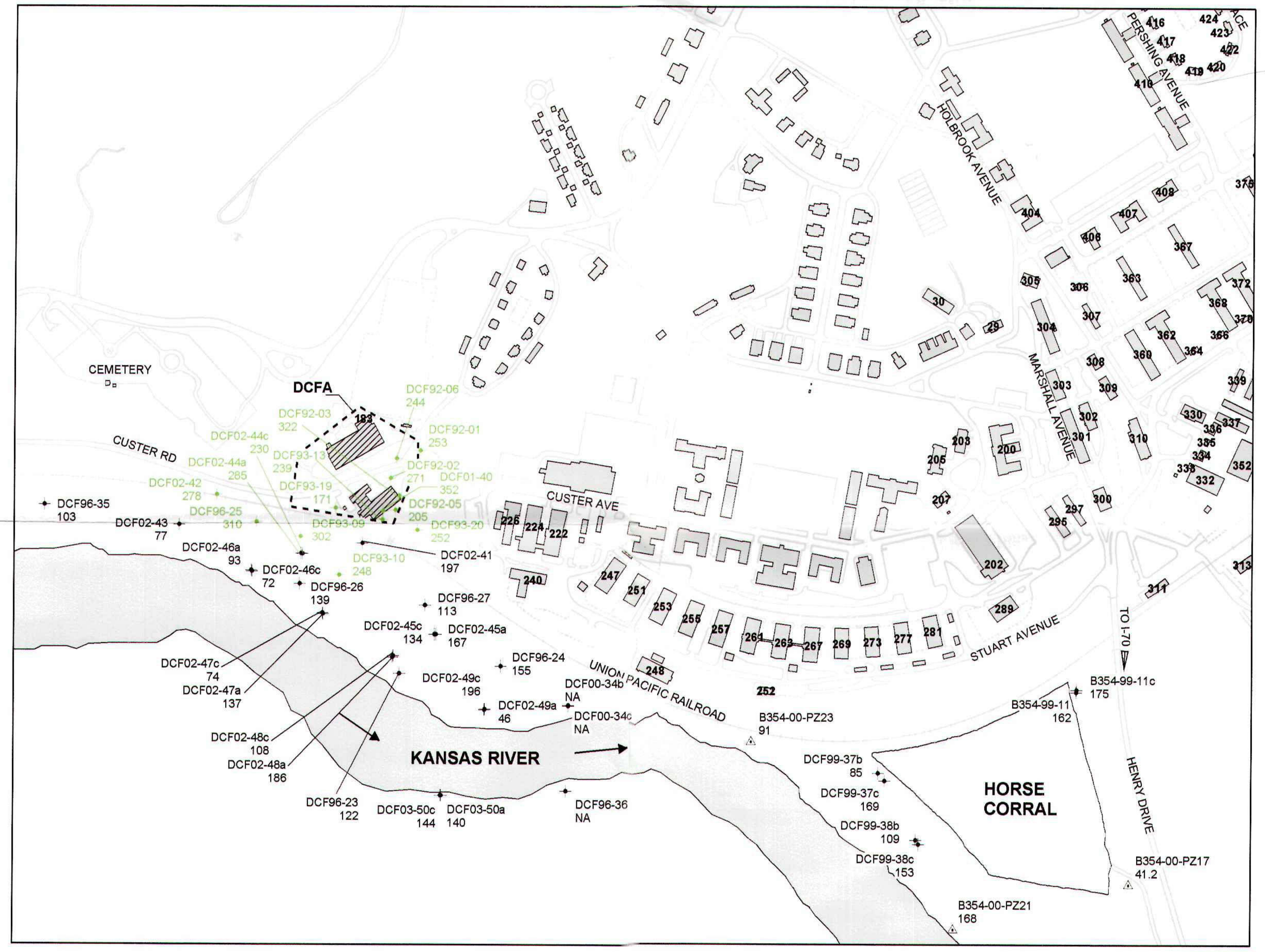
Dissolved Oxygen (Favorable Geochemical Condition < 0.5 mg/L)



Nitrate, as N (Favorable Geochemical Condition < 1 mg/L)



Oxidation/Reduction Potential (Favorable Geochemical Condition < 50mV)



Chloride (Favorable Geochemical Condition > 206 mg/L South of Railroad; > 86 mg/L North of Railroad)

LEGEND

- Monitoring Well (Favorable)
- Monitoring Well (Not Favorable)
- Piezometer (Favorable)
- Piezometer (Not Favorable)
- Road or Parking Lot
- Fence
- Railroad
- Flow Direction
- Current Building
- Former Building
- ND Not Detected
- NA Not Analyzed

NORTH

490 0 490 Feet

Burns & McDonnell

Figure 6-4
NATURAL ATTENUATION PARAMETERS
APRIL 2004
FS Addendum
DCF Study Area
Fort Riley, Kansas

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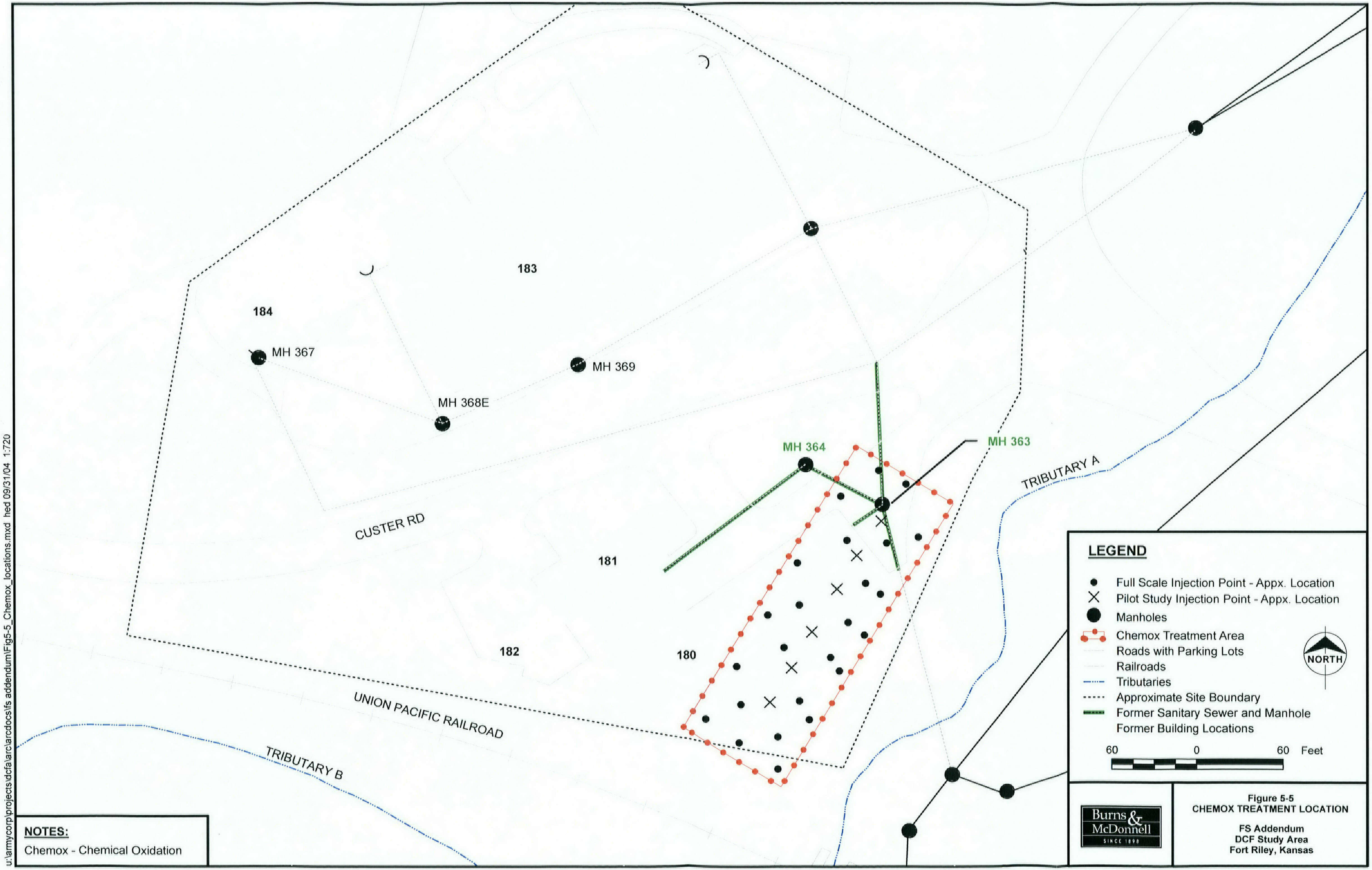

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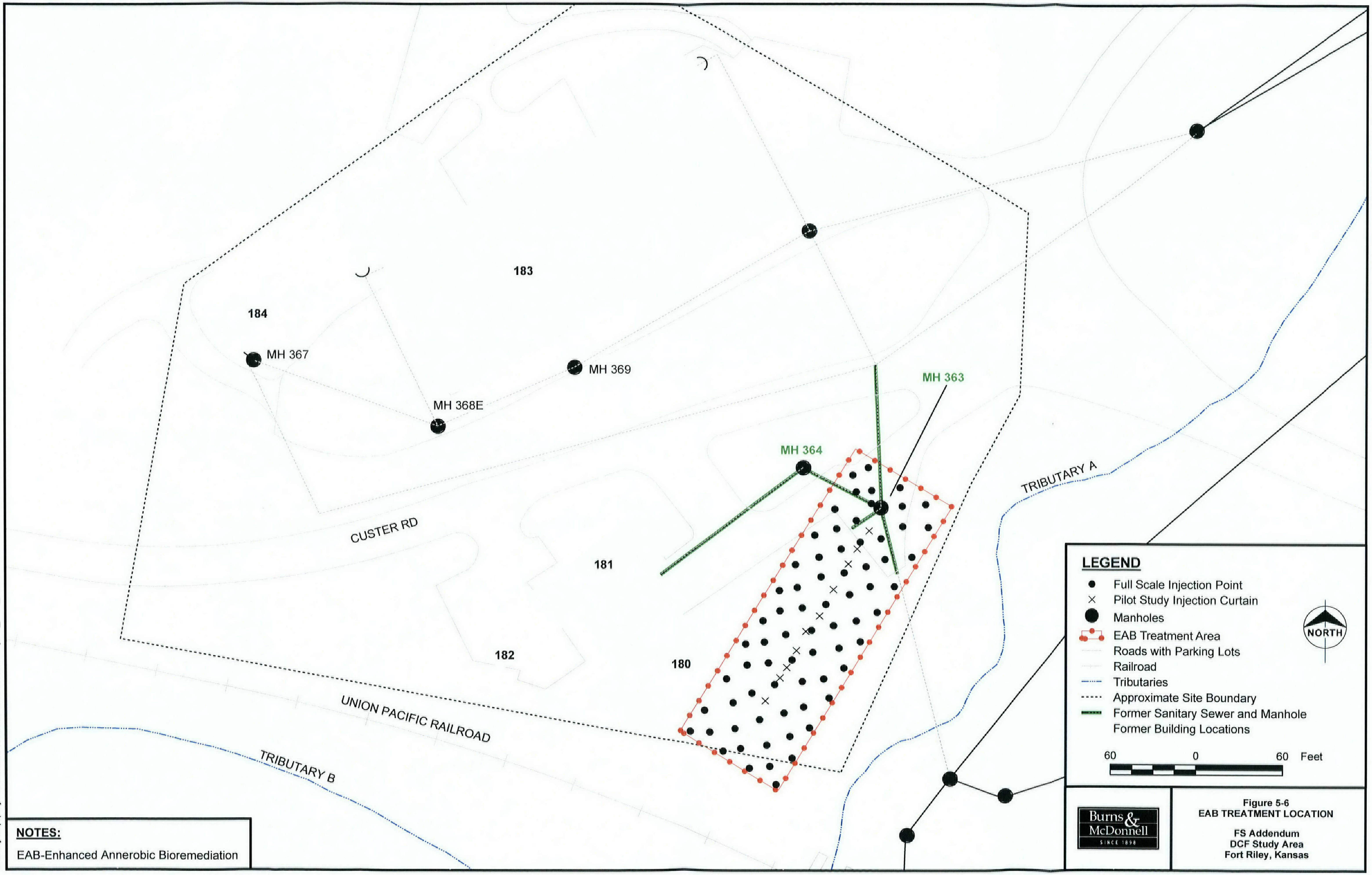

NOTES:

EAB-Enhanced Annerobic Bioremediation

Burns & McDonnell SINCE 1898

Figure 5-6
EAB TREATMENT LOCATION

FS Addendum
DCF Study Area
Fort Riley, Kansas

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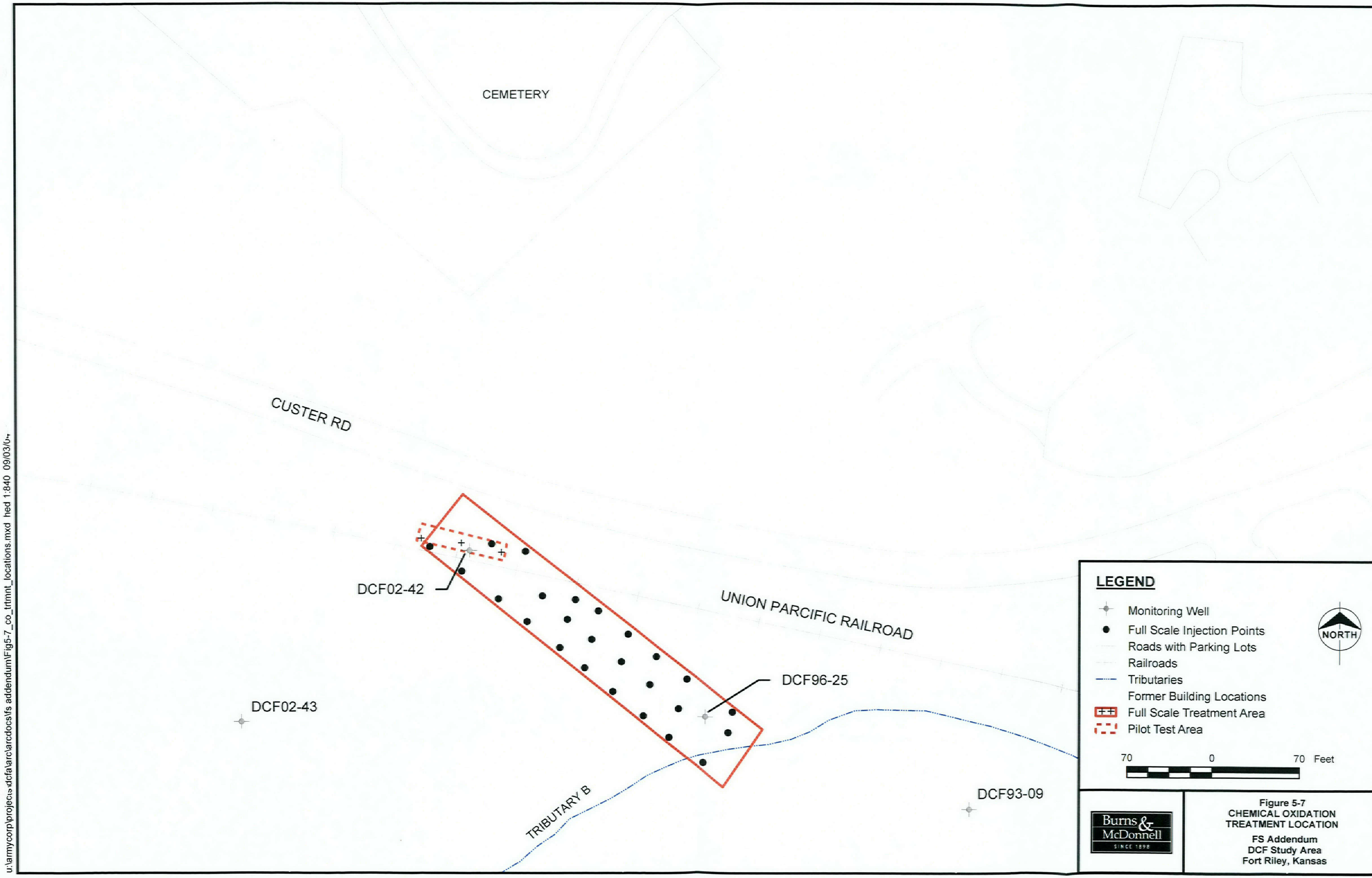

Figure 5-7
CHEMICAL OXIDATION TREATMENT LOCATION
FS Addendum
DCF Study Area
Fort Riley, Kansas

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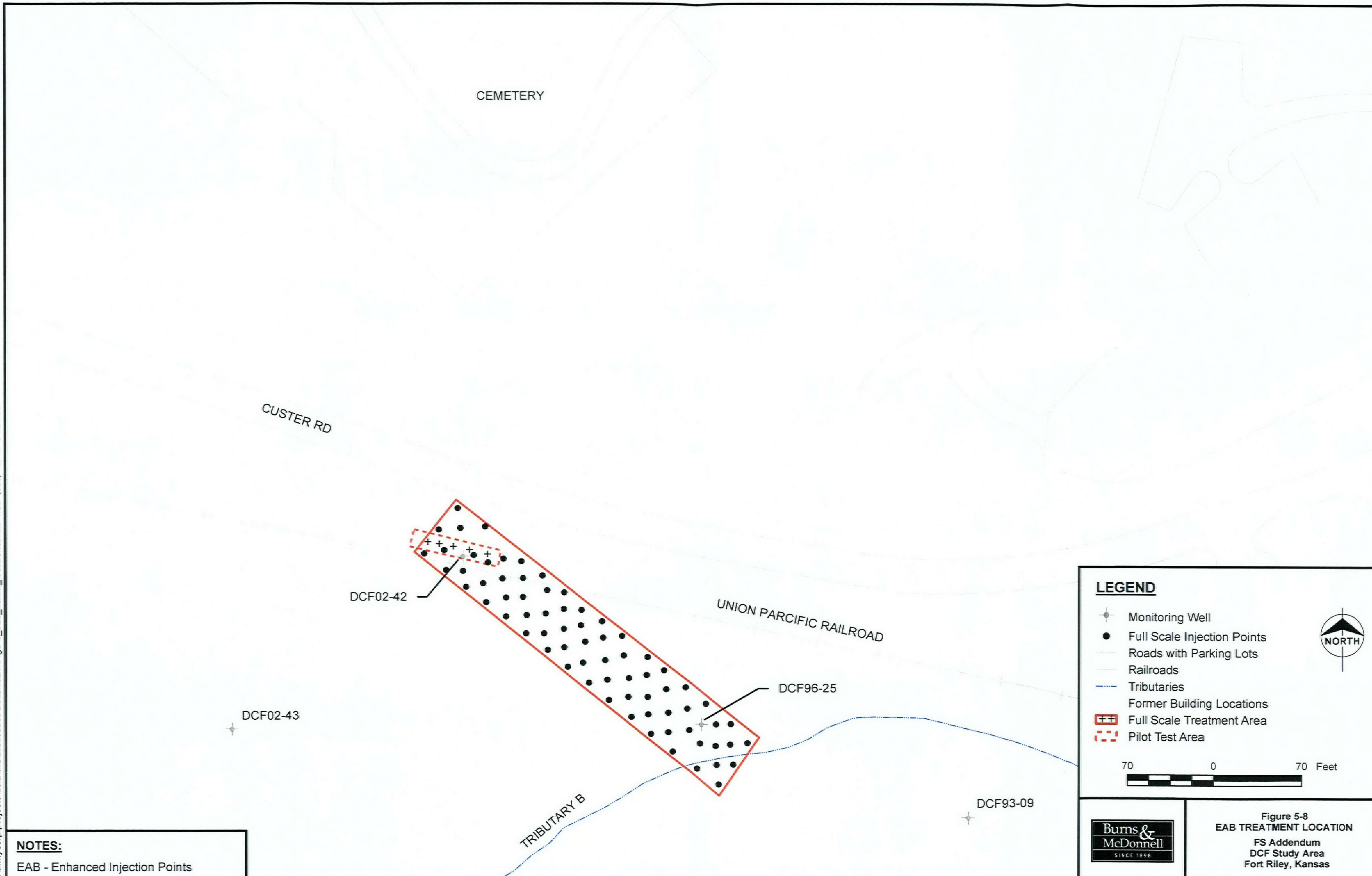

Figure 5-8
EAB TREATMENT LOCATION
FS Addendum
DCF Study Area
Fort Riley, Kansas

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Appendix 5A
Cost Analysis Tables

Table 5A-1
Cost Estimate for Alternative 1
Feasibility Study Addendum
DCF Study Area

No Action

	Description	Quantity	Unit	Unit Cost	Line Cost	Source[1]
Periodic Costs						
1.0	Five-Year Review of Remedial Action[2]	ea	1	$ 20,000.00	$ 20,000	BMcD
1.1	Groundwater Sampling[2]	ea	1	$ 100,000.00	$ 100,000	BMcD
1.2	Closure Report	ls	1	$ 30,000.00	$ 30,000	BMcD
				Subtotal Periodic Costs	**$ 150,000**	
				Contingency (20%)[3]	**$ 30,000**	
				Total Periodic Costs	**$ 180,000**	
				Total Project Cost	**$ 612,000**	
				Total Present Value Project Cost at 3.2%[4]	**$ 413,754**	

Notes:

1) BMcD costs represent estimates obtained from similar projects and/or professional experience.
2) It is assumed that five-year reviews performed under the "no action" alternative will require groundwater samples to be collected once every five years. The estimated cost of one round of groundwater sampling is assumed to be the same as described in Alternative 2 (Table 5A-3).
3) Contingency covers unknowns, unforeseen circumstances, or unanticipated conditions associated with remediation. Twenty percent is an average contingency factor (EPA, 2000a).
4) Total present value based on 20 years with 5-year reviews until closure.

BMcD Burns & McDonnell Engineering Company, Inc.
ea Each
ls Lump Sum

Table 5A-2
Present Value Costs for Alternative 1
Feasibility Study Addendum
DCF Study Area

No Action

Year	Capital Costs	Annual O&M Costs	Periodic Costs[1]	Total Cost	Discount Factor at 3.2%	Total Present Value Cost at 3.2%
0	$ -	$ -	$ -	$ -	1.000	$ -
1	$ -	$ -	$ -	$ -	0.969	$ -
2	$ -	$ -	$ -	$ -	0.939	$ -
3	$ -	$ -	$ -	$ -	0.910	$ -
4	$ -	$ -	$ -	$ -	0.882	$ -
5	$ -	$ -	$ 144,000	$ 144,000	0.854	$ 123,017
6	$ -	$ -	$ -	$ -	0.828	$ -
7	$ -	$ -	$ -	$ -	0.802	$ -
8	$ -	$ -	$ -	$ -	0.777	$ -
9	$ -	$ -	$ -	$ -	0.753	$ -
10	$ -	$ -	$ 144,000	$ 144,000	0.730	$ 105,091
11	$ -	$ -	$ -	$ -	0.707	$ -
12	$ -	$ -	$ -	$ -	0.685	$ -
13	$ -	$ -	$ -	$ -	0.664	$ -
14	$ -	$ -	$ -	$ -	0.643	$ -
15	$ -	$ -	$ 144,000	$ 144,000	0.623	$ 89,777
16	$ -	$ -	$ -	$ -	0.604	$ -
17	$ -	$ -	$ -	$ -	0.585	$ -
18	$ -	$ -	$ -	$ -	0.567	$ -
19	$ -	$ -	$ -	$ -	0.550	$ -
20	$ -	$ -	$ 180,000	$ 180,000	0.533	$ 95,869
Total	**$ -**	**$ -**	**$ 612,000**	**$ 612,000**		**$ 413,754**

Notes:

1. $144,000 includes the cost of a five-year review plus one round of groundwater sampling. $180,000 includes the cost of a five-year review, one round of groundwater sampling, and a closure report.

Table 5A-3
Area of Concern - 1
Cost Estimate for Alternative 2
Feasibility Study Addendum
DCF Study Area

Soil Excavation and Transportation to Existing 354 Treatment Cell with Institutional Controls

	Description	Quantity	Unit	Unit Cost	Line Cost	Source[1]
Capital Costs						
2.1	Institutional Controls: Groundwater Restrictions and Access Easements	Ls	1	$ 40,000.00	$ 40,000	BMcD
	Landfarming using Preexisting Treatment Cell	Ls	1	$ 107,500	$ 107,500	Vendor
				Subtotal Capital Costs	**$ 147,500**	
				Contingency (20%)[2]	**$ 29,500**	
				Total Capital Costs	**$ 177,000**	

	Description	Quantity	Unit	Unit Cost	Line Cost	Source
Periodic Costs						
2.3	Five-Year Review of Remedial Action	ea	1	$ 20,000.00	$ 20,000	BMcD
2.4	Closure Report	Ls	1	$ 30,000.00	$ 30,000	BMcD
				Subtotal Periodic Costs	**$ 50,000**	
				Contingency (20%)[2]	**$ 10,000**	
				Total Periodic Costs	**$ 60,000**	

Total Project Cost	**$ 309,000**
Total Present Value Project Cost at 3.2%[3]	**$ 261,937**

Notes:

1) BMcD costs represent estimates obtained from similar projects and/or professional experience.
2) Contingency covers unknowns, unforeseen circumstances, or unanticipated conditions associated with remediation. Twenty percent is an average contingency factor (EPA, 2000a). Contingency for future action (a component of this alternative) was not included in this cost estimate.
3) Total present value based on 20 years with 5-year reviews and monitoring until closure.

BMcD Burns & McDonnell Engineering Company, Inc.
ea Each
Ls Lump Sum

Table 5A-4
Area of Concern - 1
Cost Estimate for Alternative 2
Feasibility Study Addendum
DCF Study Area

Soil Excavation Using Existing 354 Treatment Cell

Item	Estimated Quantity	Unit Measure	Unit Price Dollars/Cents	Total Amount Dollars/Cents
Mobilization, Management Submittals, Site General Site Preparation, Site Demolition, Water Management, Reporting	1	Ls	$16,500.00	$16,500.00
Rework of Treatment Cell	1	Ls	$16,450.00	$16,450.00
Excavate, load, and Transport soil from DCFA to treatment cell.	1	Ls	$14,025.00	$14,025.00
Disk soil at treatment cell.	1	Ls	$4,350.00	$4,350.00
Load and transport soil from treatment cell to CD Landfill.	1	Ls	$11,220.00	$11,220.00
Removal of treatment cell restoration of site.	1	Ls	$10,900.00	$10,900.00
Load and transport soil from borrow source to DCFA.	1	Ls	$14,025.00	$14,025.00
Refill excavation and compact soil at DCFA	1	Ls	$4,675.00	$4,675.00
Grade and reseed excavation at the DCFA area.	1	Ls	$3,550.00	$3,550.00
Vac truck and driver for liquid IDW removal.	4	Each	$500.00	$2,000.00

Ls = Lump Sum

Base Cost	$97,695.00
Markup ay 10%	$9,769.50
Total Cost	$107,465.50

Table 5A-5
Area of Concern - 1
Present Value Costs for Alternative 2
Feasibility Study Addendum
DCF Study Area

Soil Excavation and Transportation to Preexisting Treatment Cell and Institutional Controls

Year	Capital Costs	Annual O&M Costs	Periodic Costs[1]	Total Cost	Discount Factor at 3.2%	Total Present Value Cost at 3.2%
0	$ 177,000	$ -	$ -	$ 177,000	1.000	$ 177,000
1	$ -		$ -	$ -	0.969	$ -
2	$ -		$ -	$ -	0.939	$ -
3	$ -		$ -	$ -	0.910	$ -
4	$ -		$ -	$ -	0.882	$ -
5	$ -		$ 24,000	$ 24,000	0.854	$ 20,503
6	$ -		$ -	$ -	0.828	$ -
7	$ -		$ -	$ -	0.802	$ -
8	$ -		$ -	$ -	0.777	$ -
9	$ -		$ -	$ -	0.753	$ -
10	$ -		$ 24,000	$ 24,000	0.730	$ 17,515
11	$ -		$ -	$ -	0.707	$ -
12	$ -		$ -	$ -	0.685	$ -
13	$ -		$ -	$ -	0.664	$ -
14	$ -		$ -	$ -	0.643	$ -
15	$ -		$ 24,000	$ 24,000	0.623	$ 14,963
16	$ -		$ -	$ -	0.604	$ -
17	$ -		$ -	$ -	0.585	$ -
18	$ -		$ -	$ -	0.567	$ -
19	$ -		$ -	$ -	0.550	$ -
20	$ -		$ 60,000	$ 60,000	0.533	$ 31,956
Total	**$ 177,000**	**$ -**	**$ 132,000**	**$ 309,000**		**$ 261,937**

Notes:

1. $24,000 includes the cost of a five-year review.
   $60,000 includes the cost of a five-year review and a closure report.

Table 5A-6
Area of Concern - 1
Cost Estimate for Alternative 3
Feasibility Study Addendum
DCF Study Area

Soil Excavation and Transportation to New Treatment Cell and Institutional Controls

	Description	Quantity	Unit	Unit Cost	Line Cost	Source[1]
Capital Costs						
2.1	Institutional Controls: Groundwater Restrictions and Access Easements	Ls	1	$ 40,000.00	$ 40,000	BMcD
	Landfarming using New Treatment Cell	Ls	1	$ 128,750.00	$ 128,750	Vendor
				Subtotal Capital Costs	**$ 168,750**	
				Contingency (20%)[2]	**$ 33,750**	
				Total Capital Costs	**$ 202,500**	

	Description	Quantity	Unit	Unit Cost	Line Cost	Source
Periodic Costs						
2.3	Five-Year Review of Remedial Action	ea	1	$ 20,000.00	$ 20,000	BMcD
2.4	Closure Report	Ls	1	$ 30,000.00	$ 30,000	BMcD
				Subtotal Periodic Costs	**$ 50,000**	
				Contingency (20%)[2]	**$ 10,000**	
				Total Periodic Costs	**$ 60,000**	

Total Project Cost	**$ 334,500**
Total Present Value Project Cost at 3.2%[3]	**$ 287,437**

Notes:
1) BMcD costs represent estimates obtained from similar projects, vendors, and/or professional experience.
2) Contingency covers unknowns, unforeseen circumstances, or unanticipated conditions associated with remediation. Twenty percent is an average contingency factor (EPA, 2000a).
3) Total present value based on 20 years with 5-year reviews and monitoring until closure.

BMcD Burns & McDonnell Engineering Company, Inc.
ea Each
Ls Lump Sum

Table 5A-7
Area of Concern - 1
Cost Estimate for Alternative 3
Feasibility Study Addendum
DCF Study Area

Soil Excavation Constructing New Treatment Cell

Item	Estimated Quantity	Unit Measure	Unit Price Dollars/Cents	Total Amount Dollars/Cents
Mobilization, Management Submittals, Site General Site Preparation, Site Demolition, Water Management, Reporting	1	Ls	$14,500.00	$14,500.00
Preparation & Installation of Treatment Cell	1	Ls	$37,800.00	$37,800.00
Excavate, load, and Transport soil from DCFA to treatment cell.	1	Ls	$14,025.00	$14,025.00
Disk soil at treatment cell.	1	Ls	$4,350.00	$4,350.00
Load and transport soil from treatment cell to CD Landfill.	1	Ls	$11,220.00	$11,220.00
Removal of treatment cell and restoration of site.	1	Ls	$10,900.00	$10,900.00
Load and transport soil from borrow source to DCFA.	1	Ls	$14,025.00	$14,025.00
Refill excavation and compact soil at DCFA	1	Ls	$4,675.00	$4,675.00
Grade and reseed excavation at the DCFA area.	1	Ls	$3,550.00	$3,550.00
Vac truck and driver for liquid IDW removal.	4	Each	$500.00	$2,000.00

Ls = Lump Sum

Base Cost	$117,045.00
Markup ay 10%	$11,704.50
Total Cost	$128,749.50

Table 5A-8
Area of Concern - 1
Present Value Costs for Alternative 3
Feasibility Study Addendum
DCF Study Area

Soil Excavation and Transportation to New Treatment Cell and Institutional Controls

Year	Capital Costs	Annual O&M Costs	Periodic Costs[1,2]	Total Cost	Discount Factor at 3.2%	Total Present Value Cost at 3.2%
0	$ 202,500	$ -	$ -	$ 202,500	1.000	$ 202,500
1	$ -		$ -	$ -	0.969	$ -
2	$ -		$ -	$ -	0.939	$ -
3	$ -		$ -	$ -	0.910	$ -
4	$ -		$ -	$ -	0.882	$ -
5	$ -		$ 24,000	$ 24,000	0.854	$ 20,503
6	$ -		$ -	$ -	0.828	$ -
7	$ -		$ -	$ -	0.802	$ -
8	$ -		$ -	$ -	0.777	$ -
9	$ -		$ -	$ -	0.753	$ -
10	$ -		$ 24,000	$ 24,000	0.730	$ 17,515
11	$ -		$ -	$ -	0.707	$ -
12	$ -		$ -	$ -	0.685	$ -
13	$ -		$ -	$ -	0.664	$ -
14	$ -		$ -	$ -	0.643	$ -
15	$ -		$ 24,000	$ 24,000	0.623	$ 14,963
16	$ -		$ -	$ -	0.604	$ -
17	$ -		$ -	$ -	0.585	$ -
18	$ -		$ -	$ -	0.567	$ -
19	$ -		$ -	$ -	0.550	$ -
20	$ -		$ 60,000	$ 60,000	0.533	$ 31,956
Total	**$ 202,500**	**$ -**	**$ 132,000**	**$ 334,500**		**$ 287,437**

Notes:

1. $24,000 includes the cost of a five-year review.
2. $60,000 includes the cost of a five-year review and a closure report.

Table 5A-9
Area of Concern - 1
Cost Estimate for Alternative 4
Feasibility Study Addendum
DCF Study Area

Soil Excavation and Transportation Off-site for Incineration and Institutional Controls

Description		Quantity	Unit	Unit Cost	Line Cost	Source[1]
Capital Costs						
2.1	Institutional Controls: Groundwater Restrictions and Access Easements	Ls	1	$ 40,000.00	$ 40,000	BMcD
	Excavation, Transportation, Off-site Incineration	Ls	1	$ 1,389,900.00	$ 1,389,900	

Subtotal Capital Costs	**$ 1,429,900**
Contingency (20%)[2]	**$ 285,980**
Total Capital Costs	**$ 1,715,880**

Periodic Costs						
2.3	Five-Year Review of Remedial Action	ea	1	$ 20,000.00	$ 20,000	BMcD
2.4	Closure Report	Ls	1	$ 30,000.00	$ 30,000	BMcD

Subtotal Periodic Costs	**$ 50,000**
Contingency (20%)[2]	**$ 10,000**
Total Periodic Costs	**$ 60,000**
Total Project Cost	**$ 1,847,880**
Total Present Value Project Cost at 3.2%[3]	**$ 1,800,817**

Notes:

1) BMcD costs represent estimates obtained from similar projects and/or professional experience.
2) Contingency covers unknowns, unforeseen circumstances, or unanticipated conditions associated with remediation. Twenty percent is an average contingency factor (EPA, 2000a). Contingency for future action (a component of this alternative) was not included in this cost estimate.
3) Total present value based on 20 years with 5-year reviews and monitoring until closure.

BMcD Burns & McDonnell Engineering Company, Inc.
ea Each
Ls Lump Sum

Table 5A-10
Area of Concern - 1
Cost Estimate for Alternative 4
Feasibility Study Addendum
DCF Study Area

Soil Excavation with Off-site Incineration and Landfarm Disposal

Item	Estimated Quantity	Unit Measure	Unit Price Dollars/Cents	Total Amount Dollars/Cents	Comments
Workplan and coordination	Ls	*	*	$33,000.00	
Excavation and Loading	Ls	*	*	$14,025.00	
Disposal	Ton	2,589	$280.00	$724,920.00	1 cubic yard = 1 ton
Soil Transportation	Load	173	$2,120.00	$366,760.00	1 load = 15 tons
Drop Fee	Ls	*	*	$5,100.00	
Rolloff box rental	Day	173	$12.00	$2,076.00	2589/15=173
Truck Liner	Each	173	$65.00	$11,245.00	New liner for each load
Demurrage[1]	Hour	87	$95.00	$8,265.00	0.5 hour per load
Site Report	Ls	*	*	$33,000.00	
Energy Recovery Fee[2]	Ls	*	*	$65,140.00	5.5% of total invoice
			Subtotal	$1,263,531	
			10% Markup	$126,353	
			Total	$1,389,884	

1). Demurrage is calculated as the number of hours truck driver is on site loading material.
2). Energy recovery fee is calculated at 5.5% of total invoice.
Ls - Lump sum
* - Not applicable
Cost are for removal of soil off-site for incineration at Clean Harbors Kimball Facility Site in Kimball, Nebraska.

Table 5A-11
Area of Concern - 1
Present Value Costs for Alternative 4
Feasibility Study Addendum
DCF Study Area

Soil Excavation and Transportation Offsite for Incineration and Institutional Controls

Year	Capital Costs	Annual O&M Costs	Periodic Costs[1,2]	Total Cost	Discount Factor at 3.2%	Total Present Value Cost at 3.2%
0	$ 1,715,880	$ -	$ -	$ 1,715,880	1.000	$ 1,715,880
1	$ -		$ -	$ -	0.969	$ -
2	$ -		$ -	$ -	0.939	$ -
3	$ -		$ -	$ -	0.910	$ -
4	$ -		$ -	$ -	0.882	$ -
5	$ -		$ 24,000	$ 24,000	0.854	$ 20,503
6	$ -		$ -	$ -	0.828	$ -
7	$ -		$ -	$ -	0.802	$ -
8	$ -		$ -	$ -	0.777	$ -
9	$ -		$ -	$ -	0.753	$ -
10	$ -		$ 24,000	$ 24,000	0.730	$ 17,515
11	$ -		$ -	$ -	0.707	$ -
12	$ -		$ -	$ -	0.685	$ -
13	$ -		$ -	$ -	0.664	$ -
14	$ -		$ -	$ -	0.643	$ -
15	$ -		$ 24,000	$ 24,000	0.623	$ 14,963
16	$ -		$ -	$ -	0.604	$ -
17	$ -		$ -	$ -	0.585	$ -
18	$ -		$ -	$ -	0.567	$ -
19	$ -		$ -	$ -	0.550	$ -
20	$ -		$ 60,000	$ 60,000	0.533	$ 31,956
Total	**$ 1,715,880**	**$ -**	**$ 132,000**	**$ 1,847,880**		**$ 1,800,817**

Notes:

1. $24,000 includes the cost of a five-year review.
2. $60,000 includes the cost of a five-year review and a closure report.

Table 5A-12
Area of Concern -2
Cost Estimate for Chemical Oxidation
Feasibility Study Addendum
DCF Study Area

Chemical Oxidation for Groundwater in the Monitoring Well DCF01-40 Area

	Description	Quantity	Unit	Unit Cost	Line Cost	Source[1]
Capital Costs						
1.1	Engineering and Design for Benchscale & Pilot test, plus permitting	ls	1	$ 15,000	$ 15,000	BMcD
1.2	Bench-scale testing					
	Field sample collection	ls	1	$ 5,000	$ 5,000	BMcD
	Laboratory Testing	ls	1	$ 10,000	$ 10,000	BMcD
1.3	Pilot test to determine spacing, application rate, and other design parameters.[2]					
	Clear Utilities	ls	1	$ 600	$ 600	BMcD
	Geoprobe/injection equipment	day	2	$ 15,000	$ 30,000	BMcD
	KMnO4 cost (est. 6 probes, 1000 lb each)	lbs	6,000	$ 1.50	$ 9,000	BMcD
	Technology vendor charges/license fees	ls	1	$ 5,000	$ 5,000	BMcD
	Field Oversight and Logistics (60 hr)	ls	1	$ 6,000	$ 6,000	BMcD
	Sampling, 1 existing monitoring wells plus temporary wells (bi-monthly for 12 months)					
	VOCs, ORP, other parameters	ea	24	$ 500	$ 12,000	BMcD
	Labor (6 events - est. 120 man-hour)	ls	1	$ 12,000	$ 12,000	BMcD
	Vehicle/mileage	trip	6	$ 200	$ 1,200	BMcD
	Interpret results and pilot test report	ls	1	$ 21,000	$ 21,000	BMcD
1.4	Full-Scale Engineering & Design, plus permitting	ls	1	$ 80,000	$ 80,000	BMcD
1.5	Full Scale Treatment[3]					
	Clear Utilities	ls	1	$ 600	$ 600	BMcD
	KMnO4 cost (30 probes, 1000lb each)	lb	30,000	$ 1.50	$ 45,000	BMcD
	Technology vendor charges/license fees	ls	1	$ 20,000.00	$ 20,000	BMcD
	Geoprobe/injection equipment	day	10	$ 10,000.00	$ 100,000	BMcD
	Field Oversight (10 days).					
	Labor (2 man crew)	day	10	$ 2,000	$ 20,000	BMcD
	Per Diem	day	10	$ 100	$ 1,000	BMcD
	Pickup Truck/mileage	day	10	$ 100	$ 1,000	BMcD
	Sampling, 4 existing monitoring wells (bi-monthly for 12 months)[4]					
	VOCs, ORP, other parameters	ea	24	$ 500	$ 12,000	BMcD
	Labor (6 events - est. 120 man-hour)	ls	1	$ 12,000	$ 12,000	BMcD
	Vehicle/mileage	trip	6	$ 200	$ 1,200	BMcD

Subtotal Capital Costs	**$ 419,600**
Contingency (20%)[5]	**$ 83,920**
Total Capital Costs	**$ 503,520**

Table 5A-12 (Continued)
Cost Estimate for Chemical Oxidation
Feasibility Study Addendum
DCF Study Area

Chemical Oxidation for Groundwater in the Monitoring Well DCF01-40 Area

Annual Operation and Maintenance (O&M) Costs						
	Semiannual Groundwater Monitoring	ea	1	$99,480	99,480	BMcD

Subtotal O&M Costs	**$**	**99,480**
Contingency (20%)	**$**	**19,896**
Total O&M Costs	**$**	**119,376**

Periodic Costs						
4.9	Reinjection at 2 years	ls	1	$ 125,000	$ 125,000	BMcD
4.10	Five-Year Review of Remedial Action	ea	1	$ 24,000	$ 24,000	BMcD
4.11	Closure Report	ls	1	$ 36,000	$ 36,000	BMcD

Subtotal Periodic Costs	**$**	**185,000**
Contingency (20%)	**$**	**37,000**
Total Periodic Costs	**$**	**222,000**

Total Project Cost	**$2,750,120**
Total Present Value Project Cost at 3.2% Cost	**$2,158,837**

Notes:

1. BMcD costs represent estimates obtained from similar projects and/or professional experience.
2. Estimate covers 6 injection points/fractures for the pilot study. The 6 injection points/fractures will be installed on 20-ft spacing downgradient of MW02-42 with 1,000 lb of KMnO4 per location.
3. Estimate covers the injection of sufficient KMnO4 to treat a 50-ft by 150-ft area in the vicinity of MW01-40. Estimate is based on 30 injection points with 1,000 lb per location. Injection/fracture locations will be based on pilot test results and site access. KMnO4 mass needed will be determined during bench-scale.
4. Contingency covers unknowns, unforeseen circumstances, or unanticipated conditions associated with remediation. Twenty percent is an average contingency factor (EPA, 2000a).

BMcD - Burns & McDonnell Engineering Company, Inc.
ea - each
ft - foot
hr - hour
lb - pound
ls - lump sum
VOC - volatile organic compound
MW- Monitoring Well
KMnO4- Potassium Permanganate
EPA- Environmental Protection Agency

Table 5A-13
Area of Concern -2
Present Value Costs for Alternative 2 - Chemox
Feasibility Study Addendum
DCF Study Area

In-Situ Chemical Oxidation with Institutional Controls and Monitored Natural Attenuation

Year	Capital Costs	Annual O&M Costs[1]	Periodic Costs[2]	Total Cost	Discount Factor at 3.2%	Total Present Value Cost at 3.2%
0	$ 503,520	$ -	$ -	$ 503,520	1.000	$ 503,520
1	$ -	$ 99,480	$ -	$ 99,480	0.969	$ 96,395
2	$ -	$ 99,480	$ 125,000	$ 224,480	0.939	$ 210,775
3	$ -	$ 99,480	$ -	$ 99,480	0.910	$ 90,510
4	$ -	$ 99,480	$ -	$ 99,480	0.882	$ 87,704
5	$ -	$ 99,480	$ 24,000	$ 123,480	0.854	$ 105,487
6	$ -	$ 99,480	$ -	$ 99,480	0.828	$ 82,349
7	$ -	$ 99,480	$ -	$ 99,480	0.802	$ 79,795
8	$ -	$ 99,480	$ -	$ 99,480	0.777	$ 77,321
9	$ -	$ 99,480	$ -	$ 99,480	0.753	$ 74,924
10	$ -	$ 99,480	$ 24,000	$ 123,480	0.730	$ 90,116
11	$ -	$ 99,480	$ -	$ 99,480	0.707	$ 70,349
12	$ -	$ 99,480	$ -	$ 99,480	0.685	$ 68,168
13	$ -	$ 99,480	$ -	$ 99,480	0.664	$ 66,054
14	$ -	$ 99,480	$ -	$ 99,480	0.643	$ 64,006
15	$ -	$ 99,480	$ 24,000	$ 123,480	0.623	$ 76,984
16	$ -	$ 99,480	$ -	$ 99,480	0.604	$ 60,098
17	$ -	$ 99,480	$ -	$ 99,480	0.585	$ 58,235
18	$ -	$ 99,480	$ -	$ 99,480	0.567	$ 56,429
19	$ -	$ 99,480	$ -	$ 99,480	0.550	$ 54,679
20	$ -	$ 99,480	$ 60,000	$ 159,480	0.533	$ 84,940
Total	**$ 503,520**	**$ 1,989,600**	**$ 257,000**	**$ 2,750,120**		**$ 2,158,837**

Notes:

1. It is assumed that groundwater monitoring will be performed annually.
2. $24,000 included the cost of a five-year review. $60,000 includes the cost of a five-year review and a closure report. Periodic cost of $125,000 is for second injection.

Table 5A-14
Area of Concern - 2
Cost Estimate for Enhanced Anerobic Bioremediation
Feasibility Study Addendum
DCF Study Area

Anerobic Bioremediation Enhancement for Groundwater in the Monitoring Well DCF01-40 Area.

	Description	Quantity	Unit	Unit Cost	Line Cost	Source[1]
Capital Costs						
1.1	Engineering and Design for Benchscale & Pilot test, plus permitting	ls	1	$ 15,000	$ 15,000	BMcD
1.2	Bench-scale testing					
	Field sample collection	ls	1	$ 5,000	$ 5,000	BMcD
	Laboratory Testing	ls	1	$ 10,000	$ 10,000	BMcD
1.3	Pilot test to determine spacing, application rate, and other design parameters.[2]					
	Clear Utilities	ls	1	$ 600	$ 600	BMcD
	Geoprobe/injection equipment	day	2	$ 2,000	$ 4,000	BMcD
	Vegetable oil (est. 10 probes, 15 lb/ft, 10 ft. thick)	lbs	1,500	$ 1.00	$ 1,500	BMcD
	Technology vendor charges/license fees	ls	1	$ 5,000	$ 5,000	BMcD
	Field Oversight and Logistics (40 hr)	ls	1	$ 4,000	$ 4,000	BMcD
	Sampling, 2 existing monitoring wells (month 1@2 times, then monthly for 6 months)					
	VOCs, MNA parameters	ea	16	$ 500	$ 8,000	BMcD
	Labor (8 events - est. 100 man-hour)	ls	1	$ 10,000	$ 10,000	BMcD
	Vehicle/mileage	trip	8	$ 200	$ 1,600	BMcD
	Interpret results and pilot test report	ls	1	$ 21,000	$ 21,000	BMcD
1.4	Full-Scale Engineering & Design, plus permitting	ls	1	$ 50,000	$ 50,000	
1.5	Full Scale Treatment[3]					
	Clear Utilities	ls	1	$ 600	$ 600	BMcD
	Vegetable oil cost (75 probes, 15lb/ft, 10 ft thick)	lb	11,250	$ 1.00	$ 11,250	BMcD
	Technology vendor charges/license fees	ls	1	$ 20,000.00	$ 20,000	
	Geoprobe/injection equipment	day	15	$ 2,000.00	$ 30,000	
	Field Oversight (15 days).					
	Labor (2 man crew)	day	15	$ 2,000	$ 30,000	BMcD
	Per Diem	day	15	$ 100	$ 1,500	BMcD
	Pickup Truck/mileage	day	15	$ 100	$ 1,500	BMcD
	Sampling, 4 existing monitoring wells (monthly for 6 months)[4]					
	VOCs, MNA parameters	ea	24	$ 500	$ 12,000	BMcD
	Labor (6 events - est. 120 man-hour)	ls	1	$ 12,000	$ 12,000	BMcD
	Vehicle/mileage	trip	6	$ 200	$ 1,200	BMcD

Subtotal Capital Costs	**$**	**255,750**
Contingency (20%)[5]	**$**	**51,150**
Total Capital Costs	**$**	**306,900**

Table 5A-14 (Continued)
Cost Estimate for Enhanced Anerobic Bioremediation
Feasibility Study Addendum
DCF Study Area

Anerobic Bioremediation Enhancement for Groundwater in the Monitoring Well DCF01-40 Area.

Annual Operation and Maintenance (O&M) Costs						
	Semiannual Groundwater Monitoring	ea	1	$99,480	99,480	BMcD

Subtotal Periodic Costs $ 99,480
Contingency (20%)[5] $ 19,896
Total Periodic Costs $ 119,376

Periodic Costs						
4.9	Reinjection at 2 years	ls	1	$ 120,050	$ 120,050	BMcD
4.10	Five-Year Review of Remedial Action	ea	1	$ 24,000	$ 24,000	BMcD
4.11	Closure Report	ls	1	$ 36,000	$ 36,000	BMcD

Subtotal Periodic Costs $ 180,050
Contingency (20%)[5] $ 36,010
Total Periodic Costs $ 216,060

Total Project Cost $2,548,550
Total Present Value Project Cost at 3.2% Cost $1,957,569

Notes:
1. BMcD costs represent estimates obtained from similar projects and/or professional experience.
2. It assumed that a partial curtain will be used for the pilot study. This estimate is based on ten injection points (100-ft wide spaced on 10-ft centers) and an assumed vegetable oil application amount of 15 lbs per vertical ft and 10-ft saturated thickness.
3. It assumed that an injection grid will be used. Injection will be applied over a 225-ft by 75-ft area with 10-ft thickness. Estimate is based on 75 injection points (spaced on 15-ft centers) and an assumed 15 pounds per vertical ft (8-ft saturated thickness) vegetable application rate.
4. Assumes a monitored natural attentuation monitoring well network and sampling protocol already exist and is covered under the cost associated with Alternative 2.
5. Contingency covers unknowns, unforeseen circumstances, or unanticipated conditions associated with remediation. Twenty percent is an average contingency factor (EPA, 2000a).

BMcD - Burns & McDonnell Engineering Company, Inc.
ea - each
ft - foot
hr - hour
lb - pound
ls - lump sum
MNA - monitored natural attenuation
VOC - volatile organic compound
EPA- Environmental Protection Agency

Table 5A-15
Area of Concern -2
Present Value Costs for Alternative 3 - Enhanced Anaerobic Bioremediation
Feasibility Study Addendum
DCF Study Area

Enhanced Anaerobic Bioremediation with Institutional Controls and Monitored Natural Attenuation

Year	Capital Costs	Annual O&M Costs[1,2]	Periodic Costs[3]	Total Cost	Discount Factor at 3.2%	Total Present Value Cost at 3.2%
0	$ 306,900	$ -	$ -	$ 306,900	1.000	$ 306,900
1	$ -	$ 99,480	$ -	$ 99,480	0.969	$ 96,395
2	$ -	$ 99,480	$ 120,050	$ 219,530	0.939	$ 206,127
3	$ -	$ 99,480	$ -	$ 99,480	0.910	$ 90,510
4	$ -	$ 99,480	$ -	$ 99,480	0.882	$ 87,704
5	$ -	$ 99,480	$ 24,000	$ 123,480	0.854	$ 105,487
6	$ -	$ 99,480	$ -	$ 99,480	0.828	$ 82,349
7	$ -	$ 99,480	$ -	$ 99,480	0.802	$ 79,795
8	$ -	$ 99,480	$ -	$ 99,480	0.777	$ 77,321
9	$ -	$ 99,480	$ -	$ 99,480	0.753	$ 74,924
10	$ -	$ 99,480	$ 24,000	$ 123,480	0.730	$ 90,116
11	$ -	$ 99,480	$ -	$ 99,480	0.707	$ 70,349
12	$ -	$ 99,480	$ -	$ 99,480	0.685	$ 68,168
13	$ -	$ 99,480	$ -	$ 99,480	0.664	$ 66,054
14	$ -	$ 99,480	$ -	$ 99,480	0.643	$ 64,006
15	$ -	$ 99,480	$ 24,000	$ 123,480	0.623	$ 76,984
16	$ -	$ 99,480	$ -	$ 99,480	0.604	$ 60,098
17	$ -	$ 99,480	$ -	$ 99,480	0.585	$ 58,235
18	$ -	$ 99,480	$ -	$ 99,480	0.567	$ 56,429
19	$ -	$ 99,480	$ -	$ 99,480	0.550	$ 54,679
20	$ -	$ 99,480	$ 60,000	$ 159,480	0.533	$ 84,940
Total	**$ 306,900**	**$ 1,989,600**	**$ 252,050**	**$ 2,548,550**		**$ 1,957,569**

Notes:

1. It is assumed that groundwater monitoring will be performed annually.
2. It is assumed that enhanced bioremediation will treat dissolved contamination; however, it is conservately assumed there will be some source material that is not treated and this results in rebound of very low contamination, such that continued monitoring is required.
3. $24,000 included the cost of a five-year review. $60,000 includes the cost of a five-year review and a closure report. $120,050 includes cost of reinjection.

Table 5A-16
Area of Concern - 3
Cost Estimate for Chemical Oxidation
Feasibility Study Addendum
DCF Study Area

Chemical Oxidation for Groundwater in the Monitoring Well DCF02-42 Area

	Description	Quantity	Unit	Unit Cost	Line Cost	Source[1]
Capital Costs						
1.1	Engineering and Design for Benchscale & Pilot test, plus permitting	ls	1	$ 15,000	$ 15,000	BMcD
1.2	Bench-scale testing					
	Field sample collection	ls	1	$ 5,000	$ 5,000	BMcD
	Laboratory Testing	ls	1	$ 10,000	$ 10,000	BMcD
1.3	Pilot test to determine spacing, application rate, and other design parameters.[2]					
	Clear Utilities	ls	1	$ 600	$ 600	BMcD
	Geoprobe/injection equipment	day	2	$ 15,000	$ 30,000	BMcD
	KMnO4 cost (est. 3 probes, 1000 lb each)	lbs	3,000	$ 1.50	$ 4,500	BMcD
	Technology vendor charges/license fees	ls	1	$ 5,000	$ 5,000	BMcD
	Field Oversight and Logistics (60 hr)	ls	1	$ 6,000	$ 6,000	BMcD
	Sampling, 1 existing monitoring wells plus temporary wells (bi-monthly for 12 months)					
	VOCs, ORP, other parameters	ea	24	$ 500	$ 12,000	BMcD
	Labor (6 events - est. 120 man-hour)	ls	1	$ 12,000	$ 12,000	BMcD
	Vehicle/mileage	trip	6	$ 200	$ 1,200	BMcD
	Interpret results and pilot test report	ls	1	$ 21,000	$ 21,000	BMcD
1.4	Full-Scale Engineering & Design, plus permitting	ls	1	$ 80,000	$ 80,000	BMcD
1.5	Full Scale Treatment[3]					
	Clear Utilities	ls	1	$ 600	$ 600	BMcD
	KMnO4 cost (25 probes, 1000lb each)	lb	25,000	$ 1.50	$ 37,500	BMcD
	Technology vendor charges/license fees	ls	1	$ 20,000.00	$ 20,000	BMcD
	Geoprobe/injection equipment	day	10	$ 10,000.00	$ 100,000	BMcD
	Field Oversight (10 days).					
	Labor (2 man crew)	day	10	$ 2,000	$ 20,000	BMcD
	Per Diem	day	10	$ 100	$ 1,000	BMcD
	Pickup Truck/mileage	day	10	$ 100	$ 1,000	BMcD
	Sampling, 4 existing monitoring wells (bi-monthly for 12 months)[4]					
	VOCs, ORP, other parameters	ea	24	$ 500	$ 12,000	BMcD
	Labor (6 events - est. 120 man-hour)	ls	1	$ 12,000	$ 12,000	BMcD
	Vehicle/mileage	trip	6	$ 200	$ 1,200	BMcD

Subtotal Capital Costs	**$ 407,600**
Contingency (20%)[5]	**$ 81,520**
Total Capital Costs	**$ 489,120**

Table 5A-16
Cost Estimate for Chemical Oxidation
Feasibility Study Addendum
DCF Study Area

Chemical Oxidation for Groundwater in the Monitoring Well DCF02-42 Area

Annual Operation and Maintenance (O&M) Costs						
	Semiannual Groundwater Monitoring	ea	1	$99,480	99,480	BMcD

Subtotal O&M Costs	**$**	**99,480**
Contingency (20%)	**$**	**19,896**
Total O&M Costs	**$**	**119,376**

Periodic Costs						
4.9	Reinjection at 2 years	ls	1	$ 125,000	$ 125,000	BMcD
4.10	Five-Year Review of Remedial Action	ea	1	$ 24,000	$ 24,000	BMcD
4.11	Closure Report	ls	1	$ 36,000	$ 36,000	BMcD

Subtotal Periodic Costs	**$**	**185,000**
Contingency (20%)[5]	**$**	**37,000**
Total Periodic Costs	**$**	**222,000**

Total Project Cost	**$2,735,720**
Total Prosent Value Project Cost at 3.2% Cost	**$2,144,437**

Notes:

1. BMcD costs represent estimates obtained from similar projects and/or professional experience.
2.
3. Estimate covers the injection of sufficient KMnO4 to treat a 200-ft by 100-ft area in the vicinity of MW02-42. Estimate is based on 25 injection points with 1,000 lb per location. Injection/fracture locations will be based on pilot test results and site access. KMnO4 mass needed will be determined during bench-scale.
4. Assumes a monitored natural attentuation monitoring well network and sampling protocol already exist and is is covered under the cost associated with Alternative 2.
5. Contingency covers unknowns, unforeseen circumstances, or unanticipated conditions associated with remediation. Twenty percent is an average contingency factor (EPA, 2000a).

BMcD - Burns & McDonnell Engineering Company, Inc.
ea - each
ft - foot
hr - hour
lb - pound
ls - lump sum
VOC - volatile organic compound
MW- Monitoring Well
KMnO4- Potassium Permanganate
EPA- Environmental Protection Agency

Table 5A-17
Area of Concern -3
Present Value Costs for Alternative 2 - Chemox
Feasibility Study Addendum
DCF Study Area

Chemical Oxidation for Groundwater in the Monitoring Well DCF02-42 Area

Year	Capital Costs	Annual O&M Costs[1]	Periodic Costs[2]	Total Cost	Discount Factor at 3.2%	Total Present Value Cost at 3.2%
0	$ 489,120	$ -	$ -	$ 489,120	1.000	$ 489,120
1	$ -	$ 99,480	$ -	$ 99,480	0.969	$ 96,395
2	$ -	$ 99,480	$ 125,000	$ 224,480	0.939	$ 210,775
3	$ -	$ 99,480	$ -	$ 99,480	0.910	$ 90,510
4	$ -	$ 99,480	$ -	$ 99,480	0.882	$ 87,704
5	$ -	$ 99,480	$ 24,000	$ 123,480	0.854	$ 105,487
6	$ -	$ 99,480	$ -	$ 99,480	0.828	$ 82,349
7	$ -	$ 99,480	$ -	$ 99,480	0.802	$ 79,795
8	$ -	$ 99,480	$ -	$ 99,480	0.777	$ 77,321
9	$ -	$ 99,480	$ -	$ 99,480	0.753	$ 74,924
10	$ -	$ 99,480	$ 24,000	$ 123,480	0.730	$ 90,116
11	$ -	$ 99,480	$ -	$ 99,480	0.707	$ 70,349
12	$ -	$ 99,480	$ -	$ 99,480	0.685	$ 68,168
13	$ -	$ 99,480	$ -	$ 99,480	0.664	$ 66,054
14	$ -	$ 99,480	$ -	$ 99,480	0.643	$ 64,006
15	$ -	$ 99,480	$ 24,000	$ 123,480	0.623	$ 76,984
16	$ -	$ 99,480	$ -	$ 99,480	0.604	$ 60,098
17	$ -	$ 99,480	$ -	$ 99,480	0.585	$ 58,235
18	$ -	$ 99,480	$ -	$ 99,480	0.567	$ 56,429
19	$ -	$ 99,480	$ -	$ 99,480	0.550	$ 54,679
20	$ -	$ 99,480	$ 60,000	$ 159,480	0.533	$ 84,940
Total	**$ 489,120**	**$ 1,989,600**	**$ 257,000**	**$ 2,735,720**		**$ 2,144,437**

Notes:

1. It is assumed that groundwater monitoring will be performed annually.
2. $24,000 included the cost of a five-year review. $60,000 includes the cost of a five-year review and a closure report. Periodic cost of $125,000 is for second injection.

Table 5A-18
Area of Concern - 3
Cost Estimate for Enhanced Anerobic Bioremediation
Feasibility Study Addendum
DCF Study Area

EAB for Groundwater in the Monitoring Well DCF02-42 Area.

	Description	Quantity	Unit	Unit Cost	Line Cost	Source[1]
Capital Costs						
1.1	Engineering and Design for Benchscale & Pilot test, plus permitting	ls	1	$ 15,000	$ 15,000	BMcD
1.2	Bench-scale testing					
	Field sample collection	ls	1	$ 5,000	$ 5,000	BMcD
	Laboratory Testing	ls	1	$ 10,000	$ 10,000	BMcD
1.3	Pilot test to determine spacing, application rate, and other design parameters.[2]					
	Clear Utilities	ls	1	$ 600	$ 600	BMcD
	Geoprobe/injection equipment	day	2	$ 2,000	$ 4,000	BMcD
	Vegetable oil (est. 5 probes, 15 lb/ft, 2 ft. thick)	lbs	150	$ 1.00	$ 150	BMcD
	Technology vendor charges/license fees	ls	1	$ 5,000	$ 5,000	BMcD
	Field Oversight and Logistics (40 hr)	ls	1	$ 4,000	$ 4,000	BMcD
	Sampling, 2 existing monitoring wells (month 1@2 times, then monthly for 6 months)					
	VOCs, MNA parameters	ea	16	$ 500	$ 8,000	BMcD
	Labor (8 events - est. 100 man-hour)	ls	1	$ 10,000	$ 10,000	BMcD
	Vehicle/mileage	trip	8	$ 200	$ 1,600	BMcD
	Interpret results and pilot test report	ls	1	$ 21,000	$ 21,000	BMcD
1.4	Full-Scale Engineering & Design, plus permitting	ls	1	$ 50,000	$ 50,000	
1.5	Full Scale Treatment[3]					
	Clear Utilities	ls	1	$ 600	$ 600	BMcD
	Vegetable oil cost (75 probes, 15lb/ft, 8 ft thick)	lb	9,000	$ 1.00	$ 9,000	BMcD
	Technology vendor charges/license fees	ls	1	$ 20,000.00	$ 20,000	
	Geoprobe/injection equipment	day	15	$ 2,000.00	$ 30,000	
	Field Oversight (15 days).					
	Labor (2 man crew)	day	15	$ 2,000	$ 30,000	BMcD
	Per Diem	day	15	$ 100	$ 1,500	BMcD
	Pickup Truck/mileage	day	15	$ 100	$ 1,500	BMcD
	Sampling, 4 existing monitoring wells (monthly for 6 months)					
	VOCs, MNA parameters	ea	24	$ 500	$ 12,000	BMcD
	Labor (6 events - est. 120 man-hour)	ls	1	$ 12,000	$ 12,000	BMcD
	Vehicle/mileage	trip	6	$ 200	$ 1,200	BMcD

Subtotal Capital Costs	**$**	**252,150**
Contingency (20%)[5]	**$**	**50,430**
Total Capital Costs	**$**	**302,580**

Table 5A-18 (Continued)
Area of Concern - 3
Cost Estimate for Enhanced Anerobic Bioremediation
Feasibility Study Addendum
DCF Study Area

EAB for Groundwater in the Monitoring Well DCF02-42 Area.

Annual Operation and Maintenance (O&M) Costs						
	Semiannual Groundwater Monitoring	ea	1	$99,480	99,480	BMcD

Subtotal Periodic Costs	**$ 99,480**
Contingency (20%)[5]	**$ 19,896**
Total Periodic Costs	**$ 119,376**

Periodic Costs						
4.9	Reinjection at 2 years	ls	1	$ 120,050	$ 120,050	BMcD
4.10	Five-Year Review of Remedial Action	ea	1	$ 24,000	$ 24,000	BMcD
4.11	Closure Report	ls	1	$ 36,000	$ 36,000	BMcD

Subtotal Periodic Costs	**$ 180,050**
Contingency (20%)[4]	**$ 36,010**
Total Periodic Costs	**$ 216,060**

Total Project Cost	**$2,544,230**
Total Present Value Project Cost at 3.2% Cost	**$1,953,249**

Notes:

1. BMcD costs represent estimates obtained from similar projects and/or professional experience.
2. It assumed that a partial curtain will be used for the pilot study. This estimate is based on five injection points (30-ft wide spaced on 5-ft centers) and an assumed vegetable oil application amount of 15 lbs per vertical ft and 2-ft saturated thickness.
3. It assumed that an injection grid will be used. Injection will be applied over a 200-ft by 30-ft area with 8-ft thickness. Estimate is based on 75 injection points (spaced on 15-ft centers) and an assumed 15 pounds per vertical ft (8-ft saturated thickness) vegetable application rate.
4. Contingency covers unknowns, unforeseen circumstances, or unanticipated conditions associated with remediation. Twenty percent is an average contingency factor (EPA, 2000a).

BMcD - Burns & McDonnell Engineering Company, Inc.
ea - each
ft - foot
hr - hour
lb - pound
ls - lump sum
MNA - monitored natural attenuation
VOC - volatile organic compound
EPA- Environmental Protection Agency

Table 5A-19
Area of Concern -3
Present Value Costs for Alternative 3 - Enhanced Anaerobic Bioremediation
Feasibility Study Addendum
DCF Study Area

EAB with Institutional Controls and MNA for the Monitoring Well DCF02-42 Area

Year	Capital Costs	Annual O&M Costs[1,2]	Periodic Costs[3]	Total Cost	Discount Factor at 3.2%	Total Present Value Cost at 3.2%
0	$ 302,580	$ -	$ -	$ 302,580	1.000	$ 302,580
1	$ -	$ 99,480	$ -	$ 99,480	0.969	$ 96,395
2	$ -	$ 99,480	$ 120,050	$ 219,530	0.939	$ 206,127
3	$ -	$ 99,480	$ -	$ 99,480	0.910	$ 90,510
4	$ -	$ 99,480	$ -	$ 99,480	0.882	$ 87,704
5	$ -	$ 99,480	$ 24,000	$ 123,480	0.854	$ 105,487
6	$ -	$ 99,480	$ -	$ 99,480	0.828	$ 82,349
7	$ -	$ 99,480	$ -	$ 99,480	0.802	$ 79,795
8	$ -	$ 99,480	$ -	$ 99,480	0.777	$ 77,321
9	$ -	$ 99,480	$ -	$ 99,480	0.753	$ 74,924
10	$ -	$ 99,480	$ 24,000	$ 123,480	0.730	$ 90,116
11	$ -	$ 99,480	$ -	$ 99,480	0.707	$ 70,349
12	$ -	$ 99,480	$ -	$ 99,480	0.685	$ 68,168
13	$ -	$ 99,480	$ -	$ 99,480	0.664	$ 66,054
14	$ -	$ 99,480	$ -	$ 99,480	0.643	$ 64,006
15	$ -	$ 99,480	$ 24,000	$ 123,480	0.623	$ 76,984
16	$ -	$ 99,480	$ -	$ 99,480	0.604	$ 60,098
17	$ -	$ 99,480	$ -	$ 99,480	0.585	$ 58,235
18	$ -	$ 99,480	$ -	$ 99,480	0.567	$ 56,429
19	$ -	$ 99,480	$ -	$ 99,480	0.550	$ 54,679
20	$ -	$ 99,480	$ 60,000	$ 159,480	0.533	$ 84,940
Total	**$ 302,580**	**$ 1,989,600**	**$ 252,050**	**$ 2,544,230**		**$ 1,953,249**

Notes:

1. It is assumed that groundwater monitoring will be performed semiannually.
2. It is assumed that enhanced bioremediation will treat dissolved contamination; however, it is conservately assumed there will be some source material that is not treated and this results in rebound of very low contamination, such that continued monitoring is required.
3. $24,000 included the cost of a five-year review. $60,000 includes the cost of a five-year review and a closure report. $120,050 includes cost of reinjection.