# FINAL

# FEASIBILITY STUDY REPORT
# FOR THE
# OPEN BURNING/OPEN DETONATION GROUND (RANGE 16)
# OPERABLE UNIT 006
# AT
# FORT RILEY, KANSAS

**February 14, 2014**

**Prepared for**

**U.S. ARMY CORPS OF ENGINEERS**
**KANSAS CITY DISTRICT**

**Prepared by**

**&**

Burns & McDonnell SINCE 1898

**Contract Number: W912DQ-08-D-0017**
**Project Number: 63598**

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# LIST OF ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| ACL | Alternate Concentration Limits |
| amsl | above mean sea level |
| AR | Army Regulation |
| ARAR | Applicable or Relevant and Appropriate Requirements |
| BER | Bureau of Environmental Remediation |
| bgs | below ground surface |
| BMcD | Burns & McDonnell Engineering Company, Inc. |
| C&D | Construction and Debris |
| CENWK | Kansas City District (USACE) |
| CERCLA | Comprehensive Environmental Response, Compensation, and Liability Act |
| CERCLIS | Comprehensive Environmental Response, Compensation, and Liability Information System |
| CFR | Code of Federal Regulations |
| cis-1,2-DCE | cis-1,2-Dichloroethene |
| $CO_2$ | Carbon Dioxide |
| COC | Chemicals of Concern |
| COEC | Chemicals of Ecological Concern |
| cm/sec | centimeters per second |
| °C | degrees Celsius |
| DA | Department of the Army |
| DAA | Detailed Analysis of Alternatives |
| 1,2-DCA | 1,2-Dichloroethane |
| DO | Dissolved Oxygen |
| DoD | United States Department of Defense |
| DSR | Data Summary Report |
| ECORA | Ecological Risk Assessment |
| EHI | Ecological Hazard Index |
| EOD | Explosive Ordnance Disposal |
| $Fe^{2+}$ | Ferrous Iron |
| FFA | Federal Facility Agreement |
| FS | Feasibility Study |
| °F | degrees Fahrenheit |
| GAC | Granular Activated Carbon |
| GC | gas chromatograph |
| GRA | General Response Action |
| $H_2O$ | Water |
| HI | Hazard Index |
| HHBLRA | Human Health Baseline Risk Assessment |
| HSWA | Hazardous and Solid Waste Amendments |
| IRP | Installation Restoration Program |
| IWSA | Installation Wide Site Assessment |

## LIST OF ACRONYMS AND ABBREVIATIONS (continued)

| | |
|---|---|
| J | Estimated Value |
| K.A.R. | Kansas Administrative Regulations |
| KDHE | Kansas Department of Health and Environment |
| $K_{oc}$ | Soil Organic Carbon Partitioning Coefficient |
| K.S.A. | Kansas Statutes Annotated |
| L/kg | liters per kilogram |
| LBA | Louis Berger & Associates |
| LBG | The Louis Berger Group, Inc. |
| LRC | Long-Range Component |
| MEC | Munitions and Explosives of Concern |
| MCL | Maximum Contaminant Level |
| mg/kg | milligrams per kilogram |
| MNA | Monitored Natural Attenuation |
| MP | Malcolm Pirnie |
| MPEO | Master Plan Environmental Overlay |
| NA | Natural Attenuation |
| NCP | National Oil and Hazardous Substance Pollution Contingency Plan |
| $NO_3^-$ | Nitrate |
| $NO_2^-$ | Nitrite |
| NPDES | National Pollutant Discharge Elimination System |
| NPL | National Priorities List |
| NTIS | National Technical Information Service |
| O&M | Operation & Maintenance |
| OB/OD | Open Burning / Open Detonation Ground |
| OMB | Office of Management and Budget |
| ORP | Oxidation Reduction Potential |
| OSHA | Occupational Safety and Health Administration |
| OSWER | Office of Solid Waste and Emergency Response |
| OU | Operable Unit |
| PP | Proposed Plan |
| PCA | 1,1,2,2-Tetrachloroethane |
| PCE | Tetrachloroethene |
| PPE | Personal Protective Equipment |
| PRG | Preliminary Remediation Goal |
| PWE | Fort Riley Directorate of Public Works – Environmental Division |
| QCSR | Quality Control Summary Report |

## LIST OF ACRONYMS AND ABBREVIATIONS (continued)

| | |
|---|---|
| RAO | Remedial Action Objective |
| RCRA | Resource Conservation and Recovery Act |
| RI | Remedial Investigation |
| RI/FS | Remedial Investigation/Feasibility Study |
| RI/FS WP | Remedial Investigation/Feasibility Study Work Plan |
| RME | Reasonable Maximum Exposure |
| RPMP | Real Property Master Plan |
| ROD | Record of Decision |
| ROI | Radius of Influence |
| RSK | Risk-Based Standards for Kansas |
| RSL | Regional Screening Level |
| | |
| SARA | Superfund Amendments and Reauthorization Act |
| SI | Site Investigation |
| $SO_4^{-2}$ | Sulfate |
| $S^{-2}$ | Sulfide |
| SVE | Soil Vapor Extraction |
| SVOC | Semivolatile Organic Compound |
| | |
| TBCs | To Be Considered |
| 1,1,2-TCA | 1,1,2-Trichloroethane |
| TCE | Trichloroethene |
| trans-1,2-DCE | trans-1,2-Dichloroethene |
| TOC | Total Organic Carbon |
| | |
| US | United States |
| USACE | United States Army Corps of Engineers |
| USC | United States Code |
| USEPA | United States Environmental Protection Agency |
| UXO | Unexploded Ordnance |
| | |
| VC | Vinyl Chloride |
| VOC | Volatile Organic Compound |
| | |
| WP | Work Plan |
| | |
| µg/L | micrograms per liter |

* * * * *

# 1.0 INTRODUCTION

## 1.1 PURPOSE OF REPORT

The purpose of this Feasibility Study (FS) Report is to develop and evaluate remedial alternatives to allow selection of an appropriate remedy for contamination associated with the Open Burning/Open Detonation Ground (OB/OD) (Range 16) Operable Unit (OU) 006 at Fort Riley, Kansas. This FS Report was developed in support of the Fort Riley Directorate of Public Works – Environment Division (PWE) under the Installation Restoration Program (IRP). This FS Report was also developed 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 and the National Oil and Hazardous Substance Pollution Contingency Plan (NCP). This FS Report was prepared by The Louis Berger Group, Inc. (LBG) and Burns & McDonnell Engineering Company, Inc. (BMcD) under the United States Army Corps of Engineers (USACE) – Kansas City District's (CENWK's) Contract Number W912DQ-08-D-0017, Task Number 0027 and represents Fort Riley's on-going fulfillment of obligations to investigate and take appropriate actions at sites posing a potential threat to human health and the environment.

## 1.2 OBJECTIVES

The objectives of this FS Report are:

- Develop remedial action objectives (RAOs) and preliminary remediation goals (PRGs) that are protective of human health and the environment;
- Identify treatment technologies relevant to the nature and extent of contamination present at the OB/OD;
- Screen and assemble appropriate technologies into remedial action alternatives;
- Identify remedial alternatives that are technically feasible, reasonable, and cost effective; and
- Define, evaluate, and compare remedial alternatives based on the criteria defined by relevant United States Environmental Protection Agency (USEPA) guidance documents.

## 1.3 REPORT ORGANIZATION

- **Section 1.0 Introduction –** A brief overview of report organization, background information, nature and extent of contamination, fate and transport, contaminant release and transport model, and risk assessment summary is included in this section. Section 1.0 essentially provides an overview of the *Remedial Investigation* (RI) *Report for the Open Burning/Open Detonation Ground (Range 16) – Operable Unit 006 at Fort Riley, Kansas* (RI Report) (LBG-BMcD, 2013).

- **Section 2.0 Applicable or Relevant and Appropriate Requirements (ARARs) and To Be Considered (TBC) Information –** Federal, state, and other statutes, regulations, and guidance documents that may be applicable and appropriate to the OB/OD are discussed in this section.

- **Section 3.0 Remedial Action Objectives and Preliminary Remedial Goals –** A discussion of media of interest, exposure pathways, chemicals of concern (COCs), RAOs, and PRGs is provided in this section.

- **Section 4.0 Technology Identification and Screening –** Review of all appropriate remedial technologies and an initial screening of potential technologies with reference to the OB/OD are provided in this section.

- **Section 5.0 Detailed Analysis of Alternatives (DAA) –** A detailed review of several remedial technologies appropriate for the OB/OD with respect to CERCLA screening criteria, including the estimated cost associated with each alternative is provided in this section.

- **Section 6.0 Comparative Evaluation of Alternatives –** A comparison of the alternatives described in Section 5.0, and a ranking of the most feasible and effective alternatives for the OB/OD is provided in this section.

- **Section 7.0 References** – The list of references used in this FS Report are provided in this section.

## 1.4 BACKGROUND INFORMATION

### 1.4.1 Site Location and Description

The Fort Riley Military Reservation is centrally located between the cities of Salina and Topeka in north central Kansas (see Figure 1-1). 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. The OB/OD is located approximately 2.5 miles to the northeast of Custer Hill, outside of the developed areas of Fort Riley (see Figure 1-1).

The OB/OD is located within Range 16 in the southern part of the Impact Area, approximately 2,300 feet north of Vinton School Road (see Figures 1-2 and 1-3). The active portion of the site is an inverted L-shaped area and consists of an area approximately 700 feet by 550 feet. The active portion of the site is centered on the north burn pit where open detonation takes place. The site is bounded on the east and west by ephemeral streams. The elevation of the southernmost point of the western ephemeral stream is approximately 1,132 feet above mean sea level (amsl). The land to the north, east, and west of the OB/OD is also part of the Impact Area and is used as training ranges. Open vacant fields surround the remainder of the OB/OD.

### 1.4.2 Site Use

#### 1.4.2.1 Historic and Current Use

Prior to 1942, the OB/OD area was used for ranching and farming. The land was obtained by the military in 1942 and has been in use by the United States (US) Army from 1942 to the present. Historic and present site use has not changed, although detonation activities have diminished. Currently, the 774th Explosive Ordnance Disposal (EOD) Detachment at Fort Riley handles ordnance materials from Fort Riley, the United States Department of Defense (DoD), and other state and federal agencies. Since 1991, the 774th EOD Detachment has been responsible for providing support to military installations, operations, and exercises; and to civilian and federal authorities within an operational area that includes the states of Kansas, Nebraska, Missouri, and South Dakota.

Ordnance was formerly disposed of by the 774th EOD Detachment at the OB/OD by open burning and open detonation. Currently, only open detonations for emergency disposal of ordnance and training are conducted. Open detonation occurs on open ground and creates crater-like pits, which typically reach a maximum size of 25 feet in diameter and 10 to 15 feet in depth. Open burning was formerly conducted within a specific area that was characterized by a small pit with a metal grating surrounded by a 9-foot high, horseshoe-shaped embankment (South Burn Pit). The open burn pit was primarily used to dispose of black powder and phosphorus-based munitions. At present, there are three active detonation pit areas, two metal debris pits, and two non-active burn pits at the OB/OD (see Figure 1-2). Open detonation is currently being conducted at the Northwest, West, and East Demolition Pits. Open detonation at the site is dynamic; generally, detonations are conducted within the same area but may not be within the same pit.

#### 1.4.2.2 Future Land Use and Plans

Based on the Fort Riley Real Property Master Plan (RPMP) (Black & Veatch, 2007), land use is not projected to change significantly in the future.

### 1.4.3 Previous Environmental Investigations

Previous environmental investigations that have been conducted at the OB/OD are detailed in this section. A chronology of environmental investigations conducted and associated documents for the OB/OD is presented in Table 1-1.

- **Fall 1993:** An initial Site Investigation (SI) was conducted at the OB/OD to evaluate the presence or absence of contamination by Louis Berger & Associates (LBA). This SI was conducted and reported in the *Site Investigation Report for High Priority Sites at Fort Riley, Kansas* (LBA, 1994). Field activities conducted during this investigation included the collection of surface soil samples from the pits used for the burning and detonation of ordnance; soil samples from subsurface borings; sediment and surface water samples from ephemeral streams; and the installation, development, and sampling of Monitoring Wells OB-93-01 through OB-93-04. Trichloroethene (TCE) was found in groundwater above the Safe Drinking Water Act Maximum Contaminant Level (MCL) of 5 micrograms per liter (µg/L) in Monitoring Well OB-93-04 (29 µg/L).
- **December 1995:** Confirmation sampling of Monitoring Wells OB-93-01 through OB-93-04 was conducted in December 1995. Analytical results were reported in the *Data Summary Report (DSR) for Confirmation Groundwater Sampling Multi-Sites, Fort Riley, Kansas* (LBA, 1996a) and the *Quality Control Summary Report (QCSR) Confirmation Groundwater Sampling at the Multi-Sites, Fort Riley, Kansas* (LBA, 1996b). The only TCE detection above the 5 µg/L MCL was in the sample from Monitoring Well OB-93-04 (17 µg/L).
- **March/April 1997 – Mobilization #1:** Additional SI activities were conducted to evaluate possible sources and extent of contamination at the OB/OD. Descriptions of the field activities are presented in the *Technical Memorandum, Overview of Mobilization # 1, Preliminary Findings and Proposed Mobilization # 2 Activities, Open Burn/Open Detonation Area, Fort Riley, Kansas* (LBA, 1997a). During this field effort, Monitoring Wells OB-97-05 through OB-97-08 were installed and groundwater samples were collected. Samples were also collected from the spring and hand-dug well. Concentrations of TCE exceeding the MCL were detected in the groundwater sample from Monitoring Well OB-97-07 (490 µg/L). Monitoring Wells OB-93-01 through OB-93-04 were not sampled during this field effort.
- **June 1997 – Mobilization #2:** Additional investigation activities were conducted to further characterize subsurface hydrogeology at the OB/OD. Field activities are summarized in the *Supplemental Technical Memorandum, Mobilization #2 Activities, Open Burn/Open Detonation*

*Area, Fort Riley, Kansas* (LBA, 1997b) and the *Technical Memorandum, Mobilization # 2 Activities, Open Burn/Open Detonation Area, Fort Riley, Kansas* (LBA, 1998a). Five sets of nested piezometers OB-97-09PZ through OB-97-13PZ were installed. One piezometer, the spring, and the hand-dug well were sampled. Water samples collected that exceeded the TCE MCL included the spring (190 µg/L) and the hand-dug well (230 µg/L).

- **September 1997 – Groundwater Sampling Event:** Groundwater samples were collected from all monitoring wells, piezometers, and the hand-dug well. One surface water sample was collected. Monitoring Well OBHD-97-14 was installed at the location of the hand-dug well. Analytical results were reported in the *DSR for Groundwater Sampling and Groundwater Elevations at the Open Burn/Open Detonation Area, Fort Riley, Kansas* (LBA, 1999). TCE concentrations above the MCL of 5 µg/L were reported in groundwater samples collected from Monitoring Wells OB-93-04 (17 µg/L), OB-97-07 (400 µg/L), OB-97-08 (200 µg/L), OBHD-97-14 (440 µg/L), and the hand dug well (260 µg/L). TCE concentrations above the MCL were also reported in groundwater samples collected from Piezometers OB-97-10PZ (3), OB-97-11PZ (0), OB-97-11PZ (1), OB-97-11PZ (4), OB-97-12PZ, and all five of OB-97-13PZs. Each piezometer location had multiple nested piezometers at varying depths noted as piezometer 0 (deep) through 4 (shallow). Tetrachloroethene (PCE) concentrations above the MCL of 5 µg/L were also reported in samples collected from Monitoring Wells OB-97-07 (14 µg/L), OB-97-08 (8 µg/L), and OBHD-97-14 (11 µg/L).

- **December 1997 – Groundwater Sampling Event:** Groundwater samples were collected from all monitoring wells, the hand-dug well, and the spring. Two surface water samples were also collected. Analytical results were reported in the *DSR for Groundwater Sampling and Groundwater Elevations at the Open Burn/Open Detonation Area, Fort Riley, Kansas* (LBA, 1999). TCE concentrations above the MCL of 5 µg/L were reported for groundwater samples collected from Monitoring Wells OB-93-04 (15 µg/L), OB-97-07 (530 µg/L), OB-97-08 (110 µg/L), OBHD-97-14 (63 µg/L), and the hand dug well (110 µg/L). TCE concentrations above the MCL were also reported in the sample from the spring (110 µg/L). A PCE concentration above the 5 µg/L MCL was reported in the sample from Monitoring Well OB-97-07 (14 µg/L). The piezometer clusters were not sampled during this field effort.

- **April 1998 – Groundwater Sampling Event:** Groundwater samples were collected from all monitoring wells, two spring locations, and five surface water locations. Analytical results were reported in the *DSR for Groundwater Sampling and Groundwater Elevations at the Open*

*Burn/Open Detonation Area, Fort Riley, Kansas* (LBA, 1999). TCE concentrations above the 5 µg/L MCL were reported for samples collected from Monitoring Wells OB-93-04 (12.8 µg/L), OB-97-07 (223 µg/L), OB-97-08 (32.4 µg/L), and OBHD-97-14 (34.3 µg/L). TCE concentrations above the MCL were also reported for the spring (62.5 µg/L). A PCE concentration at the MCL of 5 µg/L was reported for the groundwater sample collected from Monitoring Well OB-97-07 (5 µg/L). The piezometer clusters were not sampled during this field effort.

- **August 1998 – Groundwater Sampling Event:** Groundwater samples were collected from all monitoring wells, the spring, and five surface water locations. Analytical results were reported in the *DSR for Groundwater Sampling and Groundwater Elevation at the Open Burn/Open Detonation Area, Fort Riley, Kansas* (LBA, 1999). TCE concentrations above the MCL of 5 µg/L were reported for samples collected from Monitoring Wells OB-93-04 (14.1 µg/L), OB-97-07 (246 µg/L), OB-97-08 (65.3 µg/L), and OBHD-97-14 (89.6 µg/L). A TCE concentration above the MCL was also reported for the sample collected from the spring (145 µg/L). The piezometer clusters were not sampled during this field effort.

- **January 1999 – Groundwater Sampling Event:** Groundwater samples were collected from all monitoring wells, the spring, and four surface water locations. Analytical results were reported in the *DSR for Groundwater Sampling and Groundwater Elevations at the Open Burn/Open Detonation Area, Fort Riley, Kansas* (LBA, 1999). TCE concentrations above the MCL of 5 µg/L were reported for samples collected from Monitoring Wells OB-93-04 (13.1 µg/L), OB-97-07 (78.1 µg/L), OB-97-08 (9.3 µg/L), and OBHD-97-14 (49 µg/L). A TCE concentration above the MCL was also reported for the sample collected from the spring (51.4 µg/L). A concentration of cis-1,2-dichloroethene (cis-1,2-DCE) above the MCL of 70 µg/L was reported for the groundwater sample collected from Monitoring Well OBHD-97-14 (151 µg/L). The piezometer clusters were not sampled during this field effort.

- **June 1999 - Site Analysis Report:** A site analysis was conducted regarding the geology, stratigraphy, structure, and hydrology of the OB/OD. This information was presented in the *Analysis of Geological Stratigraphy, Structure, and Hydrology of the OB/OD Site, Fort Riley, Kansas* (Archer and Martin, 1999). This analysis included a historical report review, site reconnaissance in April, May, and August of 1998, an examination of existing rock cores, and an evaluation of hydrogeologic and analytical data from 1997 and 1998. It was concluded that the

OB/OD is underlain by alternating Permian limestone and shale units with joints running east-northeast and north-northwest.

- **April 2003 – Auto Sampler Event:** A surface water sample was collected on April 23, 2003 from an auto sampler located on the western ephemeral stream. The surface water sample was analyzed for volatile organic compounds (VOCs). No VOCs were detected in this sample. This information was presented in the *QCSR April 2003 Surface Water Sampling Event, OB/OD Site, Fort Riley, Kansas* (BMcD, 2003).

- **March 2004 – Auto Sampler Event:** A surface water sample was collected on March 4, 2004 from an auto sampler located on the western ephemeral stream. The surface water sample was analyzed for VOCs. No VOCs were detected in this sample. This information was presented in the *QCSR March 2004 Surface Water Sampling Event, Open Burning/Open Detonation (Range 16), Fort Riley, Kansas* (Malcolm Pirnie (MP)-BMcD, 2004a).

- **August 2005 – Monitoring Well Installation:** Monitoring Well OB-05-15 was installed down gradient of the active portion of Range 16 in the southwestern portion of the OB/OD. Monitoring Well OB-05-15 is screened within the regolith with the bottom of the well setting on the Havensville Shale Member.

- **July 2006 – Direct-Push Investigation:** Seven locations were pushed for the collection of groundwater samples. Exceedances of the TCE MCL were reported for groundwater samples collected from Direct-Push Locations DP-3 (12.6 µg/L) and DP-5 (5.9 µg/L). Locations DP-8 through DP-11 were pushed south of the DP-7 location, but these locations were dry. Locations DP-1, DP-2, DP-4, and DP-6 were not probed because TCE had been detected at a down gradient location (MP-BMcD, 2007-2011).

- **2004 - 2011– Groundwater Sampling Events:** Groundwater samples were collected from the site monitoring wells with available sample volume and surface water locations during multiple sampling events. Analytical results were reported in the *QCSR April 2004 Sampling Event, Open Burning/Open Detonation (Range 16), Fort Riley, Kansas* (MP-BMcD, 2004b) and *DSRs for Groundwater, Spring, and Seep Sampling for Open Burn/Open Detonation Ground (Range 16) at Fort Riley, Kansas* (MP-BMcD, 2007-2011).

- **2001 – 2013 – RI Field Activities:** Collection of soil, dry sediment, and surface water samples, installation of six monitoring wells, abandonment of piezometers, and four rounds of quarterly groundwater sampling from sixteen monitoring wells. Analytical results were reported in the *Remedial Investigation Report for the (OB/OD (Range 16) – Operable Unit 006 at Fort Riley, Kansas* (LBG-BMcD, 2013).

### 1.4.4 Regulatory History

Fort Riley was established in 1853 and has been owned and operated by the Department of the Army (DA) since that time. Environmental investigations were performed at Fort Riley during the 1970s and 1980s. These investigations identified activities and facilities where hazardous substances had been released or had the potential to be released to the environment. Potential sources of contamination include landfills; printing, dry cleaning, and furniture shops; and pesticide storage facilities. On July 14, 1989, the USEPA proposed inclusion of Fort Riley on the National Priorities List (NPL) pursuant to the CERCLA. The USEPA included the site on the NPL, promulgated in August 1990. Fort Riley is identified by the USEPA as the Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS) Site KS6214020756.

Effective June 1991, the DA entered into a Federal Facility Agreement (FFA) (USEPA, 1991), Docket No. VII-90-F-0015, with the Kansas Department of Health and Environment (KDHE) and the USEPA Region VII to address environmental pollution subject to the CERCLA, NCP, and/or the Resource Conservation and Recovery Act (RCRA) (USEPA, 1991). Pursuant to the FFA, Fort Riley conducted an Installation Wide Site Assessment (IWSA) in 1992 to identify sites having the potential to release hazardous substances to the environment (LBA, 1992). In January 2012, the OB/OD was formally designated an OU based on the result of previous environmental investigations, and the RI process was subsequently initiated.

The RI Report refined the physical setting at the OB/OD and identified the nature and extent of contamination, evaluated the fate and transport of COCs, presented the contaminant release and transport model, and assessed the risk to human health and the environment. A brief summary of these topics will be covered in subsequent sections of this FS Report.

### 1.4.5 Physical Setting

#### 1.4.5.1 Site Features

The topography of Fort Riley and the surrounding area consists of a low plain that has been eroded by streams and rivers. The area is designated as the Osage Plains section of the Central Lowlands physiographic province (Schoewe, 1949). Sedimentary bedrock strata dip gently to the west-northwest. East-facing escarpments of more resistant rock units are separated by gentle, westward sloping plains.

The resulting topography can be divided into upland areas with bluffs along alluvial valleys, and lowland areas that consist of alluvial plains and associated terraces. The upland areas are dissected by numerous ephemeral, intermittent, and perennial streams; the lowlands areas occur along the banks of the major rivers in the area: the Republican, Smoky Hill, and Kansas Rivers (Jewett, 1941).

The geology of Fort Riley and the surrounding area consists of Pennsylvanian and Permian Age sedimentary rock overlain by eolian and fluvial deposits of Pleistocene and Recent Age (Jewett, 1941). The Nemaha Anticline is the prominent structural feature in the area, and Fort Riley is situated on the western limb of this fold within the Salina Basin (Merriam, 1963). Bedrock dips gently (approximately 30 feet per mile) to the west-northwest and consists of alternating beds of limestone and shale of the Permian Chase and Council Grove Groups. The Barneston Formation of the Chase Group (composed of the Fort Riley Limestone, Oketo Shale, and Florence Limestone Members) is the uppermost bedrock in the upland areas. This sequence of interbedded limestones and shales continues to depths of several hundred feet. The bedrock surface has been eroded by the major rivers and streams. The major streams tend to flow to the east and south due to topography. The rivers are broad, shallow, and slow-moving.

In the major river valleys, alluvial sand, silt, and gravel deposits reach a thickness of approximately one hundred feet near the rivers and decrease in thickness toward the margins of the floodplain. Alluvium and loess cover portions of the upland areas, including terraces underlain by Buck Creek terrace deposits (Fader, 1974). These terrace deposits include both alluvium and loess. Eudora and Kenesaw soils are developed throughout Fort Riley (Jantz et al., 1975). Eudora silt loams are well drained, have moderate permeability, and normally form in coarse, silty alluvium on high flood plains or low terraces.

#### 1.4.5.2 Site-Specific Soils

The OB/OD is underlain by regolith (the layer of soil and loose rock overlying the bedrock) consisting of residual silty clays that grade into weathered bedrock. The regolith is composed of the Smolan silty loam and the Wymore silty clay loam (Jantz et al., 1975). The Smolan soils are commonly found in terrace and upland areas adjacent to the Kansas and Republican River Valleys and are formed from loess deposits. The Wymore silt, also formed from loess deposits, is also found in the upland areas. Soils originating from the weathering of terrace bedrock formations are also found in the upland areas.

#### 1.4.5.3 Site-Specific Geology

The OB/OD is underlain by an alternating sequence of limestone and shale of the Permian Chase and Council Grove Groups. Bedrock present at the OB/OD includes the Blue Springs Shale Member, Kinney Limestone Member, Wymore Shale Member, Schroyer Limestone Member, and Havensville Shale

Member. The Threemile Limestone Member and Speiser Shale Member underlie the Havensville Shale Member. The bedrock at the OB/OD generally dips toward the southwest. The localized bedrock dip is slightly steeper toward the southwest in the eastern portion of the site, but levels out in the western portion of the site. Descriptions of the specific bedrock units encountered at the OB/OD are provided below.

- Florence Limestone Member – The Florence Limestone generally consists of a fossiliferous light to yellowish-gray limestone with chert and shale (Zeller, 1994). The Florence Limestone was not observed at the OB/OD during RI field activities but outcrops north of the study area.

- Blue Springs Shale Member – The Blue Springs Shale generally consists of a red to gray shale with minor amounts of limestone (Zeller, 1994). A description of the Blue Springs at the OB/OD Area is a greenish-gray to dark reddish-brown, dry, slightly-calcareous shale with a measured thickness of 21 feet. At the OB/OD, the three detonation pits, two metal debris pits, and a portion of the north burn pit are located within the Blue Springs Shale Member.

- Kinney Limestone Member – The Kinney Limestone generally consists of two gray, fossiliferous, limestone beds separated by gray, fossiliferous shale (Zeller, 1994). The Kinney Limestone at the OB/OD is a pale-yellow, moist to wet, slightly-weathered, cherty limestone with a thickness of 4 feet. A portion of the north burn pit is located within the Kinney Limestone Member.

- Wymore Shale Member – The Wymore Shale consists of gray and yellowish-gray shale with varicolored red, green, and purple beds, and limestone and fossiliferous beds in the lower portions (Zeller, 1994). The Wymore Shale at the OB/OD is a gray to greenish-gray, calcareous shale that is wet in the upper zone, dry in the middle portion, and moist to wet in the lower portion. The Wymore has an approximate thickness of 25 feet. The south burn pit and spring are located within the Wymore Shale Member.

- Schroyer Limestone Member – The Schroyer Limestone consists of a chert-bearing, light-gray to nearly white limestone with a 3-foot, non-cherty section in the upper portion (Zeller, 1994). The Schroyer at the OB/OD is a wet, crystalline, medium-hard to dense, gray to pale-yellow limestone with an average thickness of 9 feet. A majority of the western ephemeral stream and the southern portion of the eastern ephemeral stream lie in the Schroyer Limestone Member.

- Havensville Shale Member – The Havensville Shale consists of gray calcareous shale with thin limestone beds (Zeller, 1994). The Havensville Shale at the OB/OD is a dark gray, dry, calcareous, subplaty shale with an average thickness of 15 feet. The Havensville underlies the southern portion of the OB/OD.

- Threemile Limestone Member – The Threemile Limestone consists of a light-gray to nearly white limestone with chert-bearing zones. Massive non-cherty beds are located in the middle and lower portions of the member (Zeller, 1994). The Threemile Limestone at the OB/OD is a dark gray limestone with interbedded shales with an average thickness of 12 to 20 feet.

- Speiser Shale – The Speiser Shale consists of fossiliferous shale underlain by a limestone in the upper portion of the unit while the remainder of the unit is composed of varicolored beds with red as the predominant color (Zeller, 1994). The Speiser Shale has an average thickness of 15 to18 feet.

#### 1.4.5.4 Site-Specific Hydrogeology

Groundwater at the OB/OD is present from up-gradient aquifer recharge and through precipitation. Precipitation that falls on the site infiltrates downward through the soil into the underlying bedrock. (During rain events, overland flow also occurs from the higher elevation portions of the sites to the two ephemeral streams located to the east and west of the site.) Groundwater moves horizontally along bedding planes in the shale and limestone formations and vertically through joints and fractures. Joint sets running east northeast and north northwest are present at the site in the bedrock. Additional fractures are also possible at the site due to the historical and continued use of the site as a range for detonation of explosives. Spring and wet weather seeps are present at the OB/OD. The wet weather seeps, which are located within or near the drainage areas, produce water mainly after heavier precipitation events. The spring produces water on a more consistent basis; however, it is more commonly dry than flowing.

Groundwater at the OB/OD is found mainly within two horizons, the regolith/weathered bedrock horizon and the Threemile Limestone Member. Hydraulic conductivity testing at Monitoring Well OB-05-15, which is screened within the regolith, resulted in a conductivity value of $4.05 \times 10^{-3}$ centimeters per second (cm/sec) and at Monitoring Well OB-97-06, which is screened within the Schroyer Limestone Member, resulted in a conductivity value of $5.30 \times 10^{-2}$ cm/sec.

Groundwater within the Threemile Limestone has a significantly lower piezometric level, as shown in Monitoring Wells OB-93-03, OB-93-04, OB-12-19D, and OB-12-20D. Hydraulic conductivity testing at Monitoring Well OB-12-19D resulted in a conductivity value of $7.30 \times 10^{-2}$ cm/sec.

#### 1.4.5.5 Site-Specific Surface Water Drainage

During rainfall events, surface runoff from the surrounding area travels into one of the two ephemeral streams bordering the OB/OD on the east and west based on topographic elevation. These two ephemeral streams join approximately 1,500 feet south of the OB/OD. This ephemeral stream intercepts the Threemile Creek approximately 3,700 feet south of the site and eventually enters the Kansas River to the southeast.

Surface water in the ephemeral streams generally occurs following precipitation events. During these events, surface water flows in the stream bed while precipitation infiltrates the overlying regolith and migrates into bedrock through fractures, joints, and bedding planes. Where the bedrock outcrops along the stream beds, temporary seeps are developed which allows water to seep from the outcropping bedrock into the streams. Following the precipitation events, the stream flow gradually reduces until flow no longer occurs and ponded areas are formed, which eventually dry up. Additionally, seeps and springs dry up when there is no longer any infiltration to support a continuing flow. Examples of this are the spring located at the base of the Kinney Limestone and the seeps along the western ephemeral stream located within the outcropping Schroyer Limestone.

## 1.5 NATURE AND EXTENT OF CONTAMINATION

Contaminants which were identified as subsurface soil, surface water, and/or groundwater COCs at the OB/OD in the RI Report included VOCs and semivolatile organic compounds (SVOCs) (LBG-BMcD, 2013). This section provides a brief summary of the nature and extent of contamination at the OB/OD.

Surface and subsurface soil, sediment, surface water and groundwater samples were collected from the OB/OD during RI field activities and analyzed for VOCs, SVOCs, perchlorate, explosives, and metals. The results of the analyses were compared to appropriate industrial screening levels. Nature and extent of contaminants at the OB/OD can be summarized by the following statements:

- VOCs – Exceedances of TCE were detected in subsurface soil. Exceedances of 1,1,2,2-tetrachloroethane (PCA), naphthalene, and TCE were detected in groundwater. Exceedances of PCA and TCE were detected in surface water.
- SVOCs – Exceedances of bis(2-ethylhexyl)phthalate and benzo(a)pyrene were detected in groundwater. Surface water had one exceedance of benzo(a)pyrene.
- Explosives – There were no exceedances of explosives in any of the media sampled.
- Perchlorate – There were no exceedances of perchlorate in any of the media sampled.

- Metals – There were no exceedances of metals in any of the media sampled.

COCs identified in the RI Report are presented in Section 3.3 of this FS Report, include PCA, TCE, naphthalene, benzo(a)pyrene, and bis(2-ethylhexly)phthalate.

There is no known historical or current use of solvents or knowledge of solvent disposal at the OB/OD. The metal debris pits were identified in the RI Report as the possible contaminant source area. TCE exceedances in soil are near or immediately down gradient of the metal debris pits as shown on Figures 1-4 and 1-5. Due to the presence of a metallic signature, the central portion of the northern metal debris pit was not sampled for chemical analysis. Based upon the pattern of contamination detected, it is probable that the soil within this area also has exceedances. Vertically, groundwater contamination at the OB/OD extends from the regolith/weathered bedrock aquifer down through to the lower aquifer (Threemile Limestone) as depicted on the geologic cross sections (see Figures 1-6, 1-7, and 1-8). Horizontally, groundwater contamination at the OB/OD extends down gradient (southwest) from the metal debris pits toward the western ephemeral stream as shown on Figures 1-9, 1-10, 1-11, and 1-12. During periods of heavier precipitation, wet weather features like ephemeral streams, springs, and seeps tend to flow and weep. During wetter weather conditions, contaminants in the seeps, spring, and the ephemeral streams down gradient of the metal debris pits appear (see Figure 1-13).

## 1.6 FATE AND TRANSPORT

The primary fate and transport mechanisms in the groundwater at the site are sorption and volatilization. Advection and dispersion appear to be active at the site; however, they are affecting fate and transport of the COCs at a lesser rate. Biodegradation appears to be minimal at the OB/OD.

Sorption plays a primary role in the fate and transport of constituent groups. Per the RI Report, the soil organic carbon partitioning coefficient ($K_{oc}$) values ranged from 60.7 liters per kilogram (L/kg) to 1,557 L/kg. These values fall below the 2,000 L/kg where the VOCs would be tightly adsorbed, therefore, the VOCs would have a range of mobility and can move from easily to more slowly through the soil strata to groundwater at the upper end of the range. Given the prevalence of VOCs in the site matrices, volatilization is also likely a primary factor affecting fate and transport at the site in both the vadose zone and at the surface of the saturated zone.

As mentioned, it is likely that advection and dispersion affect fate and transport of COCs at the site with biodegradation playing only a minor role; however, their effect on the overall contaminant mass and movement are minimal compared to sorption and volatilization.

## 1.7 CONTAMINANT RELEASE AND TRANSPORT MODEL

Based on investigation data, the primary chlorinated solvent source appears to be located in the vicinity of the metal debris pits located in the north central portion of the site. Within this area, soil results are the highest in the eastern portion of the metal debris pits near the area with a metallic signature. VOCs are present within both the surface and subsurface soil in this area. VOC results for soil samples directly down gradient of this area are higher for the deeper soils near the bedrock interface.

Groundwater within this area is primarily recharged through precipitation. Precipitation is transported along the ground surface via overland flow and also migrates downward by infiltration and percolation through micro- and macro-fractures within the regoligth. Following infiltration and percolation, precipitation then moves downward by preferential and non-preferential pathways into the weathered bedrock mass through fractures and joints. As the infiltrated precipitation moves through the VOC-contaminated soil, the water dissolves and transports the VOCs. The VOCs-impacted fluids migrate downward into the uppermost groundwater surface located within the regolith and weathered bedrock at the OB/OD. Results from groundwater samples indicate that the VOCs are migrating down gradient within this aquifer and also downward into the lower aquifer in some locations.

During periods of heavier precipitation, wet weather seeps (including the spring) flow as the facture and joint network within the weathered bedrock mass reach maximum pore volume/fracture aperture capacities. This allows wet weather features like ephemeral streams, springs, and seeps to flow and weep. Samples collected from the seeps, spring, and the western ephemeral stream located during wetter weather conditions down gradient of the soil source contain chlorinated VOCs as found in the soil and groundwater samples. This flow path along the top of more resistant units in the soil/weathered bedrock interface is also the probable source of the VOC detections within the deeper soils near the bedrock interface located down gradient of the metal debris pits.

## 1.8 RISK ASSESSMENT SUMMARIES

### 1.8.1 Human Health Baseline Risk Assessment

The following results of the Human Health Baseline Risk Assessment (HHBLRA) were obtained from the RI Report (LBG-BMcD, 2013). The potential for human health risk from exposure to COCs at the site was evaluated for soil, sediment, surface water, and groundwater. COCs at the OB/OD include the following: PCA, TCE, naphthalene, benzo(a)pyrene, and bis(2-ethylhexyl)phthalate. Media evaluated in the HHBLRA were shallow soil, subsurface soil, sediment, surface water, and groundwater.

The site is part of the Impact Area for weapons training at Fort Riley. Information regarding current and potential future land and water use was used to develop the exposure scenarios evaluated. Future land use is scheduled to remain as ordnance disposal. Based on the current and potential future uses of the site, current site worker, future site worker, and current and future demolition worker scenarios were evaluated.

Current site workers were assumed to be potentially exposed to COCs in shallow soil through incidental ingestion, dermal contact, and inhalation of dust and vapors in outdoor air and in surface water through dermal contact and inhalation of vapors in outdoor air. Future site workers were assumed to be potentially exposed to COCs in shallow soil through incidental ingestion, dermal contact, and inhalation of dust and vapors in outdoor air; in surface water through dermal contact and inhalation of vapors in outdoor air; and in groundwater through ingestion as a drinking water source. Current and future demolition workers were assumed to be potentially exposed to COCs in shallow and subsurface soil through incidental ingestion, dermal contact, and inhalation of dust and vapors in outdoor air; in surface water through dermal contact and inhalation of vapors in outdoor air; and in groundwater through ingestion as a drinking water source and dermal contact with infiltrating groundwater in an excavation.

The noncancer hazard indices (HIs) and excess lifetime cancer risk values were calculated for each of the potentially exposed populations evaluated in the risk assessment. HIs for each of the populations being evaluated exceeded the USEPA level of concern for noncancer risk, which is a HI greater than one. The excess lifetime cancer risk value for the current and future demolition worker was within the USEPA 1E-04 to 1E-06 (one in 10,000 to one in a million) risk management range. The excess lifetime cancer risk values for the current site worker and future site worker were above the USEPA 1E-04 to 1E-06 (one in 10,000 to one in a million) risk management range (LBG-BMcD, 2013). A summary of the human health risk results are presented in Table 1-2.

### 1.8.2 Ecological Risk Assessment

The following results of the Ecological Risk Assessment (ECORA) were obtained from the RI Report (LBG-BMcD, 2013). The OB/OD site was evaluated both qualitatively and quantitatively to assess risk to ecological receptors during the ECORA. Ecological surveys were conducted on December 15, 2011, at the OB/OD to identify any wildlife or potential habitat affected by site-related constituents. The entire OB/OD was evaluated for the presence of completed ecological exposure pathways. Based on the site visit, it was concluded that flora and fauna could be exposed to site-related constituents through direct contact and/or ingestion of soil, surface water, and sediments and that area fauna could be exposed through the bioaccumulation of site-related constituents in benthic invertebrates, aquatic and terrestrial invertebrates, aquatic and terrestrial plants, small mammal prey, and fish.

The results of the qualitative assessment of the OB/OD concluded that, no significant effects were observed during the December 15, 2011, site visit. The OB/OD was occupied by a variety of common plant and animal species tolerant of human disturbances. Fish and crayfish were observed in a pool along an ephemeral stream located downstream of the OB/OD. Areas devoid of vegetation or stressed vegetation were not observed during the site visit.

Currently, the OB/OD site is being used as an ordnance disposal area with plans to continue to use the site as an ordnance disposal area. The OB/OD consists of managed and unmanaged grasslands with open riparian corridors occurring along the two ephemeral stream drainages along the western, eastern and southern edges of the OB/OD. The lands surrounding OB/OD consist of undeveloped wooded and grassy lands. The current disturbed nature of the OB/OD site is unlikely to attract populations of rare or protected species. Common wildlife species that are tolerant of humans and disturbances will remain in the area and continue to use the OB/OD. It was assumed that, regardless of the future of the OB/OD site, the existing representative wildlife species would continue to enter the OB/OD site when human disturbances are minimal and continue to come into contact with chemicals of ecological concern (COECs) through various daily activities. However, a wildlife species actual risk would be less than predicted if it spends less time on the OB/OD because of regular human disturbances or the lack of prey or forage due to regular human disturbances.

Based on the results of the quantitative evaluations to assess risk to ecological receptors, ecological receptors exposed to soils experienced the most potential risk and ecological receptors exposed to surface water experienced the least amount of potential risk. The American robin, which is an omnivore consuming soil invertebrates (earthworms), vegetation, and some surface soils from the OB/OD, experienced the greatest potential risk of all the terrestrial wildlife species (ecological hazard index [EHI] 1.0E+05). The eastern cottontail rabbit, which was assumed to feed exclusively on plants from the OB/OD, had relatively high rates of surface soil ingestion and experienced the second greatest potential risk of any mammalian species evaluated (EHI 1.7E+02). Among the terrestrial wildlife species, the species that have large home ranges, the red fox (EHI 1.2E+01), raccoon (EHI 3.3E+00), white-tailed deer (EHI 1.5E+01), and red-tailed hawk (EHI 6.9E+00), experienced the least potential risk. Among invertebrates, aquatic invertebrates (EHI 2.8+01) experienced the greatest potential risk but this could be due to fewer toxicity benchmarks for the chemicals of COECs detected in sediments than for the COECs detected in surface water. Soil invertebrates (earthworms; EHI 4.5E+00) experienced the least amount of potential risk. Plants exposed to soils at the OB/OD experienced a greater amount of potential risk from the surface soils (EHI of 3.0E+02) than subsurface soils (EHI of 2.8E+02). Fish experienced the least amount of potential risk (EHI of 1.8E+00) (LBG-BMcD, 2013). A summary of the ECORA results for representative wildlife are presented in Table 1-3.

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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

The 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. The 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 the CERCLA (42 United States Code [USC] § 9601 et. Seq.) and the 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.

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 the CERCLA comply with all pertinent federal and state 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 the 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(s) of activities the statute or regulations require, limit, or prohibit.

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 potential 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 following eight factors, as identified in the NCP (40 CFR 300.400(g)(2), are generally considered in determining if a requirement is relevant and appropriate:

- The purpose of the requirements and the purpose of the CERCLA action;
- The medium regulated or affected by the requirement and the medium contaminated or affected at the CERCLA site;
- The substances regulated by the requirements and the substances found at the CERCLA site;
- The actions or activities regulated by the requirements and the remedial action contemplated at the CERCLA site;
- Any variance, waivers, or exemptions of the requirement and their availability for the circumstances at the CERCLA site;
- The type of place regulated and the type of place affected by the release;
- Type and size of structure or facility regulated and the type and size of structure or facility affected by the release or contemplated by the CERCLA action; and
- Any consideration of use or potential use of affected resources in the requirement and the use or potential use of the affected resource [40 CFR 400(g)(2)(I) through (viii)] 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. Chemical-specific ARARs specify requirements that may define acceptable exposure levels and can be used in establishing preliminary remediation goals. Location-specific ARARs specify requirements that may set restrictions on activities within locations such as floodplains or wetlands. Action-specific ARARs may set controls or restrictions for particular treatment and disposal activities related to the management of hazardous waste (USEPA, 1988).

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 DAA. Since the preliminary chemical-specific ARARs will generally be the same for all alternatives, a single list is sufficient and does not need to be repeated 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 the CERCLA remedies should be identified.

## 2.2 PRELIMINARY ARAR AND TBC IDENTIFICATION

### 2.2.1 Introduction

An initial evaluation of potential ARARs for the OB/OD was performed as a part of the Remedial Investigation/Feasibility Study (RI/FS) Work Plan (WP) development. This was included in Section 3.0 of the *Remedial Investigation / Feasibility Study Work Plan for the Open Burning / Open Detonation Ground (Range 16) Operable Unit 006 at Fort Riley, Kansas* (LBG-BMcD, 2011) (RI/FS WP). Potential ARARs and TBCs for the OB/OD have been identified during the remedial process by using KDHE's *Potential Applicable or Relevant and Appropriate Requirements,* Bureau of Environmental Remediation (BER) Policy # BER-RS-015 (KDHE, 2005a) and review of previous FSs at Fort Riley. The list of potential ARARs and TBCs identified for the OB/OD is shown in Appendix 2A. ARAR identification is an iterative process and possible ARARs are re-examined throughout the RI/FS process.

### 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 COCs at the OB/OD. The ARAR evaluation was conducted in accordance with the *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 OB/OD were identified and are summarized in the following section. 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 the OB/OD may be updated as necessary throughout the CERCLA process.

#### 2.2.2.1 Preliminary Chemical-Specific ARARs

The preliminary chemical-specific ARARs for the OB/OD are:

- Safe Drinking Water Act of 1974 (42 USC § 300f et seq. as amended in 1986), National Primary Drinking Water Regulations and Standards (40 CFR § 141 and 142) (i.e. MCLs), National Secondary Drinking Water Standards (40 CFR § 143), and Underground Injection Control Program (40 CFR § 144-148)

- Kansas Drinking Water Standards (Kansas Administrative Regulations [K.A.R.] 28-15a-1 to 28-15a-571)

#### 2.2.2.2 Preliminary Location-Specific ARARs

The preliminary location-specific ARARs for the OB/OD are:

- Environmental Use Controls (Kansas Statutes Annotated [K.S.A.] 65-1,221 to 65-1,235)

- Archaeological and Historic 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 § 2901-2911)

- Fish and Wildlife Coordination Act (16 USC § 661-667e)

- National Historic Preservation Act of 1966 (16 USC § 470 et seq.)

- Kansas Historic Preservations Act (K.A.R. 118-3-1 to 118-3-16)

- Non-Game, Threatened or Endangered Species (K.A.R. 115-15-1 to 115-15-4)

#### 2.2.2.3 Preliminary Action-Specific ARARs

The preliminary action-specific ARARs for the OB/OD are:

- Clean Air Act of 1970 (42 USC § 7401 et seq. as amended in 1977 and 1990), Standards of performance for new Stationary Sources (40 CFR 60), National Emissions Standards for Hazardous Air Pollutants (40 CFR 61), and National Emission Standards for Hazardous Air Pollutants for Source Categories including Site Remediation (40 CFR 62)

- Clean Water Act of 1972 (33 USC § 1251 et seq. as amended in 1977 and 1987), National Pollutant Discharge Elimination System (NPDES) (40 CFR 122), Storm Water Discharge Requirements NPDES (40 CFR 122.26), Federal Water Quality Standards (40 CFR 131), General Pre-Treatment Regulations for existing and New Sources of Pollution for Publically Owned Treatment Works (40 CFR 403), and Wetlands Protection (40 CFR 22, 230-233 and 33 CFR 320-330)

- CERCLA of 1980 (42 USC § 9601 et seq. as amended by the SARA of 1986), NCP (40 CFR 300)

- RCRA of 1979 (42 USC § 6901 et seq. as amended by the Hazardous and Solid Waste Amendments (HSWA) of 1984 and 1986, the Federal Facilities Compliance Act of 1992, and the Land Disposal Program Flexibility Act of 1996;
  - Solid Waste Disposal Facility Criteria (40 CFR 257 to 258)
  - Standards for Identification and Listing of Hazardous Waste (40 CFR 261)
  - Standards Applicable to Generators of Hazardous Waste (40 CFR 262)
  - Standards Applicable to Transporters or Hazardous Waste (40 CFR 263)
  - Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities (40 CFR 264)
  - Manifesting, Record Keeping, and Reporting Requirements (40 CFR 264.70 to 264.77)
  - Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities (40 CFR 265)

- Emergency Planning and Community 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 of 1970 (29 USC § 651 et seq.), Occupational Safety and Health Administration (OSHA) Safety and Health Standards for Workplace (29 CFR 1910), and OSHA Safety and Health Standards for Construction (29 CFR 1926)

- Ambient Air Quality Standards and Air Pollution Control (K.A.R. 28-19-1 to 28-19-801)

- Hazardous Waste Management Standards and Regulations (K.A.R. 28-31-1 to 28-31-16)

- Solid Waste Management (K.A.R. 28-29-1 to 28-29-121 and 28-29-2,101 to 28-29-2,113)

- Spill Reporting (K.A.R. 28-46-1 to 28-46-44)
- Water Well Contractor's License; Water Well Construction and Abandonment (KAR 28-30-1 to 28-30-10)
- Underground Injection Control Regulations (K.A.R. 28-46-1 to 28-46-44)
- Emergency Planning and Right-to-Know (K.A.R. 28-65-1 to 28-65-4)
- Kansas Board of Technical Professions (K.A.R. 66-6-1 to 66-14-12)

### 2.2.3 Overview of Guidance and Policies

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

TBCs used to evaluate remedial alternatives for the OB/OD include the following:

- *Risk-Based Standards for Kansas (RSK) (RSK Manual – 5$^{th}$ Version)* (KDHE, 2010)
- *USEPA Regional Screening Level (RSL) Tables* (USEPA, 2012)
- *Land Use in the CERCLA Remedy Selection Process Memorandum,* Office of Emergency and Remedial Response, Office of Solid Waste and Emergency Response (OSWER) Directive 9355.7-04 (USEPA, 1995a)
- *Evaluating Future Land Use,* KDHE BER Policy #BER-RS-005 (KDHE, 2005b)
- *Consideration for Remedial Standards,* KDHE BER Policy #BER-RS-033 (KDHE, 2005c)
- *Groundwater Protection Strategy*, National Technical Information Service (NTIS) Order Number PB88-112107 (USEPA, 1984)
- *Considerations for Groundwater Use and Applying RSK Standards to Contaminated Groundwater,* KDHE BER Policy #BER-RS-045 (KDHE, 2012a)
- *Consideration for Hydraulic Containment*, KDHE BER Policy # BER-RS-028 (KDHE, 2005d)

- *Monitored Natural Attenuation of Volatile Organic Compounds in Groundwater*, KDHE BER Policy # BER-RS-042 (KDHE, 2012b)

- *Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites,* EPA OSWER Directive 9200.4-17P, EPA/540/R-99/009 (USEPA, 1999)

- *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA,* EPA OSWER Directive 9355.3-01, EPA/540/G-89/004 (USEPA, 1988)

- *Guidance for Quality Assurance Project Plans,* EPA/240/R-02/009 (USEPA, 2002a)

- *Guidance on Systematic Planning Using the Data Quality Objectives Process,* EPA/240/B-06/001 (USEPA, 2006)

- *Risk Assessment Guidance for Superfund, Volume I;*
  - *Part A,* EPA OSWER Directive 9285.7-45, EPA-540-R-89-002 (USEPA, 1989c)
  - *Part E,* EPA OSWER Directive 9285.7-02EP, EPA-540-R-99-005 (USEPA, 2004)
  - *Part F,* EPA OSWER Directive 9285.7-82, EPA-540-R-70-002 (USEPA, 2009)

- *Supplemental Guidance for Assessing Susceptibility from Early-Life Exposure to Carcinogens.* EPA/630/R-03/003F (USEPA, 2005)

- *Memorandum on Human Health Toxicity Values in Superfund Risk Assessments.* Office of Solid Waste and Emergency Response, OSWER Directive 9285.7-53 (USEPA, 2003)

- *Groundwater Sampling Guidelines for Superfund and RCRA Project Managers,* EPA/542/S-02/001 (USEPA, 2002b)

- *Remedial Design/Remedial Action Handbook,* EPA OSWER Directive 9355.0-04B, EPA/540/R-95/056 (USEPA, 1995b)

- *Best Management Practices for Soils Treatment Technologies,* EPA/530/R-97/007 (USEPA, 1997a)

- *Storm Water Management for Construction Activities,* EPA/832/R-92/005 (USEPA, 1992)

- *Safety and Health Requirements,* Engineer Manual 385-1-1 (USACE, 2008)

- *Unexploded Ordnance Support during Hazardous, Toxic, and Radioactive Waste and Construction Activities,* Engineer Pamphlet 75-1-2 (USACE, 2000)

- *Explosives Safety Management and the Department of Defense Explosives Safety Board,* DoD Directive 6055.9E (DoD, 2005)

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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 completed exposure pathways for soil contamination (surface and subsurface) at the OB/OD identified in the HHBLRA were incidental ingestion of surface and subsurface soil, absorption through dermal contact with surface and subsurface soil, inhalation of outdoor vapors from soil, and inhalation of fugitive dust from surface and subsurface soil. The results of the HHBLRA concluded that the risks for all populations were above the USEPA's allowable noncancer risk level and within the USEPA's cancer risk management range (LBG-BMcD, 2013).

### 3.2.2 Groundwater

Potential completed exposure pathways for groundwater contamination at the OB/OD identified in the HHBLRA were ingestion of groundwater as a drinking source, absorption through dermal contact with groundwater, inhalation of outdoor vapors from groundwater, and inhalation of vapors from groundwater use. The results of the HHBLRA concluded that the risks for the current site worker were below both the USEPA's allowable noncancer risk level and the USEPA's cancer risk management range. The risks for the future site worker were above the USEPA's allowable noncancer risk level and the USEPA's cancer risk management range. The risks for the future demolition worker were above the USEPA's allowable noncancer risk level and within the USEPA's cancer risk management range (LBG-BMcD, 2013).

### 3.2.3 Surface Water

Potential completed exposure pathways for surface water contamination at the OB/OD identified in the HHBLRA were for absorption through dermal contact with surface water and inhalation of outdoor vapors from surface water. The results of the HHBLRA concluded that the risks for the current and future site workers were below the USEPA's allowable noncancer risk level and above the USEPA's cancer risk management range. The risks for the current and future demolition worker were below the

USEPA's allowable noncancer risk level and within the USEPA's cancer risk management range (LBG-BMcD, 2013).

## 3.3 CHEMICALS OF CONCERN

The HHBLRA and ECORA concluded that COCs at the OB/OD present in soils, groundwater, and surface water do pose significant risks to human health or the environment.

COCs for the OB/OD were based upon those chemicals that pose a cancer risk greater than 1E-06 and a hazard quotient greater than 1.0:

***Soil***

TCE

***Groundwater***

PCA Naphthalene TCE Benzo(a)pyrene bis(2-ethylhexyl)phthalate

***Surface Water***

PCA TCE Benzo(a)pyrene

## 3.4 REMEDIAL ACTION OBJECTIVES

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

1) Cumulative excess cancer risk to an individual exceeds the 1E-04 to 1E-06 risk management range.

2) Non-cancer HI is greater than one.

3) Site contaminants cause adverse environmental impacts.

4) Chemical-specific standards, including ARARs and/or TBCs that define acceptable levels are exceeded and exposure to contaminants above these levels is predicted for the reasonable maximum exposure (RME) identified in the HHBLRA.

For the OB/OD, items 1 through 4 above apply, in that the excess cancer risk to an individual exceeds the 1E-04 to 1E-06 risk management range, the non-cancer HI is greater than one, site contaminants could cause adverse environmental impacts, and chemical-specific ARARs are being exceeded. The drinking water standard (i.e., MCL) is exceeded in the groundwater.

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.

RAOs are developed in this section considering the 1) current and future use at the OB/OD; 2) beneficial use of groundwater at the OB/OD; 3) results of risk assessment; and 4) anticipated fate and transport of contaminants beneath the OB/OD. Current land use, risk assessment (including media of interest, COCs, and exposure pathways), and anticipated fate and transport are summarized in previous sections of this report with more details provided in the RI Report (LBG-BMcD, 2013). The following sections provide additional discussion of anticipated future land use and beneficial groundwater use at the OB/OB.

### 3.4.1 Land Use

#### 3.4.1.1 General

Land use assumptions are an integral factor in the development of RAOs. Known current uses and anticipated future use assumptions are the basis for the populations and pathways evaluated in the risk assessment. 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, 1995a 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 are the following:

- RAOs should reflect the reasonably anticipated future land use or uses.
- Future land use assumptions allow the baseline risk assessment 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 OB/OD 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 OB/OD, including residential, recreational, conservation, commercial, and agricultural.

The intent of this land use evaluation is to ascertain feasible options for the development of the OB/OD as it pertains to the selection of RAOs and PRGs.

#### 3.4.1.2 Anticipated Future Land Use

It is anticipated that the US Army will retain operational control of the OB/OD and that future land use will be as described in the Fort Riley RPMP (Black & Veatch, 2007). This anticipated use consists of open detonations for emergency disposal of ordnance and training.

The anticipated land use should be considered in defining RAOs and evaluating remedial alternatives. It is anticipated that Fort Riley will continue to remain as an active US Army post into the foreseeable future with no change in its basic mission. Land use at the OB/OD should remain essentially as its current usage. Based on projected land uses, the current availability of an ample supply of potable water from existing supply wells, and the projected potable water demands for the post, it is extremely unlikely that groundwater from the OB/OD will be exploited. Future land and groundwater uses are anticipated to remain essentially the same as their current usage.

### 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 OB/OD 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 would be detrimental exposure to environmental receptors at the OB/OD, if groundwater were to be used.

Although there is no need for supply wells to be installed at the OB/OD given the current and anticipated future land use and the availability of other better sources of drinking water, any beneficial use of the groundwater would be as a potential source of domestic supply. RAO and PRG development should reflect this.

### 3.4.3 Defined RAOs

Based on the HHBLRA and ECORA, the preliminary ARARs identified in Section 2.0, the media of interest, the COCs in soil, groundwater, and surface water at the OB/OD, and the anticipated land and beneficial groundwater use, the following RAOs for the OB/OD are presented:

***Soil***

- Prevent/minimize migration of COCs that would result in groundwater with concentrations of chemicals in excess of MCLs or risk-based cleanup goals (PRGs) for the current and future site worker and current and future demolition worker.

- Prevent/minimize inhalation of vapors from soil with COCs with concentrations in excess risk-based cleanup goals (PRGs) and/or having a total excess cancer risk greater than the USEPA 1E-04 to 1E-06 risk management range or an HI greater than one for the current and future site worker and current and future demolition worker.

***Groundwater***

- Prevent/minimize ingestion of or direct contact with groundwater with COCs with concentrations in excess of MCLs or risk-based cleanup goals (PRGs) and/or have a total excess cancer risk greater than the USEPA 1E-04 to 1E-06 risk management range for the future site worker and current and future demolition worker.

- Prevent/minimize ingestion of groundwater with COCs with concentrations in excess of MCLs or risk-based cleanup goals (PRGs) and/or have a HI greater than one for the future site worker and current and future demolition worker.

- Prevent/minimize inhalation of outdoor vapors from groundwater or inhalation of vapors from groundwater use with COCs with concentrations in excess risk-based cleanup goals (PRGs) and/or having a total excess cancer risk greater than the USEPA 1E-04 to 1E-06 risk management range or an HI greater than one for the current and future site worker and current and future demolition worker.

***Surface Water***

- Prevent/minimize direct contact with surface water with COCs that exceed the risk-based cleanup goals (PRGs) and/or have a total excess cancer risk greater than the USEPA 1E-04 to 1E-06 risk management range for the current and future site worker and current and future demolition worker.

The RAOs are listed in the general sequence in which they should be addressed (USEPA, 1997b). 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 COC 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, groundwater, and surface water, and are formed from a compilation of MCLs, non-promulgated clean-up levels, and chemical, physical, and toxicological properties of the COC at the site. PRGs for the OB/OD were calculated for soil, groundwater, and surface water for both the current/future site worker and current/future demolition worker. In order to remain protective of all exposures, the most conservative PRG was chosen for each medium of concern (see Tables 3-13, 3-14, and 3-15). The PRGs for the OB/OD are presented in the sections below.

### 3.5.1 Soil

- TCE 10.72 milligrams per kilogram (mg/kg) (Table 3-13)

For soils, the PRG for TCE at the OB/OB is 10.72 mg/kg for non-residential soil, based on the calculations provided on Tables 3-1, 3-2, 3-7, and 3-8. Due to the unique nature of the site, a future demolition worker scenario was considered. This scenario represents those individuals involved in training and/or unexploded ordnance (UXO) disposal activities. As such, a site-specific exposure frequency was used. Based upon use logs obtained from Fort Riley's UXO personnel, Range 16 was accessed for a total of 55 man hours during fiscal year 2013, assuming a three man team present each time for 1.5 hours. In order to remain conservative, it was assumed one demolition worker could access Range 16 for the full duration of 55 man hours over the course of a year. Information obtained from Fort Riley UXO personnel is presented in Appendix 3-A.

### 3.5.2 Groundwater

- PCA 2.55 µg/L (Table 3-14)
- Naphthalene 2.61 µg/L (Table 3-14)
- TCE 5 µg/L (USEPA MCL)

- Benzo(a)pyrene 0.2 µg/L (USEPA MCL)
- bis(2-ethylhexly)phthalate 6 µg/L (USEPA MCL)

For groundwater, drinking water standards are used, where available, although CERCLA Alternate Concentration Limits (ACLs) may also be used if the requirements of the CERCLA Section 121 (d) (2) (B) (ii) are met. ACLs may be established in lieu of cleanup levels that would otherwise be ARARs (i.e. MCLs). 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.

The following fulfillment circumstances that may prevent the use of ACLs:

1) If the degradation of the parent product produces a daughter product with a higher toxicity or

2) If there becomes an eco-risk as a result of the contaminants entering into the surface water.

The results of the qualitative assessment of the OB/OD concluded that no significant effects were observed during the December 15, 2011, site visit. The OB/OD was occupied by a variety of common plant and animal species tolerant of human disturbances. Fish and crayfish were observed in a pool along an ephemeral stream located downstream of the OB/OD. Areas devoid of vegetation or stressed vegetation were not observed during the site visit.

Currently, the OB/OD site is being used as an ordnance disposal area with plans to continue to use the site as an ordnance disposal area. The OB/OD consists of managed and unmanaged grasslands with open riparian corridors occurring along the two ephemeral stream drainages along the western, eastern and southern edges of the OB/OD. The lands surrounding OB/OD consist of undeveloped wooded and grassy lands. The current disturbed nature of the OB/OD site is unlikely to attract populations of rare or protected species. Common wildlife species that are tolerant of humans and disturbances will remain in the area and continue to use the OB/OD. It was assumed that, regardless of the future of the OB/OD site, the existing representative wildlife species would continue to enter the OB/OD site when human disturbances are minimal and continue to come into contact with COECs through various daily activities. However, a wildlife species actual risk would be less than predicted if it spends less time on the OB/OD because of regular human disturbances or the lack of prey or forage due to regular human disturbances.

In general, ACLs may be used where the preceding conditions are satisfied (as at the OB/OD), 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 OB/OD is considered to have a potential beneficial use as a drinking water source; therefore, the PRGs are defined as the MCLs, where available. Tables 3-3, 3-4, 3-9, and 3-10 provide PRG calculations for those chemicals which do not have MCLs.

### 3.5.3 Surface Water

- PCA 63.6 µg/L (Table 3-15)
- TCE 401 µg/L (Table 3-15)
- Benzo(a)pyrene 1.07 µg/L (Table 3-15)

For surface water, PRGs were calculated using the dermal component of the groundwater PRG calculations. Tables 3-5, 3-6, 3-11, and 3-12 provide the PRG calculations for surface water.

A summary of the PRGs for soil, groundwater, and surface water are provided on Tables 3-13, 3-14, and 3-15, respectively.

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.

## 3.6 AREAS AND VOLUMES OF IMPACTED MEDIA EXCEEDING PRGs

### 3.6.1 Soil

The metal debris pits were identified in the RI Report as the possible contaminant source area. Exceedances of the TCE PRG of 10.72 mg/kg in soil are near or immediately down gradient of the metal debris pits as shown on Figures 1-4 and 1-5. Due to the presence of a metallic signature, the central portion of the northern metal debris pit was not sampled for chemical analysis. Based upon the pattern of contamination detected, it is probable that the soil within this area also has exceedances of PRGs.

For cost estimating purposes in this FS, it was estimated that approximately 460 cubic yards of soil would be removed in the source area. This would include the 10-feet by 10-feet metallic anomaly identified through geophysical testing during the RI and an additional 5 feet (minimum) on each side to allow access for inspection of the metallic anomaly, sampling, and removal and a 25 percent volume contingency factor due to the uncertainty of the extent of soil contamination. In the surrounding area, it was estimated that approximately 7,000 cubic yards of soil would be excavated in an area approximately 100-feet by 60-feet by 25-feet and a 25 percent volume contingency factor. The soil removal estimates are based on the assumption that soil conditions in the area would support use of a vertical cut for the excavation; this assumption would have to be confirmed during the remedial design. These estimates are conservative based on the available data and assumes that excavation may be required beyond the estimated limits for contaminants exceeding PRGs. The actual limits of remediation would be based on the final area where contaminates concentrations exceed soil PRGs as determined during the remedial design and construction.

### 3.6.2 Groundwater

The TCE groundwater contamination plume as shown on Figures 1-9, and 1-11 encompasses an area of approximately 17 acres. The PCA groundwater contamination plume shown on Figures 1-10 and 1-12 encompasses an area of approximately 7.5 acres. The TCE and PCA concentrations exceeding PRGs (*i.e.,* 5 µg/L for TCE and 2.55 µg/L for PCA) extend to the south and west of the presumed source area, with concentrations declining with distance away from the presumed source area.

### 3.6.3 Surface Water

Surface water exists at the OB/OD during periods of heavier precipitation, wet weather features like ephemeral streams, springs, and seeps tend to flow and weep. During wetter weather conditions, contaminants in the seeps, spring, and the ephemeral streams down gradient of the metal debris pits appear. Historically, detection in the surface water have only exceeded PRGs (PCA and benzo(a)pyrene) at two sample locations (Spring-01 and Stream-11). PCA exceeded its PRG of 63.6 µg/L in May and June of 1997 and benzo(a)pyrene exceeded its PRG of 1.07 µg/L in December of 2011.

Water in the spring is only present part time, generally in the spring when groundwater elevations are higher or following large precipitation events, and thus appears linked to fluctuations in the groundwater. With respect to the benzo(a)pyrene, the PRG exceedance at the Stream-11 location, water has only been observed once in the eastern ephemeral stream has have not been replicated during previous or subsequent event. Because of the variable nature of the surface water at the OB/OD and its apparent link to groundwater, especially at the spring, it is not possible to estimate the area and volume of surface water exceeding PRGs.

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# 4.0 TECHNOLOGY IDENTIFICATION AND SCREENING

## 4.1 INTRODUCTION

The purpose of this section is to identify and evaluate potential remedial technologies for the OB/OD. The selection of potentially feasible technologies for the OB/OD comprises two steps:

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

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 OB/OD are presented below:

***Soil***

- No Action
- Institutional Controls
- Removal and Disposal or Treatment
- Ex-Situ Biological Treatment
- In-Situ Treatment

***Groundwater***

- No Action
- Institutional Controls
- Other Controls
- Containment

- Extraction, Ex-Situ Treatment, and Discharge
- In-Situ Treatment

***Surface Water***

- No Action
- Institutional Controls
- Other Controls
- Surface Capture, Treatment, and Discharge

## 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, groundwater, and surface water. Technologies selected for preliminary screening represent a wide range of responses commonly used to address soil, groundwater, and surface water contamination. Both fully-developed and emerging process options have been considered. A list of technologies for their respective media and process options are presented in Tables 4-1 through 4-3. Technologies are grouped into distinct subsets that correspond to the identified media-specific 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 OB/OD. Technologies are removed from further consideration if they are not technically feasible based on site-specific conditions such as soil type, aquifer characteristics, the volume of impacted media, and the chemical characteristics of compounds of interest. A summary of this initial screening of technologies is presented, along with a brief description of each technology and the rationale for eliminating process options from further consideration, in Tables 4-4 through 4-6.

## 4.3 EVALUATION OF TECHNOLOGIES

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

OB/OD. This section describes the evaluation and screening procedures and criteria which result in the selection of feasible remedial technology options.

Following the 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 media specific technologies and general comments regarding potential benefits or limitations of each process option are provided in Tables 4-7 through 4-9 as part of the screening process. From the technology screening process, several process options are identified as potentially feasible options for soil, groundwater, and surface water remediation at the OB/OD 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 evaluation of technologies (Tables 4-7 through 4-9) are discussed in the following sections.

### 4.3.1 EVALUATION OF SOIL TECHNOLOGIES

Soil technology and process options which were retained in Table 4-7 are discussed below.

#### 4.3.1.1 No Action

Pursuant to Section 300.430(e)(6) of the revised NCP (July 1, 2012) and the USEPA's current guidance for conducting RI/FS investigations, 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.

#### 4.3.1.2 Institutional Controls Through the Fort Riley RPMP

Institutional controls could be applied through use of the Fort Riley RPMP. The Fort Riley RPMP ensures 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 Fort Riley RPMP. It consists of a variety of narratives and supporting graphics. One of these graphic representations is the Master Plan Environmental Overlay (MPEO). This graphic reflects operational and environmental constraints.

The Fort Riley 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 site workers and demolition workers, and tactical dig permits that control potential exposure for soldiers.

Institutional controls for soil, through the Fort Riley RPMP, although not viable as a stand-alone remedial option is retained for inclusion as a potential component of a more robust remedial package, since this option may be used in combination with other remedial technologies.

#### 4.3.1.3 Removal and Disposal or Treatment

Soil removal and disposal or treatment involves excavation of contaminated soil at the source area that contains concentrations above the PRGs. The excavation will then be backfilled with high-content clay that would retard precipitation infiltration. Excavated soil will be transported off site for disposal, treated on site in a land-farm treatment cell, or transported off site for thermal treatment and disposal.

#### 4.3.1.3.1 Off-Site Disposal in a Landfill

Subsurface soils with concentrations of TCE above the PRG value of 10.72 mg/kg will be excavated using a backhoe and placed in lined end-dump trucks for disposal off site at an approved facility. Following soil removal, clean soil with high-clay content will be used as backfill material in the excavation to retard precipitation infiltration. The excavation will be graded to match the surrounding topography.

Based on the effectiveness of excavation, backfill, and disposal, this treatment technology is retained for further consideration as a potential component of remedial alternatives.

#### 4.3.1.3.2 On-Site Land Farming

Subsurface soils with concentrations of TCE above the PRG value of 10.72 mg/kg will be excavated using a backhoe and the extracted soil will be transported to a newly constructed on-site land farm treatment cell. Land farming is an effective above ground remediation technology that reduces VOC contaminant concentrations. A land-farm treatment cell is a lined, bermed area that will contain the excavated soil. Installation of a leachate collection system will also be required to handle water that accumulates within the bermed area due to precipitation events. Excavated soil placed within the bermed area will 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. Once the soil is treated, the clean soil will then be spread on site or transported to the Fort Riley construction and debris (C&D) landfill and used as landfill cover.

Based on the potential effectiveness of treating contaminated soil in a land-farm treatment cell, this treatment technology is retained for further consideration as a potential component of remedial alternatives.

#### 4.3.1.3.3 Off-Site Thermal Incineration and Disposal

Subsurface soils with concentrations of TCE above the PRG value of 10.72 mg/kg will be excavated using a backhoe and placed in lined end-dump trucks for disposal off site for thermal incineration at the nearest approved facility (Kimball, Nebraska). Following incineration, the soil will then be used as landfill cover. Incineration operates at high temperatures between 800 to 1,200 degrees Celsius (°C) or 1,500 to 2,200 degrees Fahrenheit (°F). At these temperatures, VOCs will volatilize and combust. The destruction and removal efficiency for properly operated incinerators exceed the 99 percent requirements for hazardous waste.

Based on the effectiveness of treating contaminated soil using thermal incineration, this treatment technology is retained for further consideration as a potential component of remedial alternatives.

#### 4.3.1.4 In-Situ Treatment: Soil Vapor Extraction

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 gas leaving the soil may be treated to recover or destroy the contaminants, depending on local and state air discharge regulations. Vertical extraction vents are typically installed at depths of five feet or greater and have been successfully applied as deep as 300 feet. Horizontal extraction vents (installed in trenches or horizontal borings) can be used as warranted by contaminant zone geometry, drill rig access, or other site-specific factors. 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.

Based on the effectiveness of treating contaminated soil using SVE, this treatment technology is retained for further consideration as a potential component of remedial alternatives.

### 4.3.2 Evaluation of Groundwater Technologies

Groundwater technology and process options which were retained in Table 4-8 are discussed below.

#### 4.3.2.1 No Action

Pursuant to Section 300.430(e)(6) of the revised NCP (July 1, 2012) and the USEPA's current guidance for conducting RI/FS investigations, 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.

#### 4.3.2.2 Institutional Controls Through the Fort Riley RPMP

Institutional controls could be applied through use of the Fort Riley RPMP. The Fort Riley RPMP ensures 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. 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 LRC in the Fort Riley RPMP. It consists of a variety of narratives and supporting graphics. One of these graphic representations is the MPEO. This graphic reflects operational and environmental constraints.

The Fort Riley 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 site workers and demolition workers, and tactical dig permits that control potential exposure for soldiers.

In addition, the Fort Riley RPMP would be an appropriate planning mechanism for addressing the issue of water supply well locations. Fort Riley currently has a supply well field that is operated well below capacity. There is no valid reason to construct water supply wells within the vicinity of the OB/OD as the post has sufficient surplus supply to meet future contingencies. A restriction on the construction of supply wells at the OB/OD is to be incorporated into the Fort Riley RPMP as a remedial alternative.

Institutional controls for groundwater, through the Fort Riley RPMP, although not viable as a stand-alone remedial option is retained for inclusion as a potential component of a more robust remedial package, since this option may be used in combination with other remedial technologies.

#### 4.3.2.3 Groundwater Monitoring

Groundwater monitoring can be used to evaluate contaminant concentration and migration, Monitored Natural Attenuation (MNA) indicators, 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 unexpected contaminant migration at the OB/OD. A network of groundwater monitoring wells is currently in place at the OB/OD. If necessary, additional monitoring wells could be installed to evaluate specific remedial system requirements. Groundwater monitoring is an effective means of evaluating site conditions and could easily be implemented at the OB/OD.

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

#### 4.3.2.4 Monitored Natural Attenuation

MNA refers to the reliance on natural attenuation (NA) 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, 2012b). MNA relies on natural subsurface processes to reduce contaminant concentrations. Mechanisms which result in NA are either destructive or nondestructive. Nondestructive mechanisms include dispersion, diffusion, dilution, volatilization, and sorption. Destructive mechanisms include abiotic and biotic degradation processes.

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

- **Diffusion –** 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 –** The process by which contaminant levels are reduced by the natural introduction of clean water into an area of contaminated groundwater. The clean water mixes with the contaminated water and reduces the contaminant concentrations through dilution.

- **Volatilization** – 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 –** 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 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.

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 reductive dechlorination (an electron acceptor reaction) (Wiedemeier and Chapelle, 1998). The reductive dechlorination pathway for TCE is as follows: TCE $\rightarrow$ cis- or trans-1,2-dichloroethene (trans-1,2-DCE)

→ Vinyl Chloride (VC) → Ethene → Carbon Dioxide ($CO_2$) + Water ($H_2O$). PCA can degrade under anaerobic conditions by three main reaction pathways – a hydrogenolysis pathway that produces 1,1,2-trichloroethane (1,1,2-TCA) and 1,2-Dichloroethane (1,2-DCA) as intermediate daughter compounds; a dichloroelimination pathway that produces cis- or trans-1,2-DCE, and VC as intermediate daughter products; and an abiotic dehydrochlorination reaction that produces TCE (Vogel et al., 1987; Lorah et al., 1997; and Chen et al, 1996).

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 NA include: temperature, pH, methane, ethene/ethane, alkalinity, nitrate ($NO_3^-$) /nitrite ($NO_2^-$), sulfate ($SO_4^{-2}$) /sulfide ($S^{-2}$), 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.

Contaminant concentration trends indicate that MNA via nondestructive mechanisms is occurring within the regolith/weather bedrock aquifer at the OB/OD. Furthermore, site geochemical and contaminant concentrations, and results from the USEPA reductive dechlorination screening protocol (USEPA, 1998) performed in the RI, indicate there is strong evidence for reductive dechlorination (and thus NA) of chlorinated solvents in the deep bedrock aquifer at the OB/OD. Although MNA is not a viable stand-alone remedial alternative for the OB/OD because MNA alone does not address the source area, MNA is; however, retained for inclusion as a potential component of a more robust remedial package, since this option may be used in combination with other remedial technologies.

#### 4.3.2.5 In-Situ Treatment: Chemical Reagent Injection

In-situ treatment involves injection of one or more reactive media into the aquifer to promote conditions that are effective in the treatment of the chlorinated solvents plume(s). A wide range of reagents are available ranging from relatively common products such as edible oils and lactose to special formulations developed to treat specific contaminants under both aerobic and anaerobic conditions. Treatability studies are conducted during the design phase to identify the appropriate reagent(s) for treating each of the identified contaminants. The reagent can be injected into the groundwater using a fluid delivery system such as direct-push technology or through the use of specially constructed injection wells (vertical or horizontal).

### 4.3.3 Evaluation of Surface Water Technologies

Surface water technology and process options which were retained in Table 4-9 are presented below.

#### 4.3.3.1 No Action

Pursuant to Section 300.430(e)(6) of the revised NCP (July 1, 2012) and the USEPA's current guidance for conducting RI/FS investigations, 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.

#### 4.3.3.2 Institutional Controls Through the Fort Riley RPMP

Institutional controls could be applied through use of the Fort Riley RPMP. The Fort Riley RPMP ensures 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. 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 LRC in the Fort Riley RPMP. It consists of a variety of narratives and supporting graphics. One of these graphic representations is the MPEO. This graphic reflects operational and environmental constraints.

The Fort Riley 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 site workers and demolition workers, and tactical dig permits that control potential exposure for soldiers.

Institutional controls for soil, through the Fort Riley RPMP, although not viable as a stand-alone remedial option is retained for inclusion as a potential component of a more robust remedial package, since this option may be used in combination with other remedial technologies.

#### 4.3.3.3 Surface Water Monitoring

Surface water monitoring can be used to evaluate contaminant concentration 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 unexpected contaminant migration at the OB/OD. Surface water monitoring is an effective means of evaluating site conditions and could be implemented at the OB/OD.

Surface water monitoring is retained for inclusion as a potential component of a more robust remedial package, since this option may be used in combination with other remedial technologies.

## 4.4 REMEDIAL ALTERNATIVES

Based on the results from the screening process presented above, the following remedial alternatives are identified for soil, groundwater, and surface water at the OB/OD:

***Soil***

| | |
|---|---|
| Alternative S1 | No Action |
| Alternative S2 | Institutional Controls Through the Fort Riley RPMP |
| Alternative S3 | Removal and Disposal or Treatment:<br>S3a Off-Site Disposal in a Landfill,<br>S3b On-Site Land Farming, and<br>S3c Off-Site Thermal Incineration and Disposal |
| Alternative S4 | In-Situ Treatment: SVE |

***Groundwater***

| | |
|---|---|
| Alternative GW1 | No Action |
| Alternative GW2 | Institutional Controls Through the Fort Riley RPMP |
| Alternative GW3 | Groundwater Monitoring |
| Alternative GW4 | MNA |
| Alternative GW5 | In-Situ Treatment: Chemical Reagent Injection |

***Surface Water***

| | |
|---|---|
| Alternative SW1 | No Action |
| Alternative SW2 | Institutional Controls Through the Fort Riley RPMP |
| Alternative SW3 | Surface Water Monitoring |

* * * * *

# 5.0 DETAILED ANALYSIS OF ALTERNATIVES

## 5.1 INTRODUCTION

This discussion 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 between them in Section 6.0 of this FS 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 USEPA (USEPA, 1988). The first two criteria are the "threshold" factors. An 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 through treatment;

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. 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 preliminary 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 OB/OD are presented in Section 2.0 and Appendix 2A of this FS Report. Tables 5-1 through 5-3 present a matrix for each applicable media 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 Through Treatment

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 the risk for human exposure, (2) prevent the further degradation of site conditions or migration of contaminants to unimpacted zones, and (3) reduce volume of impacts.

### 5.2.5 Short-Term Effectiveness

This criterion addresses the effects of the remedial alternative on human health and the environment during the construction, implementation, and operational phases of remedial action until response objectives have been met. Consideration is given to protection of the community and workers during construction phases and the effectiveness and reliability of available worker protective measures. Other considerations include the potential short-term adverse environmental impacts that may result from the construction and implementation of an alternative and the time required to complete construction, implementation, and O&M activities to achieve remedial objectives. Estimated remedial times are based on the time required to remediate sites with similar COCs and conditions, COC degradation data, and professional judgment.

### 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:

- 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 estimation software (RS MEAN), vendor quotations, prior expenses, and professional judgment. 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 the USEPA guidelines (USEPA, 1993 and 2000a), the discount rate for federal projects under CERCLA is set at 7 percent in compliance with the Office of Management and Budget (OMB).

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 the costs are proportional to the 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 for soil, groundwater, and surface water are presented in Appendix 5A-1 through 5A-4, 5B-1 through 5B-5, and 5C-1 through 5C-3, respectively.

### 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 OB/OD, the state is represented by the KDHE. 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 4.0 are evaluated using the first seven criteria described above in Section 5.2. Evaluation of the last two criteria (i.e., state and community acceptance) is deferred to the ROD following receipt of state and public comments from the PP process.

In addition to the screening criteria evaluation, this DAA presents advantages and disadvantages of each alternative for addressing contaminants in soil, groundwater, and surface water. This analysis is 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 publication.

The selected remedy will need to include alternatives for soil, groundwater, and surface water remediation. For this analysis, these areas have been evaluated separately.

### 5.3.1 Soil Remediation Alternatives

Soil sampling conducted during the RI detected a number of constituents in the surface and subsurface soil. Concentrations for most constituents in the surface and subsurface soil samples were below regulatory screening levels. Surface soil sampling results indicated the presence of VOCs, SVOCs, perchlorate, explosives, and metals at relatively low concentrations. Subsurface soil samples contained a smaller suite of constituents (VOCs) in most samples as compared to surface soil samples and no SVOCs. Perchlorate was detected in approximately half of the samples analyzed although below screening levels.

In January 2013 a separate soil sampling program was conducted focusing on the metal debris area. During this sampling event, 68 surface and subsurface soil samples were collected at 20 locations. Samples were screened for chlorinated ethenes (PCE, TCE, and cis-1,2-DCE) using a field gas chromatograph (GC). Selected samples (a total of seven, or approximately 10 percent of the samples) were sent to the lab for quality control analysis where a complete VOC scan was performed. The samples analyzed by the field GC indicated concentrations of TCE above screening levels in four borings: MD-21, MD-22, MD-25 and MD-26 at depths ranging from 1 to 13 feet below ground surface (bgs). The highest concentrations were found in Boring MD-22. Samples from MD-25 and MD-26 were part of the subgroup of samples sent for off-site analysis (MD-21 and MD-22 was not in the group randomly selected to be retested) and laboratory analytical results confirmed the presence of TCE in the samples above screening levels, although the concentrations in several samples were approximately one order of magnitude less than the concentration measure by the field GC.

The soil sampling program results indicated that screening levels were exceeded for only one constituent:

- TCE – concentrations in nine samples collected from four borings.

The HHBLRA and ECORA conducted as part of the RI Report (LBG-BMcD, 2013) evaluated a range of constituents identified in soil at the OB/OD, including contaminants that were detected at concentrations below screening levels. While these constituents impact the risk to human health and the environment, only TCE was identified as a COC for the soil at the OB/OD (see Section 3.3).

Based on the results of the technology screening (Section 4.0), the following remedial alternatives for addressing contaminants in soil were identified:

| | |
|---|---|
| Alternative S1 | No Action (retained as a baseline) |
| Alternative S2 | Institutional Controls Through the Fort Riley RPMP |
| Alternative S3 | Removal and Disposal or Treatment:<br>S3a Off-Site Disposal in a Landfill,<br>S3b On-Site Land Farming, and<br>S3c Off-Site Thermal Incineration and Disposal |
| Alternative S4 | In-Situ Treatment: SVE |

#### 5.3.1.1 Alternative S1 – No Action

##### *Description*

Alternative S1, the "No Action" Alternative, is a requirement of the NCP providing a baseline for the comparison of active remedial alternatives developed for the OB/OD. Under this alternative, institutional controls are not implemented, remedial actions are not performed, and site monitoring is not conducted. By definition, this alternative requires that any current monitoring program be discontinued. At a minimum, whenever contaminants are left in place, NCP requires the following: *If a remedial action is selected that results in hazardous substances, pollutants, or contaminants remaining at the site above levels that allow for unlimited use and unrestricted exposure, the lead agency shall review such action no less than every five years after initiation of the remedial action.*.

Although under the "No Action" Alternative institutional controls are generally not enacted, it should be acknowledged that access restriction via range controls are already in place due to the location of the OB/OD on a military base within the limits of the impact area. Range controls will remain in effect as long as Fort Riley remains active.

### *Evaluation*

**Protection of Human Health and the Environment**

Based on the HHBLRA and ECORA performed in the RI Report (LBG-BMcD, 2013), this alternative is not protective of human health and the environment because the risk estimates for current and future RME scenarios exceed USEPA's accepted human and wildlife risk levels. Because this alternative would not include institutional controls there is no control of future land use, however unlikely it is that there would be a change in site usage. Therefore, an unforeseen exposure scenario (one not characterized in the RI Report) is possible when no institutional controls are acknowledged for the property. Based on this, Alternative S1 will be considered not protective of human health and the environment.

**Compliance with ARARs**

The preliminary chemical-, location-, and action-specific ARARs for Alternative S1 are presented in Table 5-1. Location- and action-specific ARARs do not apply to Alternative S1 since there are no location- or action-specific remedial measures that will be taken at the OB/OD under this alternative.

There are currently no chemical-specific ARARs for soil, although RSK (screening levels) are TBCs. Under Alternative S1 there is no regular monitoring of soil concentration trends to determine if conditions are changing and assumes that contaminant concentrations remain essentially unchanged. While surface contaminants may erode and subsurface contaminants may be flushed out of the soil over time, the time required to reach PRGs is unknown. In addition, this alternative does not address remediation of the potential source area which could potentially continue to contaminate the soil for the foreseeable future. It is anticipated that contaminant concentrations in subsurface soil will remain elevated (above PRGs) for the foreseeable future and PRGs will continue to be exceeded.

**Long-Term Effectiveness and Permanence**

Under Alternative S1, no remedial actions would be performed at the site. Based on the risk assessment results (LBG-BMcD, 2013), the current risk levels at the OB/OD to human health and the environment are above USEPA's accepted limits for human health and wildlife. Institutional controls are not acknowledged with this alternative, therefore, there is a possibility that an unforeseen exposure could occur.

A review of contaminant concentrations at the OB/OD would be required every five years to monitor contaminants remaining in the soil in accordance with the CERCLA 121(c).

## Reduction of Toxicity, Mobility, or Volume Through Treatment

No active remediation would occur at the site and what treatment that did occur would be minor and related to NA mechanisms. Reductions in contaminant toxicity, mobility or volume in vadose zone soils through some form of naturally occurring treatment mechanism are unlikely. The known depth of the contaminants (0 to 13 feet bgs) and the low permeability soils make volatilization unlikely and the lack of water in the vadose zone soils on a sustained basis makes NA unlikely. Decreases in contaminant concentrations in the soil, if they occur, are likely to be due to precipitation flushing contaminants from the vadose zone soils into the groundwater below the site. No active treatment of soil is proposed under this alternative.

## Short-Term Effectiveness

Based on the risk assessment results (LBG-BMcD, 2013), the current risk levels to human health and the environment are above USEPA's accepted limits at the OB/OD. These conditions would continue to present risks to human health and the environment in the short-term as changes in site conditions and land use to mitigate the current contamination is unlikely.

## 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 $0. There are no capital or O&M costs associated with this alternative. A detailed cost analysis for Alternative S1 is presented in Appendix 5A-1.

### *Evaluation Summary*

## Advantages

- Minimal cost.

## Limitations and Considerations

- On-going exposure above acceptable risk levels to site workers and wildlife;
- Contaminant conditions would only be assessed during the five-year reviews; and
- Potential impacts on future uses of the site.

### 5.3.1.2 Alternative S2 – Institutional Controls Through the Fort Riley RPMP

#### *Description*

This alternative involves the use of institutional controls implemented through the Fort Riley RPMP to control future uses of the OB/OD to protect human health and the environment. The inclusion of institutional controls, such as restrictions on the use of property, reduces the potential for human ingestion, inhalation, or direct contact with contaminated soil. 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 OB/OD is restricted because the site is on an active military reservation. The Fort Riley RPMP is the means that Post authorities have the ability 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 site workers and demolition workers, and tactical dig permits that control potential exposure for soldiers.

The purpose of institutional controls is to limit exposure to contaminants by restricting or controlling activities that would promote exposure. The principal institutional controls that could be applied by Fort Riley to prevent exposure to contaminants in the soil would be a prohibition against invasive activities (i.e., excavation, construction) in the impacted area (approximately 1 to 2 acres). Because the impacted area is surrounded by firing ranges and is used in the detonation of unexploded ordnance, it would not be an optimal location for the construction of new structures (buried or above ground). Given the amount of land available in the general area outside the impacted footprint, this restriction should not pose a hardship on the Post.

Figure 5-1 shows the approximate limits of the soil institutional controls that would be enacted under Alternative S2.

#### *Evaluation*

**<u>Protection of Human Health and the Environment</u>**

Based on the HHBLRA and ECORA performed as part of the RI Report (LBG-BMcD, 2013), this alternative is not protective of the environment because the exposure pathways have not been eliminated or controlled. The site exceeds USEPA's accepted risk levels for outdoor vapors for all three human exposure scenarios. While the implementation of institutional controls will limit future human exposure related to some types of activities, it does not eliminate the risk posed by contaminants in the soil for site workers who must visit the site nor does it reduce the ecological risks present at the site. Based on the exposure scenarios identified in the risk assessments, risks levels will remain above USEPA's accepted risk levels.

## Compliance with ARARs

The preliminary chemical-, location-, and action-specific ARARs for Alternative S2 are presented in Table 5-1. Currently there are no chemical-specific ARARs for soil, although RSK (screening levels) are TBCs.

Under Alternative S2 there would be no program for monitoring soil contaminant concentration trends to determine if conditions are changing and assumes that contaminant concentrations remain essentially unchanged. While surface contaminants may erode and subsurface contaminants may be flushed out of the soil over time, the time required to reach PRGs is unknown. In addition, this alternative does not address remediation of the potential source area which could potentially continue to contaminate the soil for the foreseeable future. It is anticipated that contaminant concentrations in subsurface soil will remain elevated (above PRGs) for the foreseeable future and PRGs will continue to be exceeded.

## Long-Term Effectiveness and Permanence

Under Alternative S2, no active remedial actions would be performed at the site. The long-term contaminant levels in the soil are anticipated to remain elevated above PRGs for the foreseeable future. Based on the results of the risk assessments (LBG-BMcD, 2013), the current risk levels at the OB/OD are above USEPA's accepted limits. Although institutional controls could limit future exposure related to some activities, site workers and wildlife would be exposed to contaminants based on current site usage patterns. Although a review of contaminant concentrations at the OB/OD would be required every five years to monitor contaminants remaining in the soil in accordance with the CERCLA 121(c), this would not help mitigate the risks associated with the site.

However, while institutional controls are easily implemented from a technical and administrative perspective, effective compliance may be difficult to maintain in the long term due to the limited use of the area and changes in base personnel over time.

## Reduction of Toxicity, Mobility, or Volume Through Treatment

No active treatment of soil is proposed under this alternative. Reductions in contaminant toxicity, mobility or volume in vadose zone soils through some form of naturally occurring treatment mechanism are unlikely at the OB/OD. The known depth of the contaminants (1 to 13 feet bgs based on RI data) and the low permeability soils make volatilization unlikely except within the surficial soil and the lack of water in the vadose zone on a sustained basis makes NA unlikely. Decreases in contaminant concentrations in the soil, if they occur, would likely be due to precipitation flushing contaminants from the vadose zone soils into the groundwater below the site.

**Short-Term Effectiveness**

This alternative does not involve any active remedial activities or construction and therefore poses no additional risk to construction workers or the local community in the short-term. On-going exposures to site workers and wildlife would continue from existing contaminants in the soil as identified in the risk assessments.

**Implementability**

There are no anticipated technical difficulties implementing this alternative. Because this is an active government installation, it is anticipated that there will be no problems with implementing a program of institutional controls through the Fort Riley RPMP (see Section 4.3.1.2).

**Cost Evaluation**

The present worth cost of this alternative is estimated to be $264,000. While monitoring of the site would be required to enforce restrictions, this could be conducted at minimal annual costs as part of site operations. Therefore, this alternative has a total project cost of $388,000 (undiscounted), including approximately $4,000 in capital costs for developing the institutional controls; total annual costs of $120,000 (over 30 years) involved with enforcement of the institutional controls; and $264,000 in periodic costs for five-year reviews. A detailed cost analysis for Alternative S2 is presented in Appendix 5A-2.

### *Evaluation Summary*

**Advantages**

- Minimal cost;
- Ease of implementation; and
- Reduces but does not eliminate some exposures pathways.

**Limitations and Considerations**

- Has no positive impact on ecological receptors in the area where exposure is above accepted levels and
- Potential impacts on future uses of the site.

#### 5.3.1.3 Alternative S3 – Removal and Disposal or Treatment

***Description***

This alternative involves the removal and disposal or treatment of contaminated soil at the OB/OD. Following excavation, the disturbed area would be backfilled and surface conditions restored. Disposal or treatment options that could be considered could range from off-site disposal to land farming to thermal incineration.

Alternatives incorporating treatment as well direct disposal were evaluated. It is recommended that additional data be collected during the predesign investigation studies to determine final soil disposal options.

Contaminants in the surface and subsurface soil are generally consistent with the on-going use of the site for the detonation of explosives, except for the presence of chlorinated solvents in the subsurface soil and groundwater. On the basis of available data, the contaminants are believed to be related to the metallic anomaly in the metal debris pit identified during the RI.

As part of the soil sampling program in the RI, geophysical testing was conducted in the area of the two metal debris pits. During that investigation, a metallic anomaly roughly 10 feet by 10 feet in size was detected in the southeastern corner of one of the metal debris pits (see Figure 5-2). No records are available indicating what is buried in this area but soil and groundwater sampling results suggest that this anomaly may be the source of the chlorinated solvents detected in the soil and groundwater at the OB/OD.

As part of the Remedial Design, a more detailed site investigation of the metallic anomaly would be conducted. The investigation would have two intended purposes:

- Identify the nature of the metallic signature to ensure the safety of workers in the area conducting remedial activities; and
- Confirm the suspected source area for the chlorinated solvents.

The site investigation would potentially proceed in the following manner:

- Clear the area for UXO and munitions and explosives of concern (MEC) from previous operations at the site;

- Conduct additional geophysical testing, if appropriate, of the metallic anomaly to obtain additional information on surrounding conditions. This information would include depth of cover soils, bottom depth of anomaly, and shape of metallic items in the area;
- Conduct a test pit investigation with a backhoe to expose the object and identify its condition;
- Collect additional soil and groundwater samples around the object to more fully identify contaminants in the soil; and
- Conduct sampling of the contents of any containers/drums (if found) to determine if the containers/drums and their contents can be safely removed from the site.

If the metallic anomaly is found to be related to the contaminants on the site (*e.g.*, spent solvents are identified), a work plan would be developed for safely excavating and removing the object(s) from the OB/OD and disposing of the material in accordance with state and federal regulations. This work plan could include the following activities:

- Remove the regolith and surrounding soil to expose the object;
- Remove the drums or other items for testing and, if necessary, off-site disposal of the item;
- Conduct sampling in the floor and walls of the excavation to assess contaminant levels;
- Excavate additional soil as necessary to meet PRGs;
- Characterize the excavated soil for treatment and disposal; and
- Backfill the excavation and restore the site for its intended long-term use.

Following the investigation of the metallic anomaly, the surrounding soils would be excavated for ex-situ treatment. Soil with contaminant concentrations above the PRGs would be excavated and placed in lined end-dump trucks for transport to an approved facility for treatment and disposal. Based on RI soil sampling results, an estimated 7,000 cubic yards of soil would need to be excavated and treated at the OB/OD. Following soil removal, the area would be backfilled with clean soil.

Three possible options were identified for the removal and disposal of the excavated soil:

- ***Off-Site Disposal in a Landfill:*** If it is determined through additional investigation that treatment is not required for the excavated soil under current state and federal regulation, the soil could be hauled off site for disposal in a either a Subtitle D (municipal) landfill or Subtitle C (hazardous) landfill depending on the concentration of the contaminants and whether or not they exceed regulatory thresholds. Based on the available information, it is assumed that the excavated soil could be disposed in a Subtitle D landfill located within 350 miles of Fort Riley.

- ***On-Site Land Farming:*** The excavated soil could be land farmed on site to volatilize the VOCs in the soil. Land farming has been proven effective for reducing VOC concentrations in soils and has been used at multiple sites at Fort Riley. Under this option, a land-farm treatment cell would be constructed at the OB/OD for soil treatment. The treatment cell would be bermed, lined, and a leachate collection system installed to collect and store contact water collected within the treatment cell limits. Contact water would be treated to meet applicable surface water discharge limits prior to discharge to a local stream. In the treatment cell, excavated soil would be placed in windrows and periodically disked. Solar radiation, wind, and disking of the soil would promote volatilization and biodegradation of the VOCs in the soil. At this time it has been assumed that the treatment cell would not need to be covered or air emissions controlled based on the concentrations of VOCs detected in the soil. This decision would be reevaluated during the Remedial Design. Once the soil is treated, the clean soil would be spread on site, used as general fill in selected locations, or transported to the Fort Riley C&D landfill and used as landfill cover.

- ***Off-Site Thermal Incineration and Disposal:*** The excavated soil could be transported for off-site thermal treatment at the nearest approved facility. Under this option, the soil would be excavated and placed in lined containers for transport to the selected thermal treatment facility. During the Remedial Design, potential emissions from the containers would be evaluated to determine if the use of sealed containers is necessary.

  There are a number of commercial facilities in the US that are permitted for the treatment of a range of hazardous waste materials including chlorinated solvents, the closest being in Kimball, Nebraska, approximately 650 miles from the Post. The available capacity of the different systems as well as the availability of equipment to transport the material to the facility would vary depending on the timing of remediation activities. Following thermal treatment, the soil would be disposed in a landfill operated by the incinerator facility. The cost to transport and treat contaminated soil at an incinerator facility would be high, with the estimated cost for transport and treatment potentially in excess of $400 per ton.

These three options represent the range of feasible technologies that could be implemented at the site.

##### 5.3.1.3.1 Alternative 3a – Off-Site Disposal in a Landfill

Under this alternative, excavated soil would be loaded on transfer vehicles and hauled to a landfill located in Wayoka, Oklahoma.

It is anticipated that some soil would require moisture conditioning to pass the paint filter test (required for landfill disposal). Moisture conditioning would entail mixing the excavated soil in a pug mill with a pozzolanic material (Portland cement, cement kiln dust, ash) to control the moisture content of the soil. It is anticipated that the majority of the soil would be removed well above the water table and would be moist but not saturated. On this basis, it was assumed that up to 10 percent of the material would require moisture conditioning prior to disposal.

Figure 5-2 shows the limits of the likely metallic anomaly/source area soil removal and the secondary soil removal area proposed under this alternative.

***Evaluation***

**Protection of Human Health and the Environment**

Based on the HHBLRA and ECORA performed as part of the RI Report (LBG-BMcD, 2013) the site exceeds USEPA's accepted risk levels for outdoor vapors for all three human exposure scenarios. This alternative would be protective of human health and the environment because soil with contaminant concentrations significantly above PRGs would be removed and disposed. Although an exposure scenario beyond those scenarios envisioned in the risk assessments could occur, the exposure pathway would not be complete.

**Compliance with ARARs**

The preliminary chemical-, location-, and action-specific ARARs for Alternative S3a are presented in Table 5-1. Currently there are no chemical-specific ARARs for soil although RSKs are TBCs.

Following excavation but prior to backfilling, confirmatory sampling would be conducted to ensure that soil remaining in-place meets PRGs. It is anticipated that the removal and disposal of the highly contaminated soil would comply with the preliminary PRGs.

## Long-Term Effectiveness and Permanence

Under this alternative, the removal and disposal of the contaminated soil along with the removal of a potential source area would provide a permanent, effective solution to the chlorinated solvents in soil at the OB/OD. This approach would provide a high degree of protection.

## Reduction of Toxicity, Mobility, or Volume Through Treatment

Under Alternative S3a, except for the soil in the source area, the excavated soil would not be treated. Soil with contaminant concentrations above PRGs would be excavated and hauled off site for direct disposal without treatment. Soil with contaminant concentrations below PRGs would not be treated and no steps would be taken to reduce the toxicity, mobility or volume of the remaining contaminants in the soil at the site.

## Short-Term Effectiveness

The implementation of this remedy would involve the excavation of contaminated soil, transport of the contaminated material to an off-site disposal facility disposal as well as removal of a suspected source area. Because the OB/OD is relatively isolated from residences and most site workers, construction activities should have relatively limited impacts. The risks to workers and the community are commensurate with similar construction activities including the following:

- Invasive activities in an active range have the potential to encounter UXO/MEC;
- Working around/on/with heavy equipment and hauling equipment. This risk would be similar to other remediation/construction projects. Seasonal weather conditions (cold/hot weather operations, rain and snow, wind chill) would increase the risk to workers;
- Potential exposure to soil, groundwater, and surface water containing a range of contaminants. While concentrations exceed desirable limits for routine exposure for some contaminants, in most areas contaminant concentrations are not at levels that are immediately harmful and continued, regular exposure would be required to pose a health risk to workers. Personal Protective Equipment (PPE) such as Tyvek coveralls, boot covers, and disposable gloves would be worn by site workers to prevent dermal exposure to contaminants. In areas where concentrations are detected at levels that would have the potential to cause exposures above OSHA permissible exposure limits, additional steps would be taken to minimize the exposure to construction workers;

- Some construction activities could result in a low to moderate risk to workers through potential exposure to electrical hazards, mechanical hazards, and noise hazards. The majority of these hazards can be controlled using engineering controls such as lockout/tagout procedures, safe work practices, and PPE;

- Construction traffic on area roads can pose risks to the local community both due to an increase in the number of trucks and the presence of equipment/vehicles in unfamiliar areas; and

- Construction activities would temporarily disrupt the local wildlife. Areas to be impacted are surrounded by land with similar conditions and wildlife can temporarily relocate during construction.

The majority of hazards associated with implementing this alternative could be controlled through a comprehensive health and safety protocol and notification program (*e.g.*, high visibility orange fencing, caution tape, lockout/tagout procedures, protective equipment, perimeter air monitoring, personal air monitoring for workers, heat and stress monitoring, etc.).

**Implementability**

Implementation is technically feasible. Excavation using standard construction equipment is a common approach for remediating contaminated soil. Disposal of contaminated soil in a permitted landfill is a common disposal practice.

Implementation is administratively feasible although some short-term modifications to range operations may be necessary to accommodate site investigations and removal activities. Work would be performed on the Post in an isolated area limiting potential direct impacts to the surrounding communities. However, increased truck traffic on Post roads may need to be coordinated to minimize impacts to Post operations and the local community.

**Cost Evaluation**

The present worth cost of Alternative S3a is estimated to be $9,280,000. This alternative has a total project cost of $9,334,000 (undiscounted), including approximately $9,070,000 in capital costs for remediation and $264,000 in periodic costs for five-year reviews. A detailed cost analysis for Alternative S3a is presented in Appendix 5A-3A.

### *Evaluation Summary*

**Advantages**

- Removal of possible source area limiting future impacts to soil and groundwater;
- Removal of highly contaminated soil preventing further contaminant migration or additional impacts to soil or groundwater; and
- Landfill disposal is a common practice for contaminated soil.

**Limitations and Considerations**

- Medium to high costs; and
- Short-term impact on OB/OD and surrounding ranges during site investigation and construction activities.

#### 5.3.1.3.2 Alternative 3b – On-Site Land Farming

Under this alternative, a land-farm treatment cell would be constructed at the OB/OD for soil treatment. The treatment cell would be bermed, lined, and a leachate collection system installed to collect and store contact water collected within the treatment cell limits.

Contact water would be treated in an on-site treatment plant to meet applicable surface water discharge limits prior to discharge to a local stream. In the treatment cell, excavated soil would be placed in windrows and periodically disked. Solar radiation, wind, and disking of the soil would promote volatilization and biodegradation of the VOCs in the soil. At this time it has been assumed that the treatment cell would not need to be covered or air emissions controlled based on the concentrations of VOCs detected in the soil. This decision would be reevaluated during the Remedial Design.

Once the soil is treated, the clean soil would be spread on site, used as general fill in selected on-site locations, or transported to the Fort Riley C&D landfill and used as landfill cover.

Figure 5-2 shows the limits of the likely metallic anomaly/source area soil removal and the secondary soil removal area proposed under this alternative.

### *Evaluation*

**Protection of Human Health and the Environment**

Based on the HHBLRA and ECORA performed as part of the RI Report (LBG-BMcD, 2013) the site exceeds USEPA's accepted risk levels for outdoor vapors for all three human exposure scenarios. This alternative would be protective of human health and the environment because soil with contaminant concentrations significantly above PRGs would be removed, and treated and disposed/reused. Although an exposure scenario beyond those scenarios envisioned in the risk assessments could occur, the exposure pathway would not be complete.

**Compliance with ARARs**

The preliminary chemical-, location-, and action-specific ARARs for Alternative S3b are presented in Table 5-1. Currently there are no chemical-specific ARARs for soil although RSKs are TBCs.

Following excavation but prior to backfilling, confirmatory sampling would be conducted to ensure that soil remaining in-place meets PRGs. It is anticipated that the removal and treatment and/or disposal of the highly contaminated soil would comply with the preliminary PRGs.

**Long-Term Effectiveness and Permanence**

Under this alternative, the removal and treatment of the contaminated soil along with the removal of a potential source area would provide a permanent, effective solution to the chlorinated solvents in soil at the OB/OD. This approach would provide a high degree of protection because it provides for the removal and treatment of the contaminated soil.

**Reduction of Toxicity, Mobility, or Volume Through Treatment**

Under Alternative S3b, soil with contaminant concentrations above PRGs would be excavated and treated to reduce its toxicity prior to on-site disposal or reuse. Depending on the final contaminant concentrations following treatment, the soil could be used as general fill in selected locations, or transported to the Fort Riley C&D landfill and used as landfill cover. Soil with contaminant concentrations below PRGs would not be treated and no steps would be taken to reduce the toxicity, mobility or volume of the remaining contaminants in the soil at the site. Material that is not suitable for treatment (rocks, debris) would be shipped off site for disposal in a landfill.

**Short-Term Effectiveness**

The implementation of this remedy would involve the excavation of contaminated soil, transport of the contaminated material to an on-site treatment facility, treating/processing the material, and reuse or disposal of the treated material as well as removal of a suspected source area. Because the OB/OD is relatively isolated from residences and most site workers, construction activities should have relatively limited impacts. The risks to workers and the community are commensurate with similar construction activities including the following:

- Invasive activities in an active range have the potential to encounter UXO/MEC;

- Working around/on/with heavy equipment and hauling equipment. This risk would be similar to other remediation/construction projects. Seasonal weather conditions (cold/hot weather operations, rain and snow, wind chill) would increase the risk to workers;

- Potential exposure to soil, groundwater, and surface water containing a range of contaminants. While concentrations exceed desirable limits for routine exposure for some contaminants, in most areas contaminant concentrations are not at levels that are immediately harmful and continued, regular exposure would be required to pose a health risk to workers. PPE such as Tyvek coveralls, boot covers, and disposable gloves would be worn by site workers to prevent dermal exposure to contaminants. In areas where concentrations are detected at levels that would have the potential to cause exposures above OSHA permissible exposure limits, additional steps would be taken to minimize the exposure to construction workers;

- Some construction activities could result in a low to moderate risk to workers through potential exposure to electrical hazards, mechanical hazards, and noise hazards. The majority of these hazards can be controlled using engineering controls such as lockout/tagout procedures, safe work practices, and PPE;

- Construction traffic on area roads can pose risks to the local community both due to an increase in the number of trucks and the presence of equipment/vehicles in unfamiliar areas; and

- Construction activities would temporarily disrupt the local wildlife. Areas to be impacted are surrounded by land with similar conditions and wildlife can temporarily relocate during construction.

The majority of hazards associated with implementing this alternative could be controlled through a comprehensive health and safety protocol and notification program (*e.g.*., high visibility orange fencing, caution tape, lockout/tagout procedures, protective equipment, perimeter air monitoring, personal air monitoring for workers, heat and stress monitoring, etc.).

## Implementability

Implementation is technically feasible. Excavation using standard construction equipment is a common approach for remediating contaminated soil. Land farming operations would also be performed using standard construction or similar equipment.

Implementation is administratively feasible although some modifications to range operations may be necessary to accommodate site investigations and removal activities. Work would be performed on the Post in an isolated area limiting potential direct impacts to the surrounding communities. However, increased truck traffic on Post roads may need to be coordinated to minimize impacts to Post operations and the local community.

**Cost Evaluation**

The present worth cost of Alternative S3b is estimated to be $5,070,000. This alternative has a total project cost of $5,124,000 (undiscounted), including approximately $4,860,000 in capital costs for remediation and $264,000 in periodic costs for five-year reviews. A detailed cost analysis for Alternative S3b is presented in Appendix 5A-3C.

### *Evaluation Summary*

**Advantages**

- Removal of possible source area limiting future impacts to soil and groundwater;
- Removal and treatment of highly contaminated soil preventing further contaminant migration or additional impacts to soil or groundwater; and
- Land farming has been performed successfully on Post and elsewhere to remediation VOCs in soil.

**Limitations and Considerations**

- Medium to high costs;
- Short-term impact on OB/OD and surrounding ranges during site investigation and construction activities;
- If contaminant levels in the excavated soil are higher than anticipated, emissions controls during land farming may be required; and
- Some VOCs may be harder to remove through land farming than TCE which could extend the treatment period.

#### 5.3.1.3.3 Alternative 3c – Off-Site Thermal Incineration and Disposal

Under this alternative, excavated soil would be loaded on transfer vehicles and hauled to an incinerator facility located in Kimball, Nebraska. This alternative would be appropriate if contaminant concentrations in the soil were high enough to require treatment prior to disposal or if other regulatory restrictions would limit disposal options.

It is anticipated that some soil may require moisture conditioning to pass the paint filter test (required for landfill disposal). Moisture conditioning would entail mixing the excavated soil in a pug mill with a pozzolanic material (Portland cement, cement kiln dust, ash) to control the moisture content of the soil. It is anticipated that the majority of the soil would be removed above the water table and would be moist but not saturated. On this basis, it was assumed that up to 10 percent of the material would require moisture conditioning prior to disposal.

Figure 5-2 shows the limits of the likely metallic anomaly/source area soil removal and the secondary soil removal area proposed under this alternative.

### *Evaluation*

#### Protection of Human Health and the Environment

Based on the HHBLRA and ECORA performed as part of the RI Report (LBG-BMcD, 2013) the site exceeds USEPA's accepted risk levels for outdoor vapors for all three human exposure scenarios. This alternative would be protective of human health and the environment because soil with contaminant concentrations significantly above PRGs would be removed and treated/disposed. Although an exposure scenario beyond those scenarios envisioned in the risk assessments could occur, the exposure pathway would not be complete.

#### Compliance with ARARs

The preliminary chemical-, location-, and action-specific ARARs for Alternative S3c are presented in Table 5-1. Currently there are no chemical-specific ARARs for soil although RSKs are TBCs.

Following excavation but prior to backfilling, confirmatory sampling would be conducted to ensure that soil remaining in-place meets PRGs. It is anticipated that the removal and treatment and/or disposal of the highly contaminated soil would comply with the preliminary PRGs.

#### Long-Term Effectiveness and Permanence

Under this alternative, the removal and treatment of the contaminated soil along with the removal of a potential source area would provide a permanent, effective solution to the chlorinated solvents in soil at the OB/OD. This approach would provide a high degree of protection because it provides for the removal and treatment of the contaminated soil.

#### Reduction of Toxicity, Mobility, or Volume Through Treatment

Under Alternative S3c, the excavated soil would be thermally treated prior to disposal. Soil with contaminant concentrations above PRGs would be excavated and hauled off site for incineration followed by disposal. Soil with contaminant concentrations below PRGs would not be treated and no steps would be taken to reduce the toxicity, mobility or volume of the remaining contaminants in the soil at the site. Material that is not suitable for treatment (rocks, debris) would be shipped off site for direct disposal in a landfill without treatment.

**Short-Term Effectiveness**

The implementation of this remedy would involve the excavation of contaminated soil, transport of the contaminated material to an off-site disposal facility disposal as well as removal of a suspected source area. Because the OB/OD is relatively isolated from residences and most site workers, construction activities should have relatively limited impacts. The risks to workers and the community are commensurate with similar construction activities including the following:

- Invasive activities in an active range have the potential to encounter UXO/MEC;
- Working around/on/with heavy equipment and hauling equipment. This risk would be similar to other remediation/construction projects. Seasonal weather conditions (cold/hot weather operations, rain and snow, wind chill) would increase the risk to workers;
- Potential exposure to soil, groundwater, and surface water containing a range of contaminants. While concentrations exceed desirable limits for routine exposure for some contaminants, in most areas contaminant concentrations are not at levels that are immediately harmful and continued, regular exposure would be required to pose a health risk to workers. PPE such as Tyvek coveralls, boot covers, and disposable gloves would be worn by site workers to prevent dermal exposure to contaminants. In areas where concentrations are detected at levels that would have the potential to cause exposures above OSHA permissible exposure limits, additional steps would be taken to minimize the exposure to construction workers;
- Some construction activities could result in a low to moderate risk to workers through potential exposure to electrical hazards, mechanical hazards, and noise hazards. The majority of these hazards can be controlled using engineering controls such as lockout/tagout procedures, safe work practices, and PPE;
- Construction traffic on area roads can pose risks to the local community both due to an increase in the number of trucks and the presence of equipment/vehicles in unfamiliar areas; and

- Construction activities would temporarily disrupt the local wildlife. Areas to be impacted are surrounded by land with similar conditions and wildlife can temporarily relocate during construction.

The majority of hazards associated with implementing this alternative could be controlled through a comprehensive health and safety protocol and notification program (*e.g.*, high visibility orange fencing, caution tape, lockout/tagout procedures, protective equipment, perimeter air monitoring, personal air monitoring for workers, heat and stress monitoring, etc.).

**Implementability**

Implementation is technically feasible. Excavation using standard construction equipment is a common approach for remediating contaminated soil. Incineration followed by disposal of contaminated soil in a permitted landfill is a common remediation practice.

Implementation is administratively feasible although some modifications to range operations may be necessary to accommodate site investigations and removal activities. Work would be performed on the Post in an isolated area limiting potential direct impacts to the surrounding communities. However, increased truck traffic on Post roads may need to be coordinated to minimize impacts to Post operations and the local community.

**Cost Evaluation**

The present worth cost of Alternative S3c is estimated to be $20,500,000. This alternative has a total project cost of $20,554,000 (undiscounted), including approximately $20,290,000 in capital costs for remediation and $264,000 in periodic costs for five-year reviews. A detailed cost analysis for Alternative S3c is presented in Appendix 5A-3C.

### *Evaluation Summary*

**Advantages**

- Removal of possible source area limiting future impacts to soil and groundwater;
- Removal of highly contaminated soil preventing further contaminant migration or additional impacts to soil or groundwater; and
- Incineration followed by landfill disposal is a common practice for highly contaminated soil.

**Limitations and Considerations**

- High costs; and

- Short-term impact on OB/OD and surrounding ranges during site investigation and construction activities;

#### 5.3.1.4 Alternative S4 – In-Situ Treatment: SVE

This alternative involves in-situ treatment of contaminated soil at the OB/OD. The in-situ treatment technology that was identified during the technology screening for treating contaminants in soil was SVE.

Prior to in-situ remediation, a site investigation and source removal action would be conducted to address the metallic anomaly. The steps that would be taken in the investigation and removal of the metallic anomaly/source area are discussed under Alternative S3. This removal action would be focused on conditions directly surrounding the metallic signature but would not address elevated levels of contaminants in the surrounding soil. For this analysis, it was assumed that the contaminated soil surrounding the metallic anomaly would require treatment prior to disposal due to contaminant concentrations. It is recommended that additional data be collected during the predesign investigation studies to determine whether the material can be disposed directly in a landfill without treatment. Following this removal action, the remaining contaminants in the soil would be treated using SVE.

SVE involves applying a vacuum to a well installed in the contaminated soil to induce a controlled flow of air through the soil. The air flow assists in stripping volatile, and some semivolatile, contaminants from the soil. The air would be collected and treated at a central location to remove the contaminants prior to discharge to the atmosphere in accordance with local and state air quality regulations.

Based on the RI borings sampling results, the highest concentration of contamination appears to be located approximately 7 to 13 feet bgs. This option would involve installing 15 to 20 extraction wells into the soil through the contaminant zone. A vacuum test would be conducted on a test well during the Remedial Design to determine the radius of influence (ROI) for the extraction wells. The wells would be screened through the contaminant zone starting approximately 5 feet bgs (to prevent short circuiting) and extending through the depth of the contamination. The wells would terminate above the water table to prevent groundwater being drawn into the collection system and collecting in the pipelines.

The SVE system would operate until chlorinated solvent concentrations in gas samples collected in the extraction wells remain below PRGs when the blower is turned off and conditions in the wells are allowed to equilibrate. Given the low permeability soils in the area, the current contaminant concentrations, and professional experience at other sites, it is anticipated that the system would be required to operate for 10 years or more to achieve regulatory limits. Because the site is part of an active range and used in the emergency detonation of ordnance, explosion-induced seismic activity in the area could impact the ROI of extraction wells, the integrity of the wells or extraction piping system, or the integrity of the treatment system impacting the operation of the SVE system.

Figure 5-3 shows the limits of the likely metallic anomaly/source area removal and the potential layout for a SVE network at the OB/OD to treat contaminant concentrations above PRGs.

### *Evaluation*

#### Protection of Human Health and the Environment

Based on the HHBLRA and ECORA performed as part of the RI Report (LBG-BMcD, 2013) the site exceeds USEPA's accepted risk levels for outdoor vapors for all three human exposure scenarios. This alternative would be protective of human health and the environment because soil with contaminant concentrations significantly above PRGs would be removed/disposed (source area) or treated in situ. Although an exposure scenario beyond those scenarios envisioned in the risk assessments could occur, the exposure pathway would not be complete.

#### Compliance with ARARs

The preliminary chemical-, location-, and action-specific ARARs for Alternative S4 are presented in Table 5-1. There are currently no ARARs for soil although RSKs are TBCs.

It is anticipated that that the removal of the source area and treatment of the remaining highly contaminated soil would comply with the preliminary PRGs.

#### Long-Term Effectiveness and Permanence

Under this alternative, the in-situ treatment of contaminated soil with concentrations above PRGs, in conjunction with the removal of a potential source area can provide a permanent solution to the contaminants at the OB/OD. The long-term effectiveness of this alternative may vary depending on site conditions. Low permeability soils conditions such as found in the regolith may not allow for even withdrawal of contaminants from the soil resulting in either an extended treatment period to achieve PRGs or pockets of contaminants that cannot be treated without additional SVE wells. Either issue would add to the project costs and impact future use of the site.

#### Reduction of Toxicity, Mobility, or Volume Through Treatment

Under Alternative S4, the majority of material at the OB/OD with soil contaminant concentrations above PRGs would be treated to meet soil PRGs. Limitations on treatment effectiveness are possible due to site conditions. Soil with contaminant concentrations below PRGs would not be targeted for treatment and no steps would be taken to reduce the toxicity, mobility or volume of the remaining contaminants in that soil at the site. However, it is likely that soil in areas adjacent to treatment zones would indirectly receive treatment.

## Short-Term Effectiveness

The implementation of this remedy would involve the construction of extraction wells and pipelines and a small air treatment system. The OB/OD is relatively isolated from residences and most site workers, construction activities should have relatively limited impacts. The risks to workers and the community are commensurate with these types of activities include the following:

- Invasive activities in an active range have the potential to encounter UXO/MEC.
- Working around/on/with heavy equipment and drill rigs. This risk would be similar to other remediation/construction projects. Seasonal weather conditions (cold/hot weather operations, rain and snow, wind chill) would increase the risk to workers.
- Potential exposure to soil and ground water containing a range of contaminants. While concentrations exceed desirable limits for routine exposure for some contaminants, in most areas contaminant concentrations are not at a level that is immediately harmful and continued, regular exposure would be required to pose a health risk to workers. PPE such as Tyvek coveralls, boot covers, and disposable gloves would be worn by site workers to prevent dermal exposure to contaminants. In areas where concentrations are detected at levels that would have the potential to cause exposures above OSHA permissible exposure limits, additional steps would be taken to minimize the exposure to construction workers.
- Some construction activities could result in a low to moderate risk to workers through potential exposure to electrical hazards, mechanical hazards, and noise hazards. The majority of these hazards can be controlled using engineering controls such as lockout/tagout procedures, safe work practices, and PPE.
- Construction activities would temporarily disrupt the local wildlife. Areas to be impacted are surrounded by land with similar conditions and wildlife can temporarily relocate during construction.

The majority of hazards associated with implementing this alternative could be controlled through a comprehensive health and safety protocol and notification program (*e.g.*, high visibility orange fencing, caution tape, lockout/tagout procedures, protective equipment, perimeter air monitoring, personal air monitoring for workers, heat and stress monitoring, etc.).

In addition, as noted previously, the site is part of an active range and used in the emergency demolition of ordnance. Explosive-induced seismic activity in the area could impact the ROI of extraction wells, the integrity of the wells or extraction piping system, or the integrity of the treatment system, impacting the operation of the SVE system.

**Implementability**

Implementation is technically feasible. SVE systems are a commonly used remediation system for chlorinated solvents in vadose zone soils. The construction of the SVE system is based on standard materials and construction procedures. The work would be performed on the Post limiting impact to outside groups.

Alternative S4 may be administratively difficult to implement due to potential impacts to the use of the surrounding ranges. SVE wells and pipeline systems could impact use of the site by restricting operations in areas of the OB/OD. The system would require periodic maintenance that could impact the use of the OB/OD and the surrounding ranges. The surrounding ranges could be impacted by construction activities which would include running buried power and communications lines to the site. Range and demolition operations at the OB/OD or the surrounding area could impact the integrity of the treatment system.

**Cost Evaluation**

The present worth cost of this alternative is estimated to be $11,330,000. This alternative has a total project cost of $13,720,000 (undiscounted) including approximately $8,450,000 in capital costs for remediation construction, and $11,400,000 in annual operating costs over a 30 year period, and $264,000 in periodic costs for five-year reviews. A detailed cost analysis for Alternative S4 is presented in Appendix 5A-4.

### *Evaluation Summary*

**Advantages**

- Minimal risk to the local community and site users and
- Majority of system is buried limiting risks to above ground facilities.

**Limitations and Considerations**

- High costs;

- Construction and system maintenance requirements could impact the use of the site and surrounding ranges;
- Potential damage to infrastructure from range operations and detonation work in area; and
- System may have to operate for 10 year or more to achieve PRGs.

### 5.3.2 Groundwater Remedial Alternatives

The groundwater sampling results indicate that preliminary chemical-specific ARARs (i.e., MCLs or KDHE RSKs) were exceeded for five constituents in 2012:

- TCE - multiple exceedences in 8 wells
- PCA - multiple exceedences in 4 wells
- Naphthalene - one exceedence in one well
- bis(2-ethylhexyl)phthalate - one exceedence in two wells
- Benzo(a)pyrene - one exceedence in one well.

In addition, historical sampling data indicated that PCE, cis-1,2-DCE , and perchlorate exceeded ARARs in one or more sampling events over the past 20 years. Metals detected at the site have generally not exceeded ARARs with only two samples having exceedences of the ARAR during the past 20 years of sampling.

Bis(2-ethylhexyl)phthalate, a plasticizer used in PVC, was detected in samples collected in 15 of 16 wells spread across the site at relatively low concentrations (concentrations between 1 µg/L and 2.5 µg/L versus a MCL of 6 µg/L). In only two instances were sample concentrations above the PRG – once in Monitoring Well OB-97-08 at a concentration of 24 µg/L and once in Monitoring Well OB-12-17 at a concentration of 0.3 estimated value (J) µg/L. There were no detections of bis(2-ethylhexyl)phthalate in either surface or subsurface soil samples. The source of the bis(2-ethylhexyl)phthalate is unknown but may be related to well construction (on-site wells are constructed of PVC piping).

Benzo(a)pyrene was detected in only one well – Monitoring Well OB-93-03 in December 2012– at an estimated concentration of 0.76 µg/L, (MCL - 0.2 µg/L); it was not detected in either surface or subsurface soil samples but was detected in one surface water sample (stream). Benzo(a)pyrene is byproduct of incomplete combustion and may be related to ordnance detonation activities at the site. In the past, diesel fuel was a commonly used accelerant when burning powders at the site but is no longer used at OB/OD. Its presence in the groundwater may be a result of these past practices in the area.

Naphthalene was detected in five wells in 2012 with sample concentrations of approximately 0.2 µg/L (versus a KDHE RSK of 2.11 µg/L). The five wells where naphthalene was detected varied widely in location and depth across the site. Only in Monitoring Well OB-12-18 did the naphthalene concentration exceed the PRG with a concentration of 2.5 J µg/L in the fourth quarter 2012. The source of the naphthalene is unknown but it is a petroleum-based product.

TCE, PCA, naphthalene, benzo(a)pyrene and bis(2-ethylhexyl)phthalate were identified as COCs for groundwater (see Section 3.3).

Except for the chlorinated solvents, ARAR exceedences have been periodic and limited in number. Sampling results from the soil and groundwater do not suggest an on-going release of non-chlorinated solvent contaminants from a single source area indicating that some or all of the exceedences may be related to the periodic detonation activities at the OB/OD. If so, even if remediation were to remove all traces of these contaminants, the constituents are likely to be detected periodically in the future due to on-going ordnance detonation activities or, potentially, in the case of the bis(2-ethylhexyl)phthalate due to well construction.

The chlorinated solvents have been detected on a regular basis in a number of wells. TCE is the most common contaminant observed at the site, both in number of detections and exceedences. TCE was detected in 13 of 16 wells on the site. Of the three wells where TCE was not detected, two are upgradient of the potential source area. PCA is present in a more localized area of the site with PCA detected in 7 of 16 wells although two of the wells only had two detections each. While TCE was detected both in the regolith/weathered bedrock aquifer and the deeper bedrock aquifer, PCA was not detected in the deeper bedrock aquifer. Both TCE and PCA appear to be coming from the same source area although there are variations in the distribution pattern of TCE and PCA in the groundwater. The reason for this difference is unknown but it may be related to chemical properties, source location, or heterogeneous site conditions.

Exceedences of ARARs for chlorinated solvents were primarily noted in the upper aquifer (regolith and weathered bedrock wells) with exceedences noted in 8 of 11 wells. In only one of the five deeper bedrock wells (OB-93-04) did concentrations exceed the ARAR. TCE concentrations in samples collected in this well in 2012 ranged from 5.5 µg/L to 6.2 µg/L, slightly over the MCL of 5 µg/L. TCE concentrations in this well have declined steadily from a high concentration of 29 µg/L detected in a sample collected in December 1993. While some degradation products have been detected in the well, these concentrations have not significantly increased over time suggesting that the degradation process has gone to completion. If the current rate of decay in this well continues, TCE concentrations in the deeper bedrock aquifer (as measured in this well) may be below than MCLs within five years. Because of the distribution of contaminants at the site, the focus of groundwater remediation alternatives will be on addressing contaminants in the regolith and weathered bedrock aquifer.

Based on the results of the technology screening (Section 4.0) the following remedial alternatives for groundwater were identified:

| | |
|---|---|
| Alternative GW1 | No Action (retained as a baseline) |
| Alternative GW2 | Institutional Controls Through the Fort Riley RPMP |
| Alternative GW3 | Groundwater Monitoring |
| Alternative GW4 | MNA |
| Alternative GW5 | In-Situ Treatment: Chemical Reagent Injection |

#### 5.3.2.1 Alternative GW1 – No Action

##### *Description*

Alternative GW1, the "No Action" Alternative, is a requirement of the NCP providing a baseline for the comparison of active remedial alternatives developed for the OB/OD. Under this alternative, institutional controls are not implemented and remediation and monitoring of the site conditions are not conducted. By definition, this alternative requires that any current monitoring program be discontinued. At a minimum, whenever contaminants are left in place, the NCP requires the following: *If a remedial action is selected that results in hazardous substances, pollutants, or contaminants remaining at the site above levels that allow for unlimited use and unrestricted exposure, the lead agency shall review such action no less than every five years after initiation of the remedial action.*

Although under the "No Action" Alternative institutional controls are generally not enacted, it should be acknowledged that access restriction via range controls are already in place due to the location of the OB/OD on a military base within the limits of the impact area. Range controls will remain in effect as long as Fort Riley remains active.

### *Evaluation*

#### Protection of Human Health and the Environment

Based on the HHBLRA and ECORA performed as part of the RI Report (LBG-BMcD, 2013), this alternative is not protective of human health or the environment because the risk estimates for current and future RME scenarios exceed USEPA's accepted risk levels for dermal contact and ingestion of groundwater as well as vapors from groundwater use. Because this alternative does not include institutional controls, there is no control of future groundwater use within the limits of the plume however unlikely it is that there would be a change in site usage. Therefore, an exposure scenario beyond those scenarios envisioned in the risk assessments could occur when no institutional controls are acknowledged for the property. On this basis, Alternative GW1 will be considered as not protective of human health and the environment.

#### Compliance with ARARs

The preliminary chemical-, location-, and action-specific ARARs for Alternative GW1 are presented in Table 5-2. Location- and action-specific ARARs do not apply to Alternative GW1 since there are no location- or action-specific remedial measures that will be taken at the OB/OD under this alternative.

Under Alternative GW1, there is no groundwater monitoring to determine concentration trends within the limits of the plume. Based on groundwater monitoring results, contaminants in the weathered and deeper bedrock show a downward trend in contaminant levels over the past 20 years, whereas contaminant concentrations in wells screened in the regolith have remained relatively constant with only a marginal decrease in concentrations over time. While contaminant concentrations in some wells are likely to remain above ARARs (and therefore not in compliance with ARARs) for the foreseeable future, given the isolated location of the plume and the lack of water supply wells in the immediate area, the impact to human health is likely to be limited although the impact on wildlife would remain. Without monitoring, the evolution of concentrations remains an unknown and, for the purposes of this evaluation, the assumption will be made that ARARs will continue to be exceeded.

#### Long-Term Effectiveness and Permanence

Because groundwater monitoring has been performed sporadically (typically only once or twice a year) at the site, it is difficult to determine the contaminant release mechanism but it may be related to a flushing action associated with larger precipitation events at the site. As note previously (Section 5.3.1), a potential source area for the chlorinated solvents is located adjacent to the metal debris pits.

Although contaminant concentrations in wells in the deeper bedrock and weathered bedrock appear to be trending downward this pattern is less apparent in the regolith where average concentrations appear to have only a slight downward trend. The current risk levels to human health and the environment are above USEPA's accepted limits (LBG-BMcD, 2013) and are assumed to remain so for the foreseeable future. A review of groundwater contamination at the OB/OD would be required every five years to monitor contaminants remaining in the OB/OD in accordance with the CERCLA 121(c).

Institutional controls are not acknowledged with this alternative; therefore, it is possible that an exposure scenario not anticipated in the risk assessments could occur under the "No Action" Alternative.

## Reduction of Toxicity, Mobility, or Volume Through Treatment

No active treatment of soil is proposed under this alternative. Reductions in contaminant toxicity, mobility or volume may be taking place within the aquifers based on naturally occurring conditions as suggested by the groundwater monitoring results. However, under this alternative there is no monitoring or interpretation of monitoring results to verify that NA is occurring. Therefore, when comparing Alternative GW1 to other more comprehensive alternatives, the reduction of toxicity, mobility, or volume is not reconciled until the first five-year review. The limitation of a discrete five-year review is that it is not as comprehensive as a set of measurements over time to corroborate that the sampling event results are consistent and reproducible.

## Short-Term Effectiveness

Alternative GW1 does not involve any active remedial activities and therefore poses no risks to construction workers or the local community in the short term. Based on the results of the risk assessments (LBG-BMcD, 2013), the current risk levels at the OB/OD to human health and the environment are above USEPA's accepted limits. These conditions would to continue present risks to human health and the environment in the short term as changes in site conditions to mitigate the current contamination is unlikely.

## 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 $0. There are no capital or O&M costs associated with this alternative. A detailed cost analysis for Alternative GW1 is presented in Appendix 5B-1.

### *Evaluation Summary*

**Advantages**

- Minimal cost and
- Ease of implementation.

**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 and
- No control or tracking of contaminant migration.

#### 5.3.2.2 Alternative GW2 – Institutional Controls Through the Fort Riley RPMP

### *Description*

This alternative involves the use of institutional controls implemented through the Fort Riley RPMP to control future uses of the OB/OD and the area groundwater to protect human health and the environment. The inclusion of institutional controls, such as restrictions on the use of area groundwater resources reduces the potential for human ingestion, inhalation, or direct contact with contaminated groundwater. 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 OB/OD is more restricted because the site is on an active military reservation.

The purpose of institutional controls is to limit exposure to contaminants. The principal institutional controls that would be applied by Fort Riley would be a prohibition against the use of groundwater (including seeps and springs) within a designated area, and preventing the installation of water supply wells within the OB/OD plume or in areas that would impact the flow of contaminants. Because of the proximity to the firing ranges, this area would not be an optimal location for the installation of a drinking water well(s). Since the existing Fort Riley supply well field has sufficient excess capacity to easily meet future demand, this institutional control would place no hardship on the Post. This would also eliminate a potential pathway between contaminated groundwater and potential consumers of this water. Figure 5-4 shows the approximate limits of groundwater institutional controls.

Implementation of Alternative S3 or S4 to remediate the chlorinated solvent source area under the soil remediation program would be required in conjunction with this alternative to ensure that future releases from the source area do not continue to contaminate the groundwater.

### Evaluation

#### Protection of Human Health and the Environment

Based on the HHBLRA and ECORA performed as part of the RI Report (LBG-BMcD, 2013), this alternative is not protective of human health and the environment because the exposure pathways for dermal contact and ingestion of groundwater as well as vapors from groundwater use, have not been eliminated or controlled and the site exceeds USEPA's accepted risk levels. Based on the exposure scenarios identified in the risk assessments, the human health risks are likely to remain above USEPA's accepted risk levels without active remediation of VOCs.

It is anticipated that the potential future risk to human health would not increase under this alternative because institutional controls are anticipated to limit or prevent ingestion of contaminated groundwater (one of the exposure routes evaluated in the RI). However, even if the ingestion exposure risk was eliminated, risk levels for human health and the environment would remain above accepted levels.

#### Compliance with ARARs

The preliminary chemical-, location-, and action-specific ARARs for Alternative GW2 are presented in Table 5-2. Currently there are no chemical-specific ARARs for soil, although RSK (screening levels) are TBCs.

Under Alternative GW2, there is no groundwater monitoring to determine concentration trends within the limits of the plume. Based on groundwater monitoring results, contaminants in the weathered and deeper bedrock show a downward trend in contaminant levels over the past 20 years, whereas contaminant concentrations in wells screened in the regolith have remained relatively constant with only a marginal decrease in concentrations over time. While contaminant concentrations in some wells are likely to remain above MCLs (and therefore not in compliance with ARARs) for the foreseeable future, given the isolated location of the plume and the lack of water supply wells in the immediate area, the impact to human health is likely to be limited although the impact on wildlife would remain. Without monitoring, the evolution of concentrations remains an unknown and, for the purposes of this evaluation, the assumption will be made that MCLs will continue to be exceeded.

#### Long-Term Effectiveness and Permanence

Under Alternative GW2, no active remedial actions would be performed at the site. Because groundwater monitoring has been performed sporadically (once or twice a year) in the past, it is difficult to determine the contaminant release mechanism but it may be related to a flushing action associated with larger precipitation events at the site. Although a potential source area would be addressed under the soil remediation program, the long-term contaminant levels in groundwater (particularly in the regolith) would remain above PRGs for the foreseeable future. Based on the risk assessments (LBG-BMcD, 2013), the current risk levels at the OB/OD are above USEPA's accepted limits. Although institutional controls could limit future exposure related to some activities, site workers and wildlife would be exposed to contaminants based on current site usage patterns. Although a review of contaminant concentrations at the OB/OD would be required every five years to monitor contaminants remaining in the groundwater in accordance with CERCLA 121(2), this would not help mitigate the risks associated with the site.

However, while institutional controls are easily implemented from a technical and administrative perspective through the Fort Riley RPMP, effective compliance may be difficult to maintain in the long term due to the limited use of the area and changes in base personnel over time.

**Reduction of Toxicity, Mobility, or Volume**

No active treatment of soil is proposed under this alternative; Alternative GW2 does not reduce the toxicity, mobility or volume of contaminants at the site. Reductions in contaminant toxicity, mobility or volume through NA may be occurring and may reduce contaminant levels in groundwater to a degree but contaminant concentrations are unlikely to fall below PRGs in the foreseeable future. As noted in the RI, natural conditions in the aquifer are not conducive to the NA of highly chlorinated VOCs such as TCE and PCE although it may be occurring to some extent at some locations. In addition, the generally aerobic conditions of the groundwater do not promote the degradation of PCA. While some degradation of TCE may be occurring at the site, particularly in the bedrock formations, contaminant concentrations in the regolith have not decreased substantially over time.

**Short-Term Effectiveness**

This alternative does not involve active remedial activities or construction and poses no risk to construction workers or the local community in the short term. On-going exposures to site workers and wildlife would continue.

**Implementability**

There are no anticipated technical or administrative difficulties implementing this alternative. Because this is an active government installation, it is anticipated that there will be no problems with implementing a program of institutional controls through the Fort Riley RPMP (see Section 4.3.2.2).

**Cost Evaluation**

The present worth cost of this alternative is estimated to be $740,000. While monitoring of the site would be required to enforce restrictions, this could be conducted at minimal annual costs as part of site operations. Therefore, this alternative has a total project cost of $890,000 (undiscounted), including approximately $380,000 in capital costs for developing the institutional controls; total annual costs of $120,000 (over 30 years) involved with enforcement of the institutional controls; and $390.000 in periodic costs for five-year reviews. A detailed cost analysis for Alternative S4 is presented in Appendix 5B-2.

### *Evaluation Summary*

**Advantages**

- Minimal cost;
- Ease of implementation; and
- Reduces but does not eliminate exposure pathways.

**Limitations and Considerations**

- Has no impact on ecological receptors in the area where exposure is above accepted levels;
- No control or tracking of contaminant migration; and
- Potential impacts on future uses of the site.

### 5.3.2.3 Alternative GW3 – Groundwater Monitoring

### *Description*

This alternative involves the use of quarterly groundwater monitoring to monitor and assess conditions in the area of the OB/OD. If changes in conditions in groundwater quality are detected, additional protective methods could be implemented to protect human health and the environment.

Based on groundwater monitoring results, contaminants in wells in the deeper bedrock show a downward gradient in contaminant levels over the past 20 years and may reach PRGs within five years. While contaminant concentrations in wells screened in the weathered bedrock/regolith have remained relatively constant with only a marginal decrease in concentrations over time, the extent of the contamination appears relatively localized. Although contaminant concentrations in some wells are likely to remain above MCLs (and therefore not in compliance with ARARs) for the foreseeable future, given the isolated location of the plume and the lack of water supply wells in the immediate area, the impact on human health is likely to be limited to the OB/OD.

Under this alternative, the current monitoring network would be evaluated to assess its suitability for Alternative GW3. At this time it is anticipated that 11 new monitoring wells would be installed. Figure 5-5 shows the existing and potential new monitoring well locations.

New wells would be intended to address the following conditions at the site:

- Bedrock wells down gradient of the potential source area;
- Sentinel wells down gradient and side gradient of the plume(s) in all three formations to verify and monitor plume migration; and
- Nested wells to allow tracking of vertical as well as horizontal gradients.

It is possible that following the installation of the new monitoring wells, some of the existing wells could be eliminated. Once a new baseline has been established for groundwater quality and time-related changes, with regulatory approval it may be possible to reduce quarterly monitoring to semi-annual monitoring.

Implementation of Alternative S3 or S4 to remediate the chlorinated solvent source area under the soil remediation program would be required in conjunction with this alternative to ensure that future releases from the source area do not continue to contaminate the groundwater.

### *Evaluation*

**Protection of Human Health and the Environment**

Based on the HHBLRA and ECORA performed as part of the RI Report (LBG-BMcD, 2013), this alternative is not protective of human health and the environment because the existing exposure pathways for dermal contact and ingestion of groundwater as well as vapors from groundwater use have not been eliminated or controlled and the site exceeds USEPA's accepted risk levels. Based on the exposure scenarios identified in the risk assessments, the human health risks are likely to remain above USEPA's accepted risk levels without active remediation of VOCs.

**Compliance with ARARs**

The preliminary ARARs for Alternative GW3 are presented in Table 5-2. It is anticipated that there would be no difficulties complying with any of the preliminary action- or location-specific

ARARs. However, this alternative is unlikely to comply with chemical-specific ARARs in a timely manner.

## Long-Term Effectiveness and Permanence

Under Alternative GW3, no active remedy would be implemented at the site. Although a potential source area would be addressed under the soil remediation program, the long-term contaminant levels in groundwater (particularly in the regolith) are likely to remain above PRGs for the foreseeable future. Based on the risk assessments (LBG-BMcD, 2013), the current risk levels at the OB/OD are above USEPA's accepted limits. While routine groundwater monitoring would detect changes in conditions in groundwater at the site that could be indicated future risk levels, it would not alleviate current risk levels to human health and the environment.

## Reduction of Toxicity, Mobility, or Volume

No active treatment of soil is proposed under this alternative therefore, Alternative GW3 does not reduce the toxicity, mobility or volume of contaminants at the site. Reductions in contaminant toxicity, mobility or volume in the groundwater through NA may reduce contaminant levels in the groundwater to a degree but contaminant concentrations are unlikely to fall below PRGs in the foreseeable future without active remediation. As noted in the RI, natural conditions in the aquifer are not conducive for NA of highly chlorinated VOCs such as TCE and PCE. In addition, the generally aerobic conditions in the aquifer do not promote the degradation of PCA. While some degradation of TCE and/or PCA may be occurring at the site, particularly in the bedrock formations, contaminant concentrations in the regolith have not decreased substantially over time.

## Short-Term Effectiveness

The implementation of this remedy would involve the installation of new monitoring wells and regular groundwater monitoring. The OB/OD is relatively isolated from residences and most site workers, so construction activities should have relatively limited impacts. The risks to workers and the community, commensurate with these types of activities, include the following:

- Invasive activities in an active range have the potential to encounter UXO/MEC;
- Working around/on/with drilling equipment. This risk would be similar to other remediation/construction projects;
- Potential exposure to soil and ground water containing a range of contaminants. While concentrations exceed desirable limits for routine exposure for some contaminants, the period of

exposure would be limited. PPE would be worn by site workers to limit exposure to contaminants. In areas where concentrations exceed hazardous material levels, additional steps would be taken to minimize the exposure to workers;

- Some construction activities could result in a low to moderate risk to workers through potential exposure to mechanical and noise hazards. The majority of these hazards can be controlled using engineering controls such as safe work practices, and PPE; and

- Construction activities would temporarily disrupt the local wildlife. Areas to be impacted are surrounded by land with similar conditions and wildlife can temporarily relocate during construction.

**Implementability**

There are no anticipated technical or administrative difficulties implementing this alternative. Current activities related to groundwater monitoring would continue, albeit on a more regular basis. Additional wells could increase the time required for each sampling event, thereby reducing the availability of the range; the use of additional staff could offset this concern.

**Cost Evaluation**

The present worth cost of this alternative is estimated to be $6,980,000. This alternative has a total project cost of $6,977,000 (undiscounted), including approximately $727,000 in capital costs for installing new monitoring wells and baseline sampling; total annual costs of $21,840,000 (over 30 years) involving groundwater monitoring; and $306,00 in periodic costs for five-year reviews. A detailed cost analysis for Alternative GW3 is presented in Appendix 5B-3.

### *Evaluation Summary*

**Advantages**

- Ease of implementation;
- Allows determination of changes in conditions that could have a more-widespread impact; and
- Low to medium costs.

**Limitations and Considerations**

- Has no impact on ecological receptors in the area where exposure is above accepted levels;

- No control or mitigation of contaminant migration; and

- Potential impacts on future uses of the site.

#### 5.3.2.4 Alternative GW4 – MNA

***Description***

Under Alternative GW4, no other active remedy would be implemented at the site. Alternative GW4 involves the use of MNA to remediate contaminants in groundwater at the OB/OD. NA is the process by which contaminant concentrations are reduced through mechanisms such as advection, dispersion, diffusion, volatilization, sorption, and degradation. MNA refers to the periodic sampling and monitoring of geochemical and contaminant conditions at the site to verify that NA processes are continuing to reduce contaminant concentrations below MCLs. MNA is an appropriate remediation method only where its use will be protective of human health and the environment, and where it will be capable of achieving site-specific remediation objectives within a time frame that is reasonable compared to other alternatives (USEPA, 1999).

NA parameters are indicators of conditions that support the NA and may include the following: temperature, pH, conductivity, methane, ethane, ethene, alkalinity, $NO_3^-$, $SO_4^{-2}$, $S^{-2}$, chloride, TOC, DO, ORP, and Ferrous Iron ($Fe^{+2}$). Baseline conditions were measured in the wells at the OB/OD during the RI (LBG-BMcD, 2013). While NA parameters analyzed during the RI indicated that the site has a limited potential for NA, site data suggest that biodegradation and other NA processes capable of reducing contaminant concentrations below MCLs may be occurring for some contaminants, particularly in the deeper bedrock. Historical NA results are mixed in the regolith/weathered bedrock formation.

For this alternative, 11 new monitoring would be installed to monitor MNA the OB/OD. Figure 5-6 shows the existing and potential new monitoring well locations. New wells would be intended to address the following conditions at the site:

- Bedrock wells down gradient of the potential source area;

- Sentinel wells down gradient and side gradient of the plume(s) in all three formations to verify and monitor plume migration; and

- Nested wells to allow tracking of vertical as well as horizontal gradients.

Implementation of Alternative S3 or S4 to remediate the chlorinated solvent source area under the soil remediation program would be required in conjunction with this alternative to ensure that future releases from the source area do not continue to contaminate the groundwater.

### *Evaluation*

#### Protection of Human Health and the Environment

Based on the HHBLRA and ECORA performed as part of the RI Report (LBG-BMcD, 2013), this alternative not is protective of human health and the environment because the existing exposure pathways for dermal contact and ingestion of groundwater as well as vapors from groundwater use have not been eliminated or controlled and the site exceeds USEPA's accepted risk levels. Based on the exposure scenarios identified in the risk assessments, the human health risks are likely to remain above USEPA's accepted risk levels without active remediation of VOCs.

#### Compliance with ARARs

The preliminary chemical-, location-, and action-specific ARARs for Alternative GW4 are presented in Table 5-2. It is anticipated that there would be no difficulties complying with any of the preliminary ARARs.

#### Long-Term Effectiveness and Permanence

Under Alternative GW4, no other active remedy would be implemented at the site. Although a potential source area would be addressed under the soil remediation program, the long-term contaminant levels in groundwater (particularly in the regolith) are likely to remain above PRGs for the foreseeable future. Based on the results of the risk assessments (LBG-BMcD, 2013), the current risk levels at the OB/OD are above USEPA's accepted limits. While routine groundwater monitoring would detect changes in conditions in groundwater at the site that could be indicated future risk levels, it would not alleviate current risk levels to human health and the environment.

#### Reduction of Toxicity, Mobility, or Volume

No active treatment of soil is proposed under this alternative therefore, Alternative GW4 does not reduce the toxicity, mobility or volume of contaminants at the site. Reductions in contaminant toxicity, mobility or volume in the groundwater through NA may reduce contaminant levels in the groundwater to a degree but contaminant concentrations are unlikely to fall below PRGs in the foreseeable future without active remediation. As noted in the RI, natural conditions in the aquifer are not conducive for NA of highly chlorinated VOCs such as TCE and PCE. In addition, the generally aerobic conditions in the aquifer do not promote the degradation of PCA. While some degradation of TCE and/or PCA may be occurring at the site, particularly in the bedrock formations, contaminant concentrations in the regolith have not decreased substantially over time.

## Short-Term Effectiveness

The implementation of this remedy would involve the installation of new monitoring wells and regular groundwater monitoring. The OB/OD is relatively isolated from t residences and most site workers, so construction activities should have relatively limited impacts. The risks to workers and the community, commensurate with these types of activities, include the following:

- Invasive activities in an active range have the potential to encounter UXO/MEC;
- Working around/on/with drilling equipment. This risk would be similar to other remediation/construction projects;
- Potential exposure to soil and ground water containing a range of contaminants. While concentrations exceed desirable limits for routine exposure for some contaminants, the period of exposure would be limited. PPE would be worn by site workers to limit exposure to contaminants. In areas where concentrations exceed hazardous material levels, additional steps would be taken to minimize the exposure to workers;
- Some construction activities could result in a low to moderate risk to workers through potential exposure to mechanical and noise hazards. The majority of these hazards can be controlled using engineering controls such as safe work practices and PPE; and
- Construction activities would temporarily disrupt the local wildlife. Areas to be impacted are surrounded by land with similar conditions and wildlife can temporarily relocate during construction.

## Implementability

There are no anticipated technical or administrative difficulties implementing this alternative. Current activities related to groundwater monitoring would continue, albeit on a more regular basis. Additional wells could increase the time required for each sampling event, thereby reducing the availability of the range; the use of additional staff could offset this concern.

## Cost Evaluation

The present worth cost of this alternative is estimated to be $8,323,000. This alternative has a total project cost of $27,333,000 (undiscounted), including approximately $783,000 in capital costs for installing new monitoring wells and baseline sampling; total annual costs of $26,100,000 (over 30 years) involving groundwater monitoring; and $450,000 in periodic costs for five-year reviews. A detailed cost analysis for Alternative GW4 is presented in Appendix 5B-4.

### *Evaluation Summary*

**Advantages**

- Ease of implementation;
- Allows determination of changes in conditions that could have a more-widespread impact; and
- Low to medium costs.

**Limitations and Considerations**

- Drilling in soils that contain possible UXOs/MECs.
- Has no impact on ecological receptors in the area where exposure is above accepted levels;
- No control or mitigation of contaminant migration;
- Potential impacts on future uses of the site; and
- More extensive education and outreach efforts may be required in order to gain public acceptance of MNA.

## 5.3.2.5 Alternative GW5 – In-Situ Treatment: Chemical Reagent Injection

### *Description*

Alternative GW5 was developed to assess the feasibility of in-situ treatment of contaminated groundwater at the OB/OD. Alternative GW5 involves injection of one or more reactive media into the aquifer to promote conditions that are effective in the treatment of the chlorinated solvents plume(s). A wide range of reagents are available ranging from relatively common products such as edible oils and lactose to special formulations developed to treat specific contaminants under both aerobic and anaerobic conditions. While a wide range of products have been used to treatment TCE in situ, less work has been done on in-situ treatment options for PCA. Treatability studies would need to be conducted during the Remedial Design to identify the appropriate reagent(s) for treating each of the COCs. Figure 5-7a shows the boundary of the contaminant plume at the OB/OD and the area of primary concern for treatment purposes. Based on the 2012 groundwater monitoring results, contaminant concentrations for COCs outside this boundary are at or slightly above MCLs and would be allowed to attenuation naturally. Contaminants in groundwater within the primary area of concern would receive treatment.

The reagent can be injected into the groundwater using a fluid delivery system such as direct-push technology or through the use of specially constructed injection wells (vertical or horizontal). While injection wells are initially more expensive, they have several advantages:

- Wells allow for multiple rounds of injections which can be cost effective in the long term;
- Injection wells can shorten the application time for subsequent rounds of injections; and
- Direct-push technology is limited in its effective depth of injection, depending on the formation conditions.

For evaluation of this alternative, it was assumed that vertical injection wells would be used, targeting the regolith/weathered bedrock formations.

Treatability testing during the design phase would establish the anticipated ROI for the injections wells. For this evaluation, it was assumed that the injection wells would have an ROI of approximately 15 feet. Two to three rows of wells would be placed at the down gradient edge of the primary area of concern as shown in Figure 5-7b in a staggered pattern to ensure coverage of the plume. The wells would extend to the bottom of the contaminant plume (assumed depth of 25 feet bgs). Depending on the results of the treatability study and the selected reagent(s), separate injection wells may be used to treatment the PCA plume. Figure 5-7b shows the potential layout for the injection wells.

Periodic access to the site would be required for future injections and to monitor groundwater conditions. A groundwater monitoring program, including an expanded groundwater monitoring network, would be established such that the injection program treats the chlorinated solvents and controls contaminant migration. Implementation of Alternative S3 or S4 to remediate the chlorinated solvent source area under the soil remediation program would be required in conjunction with this alternative to ensure that future releases from the source area do not continue to contaminate the groundwater.

### *Evaluation*

#### <u>Protection of Human Health and the Environment</u>

Based on the HHBLRA and ECORA performed as part of the RI Report (LBG-BMcD, 2013), this alternative would be protective of human health and the environment because exposures for dermal contact and ingestion of groundwater as well as vapors from groundwater use would be largely controlled. Groundwater with contaminant concentrations significantly above would be treated. Although an exposure scenario beyond those scenarios envisioned in the risk assessments could occur, the exposure pathway would not be complete due to treatment of the groundwater.

## Compliance with ARARs

The preliminary chemical-, location-, and action-specific ARARs for Alternative GW5 are presented in Table 5-2. It is anticipated that there would be no difficulties complying with any of the preliminary ARARs.

## Long-Term Effectiveness and Permanence

Under this alternative, the in-situ treatment of contaminated groundwater, in conjunction with treatment of a potential source area (see Section 5.3.1) would provide an effective solution to the chlorinated solvents in groundwater at the OB/OD. This alternative is a permanent solution assuming: 1) the potential source area is addressed as part of the soil remediation program (through the implementation of either Alternative S3 or S4); and 2) chlorinated solvents are not reintroduced into the area through other sources.

However, it should be recognized that in-situ treatment options often are most effective in lowering very high contaminant concentrations to within an order of magnitude of the MCLs relatively rapidly but may not always be as effective in reducing concentrations below MCLs in a timely manner. This can be a particular issue in low permeability soils which may slowly leach low concentrations of contaminants back into the groundwater for a long time creating uncertainty in the overall cost or performance period for these systems.

## Reduction of Toxicity, Mobility, or Volume

All groundwater within the influence zone of the injection wells will be treated, reducing the toxicity of the contaminants at the site and limiting the future mobility of contaminants.

## Short-Term Effectiveness

Because the OB/OD is relatively isolated from residences and most site workers, construction activities should have relatively limited impacts. The risks to workers and the community commensurate with similar construction types of activities include the following:

- Invasive activities in an active range have the potential to encounter UXO/MEC;
- Working around/on/with drilling rigs. This risk would be similar to other remediation/construction projects with monitoring well installations. Seasonal weather

conditions (cold/hot weather operations, rain and snow, wind chill) would increase the risk to workers;

- Potential exposure to soil and ground water containing a range of contaminants. While concentrations exceed desirable limits for routine exposure for some contaminants, in most areas contaminant concentrations are not at a level that is immediately harmful and continued, regular exposure would be required to pose a health risk to workers. PPE such as Tyvek coveralls, boot covers, and disposable gloves would be worn by site workers to prevent dermal exposure to contaminants. In areas where concentrations are detected at levels that would have the potential to cause exposures above OSHA permissible exposure limits, additional steps would be taken to minimize the exposure to construction workers;

- Some construction activities could result in a low to moderate risk to workers through potential exposure to mechanical hazards and noise hazards. The majority of these hazards can be controlled using engineering controls such as safe work practices and PPE; and

- Construction activities would temporarily disrupt the local wildlife. Areas to be impacted are surrounded by land with similar conditions and wildlife can temporarily relocate during construction.

The majority of hazards associated with implementing this alternative could be controlled through a comprehensive health and safety protocol and notification program (*e.g.*, high visibility orange fencing, caution tape, lockout/tagout procedures, protective equipment, perimeter air monitoring, personal air monitoring for workers, heat and stress monitoring, etc.).

**Implementability**

The alternative is technically feasible. Similar operations have been performed successfully at other sites. A number of options are available for treating TCE in situ; the primary concern is the ability to treat the PCA in situ for which there is limited experience, although some reagents have proven effective.

The alternative is administratively feasible. Work would be performed on post limiting outside involvement. The KDHE may require approval be obtained on the reagent(s) injected into the groundwater

**Cost Evaluation**

The present worth cost of this alternative is estimated to be $8,940,000. This alternative has a total project cost of $8.830,000 (undiscounted), including approximately $2,630,000 in capital costs for installing new monitoring wells and injection wells; total annual costs of $10,530,000 (over 30 years) involving groundwater monitoring; and $4,158,000 in periodic costs for periodic injections of reagents and five-year reviews. A detailed cost analysis for Alternative GW5 is presented in Appendix 5B-5.

### *Evaluation Summary*

**Advantages**

- Low operating cost;
- Includes a groundwater monitoring program to assess future changes in the site and/or contaminant conditions;
- Controls exposures pathways; and
- Minimal impact on site usage during operations.

**Limitations and Considerations**

- Medium construction;
- Periodic injections would be required until COCs in groundwater fall below ARARs; and
- In-situ treatment of PCA has limited history and identification of the appropriate reagent may be difficult.

## 5.3.3 Surface Water Remedial Alternatives

Surface water is present at the OB/OD on a sporadic basis in streams, spring, and seeps. Surface water samples have been collected periodically from the two ephemeral streams as well as a spring and several seeps on the site. Because of this, obtaining a representative sample over time can be difficult. The most recent surface sample monitoring was conducted between December 2011 and March 2012 when 12 samples were collected. During the sampling, the following exceedences of screening levels were reported:

- TCE – two exceedences
- PCA – one exceedence
- Benzo(a)pyrene – one exceedence

In addition, 13 historical samples were collected between 2004 and 2010. Screening levels were exceeded in 11 of the 13 samples for TCE (eight samples), perchlorate (two samples), and lead (one sample). PCA, TCE, and benzo(a)pyrene were identified as COCs for surface water (see Section 3.3).

The range of constituents detected in the surface water suggests two sources of contaminants. The chlorinated solvents, primarily PCA and TCE, are found commonly in site groundwater. Contaminated groundwater may be discharging to surface water in springs and seeps. Benzo(a)pyrene is a byproduct of incomplete combustion and is likely present in soil from burning and detonation of ordnance. In addition, in the past, diesel fuel was a commonly used accelerant when burning powders at the site but is no longer used at OB/OD. Its presence in the groundwater may be result of past practices in the area. In Section 4.0, the following alternatives for surface water were identified:

Alternative SW1 No Action (retained as a baseline)

Alternative SW2 Institutional Controls Through the Fort Riley RPMP

Alternative SW3 Surface Water Monitoring

#### 5.3.3.1 Alternative SW1 – No Action

##### *Description*

Alternative SW1, the “No Action” Alternative, is a requirement of the NCP providing a baseline for the comparison of active remedial alternatives developed for the OB/OD. Under this alternative, institutional controls are not implemented and remediation and monitoring of the site conditions are not conducted. By definition, this alternative requires that any current monitoring program be discontinued. At a minimum, whenever contaminants are left in place, the NCP requires the following: *If a remedial action is selected that results in hazardous substances, pollutants, or contaminants remaining at the site above levels that allow for unlimited use and unrestricted exposure, the lead agency shall review such action no less than every five years after initiation of the remedial action.*

Although under the "No Action" Alternative institutional controls are generally not enacted, it should be acknowledged that access restriction via range controls are already in place due to the location of the OB/OD on a military base within the limits of the impact area. Range controls will remain in effect as long as Fort Riley remains active.

### Evaluation

**Protection of Human Health and the Environment**

Based on the HHBLRA and ECORA performed as part of the RI Report (LBG-BMcD, 2013), this alternative is not protective of human health or the environment because the risk estimates for current and future RME scenarios exceed USEPA's accepted risk levels for dermal contact with surface water. Because this alternative does not include institutional controls, there is no control of future surface water use/exposure within the limits of the OB/OD; however unlikely it is that there would be a change in site usage. Although an exposure scenario beyond those scenarios envisioned in the risk assessments could occur when no institutional controls are acknowledged for the property. On this basis, Alternative SW1 will be considered not protective of human health and the environment.

**Compliance with ARARs**

The preliminary chemical-, location-, and action-specific ARARs for Alternative SW1 are presented in Table 5-3. Location- and action-specific ARARs do not apply to Alternative SW1 since there are no location- or action-specific remedial measures that will be taken at the OB/OD under this alternative.

**Long-Term Effectiveness and Permanence**

Because surface water monitoring has been limited at the site, it is difficult to determine the source of the contaminants. The likely source of the chlorinated solvents is groundwater; the likely source of the benzo(a)pyrene is contaminated soils from the demolition activities and surface water runoff. The current risk levels to human health and the environment are above USEPA's accepted limits (LBG-BMcD, 2013), and are assumed to remain so for the foreseeable future. However, if the soil and groundwater are remediated, surface water quality is likely to improve by addressing those contaminant source areas.

A review of surface water contamination at the OB/OD would be required every five years to monitor contaminants remaining in the OB/OD in accordance with the CERCLA 121(c).

**Reduction of Toxicity, Mobility, or Volume Through Treatment**

No active remediation would occur at the site and what treatment that did occur would be minor and related to NA mechanisms, or the result of remedial activities to address contaminants in the surrounding soil and the groundwater. Reductions in contaminant toxicity, mobility or volume in surface water through some form of naturally occurring treatment mechanism are unlikely. Decreases in contaminant concentrations in the surface water, if they occur, are likely to be due to removal of soil in source areas or the treatment of groundwater. No active treatment of surface water is proposed under this alternative.

**Short-Term Effectiveness**

Alternative SW1 does not involve any active remedy or construction and therefore poses no risks to construction workers or the local community in the short term. Based on the results of the risk assessments (LBG-BMcD, 2013), the current risk levels at the OB/OD to human health and the environment are above USEPA's accepted limits. These conditions would continue to present risks to human health and the environment in the short term.

**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 $0. There are no capital or O&M costs associated with this alternative. A detailed cost analysis for Alternative SW1 is presented in Appendix 5C-1.

### *Evaluation Summary*

**Advantages**

- Minimal cost and
- Ease of implementation.

**Limitations and Considerations**

- No control or mitigation of contaminant migration and
- Without an annual monitoring program, changes in the site and/or contaminant conditions would only be assessed during the five-year reviews.

## 5.3.3.2 Alternative SW2 – Institutional Controls Through the Fort Riley RPMP

### *Description*

This alternative involves the use of institutional controls implemented through the Fort Riley RPMP to control future uses of the OB/OD and the area surface water to protect human health and the environment. The inclusion of institutional controls such as restrictions on the use of surface water resources reduces the potential for human ingestion, inhalation, or direct contact with contaminated groundwater. 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 OB/OD is more restricted because the site is on an active military reservation.

The purpose of institutional controls is to limit exposure to contaminants. The principal institutional controls that would be applied by Fort Riley would be a prohibition against the use of surface water (including seeps and springs) within a designated area (see Figure 5-8 for approximate limits on surface water institutional controls). Because of the proximity to the firing ranges and the ephemeral nature of the water, this should not pose a direct hardship to the Post.

### *Evaluation*

#### Protection of Human Health and the Environment

Based on the HHBLRA and ECORA performed as part of the RI Report (LBG-BMcD, 2013), this alternative not is protective of human health and the environment because the exposure pathways for dermal contact with surface water have not been eliminated or controlled and the site exceeds USEPA's accepted risk levels. Based on the exposure scenarios identified in the risk assessments, the human health risks are likely to remain above USEPA's accepted risk levels without active remediation of chlorinated solvents. However, because the source of surface water contaminants appears to be related to the contaminated soil and groundwater at the site, if active remediation programs were implemented in these areas surface water quality is likely to improve.

It is anticipated that the potential future risk to human health would not increase under this alternative because institutional controls are anticipated to limit exposure to surface water (one of the exposure routes evaluated in the RI). However, even if the dermal contact exposure risk were eliminated, risk levels for human health and the environment would remain above accepted levels.

#### Compliance with ARARs

The preliminary chemical-, location-, and action-specific ARARs for Alternative SW2 are presented in Table 5-3. Currently there are no chemical-specific ARARs for soil, although RSK (screening levels) are TBCs.

#### Long-Term Effectiveness and Permanence

Because surface water monitoring has been limited at the site it is difficult to determine the source of the contaminants. Based on previous surface water monitoring results, surface water quality appears to be related to the soil and groundwater contamination at the OB/OD. The current risk levels to human health and the environment are above USEPA's accepted limits (LBG-BMcD, 2013) and are assumed to remain so for the foreseeable future. However, if the soil and groundwater are remediated at the OB/OD, surface water quality is likely to improve due to control of the sources. A review of surface water contamination at the OB/OD would be required every five years to monitor contaminants remaining at the OB/OD in accordance with the CERCLA 121(c).

However, while institutional controls are easily implemented from a technical and administrative perspective, effective compliance may be difficult to maintain in the long term due to the limited use of the area and changes in base personnel over time.

**Reduction of Toxicity, Mobility, or Volume**

No active remediation would occur at the site and what treatment that did occur would be minor and related to NA mechanisms, or the result of remedial activities to address contaminants in the surrounding soil and the groundwater. Reductions in contaminant toxicity, mobility or volume in surface water through some form of naturally occurring treatment mechanism are unlikely. Decreases in contaminant concentrations in the surface water, if they occur, are likely to be due to removal of soil in source areas or the treatment of groundwater. No active treatment of surface water is proposed under this alternative.

**Short-Term Effectiveness**

This alternative does not involve active remedial activities or construction and poses no risk to construction workers or the local community in the short term. On-going exposures to site workers and wildlife would continue.

**Implementability**

There are no anticipated technical difficulties implementing this alternative. Because this is an active government installation, it is anticipated that there will be no problems with implementing a program of institutional controls through the Fort Riley RPMP (see Section 4.3.3.2).

**Cost Evaluation**

The present worth cost of this alternative is estimated to be $144,000. This alternative has a total project cost of $226,000 (undiscounted), including approximately $4,000 in capital costs for developing institutional controls ; total annual costs of $90,000 (over 30 years) to enforce institutional controls through plan reviews and site inspections; and $132,000 in periodic costs for five-year reviews. A detailed cost analysis for Alternative SW2 is presented in Appendix 5C-2.

### *Evaluation Summary*

**Advantages**

- Minimal cost;

- Ease of implementation; and
- Reduces but does not eliminate exposure pathways.

**Limitations and Considerations**

- Has no impact on site workers who must access the site in areas where exposure is above accepted levels;
- Has no impact on ecological receptors in the area where exposure is above accepted levels;
- No control or mitigation of contaminant migration; and
- Without an annual monitoring program, changes in the site and/or contaminant conditions would only be assessed during the five-year reviews.

#### 5.3.3.3 Alternative SW3 – Surface Water Monitoring

##### *Description*

This alternative involves the use of routine surface water monitoring to assess surface water conditions in the area of the OB/OD. If negative changes in water quality are detected, additional protective methods can be implemented to protect human health and the environment.

Based on previous surface water monitoring results, surface water quality appears to be related to the soil and groundwater contamination at the OB/OD. Remediation of these areas should improve water quality over time. In the interim, surface water monitoring would be performed to monitor current conditions and provide a framework for assessing improvements. Although contaminant concentrations in some samples collected in the last round of sampling were not in compliance with ARARs, elevated concentrations have appeared only sporadically and, given the isolated location, the impact is likely to be limited.

The current monitoring network (see Figure 5-9) would be evaluated to assess its suitability for Alternative SW3. New sampling points may be established to monitor conditions during remediation activities.

##### *Evaluation*

**Protection of Human Health and the Environment**

Based on the HHBLRA and ECORA performed as part of the RI Report (LBG-BMcD, 2013), this alternative not is protective of human health and the environment because the existing exposure pathways for dermal contact with surface water are have not been eliminated or controlled and the site exceeds USEPA’s accepted risk levels. Based on the exposure scenarios identified in the risk assessments, the human health risks are likely to remain above USEPA's accepted risk levels without active remediation of chlorinated solvents.

## Compliance with ARARs

The preliminary chemical-, location-, and action-specific ARARs for Alternative SW3 are presented in Table 5-3. It is anticipated that there would be no difficulties complying with any of the preliminary ARARs.

## Long-Term Effectiveness and Permanence

Under Alternative SW3, remedial actions would be limited to monitoring water quality. Based on the results of the risk assessments (LBG-BMcD, 2013), the current risk levels at the OB/OD are above USEPA's accepted limits. While routine surface water monitoring would indicate changes in water quality, it does not alleviate current risk levels to human health and the environment. Assuming active remediation programs are implemented for soil and groundwater at the site, surface water quality monitoring could be used to assess the effectiveness of those programs in improving surface water quality.

## Reduction of Toxicity, Mobility, or Volume

No active remediation would occur at the site and what treatment that did occur would be minor and related to NA mechanisms, or the result of remedial activities to address contaminants in the surrounding soil and the groundwater. Reductions in contaminant toxicity, mobility or volume in surface water through some form of naturally occurring treatment mechanism are unlikely. Decreases in contaminant concentrations in the surface water, if they occur, are likely to be due to removal of soil in source areas or the treatment of groundwater. No active treatment of surface water is proposed under this alternative.

## Short-Term Effectiveness

This alternative does not involve active remedial activities or construction and poses no risk to construction workers or the local community in the short term. On-going exposures to site workers and wildlife would continue.

## Implementability

There are no anticipated technical difficulties implementing this alternative. Current activities related to surface water monitoring would continue albeit on a more regular basis.

**Cost Evaluation**

The present worth cost of this alternative is estimated to be $2,338,000. This alternative has a total project cost of $5,390,000 (undiscounted), including approximately $38,000 in capital costs for developing a surface water sampling program ; total annual costs of $5,220,000 (over 30 years) to monitor surface water quality; and $132,000in periodic costs for five-year reviews. A detailed cost analysis for Alternative SW3 is presented in Appendix 5C-3.

### Evaluation Summary

**Advantages**

- Minimal cost;
- Ease of implementation; and
- Reduces but does not eliminate exposure pathways.

**Limitations and Considerations**

- Has no impact on site workers who must access the site in areas where exposure is above accepted levels;
- Has no impact on ecological receptors in the area where the exposure is above accepted levels; and
- No control or mitigation of contaminant migration.

* * * * *

# 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) in Sections 6.3.1 and 6.3.2, respectively. Those alternatives passing the threshold criteria were then evaluated for the five balancing criteria on the basis of incremental differences between alternatives. Sections 6.3.4 through 6.3.8 summarize the evaluations 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. Evaluations were based on vendor information, published reports, past experiences, and professional judgment. Equal rating was given if it was not possible to differentiate performance for the given criterion. The range was on a scale of 1 to 10. Any alternative that completely fails the criterion 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 Least favorable alternative

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 6.3.4 through 6.3.8).

## 6.3 COMPARATIVE ANALYSIS

Tables 6-1, 6-2, and 6-3 provide a summary of the comparative analysis results for soil, groundwater, and surface water, respectively.

### 6.3.1 Overall Protection of Human Health and the Environment

This is a pass/fail criterion. The following analysis was based on the HHBLRA and ECORA performed in the RI Report (LBG-BMcD, 2013).

***Soil***

The results of the HHBLRA concluded that the risks for potential worker populations studied were above the USEPA's allowable noncancer risk level and within the USEPA's cancer risk management range (LBG-BMcD, 2013) for soil exposure. Ecological risks associated with soil were also found to exceed acceptable limits.

For the purposes of this comparative analysis, Alternatives S1and S2 would be considered not protective of human health and the environment. Although access restrictions are in place via range controls, Alternative S1 does not mitigate the risks posed by contaminants in the soil at the site. While institutional controls (Alternative S2) limit human exposure, these controls are likely to have limited effect. Access to the site is already restricted because of the surrounding land use and workers (both current and future) accessing the site are there of necessity. These workers would continue to be potentially exposed to contaminants in the performance of their jobs. In addition, institutional controls do not address ecological risks. Alternative S2 could be implemented in conjunction with active remediation alternatives.

Alternatives S3a, S3b, and S3c would be considered as protective of human health and the environment. Alternative S4 would be considered protective of human health and the environment with some qualifications. Under Alternatives S3a, S3b, and S3c, soil with contaminants exceeding acceptable limits would be excavated and hauled elsewhere for treatment and/or disposal. Under Alternative 3b, the treated soil would be used as fill or placed in a C&D landfill. Under Alternatives 3a and 3c, the soil would be removed from the Post and handled off site for treatment and/disposal in accordance with state and federal regulations. Alternative S4 is considered protective with some qualifications related to the potential performance of SVE in removing contaminants given site conditions. While SVE would treat subsurface soils, it would have limited, if any, impact on surficial soils which pose the greatest ecological risks.

***Groundwater***

The primary human health and environmental concern related to groundwater is direct consumption with exposure through dermal contact or inhalation through vapors of lesser concern.

For the purposes of this comparative analysis, Alternative GW1 would be considered not protective of human health and the environment. Although access restrictions are in place via range controls and exposure risks for workers associated with groundwater are limited, this alternative does not mitigate ecological risk or secondary impacts to surface water.

Alternative GW2 would not be considered protective of human health and the environment. Alternative GW2 relies on institutional controls to prevent contaminated groundwater at the site from being used as a potable water supply in the future. That approach, along with the depth of the groundwater at the site, would limit the potential for human exposure under most scenarios. The primary ecological risk associated with groundwater is from contaminated groundwater daylighting to the surface in seeps, or springs. These releases are extremely periodic and not sustained, and are primarily related to large precipitation events. However, this alternative does not address the on-going releases of contaminated groundwater, instead relying on avoidance (institutional controls).

Alternatives GW3 and GW4 would not be considered protective of human health and the environment. These alternatives do not address the on-going releases of contaminated groundwater, instead relying on contaminant tracking (monitoring) to assess future risk; and MNA to remediate groundwater resources over an extended period of time. These approaches minimize but do not completely address incidental exposures of site workers in the area or impacts to the environment.

Alternative GW5 would be considered protective of human health and the environment. Active remediation of the groundwater would facilitate the treatment of contaminants in the groundwater and reduce potential exposure.

***Surface Water***

For the purposes of this comparative analysis, Alternative SW1 would not be considered protective of human health and the environment. Although access restrictions are in place via range controls, Alternative SW1 places no limitations on surface water contact at the site although both the HHBLRA (dermal contact) and ECORA (contact, ingestion) identified risks above acceptable limits.

As noted in Section 5.3.4, a primary source of contaminants in surface water appears related to contaminants in soil and/or groundwater impacting surface water. Alternatives SW2 and SW3, if implemented independent of active soil and groundwater remediation programs for the OB/OD, would not be considered protective of the environment because neither address contaminants that have been detected in surface water at the site. However, if implemented in conjunction with active soil and groundwater remediation, both would be considered protective of the environment. Implementation of either of these alternatives in conjunction with Alternative GW5 would not eliminate the risk but would manage human exposure.

### 6.3.2 Compliance with ARARs

This is a pass/fail criterion. It appears that possible location- and action-specific ARARs would not be a factor for any of the alternatives so the focus is on preliminary chemical-specific ARARs.

***Soil***

There are currently no chemical-specific ARARs for soil although RSK (screening levels) are TBCs. Alternatives S1 and S2 do not incorporate active remediation of either the source area or the contaminants in the soil that are above PRGs and therefore would not comply with preliminary chemical-specific PRGs in a timely manner. Alternatives S3a, S3b, S3c, and S4 are anticipated to comply with preliminary chemical-specific PRGs.

***Groundwater***

Alternative GW1 does not incorporate active remediation of the contaminants in the groundwater that are above PRGs and therefore is not anticipated to comply with preliminary chemical-specific ARARs in a timely manner.

Alternatives GW2 and GW3 do not incorporate active remediation of the contaminants in the groundwater and are not anticipated to comply with preliminary ARARs in a timely manner. Alternative GW2 relies on institution controls (avoidance) to be protective of human health and the environment but does not incorporate active remediation of the contaminants in the groundwater that are above PRGs and therefore is not anticipated to comply with preliminary chemical-specific ARARs in a timely manner. Alternative GW3 relies on groundwater monitoring to track the location of the plume to control risk but does not treat contaminants exceeding ARARs.

Alternative GW4 relies on NA of contaminants in the groundwater to achieve compliance with ARARs. MNA parameters were measured during the RI and were generally not supportive of MNA being able to achieve ARARs in a timely manner. This was supported by an evaluation of contaminant levels in the groundwater over time in the three formations present at the site. This approach is reactive and does not prevent future exposures.

Alternative GW5 is anticipated to comply with preliminary chemical-specific PRGS.

***Surface Water***

Alternatives SW1, SW2, and SW3 do not incorporate any active remediation of surface water and, by themselves, would not comply with ARARs in a timely manner. However, if implemented in conjunction with a soil and groundwater remediation program, they would be anticipated to comply with ARARs in a timely manner.

### 6.3.3 Compliance with Threshold Criteria

Alternatives S1 and S2, GW1 through GW4, and SW1 are dropped from further consideration because they do not meet one or both of the two threshold criteria (i.e., either Overall Protection of Human Health and the Environment or Compliance with ARARs). Alternatives S3a, S3b, S3c, S4, GW5, SW2 and SW3 have been retained for additional evaluation.

### 6.3.4 Long-Term Effectiveness and Permanence

This criterion addresses the results of a remedial action in terms of the risk remaining at the site after response objectives have been met, including from treatment of residuals and/or untreated constituents, and the adequacy and reliability of remedial controls, if any, that are used to manage treatment of residuals or untreated constituents remaining at the site.

***Soil***

Alternatives S3a, S3b, S3c, and S4 would be permanent and effective solutions in the long term if treatment is taken to completion. Interruption of the treatment process before contaminant levels have been reduced and stabilized at a level that no longer pose unacceptable risks to human health or the environment may result in leaching of contaminants into soil or groundwater in the future.

For Alternative S3b, the end use of the treated soil would be either as general fill, landfill cover soils, or disposal at the Fort Riley C&D landfill. The end use for the soil would dictate the acceptable levels of contaminants that can remain in the soil following treatment. For Alternatives S3a and S3c, the soil would be shipped off site for treatment and/or disposal.

For Alternative S4, untreated contaminants remaining in the soil following treatment could be released to the environment. Due to the known rebounding effects associated with the SVE system, this alternative is considered less favorable in terms of long-term effectiveness and permanence than Alternatives S3a, S3b, and S3c. Rebounding effects occur when the system is shut down and contaminants diffuse out of low permeability zones within the aquifer (USEPA, 1996). In addition, the integrity of the extraction and treatment is susceptible to damage from range operations or ordnance detonation at the OB/OD increasing the risk associated with this alternative.

***Groundwater***

Alternative GW5 can be an effective and permanent alternative if the Remedial Design process considers the impact soil conditions would have on reagent distribution and the appropriate reagent is selected based on the COCs.

***Surface Water***

Both Alternatives SW2 and SW3 rely on remediation of soil and groundwater contamination at the OB/OD to control the release of contaminants to surface water. Alternative SW2 relies on institutional controls to minimize risks to human health but does not impact risks to the environment. Alternative SW3 relies on site monitoring to evaluate changes in risk levels but does not provide a permanent solution for addressing contaminants. By themselves, neither SW2 nor SW3 offer a long-term or permanent solution. But if implemented in conjunction with active remediation of soil and groundwater at the site, they would be effective in managing the risk of exposure.

### 6.3.5 Reduction of Toxicity, Mobility, or Volume Through Treatment

This 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.

***Soil***

Alternatives S3a, S3b, S3c, and S4 would both reduce the toxicity, mobility and volume of contaminants in the plume although the extent of the reduction would vary.

Alternative S3b involves the excavation of contaminated soil, including source area soils, and treatment through land farming. Land farming would only treat the VOCs in the soil; inorganics and other contaminants (including some SVOCs) would remain in the soil following treatment. The extent of contaminant reduction would depend on the treatment period and the operation of the land-farming process. Liquid waste, if present in the source area, would be removed and thermally destroyed (incinerated) at an off-site facility. Thermal destruction would destroy in excess of 99 percent of the contaminants in the source material with the remainder being landfilled. Alternative S3a would treat liquid waste and soil in the source area through thermal destruction (incineration); the remainder of the excavated soil would be placed directly into a landfill without treatment. Alternative S3c would treat the excavated soil (source area and surrounding soils) through thermal destruction.

Alternative S4 includes excavation of the source area soils and thermal destruction (i.e., incineration) of contaminants in those soils and liquids (if present). The remaining contaminants in the soil exceeding PRGs would be volatilized using SVE. Off gasses from the SVE system would be captured though an air pollution control system and treated with granular activated carbon (GAC) before the gasses are released to the atmosphere. Ultimately the GAC would be recycled or incinerated destroying the captured contaminants. SVE would only treat the VOCs in the soil; inorganics and other contaminants (including most SVOCs) would remain in the soil after treatment.

***Groundwater***

Alternative GW5 would reduce the toxicity, mobility, and volume of contaminants in the groundwater through in-situ treatment by chemical injection. The extent of the reduction would vary based on the selected reagent, the number of applications, and the effectiveness of the injection process in distributing the reagent in the treatment zone.

***Surface Water***

Alternatives SW2 and SW3 would not reduce the toxicity, mobility, or volume of contaminants in the surface water. By themselves, neither SW2 nor SW3 would reduce toxicity, mobility, or volume but if implemented in conjunction with active remediation of soil and groundwater at the site would be effective in addressing contaminants in surface water.

### 6.3.6 Short-Term Effectiveness

This criterion addresses the effects the remedial alternative would have on human health and the environment during the construction, implementation, and operational phases of the remedial actions. Consideration is given to protection of the community and workers, the effectiveness and reliability of protective measures, potential short-term adverse environmental impacts, and the time required to complete construction, implementation, and O&M activities.

***Soil***

Alternative S3a, S3b, and S3c involves the excavation and transport of contaminated soil excavated at the site, to another location on the Post for treatment (Alternative S3b) or off Post (Alternatives S3a and S3c), thereby increasing traffic on Post roads. Alternative S4 involves the in-situ treatment of contaminants resulting in significantly less on-Post traffic for the transport of contaminated soil.

The Alternatives would expose construction workers to contaminants in the soil, and potentially ground and surface water, during construction. The larger volume of soil excavated under Alternative S3a, S3b, and S3c would increase the risk to construction workers, both in the concentration of contaminants in the soil and the time of exposure. Alternative S4 would cause less disruption to in-place soils minimizing contaminant exposure levels for construction workers.

Alternatives S3a, S3b, S3c, and S4 would pose risks to construction workers involving working with heavy machinery including drilling, trenching, and hauling equipment. A site-specific safety and health plan would minimize hazards associated with construction and/or operation. Alternatives S3a, S3b, and S3c presents the greater risk to construction workers given the size of the excavation project. The Alternatives require invasive construction activities (Alternative S3a, S3b, and S3c- excavation; Alternative S4 – drilling and trenching) in an area likely containing UXO/MEC in the soil. The Alternatives would disturb approximately 1 to 2 acres of land, although Alternative S3a, S3b, and S3c would require more extensive excavation. For each alternative, the source area would be excavated with the soil being either being treated on Post (Alternatives S3b) or shipped off site for treatment (Alternatives S3a, S3c, and S4).

Alternative S4 would require periodic visits to the site to maintain equipment and change out air pollution control canisters exposing site operators to unexploded ordnance and contaminants in the soil. Alternatives S3a, S3b, and S3c would not require site maintenance after site restoration is completed.

Alternatives S3a, S3b, and S3c have the greater potential to disrupt the local community living on Post through traffic congestion for construction equipment, construction works, and transfer vehicles.

***Groundwater***

Alternative GW5 would have a limited impact on the area surrounding the OB/OD. Construction workers would be exposed to contaminants at the site during monitoring well installation, well development, and baseline sampling. In addition to 11 new monitoring wells, approximately 40 injection wells would be installed near the source area to allow in-situ treatment of groundwater. Periodic reagent injections at the site over the 30 year operating period would expose site workers and contractors to UXO/MEC and contaminants in the soil.

Impacts on the surrounding community should be minimal and limited to small increases in truck traffic from construction workers.

***Surface Water***

Alternatives SW2 and SW3 would not have a significant impact on construction workers or the local community. None of the alternatives involve construction activities although periodic sampling

(Alternative SW3) would present some risks to the sampling team from UXO/MEC and contaminants in the soil and groundwater (seeps).

### 6.3.7 Implementability

This criterion addresses the technical and administrative feasibility of implementing an alternative, and the availability of services and materials for implementation of the remedial alternative.

***Soil***

Alternatives S3, S3b, S3c, and S4 are technically and administratively feasible and have been used at a number of other sites to treat chlorinated solvents. Implementation of either alternative involves the use of commonly available construction equipment and materials.

However, low permeability conditions may increase the difficulty of in-situ treatment at the OB/OD (Alternative S4) by reducing the ROI for each extraction well. This may require increasing the number of wells or extending the treatment time. In addition, this alternative would require an extensive surface support infrastructure which would require trenching (for pipeline installation) during the construction phase. Preferential pathways for air flow may be a technical implementability issue with Alternative S4.

***Groundwater***

Alternative GW5 has been used at other sites contaminated with chlorinated solvents. Implementation of Alternative GW5 involves the use of commonly available construction equipment and materials. No permanent support infrastructure on the surface is required at the site beyond injection wells which are similar to the monitoring wells already present at the site. However, there is little information available on reagents that can treat PCA in situ and these generally involve an anaerobic environment in the aquifer. The aerobic conditions across much of the site may impact the technical feasibility of Alternative GW5 that will need to be addressed during the design phase.

***Surface Water***

The alternatives evaluated are technically and administratively feasible to implement.

### 6.3.8 Cost Evaluation

A summary of the cost evaluation for soil, groundwater, and surface water are provided in Tables 6-4, 6-5, and 6-6, respectively. Details of the cost estimates are provided in Appendix 5A-1 through 5A-4, 5B-1 through 5B-5, and 5C-1 through 5C-3.

## 6.4 COMPARATIVE ANALYSIS 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). Several alternatives were found not to comply with the threshold criteria and were removed from further consideration in the ranking of alternatives. Each alternative that met the threshold criteria was then comparatively evaluated using the five balancing criteria.

***Soil***

Alternative S3b was ranked the highest overall with Alternative S3c ranked the lowest. The three removal and disposal alternatives were ranked similarly except for Reduction in Toxicity, Mobility or Volume and Cost. Alternative S3a was ranked favorably but lower because while it would control/limit the mobility of contaminants, the other three alternatives provided more treatment. Alternative S3c was ranked the lowest on Cost due to the high cost associated with thermal treatment. Alternative S4 was ranked higher for Short-Term Effectiveness because in-situ treatment avoids the need to excavate and transport a large volume of soil on Post roads. And while Alternative S4 would be effective in remediating soil contaminants the low permeability conditions at the site raised questions on the performance of the system and the potential need for a longer than anticipated treatment period, or additional SVE wells, to achieve PRGs.

***Groundwater***

Alternative GW5 was the only alternative that survived the initial threshold screening criteria; the other alternatives were rejected as either not protective of human health and the environment or would not comply with ARARs in a timely manner.

Alternative GW5 incorporates in-situ treatment. This is a commonly used approach for treating VOCs in groundwater. Site conditions and the COCs may impact the performance of the treatment system and these parameters should be addressed during the Remedial Design. This approach was ranked the highest on Long-term Effectiveness and Performance and Reduction in the Toxicity, Mobility, or Volume because it would treat the contaminants and preventing the spread of contamination at the site.

***Surface Water***

Alternatives SW2 and SW3 do not involve active remediation of contaminants at the site and, if implemented independently of proposed soil and groundwater remediation programs, would not be effective. However both alternatives would facilitate surface water remediation if implemented in conjunction with soil and groundwater remediation. The primary difference between the two alternatives would be in the cost of implementation.

None of the alternatives would reduce contaminants at the site and were ranked low in this criterion. However, both alternatives would be implementable and would be Short-Term Effective. Alternative SW2 was ranked highest on the Cost (due to a lack of monitoring costs).

***Conclusion***

The ranking was an evaluation, not a selection, of the alternatives considered at the OB/OD. As no single alternative developed in this FS Report adequately addresses the issues and concerns encountered within the OB/OD site area, the following steps will be undertaken in the PP.

1. Combinations of the various remedial alternatives that are presented in this FS Report will be produced.

2. Those combinations of remedial alternatives will be evaluated as to their ability to meet the threshold screening criteria.

3. A final selection of an appropriate combination of remedial alternatives that best satisfies the protectiveness of human health and the environment will be put forth as the plan to be implemented by the PP.

4. State and community acceptance were not considered in this evaluation but will be evaluated after the publication of the PP as part of the development of the ROD.

* * * * *

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# TABLES

**Table 1-1**
**Chronology of Environmental Investigations**
*Feasibility Study Report*
*Open Burning / Open Detonation Ground (Range 16)*
*Fort Riley, Kansas*

| Date | Activity | Reports/References |
|---|---|---|
| Fall 1993 | Collection of surface soils samples from burning and detonation pits. Collection of soil samples from subsurface borings, sediment samples, and surface water samples from ephemeral streams. Installation, development, and sampling of Monitoring Wells OB-93-01 through OB-93-04. | *Site Investigation Report for High Priority Sites*, (LBA, 1994) |
| December 1995 | Confirmation sampling of Monitoring Wells OB-93-01 through OB-93-04. | *DSR and QCSR for Confirmation Groundwater Sampling Multi-Sites*, (LBA, 1996) |
| March/April 1997 | Installation of Monitoring Wells OB-97-05 through OB-97-08. Sampling of Monitoring Wells OB-97-05 through OB-97-08, hand dug well, and Spring 1. | *Technical Memorandum, Overview of Mobilization #1, Preliminary Findings and Proposes Mobilization #2 Activities, Open Burn/Open Detonation Area, Fort Riley, Kansas* (LBA, 1997a) |
| June 1997 | Collection of sample from the spring and hand dug well. Installation of nested piezometers OB-97-09PZ through OB-97-13PZ. | *Supplemental Technical Memorandum, Mobilization #2 Activities, Open Burn/Open Detonation Area, Fort Riley, Kansas* (LBA, 1998a) |
| September 1997 | Collection of groundwater samples from Monitoring Wells OB-93-01 through OB-97-08, Piezometers OB-97-09PZ through OB-97-13PZ, and a hand dug well. Collection of surface water samples. Installation of Monitoring Well OBHD-97-14 at the hand dug well location. | *DSR for Groundwater Sampling and Groundwater Elevations at the Open Burn/Open Detonation Area*, (LBA, 1999) |
| December 1997 | Collection of groundwater samples from Monitoring Wells OB-93-01 through OB-97-08 and a hand dug well. Collection of two surface water samples. Collection of sample from Spring 1. | *DSR for Groundwater Sampling and Groundwater Elevations at the Open Burn/Open Detonation Area*, (LBA, 1999) |
| April 1998 | Collection of groundwater samples from Monitoring Wells OB-93-01 through OBHD-97-14. Collection of five surface water samples. Collection of sample from Spring 1 and Spring 2. | *DSR for Groundwater Sampling and Groundwater Elevations at the Open Burn/Open Detonation Area*, (LBA, 1999) |
| August 1998 | Collection of groundwater samples from Monitoring Wells OB-93-01 through OBHD-97-14. Collection of five surface water samples. | *DSR for Groundwater Sampling and Groundwater Elevations at the Open Burn/Open Detonation Area*, (LBA, 1999) |

**Table 1-1**
**Chronology of Environmental Investigations**
*Feasibility Study Report*
*Open Burning / Open Detonation Ground (Range 16)*
*Fort Riley, Kansas*

| Date | Activity | Reports/References |
|---|---|---|
| January 1999 | Collection of groundwater samples from Monitoring Wells OB-93-01 through OBHD-97-14. Collection of four surface water samples. Collection of sample from Spring 1. | *DSR for Groundwater Sampling and Groundwater Elevations at the Open Burn/Open Detonation Area*, (LBA, 1999) |
| June 1999 | Site analysis regarding geology, stratigraphy, structure, and hydrology of the OB/OD Area. | *Analysis of Geological Stratigraphy, Structure, and Hydrology of the OB/OD Site, Fort Riley, Kansas*, (Archer and Martin, 1999) |
| April 2003 | Collection of surface water sample. | *QCSR April 2003 Surface Water Sampling Event, OB/OD Site, Fort Riley, Kansas*, (BMcD, 2003) |
| March 2004 | Collection of surface water sample. | *QCSR March 2004 Surface Water Sampling Event, OB/OD Site, Fort Riley, Kansas*, (MP-BMcD, 2004a) |
| April 2004 | Collection of groundwater samples from Monitoring Wells OB-93-01 through OBHD-97-14, Piezometers OB-97-09PZ(0), OB-97-10PZ(1) through (3), OB-97-11PZ(0) and (1), OB-97-12PZ(1) and (3), OB-97-13PZ(0) through (3). Collection of samples from Spring 1, Surface 1, Seep 1, and Seep 2. | *QCSR April 2004 Sampling Event, OB/OD Site, Fort Riley, Kansas*, (MP-BMcD, 2004b) |
| 2007-2011 | Collection of groundwater samples from Monitoring Wells OB-93-01 through OBHD-97-14, Piezometers OB-97-09PZ(0), OB-97-10PZ(1) through (3), OB-97-11PZ(0) and (1), OB-97-12PZ(1) and (3), OB-97-13PZ(0) through (3). Collection of samples from Spring 1, Surface 1, Seep 1, and Seep 2. | *Data Summary Reports For Ground Water, Spring, and Seep Sampling, Fort Riley, Kansas*, (MP-BMcD, 2007-2011) |
| 2011-2013 | Collection of soil, dry sediment, and surface water samples, installation of six monitoring wells, abandonment of piezometers, and four rounds of quarterly sampling of sixteen monitoring wells | Results are included in the *Remedial Investigation Report for the OB/OD (Range 16) – Operable Unit 006 at Fort Riley, Kansas*, (LBG-BMcD, 2013). |

DSR = Data Summary Report
BMcD = Burns & McDonnell
LBA = Louis Berger & Associates
LBG = The Louis Berger Group, Inc.
OB = Open Burning
OD = Open Detonation
PZ = Piezometer
QCSR = Quality Control Summary Report

# Table 1-2
## Summary of Human Health Risk Results
*Feasibility Study Report*
*Open Burning / Open Detonation Ground (Range 16)*
*Fort Riley, Kansas*

| Population | Noncancer | Cancer |
|---|---|---|
| Current Site Worker | | |
| Inhalation of Outdoor Vapors | **1** | **4E-06** |
| Dermal Contact with Surface Water | 0.3 | **6E-04** |
| Inhalation of Vapors from Surface Water | 0.0007 | 5E-09 |
| **Total** | **1.3** | **6E-04** |
| Future Site Worker | | |
| Inhalation of Outdoor Vapors | **1** | **4E-06** |
| Dermal Contact with Surface Water | 0.3 | **6E-04** |
| Inhalation of Vapors from Surface Water | 0.0007 | 5E-09 |
| Ingestion of Groundwater | **10** | **2E-04** |
| Dermal Contact with Groundwater | 0.7 | **3E-04** |
| Inhalation of Vapors from Groundwater Use | **4** | **2E-05** |
| **Total** | **16** | **1E-03** |
| Current/Future Demolition Worker | | |
| Incidental Ingestion of Shallow and Subsurface Soil | 0.3 | 4E-08 |
| Dermal Contact with Shallow and Subsurface Soil | NAp | NAp |
| Inhalation of Fugitive Dust | 0.000004 | 2E-13 |
| Inhalation of Outdoor Vapors | **17** | **1E-06** |
| Dermal Contact with Surface Water | 0.3 | **1E-05** |
| Inhalation of Vapors from Surface Water | 0.0007 | 9E-11 |
| Ingestion of Groundwater | **11** | **4E-06** |
| Dermal Contact with Groundwater | 0.7 | **6E-06** |
| **Total** | **30** | **2E-05** |

Notes:
Bold indicates a hazard index greater than one and/or a cancer risk greater than 1E-06.
NAp = Not Applicable

**Table 1-3**
**Summary of Ecological Risk Results for Representative Wildlife**
*Feasibility Study Report*
*Open Burning / Open Detonation Ground (Range 16)*
*Fort Riley, Kansas*

| Representative Wildlife Species | Ecological Hazard Index (EHI) |
|---|---|
| Terrestrial Invertebrate (i.e., Earthworm) | 4.6E+00 |
| Benthic Invertebrate | 7.6E+00 |
| Terrestrial Plant (Surface Soil Exposure) | 3.2E+02 |
| Terrestrial Plant (Subsurface Soil Exposure) | 2.8E+02 |
| Aquatic Plant | 9.2E+00 |
| Aquatic Invertebrate | 2.8E+01 |
| Fish | 3.2E+00 |
| Short-tailed Shrew | 4.6E+01 |
| White-footed Mouse | 4.9E+01 |
| Meadow Vole | 2.5E+01 |
| Eastern Cottontail Rabbit | 1.7E+02 |
| Red Fox | 1.2E+01 |
| Raccoon | 3.4E+00 |
| White-tailed Deer | 1.5E+01 |
| American Robin | 1.0E+05 |
| Red-tailed Hawk | 6.9E+00 |

# Table 3-1
## Allowable Chemical Concentrations in Soil for Noncancer Effects
## Current/Future Demolition Worker Scenario
*Feasibility Study Report*
*Open Burning / Open Detonation Ground (Range 16)*
*Fort Riley, Kansas*

Equation:

$$SLing = \frac{THI \times BW \times AT}{ED \times EF \times CF_1 \times IRs \times FI \times 1/RfDo}$$

$$SLinh = \frac{THI \times AT}{ED \times EF \times ET \times CF_2 \times (1/PEF + 1/VFout) \times 1/RfC}$$

$$SLder = \frac{THI \times BW \times AT}{ED \times EF \times SA \times AF \times ABS \times CF_1 \times 1/RfDd}$$

$$C = \frac{1}{(1/SLing) + (1/SLinh) + (1/SLder)}$$

| Variables: | | Variable Values | Reference |
|---|---|---|---|
| C = | Allowable concentration in soil [milligrams per kilogram (mg/kg)] | Chemical-specific | Calculated |
| THI = | Target hazard index (unitless) | 1 | USEPA, 1991 |
| BW = | Body weight (kg) | 70 | USEPA, 1989 |
| AT = | Averaging time (days) | 180 | 30 days/month x 6 months |
| ED = | Exposure duration (years) | 1 | Standard |
| EF = | Exposure frequency (days/year) | 37 | Assumed 6 months of utility work |
| $CF_1$ = | Conversion factor (kg/mg) | 1E-06 | Standard |
| $CF_2$ = | Conversion factor (day/hours) | 4E-02 | Standard |
| IRs = | Ingestion rate of soil (mg/day) | 330 | USEPA, 2002 |
| FI = | Fraction ingested from contaminated source (unitless) | 1 | Assumed worst case value |
| RfDo = | Oral reference dose (mg/kg/day) | Chemical-specific | USEPA, 2013 |
| ET = | Exposure time (hours/day) | 1.5 | Standard working day |
| PEF = | Particle emission factor ($m^3$/kg) | 1.32E+09 | USEPA, 2002 |
| VFout = | Volatilization factor for outdoor air ($m^3$/kg) | Chemical-specific | Calculated |
| RfC = | Reference concentration (mg/$m^3$) | Chemical-specific | USEPA, 2013 |
| SA = | Surface area of exposed skin [square centimeters per day ($cm^2$/day)] | 3,300 | USEPA, 1997 |
| AF = | Soil-to-skin adherence factor (mg/$cm^2$) | 0.3 | USEPA, 2002 |
| ABS = | Absorption factor (unitless) - VOCs | 0 | USEPA, 2004 |
| RfDd = | Adjusted oral reference dose for dermal exposure (mg/kg/day) | Chemical-specific | USEPA, 2013 |
| SLing = | Allowable concentration for ingestion of soil (mg/kg) | Chemical-specific | Calculated |
| SLinh = | Allowable concentration for inhalation of particulates and vapors (mg/kg) | Chemical-specific | Calculated |
| SLder = | Allowable concentration for dermal contact with soil (mg/kg) | Chemical-specific | Calculated |

| Chemicals Detected Above Screening Levels | VFout ($m^3$/kg) | Toxicity Information RfDo (mg/kg/day) | RfC (mg/$m^3$) | RfDd (mg/kg/day) | SLing (mg/kg) | SLinh (mg/kg) | SLder (mg/kg) | Allowable Chemical Concentration in Soil (mg/kg) |
|---|---|---|---|---|---|---|---|---|
| Trichloroethene (TCE) | 2.86E+02 | 5E-04 | 2E-03 | 5E-04 | 5.16E+02 | 4.45E+01 | 0 | 4.10E+01 |

**Notes:**

NAv - Not available

NC - Not calculated

# Table 3-2
## Allowable Chemical Concentrations in Soil for Cancer Effects
## Current/Future Demolition Worker Scenario
*Feasibility Study Report*
*Open Burning / Open Detonation Ground (Range 16)*
*Fort Riley, Kansas*

Equation:

$$SLing = \frac{TR \times BW \times AT}{ED \times EF \times CF_1 \times IRs \times FI \times SFo}$$

$$SLinh = \frac{TR \times AT}{ED \times EF \times ET \times CF_2 \times (1/PEF + 1/VFout) \times IUR}$$

$$SLder = \frac{TR \times BW \times AT}{ED \times EF \times SA \times AF \times ABS \times CF_1 \times SFd}$$

$$C = \frac{1}{(1/SLing) + (1/SLinh) + (1/SLder)}$$

| Variables: | | Variable Values | Reference |
|---|---|---|---|
| C = | Allowable concentration in soil [milligrams per kilogram (mg/kg)] | Chemical-specific | Calculated |
| TR = | Target risk level (unitless) | 1E-05 | USEPA, 1991 |
| BW = | Body weight (kg) | 70 | USEPA, 1989 |
| AT = | Averaging time (days) | 25,550 | 70 years |
| ED = | Exposure duration (years) | 1 | Standard |
| EF = | Exposure frequency (days/year) | 37 | Assumed 6 months of utility wo |
| $CF_1$ = | Conversion factor (kg/mg) | 1E-06 | Standard |
| $CF_2$ = | Conversion factor (day/hours) | 4E-02 | Standard |
| IRs = | Ingestion rate of soil (mg/day) | 330 | USEPA, 2002 |
| FI = | Fraction ingested from contaminated source (unitless) | 1 | Assumed worst case value |
| SFo = | Oral slope factor 1/(mg/kg/day) | Chemical-specific | USEPA, 2013 |
| ET = | Exposure time (hours/day) | 1.5 | Standard working day |
| PEF = | Particle emission factor ($m^3$/kg) | 1.32E+09 | USEPA, 2002 |
| VFout = | Volatilization factor for outdoor air ($m^3$/kg) | Chemical-specific | Calculated |
| IUR = | Inhalation unit risk 1/(mg/$m^3$) | Chemical-specific | USEPA, 2013 |
| SA = | Surface area of exposed skin [square centimeters per day ($cm^2$/day)] | 3,300 | USEPA, 1997 |
| AF = | Soil-to-skin adherence factor (mg/$cm^2$) | 0.3 | USEPA, 2002 |
| ABS = | Absorption factor (unitless) - VOCs | 0 | USEPA, 2004 |
| SFd = | Adjusted oral slope factor for dermal exposure 1/(mg/kg/day) | Chemical-specific | USEPA, 2013 |
| SLing = | Allowable concentration for ingestion of soil (mg/kg) | Chemical-specific | Calculated |
| SLinh = | Allowable concentration for inhalation of particulates and vapors (mg/kg) | Chemical-specific | Calculated |
| SLder = | Allowable concentration for dermal contact with soil (mg/kg) | Chemical-specific | Calculated |

| Chemicals Detected Above Screening Levels | VFout ($m^3$/kg) | Toxicity Information SFo 1/(mg/kg/day) | IUR 1/(mg/$m^3$) | SFd 1/(mg/kg/day) | SLing (mg/kg) | SLinh (mg/kg) | SLder (mg/kg) | Allowable Chemical Concentration in Soil (mg/kg) |
|---|---|---|---|---|---|---|---|---|
| Trichloroethene (TCE) | 2.86E+02 | 4.6E-02 | 4.1E-03 | 4.6E-02 | 3.2E+04 | 7.7E+03 | 0 | 6.21E+03 |

**Notes:**
NAp - Not applicable
NAv - Not available
NC - Not calculated

## Table 3-3
## Allowable Chemical Concentrations in Groundwater for Noncancer Effects
## Current/Future Demolition Worker Scenario
*Feasibility Study Report*
*Open Burning / Open Detonation Ground (Range 16)*
*Fort Riley, Kansas*

Equation:

$$SLing = \frac{THI \times BW \times AT \times CF_1}{ED \times EF \times IRw \times 1/RfDo}$$

$$SLinh = \frac{THI \times AT \times CF_1}{ED \times EF \times ET \times CF_2 \times 1/RfC \times K}$$

$$SLder = \frac{DAevent \times CF_3}{FA \times Kp \times [(ETd/1+B)+(2 \times Tevent \times (1+3B+3B^2)/(1+B)^2)]}$$ Or $$SLder = \frac{DAevent \times CF_3}{2 \times FA \times Kp \times ((6 \times Tevent \times ETd)/\pi)^{1/2}}$$

$$C = \frac{1}{(1/SLing) + (1/SLinh) + (1/SLder)}$$

Variables:

| Variables: | | Variable Values | Reference |
|---|---|---|---|
| C = | Allowable concentration in groundwater [micrograms per liter (ug/L)] | Chemical-specific | Calculated |
| THI = | Target hazard index (unitless) | 1 | USEPA, 1991 |
| BW = | Body weight (kg) | 70 | USEPA, 1989 |
| AT = | Averaging time (days) | 180 | 30 days/month x 6 months |
| $CF_1$ = | Conversion factor (ug/mg) | 1E+03 | Standard |
| ED = | Exposure duration (years) | 1 | Standard |
| EF = | Exposure frequency (days/year) | 37 | Assumed 6 months of utility work |
| IRw = | Ingestion rate of tapwater (L/day) | 2 | USEPA, 1991 |
| RfDo = | Oral reference dose (mg/kg/day) | Chemical-specific | USEPA, 2013 |
| ET = | Exposure time (hours/day) | 1.5 | Standard working day |
| $CF_2$ = | Conversion factor (day/hours) | 4E-02 | Standard |
| ETd = | Exposure time (hours/event) | 1 | USEPA, 2004 |
| RfC = | Reference concentration ($mg/m^3$) | Chemical-specific | USEPA, 2013 |
| K = | Volatilization factor ($L/m^3$) | 0.5 | Standard |
| DAevent = | Absorbed dose per event ($ug/cm^2$-event) | Chemical-specific | Calculated |
| $CF_3$ = | Conversion factor ($cm^3/L$) | 1E+03 | Standard |
| FA = | Fraction absorbed water (unitless) | Chemical-specific | USEPA, 2004 |
| Kp = | Dermal permeability coefficient in water (cm/hour) | Chemical-specific | USEPA, 2004 |
| B = | Dimensionless ratio of the permeability coefficient of a compound through the stratum corneum relative to its permeability coefficient across the viable epidermis (ve) (unitless) | Chemical-specific | USEPA, 2004 |
| Tevent = | Lag time per event (hours/event) | Chemical-specific | USEPA, 2004 |
| SLing = | Allowable concentration for ingestion of soil (mg/kg) | Chemical-specific | Calculated |
| SLinh = | Allowable concentration for inhalation of particulates and vapors (mg/kg) | Chemical-specific | Calculated |
| SLder = | Allowable concentration for dermal contact with soil (mg/kg) | Chemical-specific | Calculated |

**Table 3-3**
**Allowable Chemical Concentrations in Groundwater for Noncancer Effects**
**Current/Future Demolition Worker Scenario**
*Feasibility Study Report*
*Open Burning / Open Detonation Ground (Range 16)*
*Fort Riley, Kansas*

| Chemicals Detected Above Screening Levels | Toxicity Information RfDo (mg/kg/day) | RfC ($mg/m^3$) | DAevent ($ug/cm^2$-event) | FA (unitless) | Kp (cm/hour) | B (unitless) | Tevent (hours/event) | SLing (ug/L) | SLinh (ug/L) | SLder (ug/L) | Allowable Chemical Concentration in Groundwater (ug/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Naphthalene | 2E-02 | 3E-03 | 4.17E-04 | 1.0 | 4.70E-02 | 2.00E-01 | 5.60E-01 | 3.41E+03 | 4.67E+02 | 4.09E+00 | 4.05E+00 |
| 1,1,2,2-Tetrachloroethane (PCA) | 2E-02 | NAv | 1.17E-03 | 1.0 | 6.90E-03 | 0.00E+00 | 9.30E-01 | 3.41E+03 | NC | 6.36E+01 | 6.24E+01 |
| Bis(2-ethylhexyl)phthalate | 2E-02 | NAv | NAv | NAv | NAv | NAv | NAv | 3.41E+03 | NC | NC | 3.41E+03 |

**Notes:**
NAv - Not available
NC - Not calculated

## Table 3-4
## Allowable Chemical Concentrations in Groundwater for Cancer Effects
## Current/Future Demolition Worker Scenario
*Feasibility Study Report*
*Open Burning / Open Detonation Ground (Range 16)*
*Fort Riley, Kansas*

Equation:

$$SLing = \frac{TR \times BW \times AT \times CF_1}{ED \times EF \times IRw \times SFo}$$

$$SLinh = \frac{TR \times AT}{ED \times EF \times ET \times CF_2 \times IUR \times K}$$

$$SLder = \frac{DAevent \times CF_3}{FA \times Kp \times [(ETd/1+B)+(2 \times Tevent \times (1+3B+3B^2)/(1+B)^2)]} \quad \text{Or} \quad SLder = \frac{DAevent \times CF_3}{2 \times FA \times Kp \times ((6 \times Tevent \times ETd)/\pi)^{1/2}}$$

$$C = \frac{1}{(1/SLing) + (1/SLinh) + (1/SLder)}$$

Variables:

| | | Variable Values | Reference |
|---|---|---|---|
| C = | Allowable concentration in groundwater [micrograms per liter (ug/L)] | Chemical-specific | Calculated |
| TR = | Target risk level (unitless) | 1E-05 | USEPA, 1991 |
| BW = | Body weight (kg) | 70 | USEPA, 1989 |
| AT = | Averaging time (days) | 25,550 | 70 years |
| $CF_1$ = | Conversion factor (ug/mg) | 1E+03 | Standard |
| ED = | Exposure duration (years) | 1 | Standard |
| EF = | Exposure frequency (days/year) | 37 | Assumed 6 months of utility work |
| IRw = | Ingestion rate of tapwater (L/day) | 2 | USEPA, 1991 |
| SFo = | Oral slope factor 1/(mg/kg/day) | Chemical-specific | USEPA, 2013 |
| ET = | Exposure time (hours/day) | 1.5 | Standard working day |
| $CF_2$ = | Conversion factor (day/hours) | 4.2E-02 | Standard |
| ETd = | Exposure time (hours/event) | 1 | USEPA, 2004 |
| IUR = | Inhalation unit risk 1/(ug/$m^3$) | Chemical-specific | USEPA, 2013 |
| K = | Volatilization factor (L/$m^3$) | 0.5 | Standard |
| DAevent = | Absorbed dose per event (ug/$cm^2$-event) | Chemical-specific | Standard |
| $CF_3$ = | Conversion factor ($cm^3$/L) | 1E+03 | Standard |
| FA = | Fraction absorbed water (unitless) | Chemical-specific | USEPA, 2004 |
| Kp = | Dermal permeability coefficient in water (cm/hour) | Chemical-specific | USEPA, 2004 |
| B = | Dimensionless ratio of the permeability coefficient of a compound through the stratum corneum relative to its permeability coefficient across the viable epidermis (ve) (unitless) | Chemical-specific | USEPA, 2004 |
| Tevent = | Lag time per event (hours/event) | Chemical-specific | USEPA, 2004 |
| SLing = | Allowable concentration for ingestion of soil (ug/L) | Chemical-specific | Calculated |
| SLinh = | Allowable concentration for inhalation of particulates and vapors (ug/L) | Chemical-specific | Calculated |
| SLder = | Allowable concentration for dermal contact with soil (ug/L) | Chemical-specific | Calculated |

## Table 3-4
## Allowable Chemical Concentrations in Groundwater for Cancer Effects
## Current/Future Demolition Worker Scenario
*Feasibility Study Report*
*Open Burning / Open Detonation Ground (Range 16)*
*Fort Riley, Kansas*

| Chemicals Detected Above Screening Levels | Toxicity Information SFo 1/(mg/kg/day) | IUR 1/(ug/m$^3$) | DAevent (ug/cm$^2$-event) | FA (unitless) | Kp (cm/hour) | B (unitless) | Tevent (hours/event) | SLing (ug/L) | SLinh (ug/L) | SLder (ug/L) | Allowable Chemical Concentration in Groundwater (ug/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Naphthalene | NAv | 3.4E-05 | 4.17E-04 | 1.0 | 4.70E-02 | 2.00E-01 | 5.60E-01 | NC | 6.50E+03 | 4.09E+00 | 4.08E+00 |
| 1,1,2,2-Tetrachloroethane (PCA) | 2.0E-01 | 5.8E-05 | 1.17E-03 | 1.0 | 6.90E-03 | 0.00E+00 | 9.30E-01 | 1.21E+03 | 3.81E+03 | 6.36E+01 | 5.95E+01 |
| Bis(2-ethylhexyl)phthalate | 1.4E-02 | 2.4E-06 | NAv | NAv | NAv | NAv | NAv | 1.73E+04 | 9.21E+04 | NC | 1.45E+04 |

**Notes:**
NAv - Not available
NC - Not calculated

# Table 3-5
## Allowable Chemical Concentrations in Surface Water for Noncancer Effects
## Current/Future Demolition Worker Scenario
*Feasibility Study Report*
*Open Burning / Open Detonation Ground (Range 16)*
*Fort Riley, Kansas*

Equation:

$$C = \frac{DAevent \times CF}{FA \times Kp \times [(ETd/1+B)+(2 \times Tevent \times (1+3B+3B^2)/(1+B)^2)]}$$

Or

$$C = \frac{DAevent \times CF}{2 \times FA \times Kp \times ((6 \times Tevent \times ET)/\pi)^{1/2}}$$

Variables:

| | | Variable Values | Reference |
|---|---|---|---|
| C = | Allowable concentration in surface water [micrograms per liter (ug/L)] | Chemical-specific | Calculated |
| DAevent = | Absorbed dose per event (ug/cm$^2$-event) | Chemical-specific | Calculated |
| CF = | Conversion factor (cm$^3$/L) | 1E+03 | Standard |
| FA = | Fraction absorbed water (unitless) | Chemical-specific | USEPA, 2004 |
| Kp = | Dermal permeability coefficient in water (cm/hour) | Chemical-specific | USEPA, 2004 |
| ETd = | Exposure time (hours/event) | 1 | USEPA, 2004 |
| B = | Dimensionless ratio of the permeability coefficient of a compound through the stratum corneum relative to its permeability coefficient across the viable epidermis (ve) (unitless) | Chemical-specific | USEPA, 2004 |
| Tevent = | Lag time per event (hours/event) | Chemical-specific | USEPA, 2004 |

| Chemicals Detected Above Screening Levels | Toxicity Information | | DAevent | FA | Kp | B | Tevent | Allowable Chemical Concentration in Surface Water |
|---|---|---|---|---|---|---|---|---|
| | RfDo (mg/kg/day) | RfC (mg/m$^3$) | (ug/cm$^2$-event) | (unitless) | (cm/hour) | (unitless) | (hours/event) | (ug/L) |
| 1,1,2,2-Tetrachloroethane (PCA) | 2E-02 | NAv | 1.17E-03 | 1.0 | 6.90E-03 | 0.00E+00 | 9.30E-01 | 6.36E+01 |
| Trichloroethene (TCE) | 5E-04 | 2E-03 | 1.05E-02 | 1.0 | 1.20E-02 | 1.00E-01 | 5.80E-01 | 4.01E+02 |
| Benzo(a)pyrene | NAv | NAv | 3.41E-03 | 1.0 | 7.00E-01 | 4.30E+00 | 2.69E+00 | 1.07E+00 |

**Notes:**

NAv - Not available
NC - Not calculated

# Table 3-6
## Allowable Chemical Concentrations in Surface Water for Cancer Effects
## Current/Future Demolition Worker Scenario
*Feasibility Study Report*
*Open Burning / Open Detonation Ground (Range 16)*
*Fort Riley, Kansas*

Equation:

$$C = \frac{DAevent \times CF}{FA \times Kp \times [(ETd/1+B)+(2 \times Tevent \times (1+3B+3B^2)/(1+B)^2)]}$$

Or

$$C = \frac{DAevent \times CF}{2 \times FA \times Kp \times ((6 \times Tevent \times ET)/\pi)^{1/2}}$$

Variables:

| Variable | Description | Variable Values | Reference |
|---|---|---|---|
| C = | Allowable concentration in surface water [micrograms per liter (ug/L)] | Chemical-specific | Calculated |
| DAevent = | Absorbed dose per event (ug/cm$^2$-event) | Chemical-specific | Standard |
| CF = | Conversion factor (cm$^3$/L) | 1E+03 | Standard |
| FA = | Fraction absorbed water (unitless) | Chemical-specific | USEPA, 2004 |
| Kp = | Dermal permeability coefficient in water (cm/hour) | Chemical-specific | USEPA, 2004 |
| ETd = | Exposure time (hours/event) | 1 | USEPA, 2004 |
| B = | Dimensionless ratio of the permeability coefficient of a compound through the stratum corneum relative to its permeability coefficient across the viable epidermis (ve) (unitless) | Chemical-specific | USEPA, 2004 |
| Tevent = | Lag time per event (hours/event) | Chemical-specific | USEPA, 2004 |

| Chemicals Detected Above Screening Levels | Toxicity Information SFo 1/(mg/kg/day) | Toxicity Information IUR 1/(ug/m$^3$) | DAevent (ug/cm$^2$-event) | FA (unitless) | Kp (cm/hour) | B (unitless) | Tevent (hours/event) | Allowable Chemical Concentration in Groundwater (ug/L) |
|---|---|---|---|---|---|---|---|---|
| 1,1,2,2-Tetrachloroethane (PCA) | 2.0E-01 | 5.8E-05 | 1.17E-03 | 1.0 | 6.90E-03 | 0.00E+00 | 9.30E-01 | 6.36E+01 |
| Trichloroethene (TCE) | 4.6E-02 | 4.1E-06 | 1.05E-02 | 1.0 | 1.20E-02 | 1.00E-01 | 5.80E-01 | 4.01E+02 |
| Benzo(a)pyrene | 7.3E+00 | 1.1E-03 | 3.41E-03 | 1.0 | 7.00E-01 | 4.30E+00 | 2.69E+00 | 1.07E+00 |

**Notes:**
NAv - Not available
NC - Not calculated

## Table 3-7
## Allowable Chemical Concentrations in Soil for Noncancer Effects
## Current/Future Site Worker Scenario

*Feasibility Study Report*

*Open Burning / Open Detonation Ground (Range 16)*

*Fort Riley, Kansas*

Equation:

$$SLing = \frac{THI \times BW \times AT}{ED \times EF \times CF_1 \times IRs \times FI \times 1/RfDo}$$

$$SLinh = \frac{THI \times AT}{ED \times EF \times ET \times CF_2 \times (1/PEF + 1/VFout) \times 1/RfC}$$

$$SLder = \frac{THI \times BW \times AT}{ED \times EF \times SA \times AF \times ABS \times CF_1 \times 1/RfDd}$$

$$C = \frac{1}{(1/SLing) + (1/SLinh) + (1/SLder)}$$

| Variables: | | Variable Values | Reference |
|---|---|---|---|
| C = | Allowable concentration in soil [milligrams per kilogram (mg/kg)] | Chemical-specific | Calculated |
| THI = | Target hazard index (unitless) | 1 | USEPA, 1991 |
| BW = | Body weight (kg) | 70 | USEPA, 1989 |
| AT = | Averaging time (days) | 9,125 | ED x 365 days/year |
| ED = | Exposure duration (years) | 25 | USEPA, 1991 |
| EF = | Exposure frequency (days/year) | 250 | USEPA, 1991 |
| $CF_1$ = | Conversion factor (kg/mg) | 1E-06 | Standard |
| $CF_2$ = | Conversion factor (day/hours) | 4E-02 | Standard |
| IRs = | Ingestion rate of soil (mg/day) | 100 | USEPA, 2002 |
| FI = | Fraction ingested from contaminated source (unitless) | 1 | Assumed worst case value |
| RfDo = | Oral reference dose (mg/kg/day) | Chemical-specific | USEPA, 2013 |
| ET = | Exposure time (hours/day) | 8 | Standard working day |
| PEF = | Particle emission factor ($m^3$/kg) | 1.32E+09 | USEPA, 2002 |
| VFout = | Volatilization factor for outdoor air ($m^3$/kg) | Chemical-specific | Calculated |
| RfC = | Reference concentration (mg/$m^3$) | Chemical-specific | USEPA, 2013 |
| SA = | Surface area of exposed skin [square centimeters per day ($cm^2$/day)] | 3,300 | USEPA, 1997 |
| AF = | Soil-to-skin adherence factor (mg/$cm^2$) | 0.2 | USEPA, 2002 |
| ABS = | Absorption factor (unitless) - VOCs | 0 | USEPA, 2004 |
| RfDd = | Adjusted oral reference dose for dermal exposure (mg/kg/day) | Chemical-specific | USEPA, 2013 |
| SLing = | Allowable concentration for ingestion of soil (mg/kg) | Chemical-specific | Calculated |
| SLinh = | Allowable concentration for inhalation of particulates and vapors (mg/kg) | Chemical-specific | Calculated |
| SLder = | Allowable concentration for dermal contact with soil (mg/kg) | Chemical-specific | Calculated |

| Chemicals Detected Above Screening Levels | VFout ($m^3$/kg) | Toxicity Information RfDo (mg/kg/day) | RfC (mg/$m^3$) | RfDd (mg/kg/day) | SLing (mg/kg) | SLinh (mg/kg) | SLder (mg/kg) | Allowable Chemical Concentration in Soil (mg/kg) |
|---|---|---|---|---|---|---|---|---|
| Trichloroethene (TCE) | 1.25E+03 | 5E-04 | 2E-03 | 5E-04 | 5.11E+02 | 1.09E+01 | 0 | 1.07E+01 |

**Notes:**

NAv - Not available

NC - Not calculated

# Table 3-8
# Allowable Chemical Concentrations in Soil for Cancer Effects
# Current/Future Site Worker Scenario

*Open Burning / Open Detonation Ground (Range 16)*
*Fort Riley, Kansas*

Equation:

$$SLing = \frac{TR \times BW \times AT}{ED \times EF \times CF_1 \times IRs \times FI \times SFo}$$

$$SLinh = \frac{TR \times AT}{ED \times EF \times ET \times CF_2 \times (1/PEF + 1/VFout) \times IUR}$$

$$SLder = \frac{TR \times BW \times AT}{ED \times EF \times SA \times AF \times ABS \times CF_1 \times SFd}$$

$$C = \frac{1}{(1/SLing) + (1/SLinh) + (1/SLder)}$$

| Variables: | | Variable Values | Reference |
|---|---|---|---|
| C = | Allowable concentration in soil [milligrams per kilogram (mg/kg)] | Chemical-specific | Calculated |
| TR = | Target risk level (unitless) | 1E-05 | USEPA, 1991 |
| BW = | Body weight (kg) | 70 | USEPA, 1989 |
| AT = | Averaging time (days) | 25,550 | 70 years |
| ED = | Exposure duration (years) | 25 | USEPA, 1991 |
| EF = | Exposure frequency (days/year) | 250 | USEPA, 1991 |
| $CF_1$ = | Conversion factor (kg/mg) | 1E-06 | Standard |
| $CF_2$ = | Conversion factor (day/hours) | 4E-02 | Standard |
| IRs = | Ingestion rate of soil (mg/day) | 100 | USEPA, 2002 |
| FI = | Fraction ingested from contaminated source (unitless) | 1 | Assumed worst case value |
| SFo = | Oral slope factor 1/(mg/kg/day) | Chemical-specific | USEPA, 2013 |
| ET = | Exposure time (hours/day) | 8 | Standard working day |
| PEF = | Particle emission factor ($m^3$/kg) | 1.32E+09 | USEPA, 2002 |
| VFout = | Volatilization factor for outdoor air ($m^3$/kg) | Chemical-specific | Calculated |
| IUR = | Inhalation unit risk 1/($mg/m^3$) | Chemical-specific | USEPA, 2013 |
| SA = | Surface area of exposed skin [square centimeters per day ($cm^2$/day)] | 3,300 | USEPA, 1997 |
| AF = | Soil-to-skin adherence factor (mg/$cm^2$) | 0.2 | USEPA, 2002 |
| ABS = | Absorption factor (unitless) - VOCs | 0 | USEPA, 2004 |
| SFd = | Adjusted oral slope factor for dermal exposure 1/(mg/kg/day) | Chemical-specific | USEPA, 2013 |
| SLing = | Allowable concentration for ingestion of soil (mg/kg) | Chemical-specific | Calculated |
| SLinh = | Allowable concentration for inhalation of particulates and vapors (mg/kg) | Chemical-specific | Calculated |
| SLder = | Allowable concentration for dermal contact with soil (mg/kg) | Chemical-specific | Calculated |

| Chemicals Detected Above Screening Levels | VFout ($m^3$/kg) | Toxicity Information SFo 1/(mg/kg/day) | IUR 1/($mg/m^3$) | SFd 1/(mg/kg/day) | SLing (mg/kg) | SLinh (mg/kg) | SLder (mg/kg) | Allowable Chemical Concentration in Soil (mg/kg) |
|---|---|---|---|---|---|---|---|---|
| Trichloroethene (TCE) | 1.25E+03 | 4.6E-02 | 4.1E-03 | 4.6E-02 | 6.2E+02 | 3.7E+01 | 0 | 3.53E+01 |

**Notes:**
NAp - Not applicable
NAv - Not available
NC - Not calculated

# Table 3-9
## Allowable Chemical Concentrations in Groundwater for Noncancer Effects
## Current/Future Site Worker Scenario

*Open Burning / Open Detonation Ground (Range 16)*
*Fort Riley, Kansas*

Equation:

$$SLing = \frac{THI \times BW \times AT \times CF_1}{ED \times EF \times IRw \times 1/RfDo}$$

$$SLinh = \frac{THI \times AT \times CF_1}{ED \times EF \times ET \times CF_2 \times 1/RfC \times K}$$

$$SLder = \frac{DAevent \times CF_3}{FA \times Kp \times [(ETd/1+B)+(2 \times Tevent \times (1+3B+3B^2)/(1+B)^2)]}$$

Or

$$SLder = \frac{DAevent \times CF_3}{2 \times FA \times Kp \times ((6 \times Tevent \times ETd)/\pi)^{1/2}}$$

$$C = \frac{1}{(1/SLing) + (1/SLinh) + (1/SLder)}$$

| Variables: | | Variable Values | Reference |
|---|---|---|---|
| C = | Allowable concentration in groundwater [micrograms per liter (ug/L)] | Chemical-specific | Calculated |
| THI = | Target hazard index (unitless) | 1 | USEPA, 1991 |
| BW = | Body weight (kg) | 70 | USEPA, 1989 |
| AT = | Averaging time (days) | 9,125 | ED x 365 days/year |
| $CF_1$ = | Conversion factor (ug/mg) | 1E+03 | Standard |
| ED = | Exposure duration (years) | 25 | USEPA, 1991 |
| EF = | Exposure frequency (days/year) | 250 | USEPA, 1991 |
| IRw = | Ingestion rate of tapwater (L/day) | 2 | USEPA, 1991 |
| RfDo = | Oral reference dose (mg/kg/day) | Chemical-specific | USEPA, 2013 |
| ET = | Exposure time (hours/day) | 8 | Standard working day |
| $CF_2$ = | Conversion factor (day/hours) | 4E-02 | Standard |
| ETd = | Exposure time (hours/event) | 1 | USEPA, 2004 |
| RfC = | Reference concentration ($mg/m^3$) | Chemical-specific | USEPA, 2013 |
| K = | Volatilization factor ($L/m^3$) | 0.5 | Standard |
| DAevent = | Absorbed dose per event ($ug/cm^2$-event) | Chemical-specific | Calculated |
| $CF_3$ = | Conversion factor ($cm^3/L$) | 1E+03 | Standard |
| FA = | Fraction absorbed water (unitless) | Chemical-specific | USEPA, 2004 |
| Kp = | Dermal permeability coefficient in water (cm/hour) | Chemical-specific | USEPA, 2004 |
| B = | Dimensionless ratio of the permeability coefficient of a compound through the stratum corneum relative to its permeability coefficient across the viable epidermis (ve) (unitless) | Chemical-specific | USEPA, 2004 |
| Tevent = | Lag time per event (hours/event) | Chemical-specific | USEPA, 2004 |
| SLing = | Allowable concentration for ingestion of soil (mg/kg) | Chemical-specific | Calculated |
| SLinh = | Allowable concentration for inhalation of particulates and vapors (mg/kg) | Chemical-specific | Calculated |
| SLder = | Allowable concentration for dermal contact with soil (mg/kg) | Chemical-specific | Calculated |

**Table 3-9**
**Allowable Chemical Concentrations in Groundwater for Noncancer Effects**
**Current/Future Site Worker Scenario**
*Feasibility Study Report*
*Open Burning / Open Detonation Ground (Range 16)*

| Chemicals Detected Above Screening Levels | Toxicity Information | | DAevent | FA | Kp | B | Tevent | SLing | SLinh | SLder | Allowable Chemical Concentration in Groundwater |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | RfDo (mg/kg/day) | RfC ($mg/m^3$) | ($ug/cm^2$-event) | (unitless) | (cm/hour) | (unitless) | (hours/event) | (ug/L) | (ug/L) | (ug/L) | (ug/L) |
| Naphthalene | 2E-02 | 3E-03 | 4.17E-04 | 1.0 | 4.70E-02 | 2.00E-01 | 5.60E-01 | 1.02E+03 | 2.63E+01 | 4.09E+00 | 3.52E+00 |
| 1,1,2,2-Tetrachloroethane (PCA) | 2E-02 | NAv | 1.17E-03 | 1.0 | 6.90E-03 | 0.00E+00 | 9.30E-01 | 1.02E+03 | NC | 6.36E+01 | 5.99E+01 |

**Notes:**
NAv - Not available
NC - Not calculated

# Table 3-10
## Allowable Chemical Concentrations in Groundwater for Cancer Effects
## Current/Future Site Worker Scenario

*Open Burning / Open Detonation Ground (Range 16)*
*Fort Riley, Kansas*

Equation:

$$SLing = \frac{TR \times BW \times AT \times CF_1}{ED \times EF \times IRw \times SFo}$$

$$SLinh = \frac{TR \times AT}{ED \times EF \times ET \times CF_2 \times IUR \times K}$$

$$SLder = \frac{DAevent \times CF_3}{FA \times Kp \times [(ETd/1+B)+(2 \times Tevent \times (1+3B+3B^2)/(1+B)^2)]}$$

Or

$$SLder = \frac{DAevent \times CF_3}{2 \times FA \times Kp \times ((6 \times Tevent \times ETd)/\pi)^{1/2}}$$

$$C = \frac{1}{(1/SLing) + (1/SLinh) + (1/SLder)}$$

| Variables: | | Variable Values | Reference |
|---|---|---|---|
| C = | Allowable concentration in groundwater [micrograms per liter (ug/L)] | Chemical-specific | Calculated |
| TR = | Target risk level (unitless) | 1E-05 | USEPA, 1991 |
| BW = | Body weight (kg) | 70 | USEPA, 1989 |
| AT = | Averaging time (days) | 25,550 | 70 years |
| $CF_1$ = | Conversion factor (ug/mg) | 1E+03 | Standard |
| ED = | Exposure duration (years) | 25 | USEPA, 1991 |
| EF = | Exposure frequency (days/year) | 250 | USEPA, 1991 |
| IRw = | Ingestion rate of tapwater (L/day) | 2 | USEPA, 1991 |
| SFo = | Oral slope factor 1/(mg/kg/day) | Chemical-specific | USEPA, 2013 |
| ET = | Exposure time (hours/day) | 8 | Standard working day |
| $CF_2$ = | Conversion factor (day/hours) | 4.2E-02 | Standard |
| ETd = | Exposure time (hours/event) | 1 | USEPA, 2004 |
| IUR = | Inhalation unit risk 1/(ug/$m^3$) | Chemical-specific | USEPA, 2013 |
| K = | Volatilization factor (L/$m^3$) | 0.5 | Standard |
| DAevent = | Absorbed dose per event (ug/$cm^2$-event) | Chemical-specific | Standard |
| $CF_3$ = | Conversion factor ($cm^3$/L) | 1E+03 | Standard |
| FA = | Fraction absorbed water (unitless) | Chemical-specific | USEPA, 2004 |
| Kp = | Dermal permeability coefficient in water (cm/hour) | Chemical-specific | USEPA, 2004 |
| B = | Dimensionless ratio of the permeability coefficient of a compound through the stratum corneum relative to its permeability coefficient across the viable epidermis (ve) (unitless) | Chemical-specific | USEPA, 2004 |
| Tevent = | Lag time per event (hours/event) | Chemical-specific | USEPA, 2004 |
| SLing = | Allowable concentration for ingestion of soil (ug/L) | Chemical-specific | Calculated |
| SLinh = | Allowable concentration for inhalation of particulates and vapors (ug/L) | Chemical-specific | Calculated |
| SLder = | Allowable concentration for dermal contact with soil (ug/L) | Chemical-specific | Calculated |

**Table 3-10**
**Allowable Chemical Concentrations in Groundwater for Cancer Effects**
**Current/Future Site Worker Scenario**
*Feasibility Study Report*
*Open Burning / Open Detonation Ground (Range 16)*

| Chemicals Detected Above Screening Levels | Toxicity Information SFo 1/(mg/kg/day) | Toxicity Information IUR $1/(ug/m^3)$ | DAevent $(ug/cm^2\text{-event})$ | FA (unitless) | Kp (cm/hour) | B (unitless) | Tevent (hours/event) | SLing (ug/L) | SLinh (ug/L) | SLder (ug/L) | Allowable Chemical Concentration in Groundwater (ug/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Naphthalene | NAv | 3.4E-05 | 4.17E-04 | 1.0 | 4.70E-02 | 2.00E-01 | 5.60E-01 | NC | 7.21E+00 | 4.09E+00 | 2.61E+00 |
| 1,1,2,2-Tetrachloroethane (PCA) | 2.0E-01 | 5.8E-05 | 1.17E-03 | 1.0 | 6.90E-03 | 0.00E+00 | 9.30E-01 | 7.15E+00 | 4.23E+00 | 6.36E+01 | 2.55E+00 |

**Notes:**
NAv - Not available
NC - Not calculated

# Table 3-11
## Allowable Chemical Concentrations in Surface Water for Noncancer Effects
## Current/Future Site Worker Scenario
*Feasibility Study Report*
*Open Burning / Open Detonation Ground (Range 16)*
*Fort Riley, Kansas*

Equation:

$$C = \frac{DAevent \times CF}{FA \times Kp \times [(ETd/1+B)+(2 \times Tevent \times (1+3B+3B^2)/(1+B)^2)]}$$

Or

$$C = \frac{DAevent \times CF}{2 \times FA \times Kp \times ((6 \times Tevent \times ET)/\pi)^{1/2}}$$

Variables:

| | | Variable Values | Reference |
|---|---|---|---|
| C = | Allowable concentration in surface water [micrograms per liter (ug/L)] | Chemical-specific | Calculated |
| DAevent = | Absorbed dose per event (ug/cm$^2$-event) | Chemical-specific | Calculated |
| CF = | Conversion factor (cm$^3$/L) | 1E+03 | Standard |
| FA = | Fraction absorbed water (unitless) | Chemical-specific | USEPA, 2004 |
| Kp = | Dermal permeability coefficient in water (cm/hour) | Chemical-specific | USEPA, 2004 |
| ETd = | Exposure time (hours/event) | 1 | USEPA, 2004 |
| B = | Dimensionless ratio of the permeability coefficient of a compound through the stratum corneum relative to its permeability coefficient across the viable epidermis (ve) (unitless) | Chemical-specific | USEPA, 2004 |
| Tevent = | Lag time per event (hours/event) | Chemical-specific | USEPA, 2004 |

| Chemicals Detected Above Screening Levels | Toxicity Information | | DAevent (ug/cm$^2$-event) | FA (unitless) | Kp (cm/hour) | B (unitless) | Tevent (hours/event) | Allowable Chemical Concentration in Surface Water (ug/L) |
|---|---|---|---|---|---|---|---|---|
| | RfDo (mg/kg/day) | RfC (mg/m$^3$) | | | | | | |
| 1,1,2,2-Tetrachloroethane (PCA) | 2E-02 | NAv | 1.17E-03 | 1.0 | 6.90E-03 | 0.00E+00 | 9.30E-01 | 6.36E+01 |
| Trichloroethene (TCE) | 5E-04 | 2E-03 | 1.05E-02 | 1.0 | 1.20E-02 | 1.00E-01 | 5.80E-01 | 4.01E+02 |
| Benzo(a)pyrene | NAv | NAv | 3.41E-03 | 1.0 | 7.00E-01 | 4.30E+00 | 2.69E+00 | 1.07E+00 |

**Notes:**

NAv - Not available
NC - Not calculated

# Table 3-12
## Allowable Chemical Concentrations in Surface Water for Cancer Effects
## Current/Future Site Worker Scenario
*Feasibility Study Report*
*Open Burning / Open Detonation Ground (Range 16)*
*Fort Riley, Kansas*

Equation:

$$C = \frac{DAevent \times CF}{FA \times Kp \times [(ETd/1+B)+(2 \times Tevent \times (1+3B+3B^2)/(1+B)^2)]}$$

Or

$$C = \frac{DAevent \times CF}{2 \times FA \times Kp \times ((6 \times Tevent \times ET)/\pi)^{1/2}}$$

Variables:

| | | Variable Values | Reference |
|---|---|---|---|
| C = | Allowable concentration in surface water [micrograms per liter (ug/L)] | Chemical-specific | Calculated |
| DAevent = | Absorbed dose per event ($ug/cm^2$-event) | Chemical-specific | Standard |
| CF = | Conversion factor ($cm^3/L$) | 1E+03 | Standard |
| FA = | Fraction absorbed water (unitless) | Chemical-specific | USEPA, 2004 |
| Kp = | Dermal permeability coefficient in water (cm/hour) | Chemical-specific | USEPA, 2004 |
| ETd = | Exposure time (hours/event) | 1 | USEPA, 2004 |
| B = | Dimensionless ratio of the permeability coefficient of a compound through the stratum corneum relative to its permeability coefficient across the viable epidermis (ve) (unitless) | Chemical-specific | USEPA, 2004 |
| Tevent = | Lag time per event (hours/event) | Chemical-specific | USEPA, 2004 |

| Chemicals Detected Above Screening Levels | Toxicity Information SFo 1/(mg/kg/day) | Toxicity Information IUR $1/(ug/m^3)$ | DAevent ($ug/cm^2$-event) | FA (unitless) | Kp (cm/hour) | B (unitless) | Tevent (hours/event) | Allowable Chemical Concentration in Groundwater (ug/L) |
|---|---|---|---|---|---|---|---|---|
| 1,1,2,2-Tetrachloroethane (PCA) | 2.0E-01 | 5.8E-05 | 1.17E-03 | 1.0 | 6.90E-03 | 0.00E+00 | 9.30E-01 | 6.36E+01 |
| Trichloroethene (TCE) | 4.6E-02 | 4.1E-06 | 1.05E-02 | 1.0 | 1.20E-02 | 1.00E-01 | 5.80E-01 | 4.01E+02 |
| Benzo(a)pyrene | 7.3E+00 | 1.1E-03 | 3.41E-03 | 1.0 | 7.00E-01 | 4.30E+00 | 2.69E+00 | 1.07E+00 |

**Notes:**
NAv - Not available
NC - Not calculated

## Table 3-13
## Summary of Allowable Chemical Concentrations in Soil
*Feasibility Study Report*
*Open Burning / Open Detonation Ground (Range 16)*
*Fort Riley, Kansas*

| Chemical | Future Demolition Worker (mg/kg) | | Current/Future Site Worker (mg/kg) | | Preliminary Remedial Goal[2] (mg/kg) |
|---|---|---|---|---|---|
| | Noncancer | Cancer[1] | Noncancer | Cancer[1] | |
| **Volatile Organic Compounds** | | | | | |
| Trichloroethene (TCE) | 40.99 | 6,205 | 10.72 | 35.27 | 10.72 |

**Note:**

[1] - Values calculated using a target cancer risk of 1E-05.

[2] - Preliminary Remedial Goal represents the most conservative of the calculated individual allowable concentrations, in order to remain protective of all exposures.

# Table 3-14
## Summary of Allowable Chemical Concentrations in Groundwater
*Feasibility Study Report*
*Open Burning / Open Detonation Ground (Range 16)*
*Fort Riley, Kansas*

| Chemical | Future Demolition Worker (ug/L) | | Current/Future Site Worker (ug/L) | | Preliminary Remedial Goal[2] (ug/L) |
|---|---|---|---|---|---|
| | Noncancer | Cancer[1] | Noncancer | Cancer[1] | |
| **Volatile Organic Compounds** | | | | | |
| Naphthalene | 4.05 | 4.08 | 3.52 | 2.61 | 2.61 |
| 1,1,2,2-Tetrachloroethane (PCA) | 62.4 | 59.5 | 59.9 | 2.55 | 2.55 |

**Note:**
[1] - Values calculated using a target cancer risk of 1E-05.
[2] - Preliminary Remedial Goal represents the most conservative of the calculated individual allowable concentrations, in order to remain protective of all exposures.

# Table 3-15
## Summary of Allowable Chemical Concentrations in Surface Water
*Feasibility Study Report*
*Open Burning / Open Detonation Ground (Range 16)*
*Fort Riley, Kansas*

| Chemical | Future Demolition Worker (ug/L) | | Current/Future Site Worker (ug/L) | | Preliminary Remedial Goal[2] (ug/L) |
|---|---|---|---|---|---|
| | Noncancer | Cancer[1] | Noncancer | Cancer[1] | |
| **Volatile Organic Compounds** | | | | | |
| 1,1,2,2-Tetrachloroethane (PCA) | 63.6 | 63.6 | 63.6 | 63.6 | 63.6 |
| Trichloroethene (TCE) | 401 | 401 | 401 | 401 | 401 |
| Benzo(a)pyrene | 1.07 | 1.07 | 1.07 | 1.07 | 1.07 |

**Note:**

[1] - Values calculated using a target cancer risk of 1E-05.

[2] - Preliminary Remedial Goal represents the most conservative of the calculated individual allowable concentrations, in order to remain protective of all exposures.

**Table 4-1**
**Technologies and Process Options for Soil Remediation**
*Feasibility Study Report*
*Open Burning / Open Detonation Ground (Range 16)*
*Fort Riley, Kansas*

| General Response Actions | Technologies | Process Options |
|---|---|---|
| **No Action** | No Action | No Action |
| **Institutional Controls** | Governmental Controls | Zoning Ordinance Amendment<br>County Resolution |
| | Proprietary Controls | Negative Easements and Restrictive Covenants<br>Affirmative Easements |
| | Other Institutional Controls | Fort Riley Real Property Master Plan |
| **Removal and Disposal or Treatment** | Soil Excavation, Backfill, and Disposal | Off-Ste Disposal in a Landfill |
| | | On-Site Land Farming<br>On-Site Thermal Incineration<br>Off-Site Thermal Incineration<br>Chemical Extraction<br>Chemical Reduction/Oxidation<br>Dehalogenation<br>Contaminant Separation<br>Solidification and Stabilization<br>Soil Washing |
| **Ex-Situ Biological Treatment** | Biological Treatment | Slurry Treatment in Bioreactor<br>Solid Phase Biopiles |
| **In-Situ Treatment** | Physical/Chemical Treatment | Soil Vapor Extraction<br>In-Situ Chemical Oxidation<br>In-Situ Radio Frequency Heating<br>Electrical Resistivity Heating<br>Thermal Conductive Heating<br>Dynamic Underground Stripping<br>Hydrous Pyrolysis/Oxidation<br>Six-Phase Soil Heating |

## Table 4-2
## Technologies and Process Options for Groundwater Remediation
*Feasibility Study Report*
*Open Burning / Open Detonation Ground (Range 16)*
*Fort Riley, Kansas*

| General Response Actions | Technologies | Process Options |
|---|---|---|
| **No Action** | No Action | No Action |
| **Institutional Controls** | Governmental Controls | Zoning Ordinance Amendment<br>County Resolution |
| | Proprietary Controls | Negative Easements and Restrictive Covenants<br>Affirmative Easements |
| | Other Institutional Controls | Fort Riley Real Property Master Plan |
| **Other Controls** | Monitoring | Groundwater Monitoring |
| | Alternative Water Supply | Rural Water Supply<br>New Supply Wells |
| | Individual Well Treatment | Low Profile Air Stripping<br>Activated Carbon Adsorption<br>UV Oxidation |
| **Containment** | Low Permeability Barrier | Vertical Barriers<br>Horizontal Barriers |
| | Permeable Reactive Barrier | Organic Mulch<br>Zero Valent Iron<br>In-Situ Air Stripping<br>In-Situ Microbial Consortium |
| | Surface Capping | Surface Capping |
| **Extraction, Ex-Situ Treatment, and Discharge** | Collection/Extraction | Interceptor Trenches<br>Pumping Wells: Vertical<br>Pumping Wells: Horizontal<br>Dual Phase Vapor Extraction (DPVE) |
| | Biological Treatment | Aerobic Biological Reactors<br>Cometabolic Aerobic Biological Reactors<br>Anaerobic Biological Reactors |
| | Physical/Chemical Treatment | Oil/Water Separation<br>Precipitation<br>Flocculation<br>Air Stripping<br>Steam Stripping<br>Carbon Adsorption<br>Resin Adsorption<br>Organoclay Adsorption<br>Oxidation/Reduction |

**Table 4-2 (Continued)**
**Technologies and Process Options for Groundwater Remediation**
*Feasibility Study Report*
*Open Burning / Open Detonation Ground (Range 16)*
*Fort Riley, Kansas*

| General Response Actions | Technologies | Process Options |
|---|---|---|
| **Extraction, Ex-Situ Treatment, and Discharge (Continued)** | Physical/Chemical Treatment (Continued) | Ultrafiltration/Reverse Osmosis<br>Cross-Flow Pervaporation<br>Ion Exchange<br>Distillation<br>Liquefied Gas Solvent Extraction<br>High-Energy Electron Irradiation<br>Surfactants |
| | Thermal Treatment | Evaporation<br>Wet Air/Supercritical Oxidation<br>Catalytic Oxidation<br>Gas-Phase Chemical Reduction<br>Photo-Dechlorination<br>Pyrolysis<br>Incineration |
| | Off-Gas Treatment | Biofiltration<br>Vapor Phase Carbon Adsorption<br>Catalytic/Thermal Oxidation<br>High Energy Corona<br>Membrane Separation<br>Photolytic Oxidation |
| | Discharge (treated or untreated) | Spray/Sprinkler Irrigation<br>Groundwater Recharge<br>Deep Well Injection |
| **In-Situ Treatment** | Biological Treatment | Biosparging<br>Monitored Natural Attenuation<br>Aerobic Bioremediation with Lab-Isolated Solvent-Degrading Bacteria<br>Cometabolic Aerobic Bioremediation<br>Enhanced Anaerobic Bioremediation<br>Nitrate Enhanced Bioremediation<br>Hydrogen Peroxide Enhanced Bioremediation<br>Electric Induced Redox Barriers<br>Oxygen Release Compound® (ORC)<br>In-Situ Biofilters |

**Table 4-2 (Continued)**
**Technologies and Process Options for Groundwater Remediation**
*Feasibility Study Report*
*Open Burning / Open Detonation Ground (Range 16)*
*Fort Riley, Kansas*

| General Response Actions | Technologies | Process Options |
|---|---|---|
| **In-Situ Treatment (Continued)** | Physical/Chemical Treatment | Air Sparging<br>C-Sparger™<br>Groundwater Circulation Wells<br>In-Situ Chemical Reagent Injection<br>In-Situ Redox Manipulation<br>Bimetallic Nanoscale Particles<br>In-Situ Chemical Flushing<br>Electrical Separation<br>In-Situ Radio Frequency Heating<br>Steam Injection |
| | Components - Fluid Delivery Systems | Vertical Wells<br>Horizontal Wells<br>Direct-Push Injection Points |

## Table 4-3
## Technologies and Process Options for Surface Water Remediation
*Feasibility Study Report*
*Open Burning / Open Detonation Ground (Range 16)*
*Fort Riley, Kansas*

| General Response Actions | Technologies | Process Options |
|---|---|---|
| **No Action** | No Action | No Action |
| **Institutional Controls** | Governmental Controls | Zoning Ordinance Amendment<br>County Resolution |
| | Proprietary Controls | Negative Easements and Restrictive Covenants<br>Affirmative Easements |
| | Other Institutional Controls | Fort Riley Real Property Master Plan |
| **Other Controls** | Monitoring | Surface Water Monitoring |
| | Alternative Water Supply | Rural Water Supply<br>New Supply Wells |
| **Surface Capture, Treatment, and Discharge** | Surface Capture | French Drains<br>Sumps<br>Weirs |
| | Biological Treatment | Aerobic Biological Reactors<br>Cometabolic Aerobic Biological Reactors<br>Anaerobic Biological Reactors |
| | Physical/Chemical Treatment | Oil/Water Separation<br>Precipitation<br>Flocculation<br>Air Stripping<br>Steam Stripping<br>Carbon Adsorption<br>Resin Adsorption<br>Organoclay Adsorption<br>Oxidation/Reduction<br>Ultrafiltration/Reverse Osmosis<br>Cross-Flow Pervaporation<br>Ion Exchange<br>Distillation<br>Liquefied Gas Solvent Extraction<br>High-Energy Electron Irradiation<br>Surfactants |

**Table 4-3 (Continued)**
**Technologies and Process Options for Surface Water Remediation**
*Feasibility Study Report*
*Open Burning / Open Detonation Ground (Range 16)*
*Fort Riley, Kansas*

| General Response Actions | Technologies | Process Options |
|---|---|---|
| **Surface Capture, Treatment, and Discharge (Continued)** | Thermal Treatment | Evaporation<br>Wet Air/Supercritical Oxidation<br>Catalytic Oxidation<br>Gas-Phase Chemical Reduction<br>Photo-Dechlorination<br>Pyrolysis<br>Incineration |
| | Off-Gas Treatment | Biofiltration<br>Vapor Phase Carbon Adsorption<br>Catalytic/Thermal Oxidation<br>High Energy Corona<br>Membrane Separation<br>Photolytic Oxidation |
| | Discharge (treated or untreated) | Discharge to Groundwater Treatment System<br>Ephemeral Stream Discharge<br>Spray/Sprinkler Irrigation<br>Deep Well Injection |

**Table 4-4**
**Initial Screening of Potential Technologies for Soil Remediation**
*Feasibility Study Report*
*Open Burning / Open Detonation Ground (Range 16)*
*Fort Riley, Kansas*

| 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** | | | |
| Fort Riley Real Property Master Plan (RPMP) | The Fort Riley RPMP is the means for codifying land use controls, on the post. | Yes | Potentially applicable. |
| **Removal and Disposal or Treatment** | | | |
| **Soil Excavation, Backfill, and Disposal** | | | |
| Off-Site Disposal in a Landfill | Soil with contaminant concentrations above the Preliminary Remedial Goals (PRGs) are removed and clean soil is used for backfill. Soil is disposed of off site. | Yes | Potentially applicable. |
| On-Site Land Farming | Soil with contaminant concentrations above the PRGs are excavated and clean soil is used for backfill. Contaminated soils treated at newly constructed on-site land farm. Once treated, soil is disposed of as landfill cover or spread on site. | Yes | Potentially applicable. |
| On-Site Thermal Incineration | Soil with contaminant concentrations above the PRGs are excavated and clean soil is used for backfill. Contaminated soils transported to on-site incinerator. | No | Extremely high cost and long lead time for processing small amounts of soil. |
| Off-Site Thermal Incineration | Soil with contaminant concentrations above the PRGs are excavated and clean soil is used for backfill. Contaminated soils transported off site for incineration and disposal. | Yes | Potentially applicable. |
| 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. |
| Chemical Reduction/Oxidation | Reduction/oxidation reaction chemically converts hazardous contaminants to nonhazardous or less toxic compounds. | No | Ineffective in soils with low permeability. |
| Dehalogenated | Contaminated soil is screened, processed, and mixed with reagents. The mixture is then heated in a reactor causing either the replacement of the halogen molecules or the decomposition and partial volatilization of contaminants. | No | Can be used to treat halogenated VOCs but is generally more expensive than other technologies. High clay content will increase treatment costs. |
| Contaminant Separation | Separation using gravity of sieving/physical separation to remove contaminated concentrations from soils leaving a relatively uncontaminated fraction. | No | Can only be used on selected VOCs. High clay and moisture increase treatment cost. |

**Table 4-4 (Continued)**
**Initial Screening of Potential Technologies for Soil Remediation**
*Feasibility Study Report*
*Open Burning / Open Detonation Ground (Range 16)*
*Fort Riley, Kansas*

| Process Options | Description | Retain* | Screening Comments |
|---|---|---|---|
| **Ex-Situ Physical Treatment (Continued)** | | | |
| Solidification and Stabilization | Contaminants 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 contaminant/process combination. |
| Soil Washing | Removes contaminants from soil by dissolving or suspending in the wash solution, then separating 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 amendments and placed in above ground enclosures. System typically includes leachate collection and aeration systems. | No | Questionable effectiveness for halogenated VOCs. |
| **In-Situ Treatment** | | | |
| **Physical/Chemical Treatment** | | | |
| 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. |
| In-Situ Chemical Oxidation | Solubilized oxidant and sometimes catalysts, are circulated throughout contaminated zone to chemically oxidize organic | Yes | Potentially applicable. |
| In-Situ Radio Frequency Heating | Heat is applied to the subsurface through electromagnetic radiation, which raises the soil temperature to enhance soil vapor extraction. | No | More applicable to vadose zone remediation. Requires extensive above ground support and infrastructure that may deter the military mission. |
| Electrical Resistivity Heating | Uses the flow of alternating current electricity to heat soil and groundwater and evaporate contaminants. Electric current is passed through a targeted soil volume between subsurface electrode elements. The resistance to electrical flow that exists in the soil causes the formation of heat; resulting in an increase in temperature until the boiling point of water at depth is reached. After reaching this temperature, further energy input causes a phase change, forming steam and removing volatile contaminants. | No | Can be used on site-specific contaminants. Requires extensive above ground support and infrastructure that may deter the military mission. |
| Thermal Conductive Heating | Simultaneous application of both heat and vacuum to impacted subsurface soils using thermal wells. As soils are heated (800-900 C), contaminants are vaporized or destroyed by evaporation into air stream, steam distillation into the water vapor stream, boiling, oxidation, and pyrolysis. | No | Can be used on site-specific contaminants. Requires extensive above ground support and infrastructure that may deter the military mission. |
| Dynamic Underground Stripping (DUS) | Uses steam to heat permeable layers and electric current to heat impermeable layers. Vaporized volatile and semivolatile components are then removes via SVE. | No | Can be used on site-specific contaminants. Requires extensive above ground support and infrastructure that may deter the military mission. |

**Table 4-4 (Continued)**
**Initial Screening of Potential Technologies for Soil Remediation**
*Feasibility Study Report*
*Open Burning / Open Detonation Ground (Range 16)*
*Fort Riley, Kansas*

| | | | |
|---|---|---|---|
| **In-Situ Treatment (Continued)** | | | |
| **Physical/Chemical Treatment (Continued)** | | | |
| Hydrous Pyrolysis/Oxidation | Used in combination with DUS, or similar heating technology, where oxygen is injected into the pre-heated subsurface to rapidly oxidize VOCs. | No | Can be used on site-specific contaminants. Requires extensive above ground support and infrastructure that may deter the military mission. |
| Six-Phase Soil Heating | Electricity is used to heat subsurface materials to enhance the volatilization of VOCs. Volatilized VOCs are then removed via SVE. | No | Can be used on site-specific contaminants. Requires extensive above ground support and infrastructure that may deter the military mission. |

NOTES:

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

No — Technology eliminated from further consideration based on technical implementability.

**Table 4-5**
**Initial Screening of Potential Technologies for Groundwater Remediation**
*Feasibility Study Report*
*Open Burning / Open Detonation Ground (Range 16)*
*Fort Riley, Kansas*

| 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** | | | |
| Fort Riley Real Property Master Plan (RPMP) | The Fort Riley RPMP is the means for codifying land use controls, including the location of water supply wells, on the post. | Yes | Potentially applicable. |
| **Other Controls** | | | |
| **Monitoring** | | | |
| Groundwater Monitoring | Periodic sampling and analysis of groundwater from monitoring wells. | Yes | Potentially applicable. |
| **Alternative Water Supply** | | | |
| Rural/Municipal Water Supply | Extension of rural/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. |

**Table 4-5 (Continued)**
**Initial Screening of Potential Technologies for Groundwater Remediation**
*Feasibility Study Report*
*Open Burning / Open Detonation Ground (Range 16)*
*Fort Riley, Kansas*

| Process Options | Description | Retain* | Screening Comments |
|---|---|---|---|
| **Containment** | | | |
| **Low Permeability Barrier** | | | |
| Vertical Barrier | Low permeability wall made of soil-bentonite, reinforced concrete, chemical grout, or steel sheets. | No | Process not applicable due the nature of the fractured bedrock at the OB/OD |
| Horizontal Barrier | Low permeability barrier typically used to prevent leaching of contaminants to groundwater. | No | Process not applicable due to the OB/OD being an active open detonation range. |
| **Permeable Reactive Barrier** | | | |
| Organic Mulch | A permeable organic mulch wall is installed across the flow path of contaminant plume creating an anaerobic environment. Groundwater which moves through the wall under natural gradient undergoes chemical reduction removing chlorine ions. | No | Can be used on site-specific contaminants. Requires trenching activity within an active open detonation range with high possibility of UXOs. Construction activity may deter the military mission. |
| In-Situ Air Stripping | A 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 | Can be used on site-specific contaminants. Requires trenching activity within an active open detonation range with high possibility of UXOs. Construction activity may deter the military mission. |
| In-Situ Microbial Consortium | A permeable reaction trench is installed across flow path of the contaminant plume, which moves through the treatment zone under natural gradient. A microbial consortium slurry wall is placed into the trench. Groundwater which moves through the wall under natural gradient undergoes biodegradation. | No | Can be used on site-specific contaminants. Requires trenching activity within an active open detonation range with high possibility of UXOs. Construction activity may deter the military mission. |
| **Surface Capping** | | | |
| Surface Capping | Surface is covered with impermeable materials to prevent leaching of contaminants to groundwater. | No | Not applicable. Site is located at an active open detonation range. |
| **Extraction, Ex-Situ Treatment, and Discharge** | | | |
| **Collection/Extraction** | | | |
| Interceptor Trenches | Perforated pipe is placed in trenches backfilled with porous media to collect contaminated water for further treatment or disposal. | No | Requires extensive above ground support and infrastructure that may deter military mission. |
| Pumping Wells: Vertical | Series of vertical wells with water pumps to extract contaminated groundwater. | No | Vertical pumping wells more applicable to high-yield aquifers. |
| Pumping Wells: Horizontal | Series of horizontal or inclined wells with water pumps to extract contaminated groundwater. | No | Horizontal pumping wells more applicable to high-yield aquifers. |
| Dual Phase Vapor Extraction (DPVE) | A high vacuum system is applied to simultaneously remove various combinations of contaminated groundwater, free-phase petroleum product, and hydrocarbon vapor from the subsurface. | No | This technology is more applicable to low yield aquifers, soil remediation, and for the removal of light non-aqueous phase liquids. DPVE is more applicable to source zone remediation. |
| **Biological Treatment** | | | |
| Aerobic Biological Reactors | Contaminated water is pumped to a suspended growth- or attached growth-type reactor where microbial population aerobically oxidizes organics. | No | Process is not applicable to treat all of the compounds present at the OB/OD. |
| Cometabolic Aerobic Biological Reactors | Chlorinated VOCs are transformed as secondary substrate by methanotrophic bacteria (methane degraders). For this to occur, methane and $O_2$ must be provided to the reactor. | No | Process is not applicable to treat all of the compounds present at the OB/OD. |
| Anaerobic Biological Reactors | Contaminated water is pumped to a closed reactor where microbial populations degrades organic contaminants in absence of oxygen. Other carbon sources, such as acetate, are added to act as electron donors in anaerobic conditions. | No | Additional carbon sources would need to be added in excess to sustain microbial population. Lengthy treatment times may also be required. |

# Table 4-5 (Continued)
## Initial Screening of Potential Technologies for Groundwater Remediation
*Feasibility Study Report*
*Open Burning / Open Detonation Ground (Range 16)*
*Fort Riley, Kansas*

| Process Options | Description | Retain* | Screening Comments |
|---|---|---|---|
| **Extraction, Ex-Situ Treatment, and Discharge (Continued)** | | | |
| **Physical/Chemical Treatment** | | | |
| Oil/Water Separation | Separation of free oils by gravity and/or emulsified products by chemical pretreatment and/or coalescing media. | No | Contaminants are dissolved in groundwater, so there is no free-phase product. |
| Precipitation | Alteration of chemical equilibrium to reduce solubility of dissolved contaminants, such as metals. | No | Contaminants are below the solubility limit, so precipitation is not applicable. Requires extensive above ground support and infrastructure that may deter the military mission. |
| Flocculation | Destabilization of colloids to aggregate them into flocs. | No | Typically used to remove metals from water. Requires extensive above ground support and infrastructure that may deter the military mission. |
| Air Stripping | Volatilization of contaminants from water by either passing air through water or water through air. | No | Requires extensive above ground support and infrastructure that may deter the military mission. |
| Steam Stripping | Volatilization of contaminants from water by passing steam through water usually in multiple tray columns. | No | Requires extensive above ground support and infrastructure that may deter the military mission. |
| Carbon Adsorption | Adsorption of contaminants onto activated carbon by passing water through carbon column. | No | Requires extensive above ground support and infrastructure that may deter the military mission. |
| Resin Adsorption | A regenerable resin-type adsorbent that treats groundwater contaminated with hazardous organics. It has 5 to 10 times the capacity of activated carbon for low concentrations of VOCs. | No | The availability of resin adsorbents for full-scale projects is questionable. Requires extensive above ground support and infrastructure that may deter the military mission. |
| Organoclay Adsorption | Bentonite is organically modified to render it hydrophobic and oleophilic. This organoclay attracts a wide range of organic contaminants. | No | Requires extensive above ground support and infrastructure that may deter the military mission. |
| Oxidation/Reduction | Oxidation or reduction of organic contaminants through addition of strong oxidizing or reducing agents. May be coupled with irradiation from UV light. | No | Requires extensive above ground support and infrastructure that may deter the military mission. |
| Ultrafiltration/Reverse Osmosis | Use of high pressure to force water through a semi-permeable membrane leaving contaminants behind. | No | Ultrafiltration/reverse osmosis has been typically used for separating inorganics from solution, although some semipermeable membranes also reject organics. Requires extensive above ground support and infrastructure that may deter the military mission. |
| Cross-Flow Pervaporation | Membrane-process that uses an organophilic membrane that absorbs organics in solution. The organics diffuse through membrane by a vacuum and condense into a highly concentrated permeate. | No | Requires extensive above ground support and infrastructure that may deter the military mission. |
| Ion Exchange | Contaminated water is passed through a resin bed where ions are exchanged between resin and water. | No | Applicable only to ions (anions or cations). Requires extensive above ground support and infrastructure that may deter the military mission. |
| Distillation | Separation of substances (e.g., contaminants and water) relying on boiling point differences. | No | Requires extensive above ground support and infrastructure that may deter the military mission. |
| Liquefied Gas Solvent Extraction | Contaminated organics in groundwater are extracted by liquefied carbon dioxide in a continuous trayed extraction tower. The solvent ($CO_2$) is subsequently vaporized and recycled. | No | Requires extensive above ground support and infrastructure that may deter the military mission. |
| High-Energy Electron Irradiation | Contaminated water is irradiated with high-energy electrons which promote reductive dehalogenation and also produce highly oxidizing chemical species, such as $OH^0$, which break down contaminants. | No | Will not work on all site contaminants at the OB/OD. Requires extensive above ground support and infrastructure that may deter the military mission. |
| Surfactants | Surfactants are added to the groundwater to dissolve NAPL or highly adsorbed contaminants. The mixture is then separated using phase separation, ultrafiltration, and air flotation. Contaminants are finally separated from surfactants by desorption. | No | Requires extensive above ground support and infrastructure that may deter the military mission. |

**Table 4-5 (Continued)**
**Initial Screening of Potential Technologies for Groundwater Remediation**
*Feasibility Study Report*
*Open Burning / Open Detonation Ground (Range 16)*
*Fort Riley, Kansas*

| Process Options | Description | Retain* | Screening Comments |
|---|---|---|---|
| **Extraction, Ex-Situ Treatment, and Discharge (Continued)** | | | |
| **Thermal Treatment** | | | |
| Evaporation | Complete volatilization of solvent(s) leaving the solutes behind. | No | Can be used on site-specific contaminants. Requires extensive above ground support and infrastructure that may deter the military mission. |
| Wet Air/Supercritical Oxidation | Oxidation of organic contaminants by $O_2$ or $H_2O_2$ under elevated temperatures and pressures. | No | Can be used on site-specific contaminants. Requires extensive above ground support and infrastructure that may deter military mission. |
| Catalytic Oxidation | Oxidation of organic contaminants by $O_2$ at elevated temperatures and under the presence of catalysts such as $V_2O_5$. | No | Technology is more applicable to high concentration waste streams. Little reported experience with liquid phase chlorinated solvents. |
| Gas-Phase Chemical Reduction | Gas-phase reductive reaction of hydrogen with chlorinated VOCs at elevated temperatures. After passing through scrubber, main gas products are $H_2$, $N_2$, $CH_4$, CO and $H_2O$. | No | Technology is potentially applicable to chlorinated VOCs. However, PCBs have been the main application. Technology is more applicable to high concentration waste streams. |
| Photo-Dechlorination | This technology uses ultraviolet light in a reducing atmosphere to dechlorinate (break Cl - C bonds) chlorinated organic contaminants. Products are hydrocarbons and HCl and separated in a scrubber. | No | Liquids need to be vaporized before treatment. Process is more suited for vapor phase treatment. |
| Pyrolysis | Degradation of organic compounds at elevated temperatures and absence of oxygen. | No | Can be used on site-specific contaminants. Requires extensive above ground support and infrastructure that may deter the military mission. |
| Incineration | Combustion of organic compounds. | No | Can be used on site-specific contaminants. Requires extensive above ground support and infrastructure that may deter the military mission. |
| **Off-Gas Treatment** | | | |
| Biofiltration | Vapor-phase organic contaminants are passed through a bed (organic or inert) where they are degraded by microorganisms. | No | Treatment unnecessary. Expected vapor concentrations are below regulatory levels. Vapors are allowed to discharge directly to the atmosphere. |
| Vapor Phase Carbon Adsorption | Pollutants are removed from air by adsorption onto activated carbon grains. | No | Treatment unnecessary. Expected vapor concentrations are below regulatory levels. Vapors are allowed to discharge directly to the atmosphere. |
| Catalytic/Thermal Oxidation | Contaminated air is passed through catalyst bed where pollutants are oxidized at elevated temperatures. | No | Treatment unnecessary. Expected vapor concentrations are below regulatory levels. Vapors are allowed to discharge directly to the atmosphere. |
| High Energy Corona | Technology uses high-voltage electricity to destroy VOCs at room temperature. | No | Treatment unnecessary. Expected vapor concentrations are below regulatory levels. Vapors are allowed to discharge directly to the atmosphere. |
| Membrane Separation | High pressure separation system based on the preferential transport of organic vapors through nonporous gas separation membrane. | No | Treatment unnecessary. Expected vapor concentrations are below regulatory levels. Vapors are allowed to discharge directly to the atmosphere. |
| Photolytic Oxidation | Process applies short wavelength UV light at very high intensities to contaminants in the gas phase. UV light energy transforms electrons to higher energy states and breaks molecular bonds. | No | Treatment unnecessary. Expected vapor concentrations are below regulatory levels. Vapors are allowed to discharge directly to the atmosphere. |

**Table 4-5 (Continued)**
**Initial Screening of Potential Technologies for Groundwater Remediation**
*Feasibility Study Report*
*Open Burning / Open Detonation Ground (Range 16)*
*Fort Riley, Kansas*

| Process Options | Description | Retain* | Screening Comments |
|---|---|---|---|
| **Extraction, Ex-Situ Treatment, and Discharge (Continued)** | | | |
| **Discharge (treated or untreated)** | | | |
| Spray/Sprinkler Irrigation | Direct irrigation of water onto land surface. Sprinkler heads are designed to treat (volatilize) VOCs during application. | No | Discharge unnecessary due to all extraction and ex-situ treatment options failing screening. |
| Ephemeral Stream Discharge | Water is discharged in to the western ephemeral stream. | No | Discharge unnecessary due to all extraction and ex-situ treatment options failing screening. |
| Groundwater Recharge | Water is recharged back to the aquifer it was removed from via injection wells, recharge trenches, or recharge basins. | No | Discharge unnecessary due to all extraction and ex-situ treatment options failing screening. |
| Deep Well Injection | Water is injected into underlying aquifers, which are hydraulically disconnected from the aquifer it was removed from through deep wells. | No | Discharge unnecessary due to all extraction and ex-situ treatment options failing screening. |
| **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 the OB/OD are not readily biodegradable under aerobic conditions. |
| Monitored Natural Attenuation | Natural subsurface processes such as dispersion, volatilization, biodegradation, adsorption, and chemical reactions combine to reduce contaminant levels over time. | Yes | Potentially applicable. |
| 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 the OB/OD are not readily biodegradable under aerobic conditions. |
| 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. |

## Table 4-5 (Continued)
## Initial Screening of Potential Technologies for Groundwater Remediation
*Feasibility Study Report*
*Open Burning / Open Detonation Ground (Range 16)*
*Fort Riley, Kansas*

| Process Options | Description | Retain* | Screening Comments |
|---|---|---|---|
| **In-Situ Treatment (Continued)** | | | |
| **Biological Treatment (Continued)** | | | |
| Nitrate Enhanced Bioremediation | Solubilized nitrate is circulated throughout contaminated zone to provide electron acceptors for biological degradation. | No | Some chlorinated solvents present at the OB/OD are not readily biodegradable under aerobic (presence of electron acceptors) conditions. |
| Hydrogen Peroxide 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 OB/OD 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 OB/OD (TCE and PCA) are not readily biodegradable under aerobic conditions. ORC may inhibit the natural anaerobic biodegradation that is occurring at the OB/OD. 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 limit 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. | No | Requires extensive above ground support and infrastructure that may deter the military mission. |
| 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. | No | Requires extensive above ground support and infrastructure that may deter military mission. |
| In-Situ Chemical Reagent Injection | Solubilized reactive media and sometimes catalysts, are injected into the aquifer throughout contaminated zone to promote conditions that are effective in the treatment of chlorinated solvents. | Yes | Potentially applicable. |
| 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. | No | Process is not applicable to treat all of the compounds present at the OB/OD. |

**Table 4-5 (Continued)**
**Initial Screening of Potential Technologies for Groundwater Remediation**
*Feasibility Study Report*
*Open Burning / Open Detonation Ground (Range 16)*
*Fort Riley, Kansas*

| Process Options | Description | Retain* | Screening Comments |
|---|---|---|---|
| **In-Situ Treatment (Continued)** | | | |
| **Physical/Chemical Treatment (Continued)** | | | |
| 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. |
| 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. |
| **Components - Fluid Delivery Systems** | | | |
| Vertical Wells | Permanent or temporary (i.e., using direct-push technology) 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.

No — Technology eliminated from further consideration based on technical implementability.

**Table 4-6**
**Initial Screening of Potential Technologies for Surface Water Remediation**
*Feasibility Study Report*
*Open Burning / Open Detonation Ground (Range 16)*
*Fort Riley, Kansas*

| 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** | | | |
| Fort Riley Real Property Master Plan (RPMP) | The Fort Riley RPMP is the means for codifying land use controls on the post. | Yes | Potentially applicable. |
| **Other Controls** | | | |
| **Monitoring** | | | |
| Surface Water Monitoring | Periodic sampling and analysis of surface water from the streams, springs, and seeps. | Yes | Potentially applicable. |
| **Alternative Water Supply** | | | |
| Rural/Municipal Water Supply | Extension of rural/municipal water distribution system to serve residents in the area of influence. | No | Not applicable. |
| New Supply Wells | New uncontaminated wells to serve residents in the area of influence. | No | Not applicable. |
| **Surface Capture, Treatment, and Discharge** | | | |
| **Surface Capture** | | | |
| French Drains | Surface water is captured in french drain system and diverted to sump using gravity flow. | No | Requires extensive above ground support and infrastructure that may deter military mission. |
| Sumps | Series of surface water collection sumps used to capture contaminated surface water for treatment. | No | Requires extensive above ground support and infrastructure that may deter military mission. |
| Weirs | Installation of weirs and sumps to capture contaminated surface water for treatment. | No | Requires extensive above ground support and infrastructure that may deter military mission. |

**Table 4-6 (Continued)**
**Initial Screening of Potential Technologies for Surface Water Remediation**
*Feasibility Study Report*
*Open Burning / Open Detonation Ground (Range 16)*
*Fort Riley, Kansas*

| Process Options | Description | Retain* | Screening Comments |
|---|---|---|---|
| **Surface Capture, Treatment, and Discharge (Continued)** | | | |
| **Biological Treatment** | | | |
| Aerobic Biological Reactors | Contaminated water is pumped to a suspended growth- or attached growth-type reactor where microbial population aerobically oxidizes organics. | No | Process is not applicable to treat all of the compounds present at the OB/OD. |
| Cometabolic Aerobic Biological Reactors | Chlorinated VOCs are transformed as secondary substrate by methanotrophic bacteria (methane degraders). For this to occur, methane and $O_2$ must be provided to the reactor. | No | Process is not applicable to treat all of the compounds present at the OB/OD. |
| Anaerobic Biological Reactors | Contaminated water is pumped to a closed reactor where microbial population degrades organic contaminants in absence of oxygen. Other carbon sources, such as acetate, are added to act as electron donors in anaerobic conditions. | No | Process is not applicable to treat all of the compounds present at the OB/OD. |
| **Physical/Chemical Treatment** | | | |
| Oil/Water Separation | Separation of free oils by gravity and/or emulsified products by chemical pretreatment and/or coalescing media. | No | Contaminants are dissolved in surface water, so there is no free-phase product. |
| Precipitation | Alteration of chemical equilibrium to reduce solubility of dissolved contaminants, such as metals. | No | Contaminants are below the solubility limit, so precipitation is not applicable. |
| Flocculation | Destabilization of colloids to aggregate them into flocs. | No | Typically used to remove metals from water. |
| Air Stripping | Volatilization of contaminants from water by either passing air through water or water through air. | No | Potentially applicable. |
| Steam Stripping | Volatilization of contaminants from water by passing steam through water usually in multiple tray columns. | No | Technology is more applicable to high concentration waste streams. |
| Carbon Adsorption | Adsorption of contaminants onto activated carbon by passing water through carbon column. | No | Requires extensive above ground support and infrastructure that may deter military mission. |
| Resin Adsorption | Ambersorb® is a regenerable resin-type adsorbent that treats groundwater contaminated with hazardous organics. It has 5 to 10 times the capacity of activated carbon for low concentrations of VOCs. | No | The availability of resin adsorbents for full-scale projects is questionable. Not commonly used full-scale to remove organics from wastewater. |
| Organoclay Adsorption | Bentonite is organically modified to render it hydrophobic and oleophilic. This organoclay attracts a wide range of organic contaminants. | No | Requires extensive above ground support and infrastructure that may deter military mission. |
| Oxidation/Reduction | Oxidation or reduction of organic contaminants through addition of strong oxidizing or reducing agents. May be coupled with irradiation from UV light. | No | Requires extensive above ground support and infrastructure that may deter military mission. |
| Ultrafiltration/Reverse Osmosis | Use of high pressure to force water through a semi-permeable membrane leaving contaminants behind. | No | Ultrafiltration/reverse osmosis has been typically used for separating inorganics from solution, although some semipermeable membranes also reject organics, including halogenated solvents. It usually requires extensive pretreatment. |

## Table 4-6 (Continued)
## Initial Screening of Potential Technologies for Surface Water Remediation
*Feasibility Study Report*
*Open Burning / Open Detonation Ground (Range 16)*
*Fort Riley, Kansas*

| Process Options | Description | Retain* | Screening Comments |
|---|---|---|---|
| **Surface Capture, Treatment, and Discharge (Continued)** | | | |
| **Physical/Chemical Treatment (Continued)** | | | |
| Cross-Flow Pervaporation | Membrane-process that uses an organophilic membrane that absorbs organics in solution. The organics diffuse through membrane by a vacuum and condense into a highly concentrated permeate. | No | Since water needs to be heated to 165°F, process is applicable only to high contaminant concentrations. |
| Ion Exchange | Contaminated water is passed through a resin bed where ions are exchanged between resin and water. | No | Applicable only to ions (anions or cations). |
| Distillation | Separation of substances (e.g., contaminants and water) relying on boiling point differences. | No | Technology is more applicable to high concentration waste streams and/or small volumes of waste. |
| Liquefied Gas Solvent Extraction | Contaminated organics in groundwater are extracted by liquefied carbon dioxide in a continuous trayed extraction tower. The solvent ($CO_2$) is subsequently vaporized and recycled. | No | Technology is more applicable to soils. May be feasible when other ex-situ technologies, such as air stripping, are not. |
| High-Energy Electron Irradiation | Contaminated water is irradiated with high-energy electrons which promote reductive dehalogenation and also produce highly oxidizing chemical species, such as $OH^0$, which break down contaminants. | No | Technology is more applicable to high concentration waste streams. May be feasible when other ex-situ technologies, such as air stripping, are not. |
| Surfactants | Surfactants are added to the groundwater to dissolve NAPL or highly adsorbed contaminants. The mixture is then separated using phase separation, ultrafiltration, and air flotation. Contaminants are finally separated from surfactants by desorption. | No | Technology is more applicable to high concentration waste streams. May be feasible when other ex-situ technologies, such as air stripping, are not. |
| **Thermal Treatment** | | | |
| Evaporation | Complete volatilization of solvent(s) leaving the solutes behind. | No | Technology is more applicable to small volumes of waste. |
| Wet Air/Supercritical Oxidation | Oxidation of organic contaminants by $O_2$ or $H_2O_2$ under elevated temperatures and pressures. | No | Technology is more applicable to high concentration waste streams. Still in development/pilot status. |
| Catalytic Oxidation | Oxidation of organic contaminants by $O_2$ at elevated temperatures and under the presence of catalysts such as $V_2O_5$. | No | Technology is more applicable to high concentration waste streams. Little reported experience with liquid phase chlorinated solvents. |
| Gas-Phase Chemical Reduction | Gas-phase reductive reaction of hydrogen with chlorinated VOCs at elevated temperatures. After passing through scrubber, main gas products are $H_2$, $N_2$, $CH_4$, CO and $H_2O$. | No | Technology is potentially applicable to chlorinated VOCs. However, PCBs have been the main application. Technology is more applicable to high concentration waste streams. |
| Photo-Dechlorination | This technology uses ultraviolet light in a reducing atmosphere to dechlorinate (break Cl - C bonds) chlorinated organic contaminants. Products are hydrocarbons and HCl. The latter is separated in a scrubber. | No | Liquids need to be vaporized before treatment. Process is more suited for vapor phase treatment. |
| Pyrolysis | Degradation of organic compounds at elevated temperatures and absence of oxygen. | No | Technology is more applicable to small volumes of waste. |
| Incineration | Combustion of organic compounds. | No | Technology is more applicable to small volumes of waste. |

## Table 4-6 (Continued)
## Initial Screening of Potential Technologies for Surface Water Remediation
*Feasibility Study Report*
*Open Burning / Open Detonation Ground (Range 16)*
*Fort Riley, Kansas*

| Process Options | Description | Retain* | Screening Comments |
|---|---|---|---|
| **Surface Capture, Treatment, and Discharge (Continued)** | | | |
| **Off-Gas Treatment** | | | |
| Biofiltration | Vapor-phase organic contaminants are passed through a bed (organic or inert) where they are degraded by microorganisms. | No | Treatment unnecessary. Expected vapor concentrations are below regulatory levels. Vapors are allowed to discharge directly to the atmosphere. |
| Vapor Phase Carbon Adsorption | Pollutants are removed from air by adsorption onto activated carbon grains. | No | Treatment unnecessary. Expected vapor concentrations are below regulatory levels. Vapors are allowed to discharge directly to the atmosphere. |
| Catalytic/Thermal Oxidation | Contaminated air is passed through catalyst bed where pollutants are oxidized at elevated temperatures. | No | Treatment unnecessary. Expected vapor concentrations are below regulatory levels. Vapors are allowed to discharge directly to the atmosphere. |
| High Energy Corona | Technology uses high-voltage electricity to destroy VOCs at room temperature. | No | Treatment unnecessary. Expected vapor concentrations are below regulatory levels. Vapors are allowed to discharge directly to the atmosphere. |
| Membrane Separation | High pressure separation system based on the preferential transport of organic vapors through nonporous gas separation membrane. | No | Treatment unnecessary. Expected vapor concentrations are below regulatory levels. Vapors are allowed to discharge directly to the atmosphere. |
| Photolytic Oxidation | Process applies short wavelength UV light at very high intensities to contaminants in the gas phase. UV light energy transforms electrons to higher energy states and breaks molecular bonds. | No | Treatment unnecessary. Expected vapor concentrations are below regulatory levels. Vapors are allowed to discharge directly to the atmosphere. |
| **Discharge (treated or untreated)** | | | |
| Discharge to Groundwater Treatment System | Water discharged to Groundwater Treatment System. | No | Requires extensive above ground support and infrastructure that may deter military mission. |
| Ephemeral Stream Discharge | Water discharged to the western ephemeral stream. | No | Requires extensive above ground support and infrastructure that may deter military mission. |
| Spray/Sprinkler Irrigation | Direct irrigation of water onto land surface. Sprinkler heads are designed to treat (volatilize) VOCs during application. | No | Requires extensive above ground support and infrastructure that may deter military mission. |
| Deep Well Injection | Water is injected into underlying aquifers, which are hydraulically disconnected from the aquifer it was removed from, through deep wells. | No | Difficult and lengthy process to obtain permit. May not be possible if underlying aquifer is a potential drinking water source. |

NOTES:

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

No — Technology eliminated from further consideration based on technical implementability.

**Table 4-7**
**Evaluation of Technologies for Soil Remediation**
*Feasibility Study Report*
*Open Burning / Open Detonation Ground (Range 16)*
*Fort Riley, Kansas*

| 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** | | | | | | |
| Fort Riley Real Property Master Plan (RPMP) | The Fort Riley RPMP is the mechanism by which the post codifies land use controls. | + | + | + | Yes | The Fort Riley RPMP is used to formalize land use controls on the post. The Fort Riley RPMP could be used to establish areas where supply wells could not be installed; for example, within the OB/OD boundary. It could be used to codify other types of restrictions as well. |
| **Removal and Disposal or Treatment** | | | | | | |
| **Soil Excavation, Backfill, and Disposal** | | | | | | |
| Off-Site Disposal in a Landfill | Soil with contaminant concentrations above the Preliminary Remedial Goals (PRGs)are removed and clean soil is used for backfill. Soil is disposed of off site. | + | + | - | Yes | Due to land disposal restrictions waste will have to be treated before disposal. |
| On-Site Landfarming | Soil with contaminant concentrations above the PRGs are excavated and clean soil is used for backfill. Contaminated soils treated at newly constructed on-site landfarm. Once treated soil is disposed of as landfill cover or spread on-site. | + | + | + | Yes | Will remove subsurface soil source and high clay content backfill will retard precipitation infiltration. Excavated soil will be disked in treatment cell until VOCs are below PRGs. Soil then will be used as landfill cover or spread on-site. |
| Off-Site Thermal Incineration | Soil with contaminant concentrations above the PRGs are excavated and clean soil is used for backfill. Contaminated soils transported off site for incineration and disposal. | + | o | - | Yes | Will remove subsurface soil source and high clay content backfill will retard precipitation infiltration. Excavated soil will be transported off site and incinerated and disposed. |

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

**Table 4-7 (Continued)**
**Evaluation of Technologies for Soil Remediation**
*Feasibility Study Report*
*Open Burning / Open Detonation Ground (Range 16)*
*Fort Riley, Kansas*

| Process Options | Description | Effectiveness | Implementability | Relative Cost | Retain* | Screening Comments |
|---|---|---|---|---|---|---|
| **In-Situ Treatment** | | | | | | |
| **Physical/Chemical Treatment** | | | | | | |
| Soil Vapor Extraction | 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 | High clay content soils at the site may possibly reduce SVE effectiveness. SVE also needs above ground infrastructure. |
| In-Situ Chemical Oxidation | Solubilized oxidant and sometimes catalysts, are circulated throughout contaminated zone to chemically oxidize organic contaminants. | o | + | o | No | High clay content soils at the site may possibly reduce effectiveness. Will treat chlorinated ethenes such as TCE. Does not treat chlorinated ethanes such as PCA.. |

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

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.
- [pink box] Technology eliminated from further consideration

# Table 4-8
## Evaluation of Technologies for Groundwater Remediation
*Feasibility Study Report*
*Open Burning / Open Detonation Ground (Range 16)*
*Fort Riley, Kansas*

| 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** | | | | | | |
| Fort Riley 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 OB/OD boundary. 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 can be implemented easily at the OB/OD. |
| **In-Situ Treatment** | | | | | | |
| **Biological Treatment** | | | | | | |
| Monitored Natural Attenuation | Natural subsurface processes such as dispersion, volatilization, biodegradation, adsorption, and chemical reactions combine to reduce contaminant levels over time. | + | + | + | Yes | Data indicates that natural attenuation processes are acting to reduce contaminant concentrations in the deep bedrock at the OB/OD. |

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

**Table 4-8 (Continued)**
**Evaluation of Technologies for Groundwater Remediation**
*Feasibility Study Report*
*Open Burning / Open Detonation Ground (Range 16)*
*Fort Riley, Kansas*

| Process Options | Description | Effectiveness | Implementability | Relative Cost | Retain* | Screening Comments |
|---|---|---|---|---|---|---|
| **In-Situ Treatment (Continued)** | | | | | | |
| **Biological 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. | - | o | - | No | Limited natural biological biodegradation is occuring at the site. |
| **Physical/Chemical Treatment** | | | | | | |
| In-Situ Treatment Chemical Reagent Injection | Solubilized reactive media and sometimes catalysts, are injected into the aquifer throughout contaminated zone to promote conditions that are effective in the treatment of chlorinated solvents. | + | + | + | Yes | Effective technology that will treat groundwater contaminants. |

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

* 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.
- [pink box] Technology eliminated from further consideration

**Table 4-8 (Continued)**
**Evaluation of Technologies for Groundwater Remediation**
*Feasibility Study Report*
*Open Burning / Open Detonation Ground (Range 16)*
*Fort Riley, Kansas*

| Process Options | Description | Effectiveness | Implementability | Relative Cost | Retain* | Screening Comments |
|---|---|---|---|---|---|---|
| **In-Situ Treatment (Continued)** | | | | | | |
| **Componenets - Fluid Delivery Systems** | | | | | | |
| Vertical Wells | Permanent or temporary (i.e., using direct-push technology) wells used to distribute chemicals or other fluids (i.e., air, nutrients, etc.) into the aquifer. | + | + | + | Yes | Effective fluid delivery method for introducing chemical reagents into the groundwater. |
| Horizontal Wells | Horizontally placed wells used to distribute chemicals or other fluids (i.e., air, nutrients, etc.) into the aquifer. | + | + | + | Yes | Effective fluid delivery method for introducing chemical reagents into the groundwater. |
| 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 | Effective fluid delivery method for introducing chemical reagents into the groundwater. |

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

* 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.
- (pink box) Technology eliminated from further consideration

**Table 4-9**
**Evaluation of Technologies for Surface Water Remediation**
*Feasibility Study Report*
*Open Burning / Open Detonation Ground (Range 16)*
*Fort Riley, Kansas*

| 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** | | | | | | |
| Fort Riley Real Property Master Plan (RPMP) | The Fort Riley RPMP is the mechanism by which the post codifies land use controls. | + | + | + | Yes | The Fort Riley RPMP is used to formalize land use controls on the post. The Fort Riley RPMP could used to codify other types of restrictions as well. |
| **Other Controls** | | | | | | |
| **Monitoring** | | | | | | |
| Surface Water Monitoring | Periodic sampling and analysis of surface water from the streams, springs, and seeps. | o | + | - | Yes | Surface water monitoring can be implemented at the OB/OD. |

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

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.
- [pink box] Technology eliminated from further consideration

## Table 5-1
## Preliminary Soil ARARs Matrix
*Feasibility Study Report*
*Open Burning / Open Detonation Ground (Range 16)*
*Fort Riley, Kansas*

| | Alternative S1 No Action | Alternative S2 IC Through the Fort Riley RPMP | Alternative S3a Off-Site Disposal in a Landfill | Alternative S3b On-Site Land Farming | Alternative S3c Off-Site Thermal Incineration and Disposal | Alternative S4 SVE |
|---|---|---|---|---|---|---|
| **Chemical-Specific ARARs[1]** | | | | | | |
| Risk-Based Standards for Kansas[2] | X | X | X | X | X | X |
| **Location-Specific ARARs[1]** | | | | | | |
| Environmental Use Controls | | X | X | X | X | X |
| Archaeological and Historic Preservation Act of 1974 | | | | | | |
| Endangered Species Act of 1973 | | | X | X | X | X |
| Fish and Wildlife Conservation Act | | | X | X | X | X |
| Fish and Wildlife Coordination Act | | | X | X | X | X |
| National Historic Preservation Act of 1966 | | | | | | |
| Kansas Historic Preservation Act (State of Kansas) | | | | | | |
| Non-Game, Threatened, or Endangered Species (State of Kansas) | | | X | X | X | X |
| **Action-Specific ARARs[1]** | | | | | | |
| Clean Air Act of 1970 | | | X | X | X | X |
| Clean Water Act of 1972 | | | | | | |
| Comprehensive Environmental Response, Compensation, and Liability Act of 1980 | | | X | X | X | X |
| Resource Conservation and Recovery Act of 1979 | | | X | X | X | X |
| Emergency Planning and Community Right-to-Know Act of 1986 | | | X | X | X | X |
| Federal Hazardous Material Transportation Law | | | X | X | X | X |
| Occupational Saftey and Health Act of 1970, Safety and Health Standards for Workplace and Safety and Health Standards for Construction | | | X | X | X | X |
| Ambient Air Quality Standards and Air Pollution Control (State of Kansas) | | | X | X | X | X |
| Hazardous Waste Management Standards and Regulations (State of Kansas) | | | X | X | X | X |
| Solid Waste Management (State of Kansas) | | | X | X | X | X |
| Spill Reporting (State of Kansas) | | | X | X | X | X |
| Water Well Contractor License; Water Well Construction and Abandonment (State of Kansas) | | | | | | X |
| Underground Injection Control Regulations (State of Kansas) | | | X | X | X | X |
| Emergency Planning and Right-to-Know (State of Kansas) | | | X | X | X | X |
| Kansas Board of Technial Professions (State of Kansas) | | X | X | X | X | X |

Notes:
1. See Section 2.2.2 and Appendix 2A 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.
ARAR - Applicable or Relevant and Appropriate Requirements
IC - Institutional Controls
RPMP - Real Property Master Plan
SVE - Soil Vapor Extraction

**Table 5-2**
**Preliminary Groundwater ARARs Matrix**
*Feasibility Study Report*
*Open Burning / Open Detonation Ground (Range 16)*
*Fort Riley, Kansas*

| | Alternative GW1 No Action | Alternative GW2 IC Through the Fort Riley RPMP | Alternative GW3 Groundwater Monitoring | Alternative GW4 MNA | Alternative GW5 Chemical Reagent Injection |
|---|---|---|---|---|---|
| **Chemical-Specific ARARs[1]** | | | | | |
| Safe Drinking Water Act of 1974 | X | X | X | X | X |
| Kansas Drinking Water Standards (State of Kansas) | X | X | X | X | X |
| Risk-Based Standards for Kansas[2] | X | X | X | X | X |
| **Location-Specific ARARs[1]** | | | | | |
| Environmental Use Controls | | X | X | X | X |
| Archaeological and Historic Preservation Act of 1974 | | | | | |
| Endangered Species Act of 1973 | | | X | X | X |
| Fish and Wildlife Conservation Act | | | X | X | X |
| Fish and Wildlife Coordination Act | | | X | X | X |
| National Historic Preservation Act of 1966 | | | | | |
| Kansas Historic Preservation Act (State of Kansas) | | | | | |
| Non-Game, Threatened, or Endangered Species (State of Kansas) | | | X | X | X |
| **Action-Specific ARARs[1]** | | | | | |
| Clean Air Act of 1970 | | | | | |
| Clean Water Act of 1972 | | | | | X |
| Comprehensive Environmental Response, Compensation, and Liability Act of 1980 | | | X | X | X |
| Resource Conservation and Recovery Act of 1979 | | | X | X | X |
| Emergency Planning and Community Right-to-Know Act of 1986 | | | X | X | X |
| Federal Hazardous Material Transportation Law | | | X | X | X |
| Occupational Saftey and Health Act of 1970, Safety and Health Standards for Workplace and Safety and Health Standards for Construction | | | X | X | X |
| Ambient Air Quality Standards and Air Pollution Control (State of Kansas) | | | | | |
| Hazardous Waste Management Standards and Regulations (State of Kansas) | | | X | X | |
| Solid Waste Management (State of Kansas) | | | | | |
| Spill Reporting (State of Kansas) | | | X | X | X |
| Water Well Contractor License; Water Well Construction and Abandonment (State of Kansas) | | | X | X | X |
| Underground Injection Control Regulations (State of Kansas) | | | | | X |
| Emergency Planning and Right-to-Know (State of Kansas) | | | X | X | X |
| Kansas Board of Technial Professions (State of Kansas) | | X | X | X | X |

Notes:
1. See Section 2.2.2 and Appendix 2A for a detailed description of these ARARs
2. This is actually a To Be Considered (TBC) but is listed here as an additional guide for groundwater.
ARAR - Applicable or Relevant and Appropriate Requirements
IC - Institutional Controls
MNA - Monitored Natural Attenuation
RPMP - Real Property Master Plan

# Table 5-3
## Preliminary Surface Water ARARs Matrix
*Feasibility Study Report*
*Open Burning / Open Detonation Ground (Range 16)*
*Fort Riley, Kansas*

| | Alternative SW1 No Action | Alternative SW2 IC Through the Fort Riley RPMP | Alternative SW3 Surface Water Monitoring |
|---|---|---|---|
| **Chemical-Specific ARARs[1]** | | | |
| Safe Drinking Water Act of 1974 [2] | X | X | X |
| Kansas Drinking Water Standards (State of Kansas) [2] | X | X | X |
| Risk-Based Standards for Kansas [3] | X | X | X |
| **Location-Specific ARARs[1]** | | | |
| Environmental Use Controls | | X | X |
| Archaeological and Historic Preservation Act of 1974 | | | |
| Endangered Species Act of 1973 | | | X |
| Fish and Wildlife Conservation Act | | | X |
| Fish and Wildlife Coordination Act | | | X |
| National Historic Preservation Act of 1966 | | | |
| Kansas Historic Preservation Act (State of Kansas) | | | |
| Non-Game, Threatened, or Endangered Species (State of Kansas) | | | X |
| **Action-Specific ARARs[1]** | | | |
| Clean Air Act of 1970 | | | |
| Clean Water Act of 1972 | | | |
| Comprehensive Environmental Response, Compensation, and Liability Act of 1980 | | | X |
| Resource Conservation and Recovery Act of 1979 | | | X |
| Emergency Planning and Community Right-to-Know Act of 1986 | | | X |
| Federal Hazardous Material Transportation Law | | | X |
| Occupational Saftey and Health Act of 1970, Safety and Health Standards for Workplace and Safety and Health Standards for Construction | | | X |
| Ambient Air Quality Standards and Air Pollution Control (State of Kansas) | | | |
| Hazardous Waste Management Standards and Regulations (State of Kansas) | | | X |
| Solid Waste Management (State of Kansas) | | | |
| Spill Reporting (State of Kansas) | | | X |
| Water Well Contractor License; Water Well Construction and Abandonment (State of Kansas) | | | X |
| Underground Injection Control Regulations (State of Kansas) | | | |
| Emergency Planning and Right-to-Know (State of Kansas) | | | X |
| Kansas Board of Technial Professions (State of Kansas) | | X | X |

Notes:
1. See Section 2.2.2 and Appendix 2A for a detailed description of these ARARs
2. Surface water was screened using groundwater screening values during the risk assessment because of their ephimeral status.
3. This is actually a To Be Considered (TBC) but is listed here as an additional guide for groundwater.
ARAR - Applicable or Relevant and Appropriate Requirements
IC - Institutional Controls
RPMP - Real Property Master Plan

**Table 6-1**
**Comparative Analysis of Soil Alternatives**
*Feasibility Study Report*
*Open Burning / Open Detonation Ground (Range 16)*
*Fort Riley, Kansas*

| Evaluation Criteria | Soil Alternatives | | | | | |
|---|---|---|---|---|---|---|
| | Alternative S1 | Alternative S2 | Alternative S3a | Alternative S3b | Alternative S3c | Alternative S4 |
| Protection of Human Health and the Environment | No | No | Yes | Yes | Yes | Yes |
| Compliance with ARARs | No | No | Yes | Yes | Yes | Yes |
| Long-term Effectiveness and Permanence | NC | NC | 1 | 1 | 1 | 3 |
| Reduction of Toxicity, Mobility, or Volume Through Treatment | NC | NC | 3 | 1 | 1 | 2 |
| Short-term Effectiveness | NC | NC | 3 | 3 | 3 | 1 |
| Implementability | NC | NC | 1 | 1 | 1 | 1 |
| Cost | NC | NC | 2 | 1 | 10 | 5 |
| **Total of Rankings** | **NC** | **NC** | **10** | **7** | **16** | **12** |
| **Overall Rank** | **NC** | **NC** | **2** | **1** | **4** | **3** |

Notes:
Alternative S1 - No Action
Alternative S2 - Institutional Controls Through the Fort Riley Real Property Master Plan
Alternative S3a - Off-Site Disposal in a Landfill
Alternative S3b - On-Site Land Farming
Alternative S3c - Off-Site Thermal Incineration and Disposal
Alternative S4 - In-Situ Treatment: Soil Vapor Extraction
Yes - Meets the requirements of the threshold criteria.
No - Does not meet the requirements of the threshold criteria.
NC - Not considered. Does not meet the threshold criteria.

| **Ranking** | |
|---|---|
| **1** | **Most favorable alternative** |
| **3** | **Good, generally favorable** |
| **5** | **Fair, potentially unfavorable** |
| **7** | **Poor, unfavorable** |
| **10** | **Least favorable alternative** |

**Table 6-2**
**Comparative Analysis of Groundwater Alternatives**
*Feasibility Study Report*
*Open Burning / Open Detonation Ground (Range 16)*
*Fort Riley, Kansas*

| Evaluation Criteria | Groundwater Alternatives | | | | |
|---|---|---|---|---|---|
| | Alternative GW1 | Alternative GW2 | Alternative GW3 | Alternative GW4 | Alternative GW5 |
| Protection of Human Health and the Environment | No | No | No | No | Yes |
| Compliance with ARARs | No | No | No | No | Yes |
| Long-term Effectiveness and Permanence | NC | NC | NC | NC | 1 |
| Reduction of Toxicity, Mobility, or Volume Through Treatment | NC | NC | NC | NC | 1 |
| Short-term Effectiveness | NC | NC | NC | NC | 3 |
| Implementability | NC | NC | NC | NC | 3 |
| Cost | NC | NC | NC | NC | 3 |
| **Total of Rankings** | **NC** | **NC** | **NC** | **NC** | **11** |
| **Overall Rank** | **NC** | **NC** | **NC** | **NC** | **1** |

Notes:
Alternative GW1 - No Action
Alternative GW2 - Institutional Controls Through the Fort Riley Real Property Master Plan
Alternative GW3 - Groundwater Monitoring
Alternative GW4 - Monitored Natural Attenuation
Alternative GW5 - In-Situ Treatment: Chemical Reagent Injection
Yes - Meets the requirements of the threshold criteria.
No - Does not meet the requirements of the threshold criteria.
NC - Not considered.  Does not meet the threshold criteria.

| Ranking | |
|---|---|
| **1** | **Most favorable alternative** |
| **3** | **Good, generally favorable** |
| **5** | **Fair, potentially unfavorable** |
| **7** | **Poor, unfavorable** |
| **10** | **Least favorable alternative** |

**Table 6-3**
**Comparative Analysis of Surface Water Alternatives**
*Feasibility Study Report*
*Open Burning / Open Detonation Ground (Range 16)*
*Fort Riley, Kansas*

| Evaluation Criteria | Surface Water Alternatives | | |
|---|---|---|---|
| | Alternative SW1 | Alternative SW2 | Alternative SW3 |
| Protection of Human Health and the Environment | No | Yes | Yes |
| Compliance with ARARs | No | Yes | Yes |
| Long-term Effectiveness and Permanence | NC | 5 | 5 |
| Reduction of Toxicity, Mobility, or Volume Through Treatment | NC | 7 | 7 |
| Short-term Effectiveness | NC | 1 | 1 |
| Implementability | NC | 1 | 1 |
| Cost | NC | 1 | 3 |
| **Total of Rankings** | **NC** | **15** | **17** |
| **Overall Rank** | **NC** | **1** | **2** |

Notes:
Alternative SW1 - No Action
Alternative SW2 - Institutional Controls Through the Fort Riley Real Property Master Plan
Alternative SW3 - Surface Water Monitoring
Yes - Meets the requirements of the threshold criteria.
No - Does not meet the requirements of the threshold criteria.
NC - Not considered. Does not meet the threshold criteria.

| **Ranking** | |
|---|---|
| **1** | **Most favorable alternative** |
| **3** | **Good, generally favorable** |
| **5** | **Fair, potentially unfavorable** |
| **7** | **Poor, unfavorable** |
| **10** | **Least favorable alternative** |

## Table 6-4
## Cost Evaluation for Soil Alternatives
*Feasibility Study Report*
*Open Burning / Open Detonation Ground (Range 16)*
*Fort Riley, Kansas*

| Alternative | Description | Capital Costs | O&M Costs (per year) | Periodic Costs (per event) | Present Value of Capital Costs | Present Value of O&M | Present Value of Periodic Costs | Total Present Value |
|---|---|---|---|---|---|---|---|---|
| Alternative S1 | No Action | $ - | $ - | $ - | $ - | $ - | $ - | $ - |
| Alternative S2 | Institutional Controls | $ 4,000 | $ 4,000 | $ 44,000 | $ 4,000 | $ 50,000 | $ 210,000 | $ 264,000 |
| Alternative S3a | Off-Site Disposal in a Landfill | $ 4,640,000 | $ - | $ 44,000 | $ 4,640,000 | $ - | $ 210,000 | $ 4,850,000 |
| Alternative S3b | On-Site Land Farming | $ 3,960,000 | $ - | $ 44,000 | $ 3,960,000 | $ - | $ 210,000 | $ 4,170,000 |
| Alternative S3c | Off-Site Thermal Incineration and Disposal | $ 12,020,000 | $ - | $ 44,000 | $ 12,020,000 | $ - | $ 210,000 | $ 12,230,000 |
| Alternative S4 | In-Situ Treatment: SVE | $ 4,810,000 | $ 380,000 | $ 44,000 | $ 4,810,000 | $ 2,670,000 | $ 210,000 | $ 7,690,000 |

**Notes:**

1. The Present Value was calculated based on Discount Rate of 7% per OSWER memorandum 9355.0-75 dated July 2000.
2. For calculating present value, a 30 year operating period was assumed.
3. Details of the cost estimates are provided in Appendix 5A-1 through 5A-4.
4. Capital costs all assumed to be incurred in Year 0 for present worth calculations.

**Table 6-5**
**Cost Evaluation for Groundwater Alternatives**
*Feasibility Study Report*
*Open Burning / Open Detonation Ground (Range 16)*
*Fort Riley, Kansas*

| Alternative | Description | Capital Costs | O&M Costs (per year) | Periodic Costs (per event) | Present Value of Capital Costs | Present Value of O&M | Present Value of Periodic Costs | Total Present Value |
|---|---|---|---|---|---|---|---|---|
| Alternative GW1 | No Action | $ - | $ - | $ - | $ - | $ - | $ - | $ - |
| Alternative GW2 | Institutional Controls | $ 380,000 | $ 4,000 | $ 65,000 | $ 380,000 | $ 50,000 | $ 310,000 | $ 740,000 |
| Alternative GW3 | Groundwater Monitoring | $ 727,000 | $ 728,000 | $ 51,000 | $ 727,000 | $ 6,010,000 | $ 240,000 | $ 6,977,000 |
| Alternative GW4 | Monitored Natural Attenuation | $ 783,000 | $ 870,000 | $ 75,000 | $ 783,000 | $ 7,180,000 | $ 360,000 | $ 8,323,000 |
| Alternative GW5 | In Situ Treatment: Chemical Reagent Injection | $ 2,630,000 | $ 351,000 | $ 693,000 | $ 2,630,000 | $ 2,900,000 | $ 3,300,000 | $ 8,830,000 |

**Notes:**

1. The Present Value was calculated based on Discount Rate of 7% per OSWER memorandum 9355.0-75 dated July 2000.
2. For calculating present value, a 30 year operating period was assumed.
3. Details of the cost estimates are provided in Appendix 5B-1 through 5B-5.
4. Capital costs all assumed to be incurred in Year 0 for present worth calculations.

**Table 6-6**
**Cost Evaluation for Surface Water Alternatives**
*Feasibility Study Report*
*Open Burning / Open Detonation Ground (Range 16)*
*Fort Riley, Kansas*

| Alternative | Description | Capital Costs | O&M Costs (per year) | Periodic Costs (per event) | Present Value of Capital Costs | Present Value of O&M | Present Value of Periodic Costs | Total Present Value |
|---|---|---|---|---|---|---|---|---|
| **Surface Water** | | | | | | | | |
| Alterantive SW1 | No Action | $ - | $ - | $ - | $ - | $ - | $ - | $ - |
| Alternative SW2 | Institutional Controls | $ 4,000 | $ 3,000 | $ 22,000 | $ 4,000 | $ 40,000 | $ 100,000 | $ 144,000 |
| Alternative SW3 | Surface Water Monitoring | $ 38,000 | $ 174,000 | $ 22,000 | $ 38,000 | $ 2,200,000 | $ 100,000 | $ 2,338,000 |

**Notes:**

1. The Present Value was calculated based on Discount Rate of 7% per OSWER memorandum 9355.0-75 dated July 2000.
2. For calculating present value, a 30 year operating period was assumed.
3. Details of the cost estimates are provided in Appendix 5C-1 through 5C-3.
4. Capital costs all assumed to be incurred in Year 0 for present worth calculations.

# FIGURES

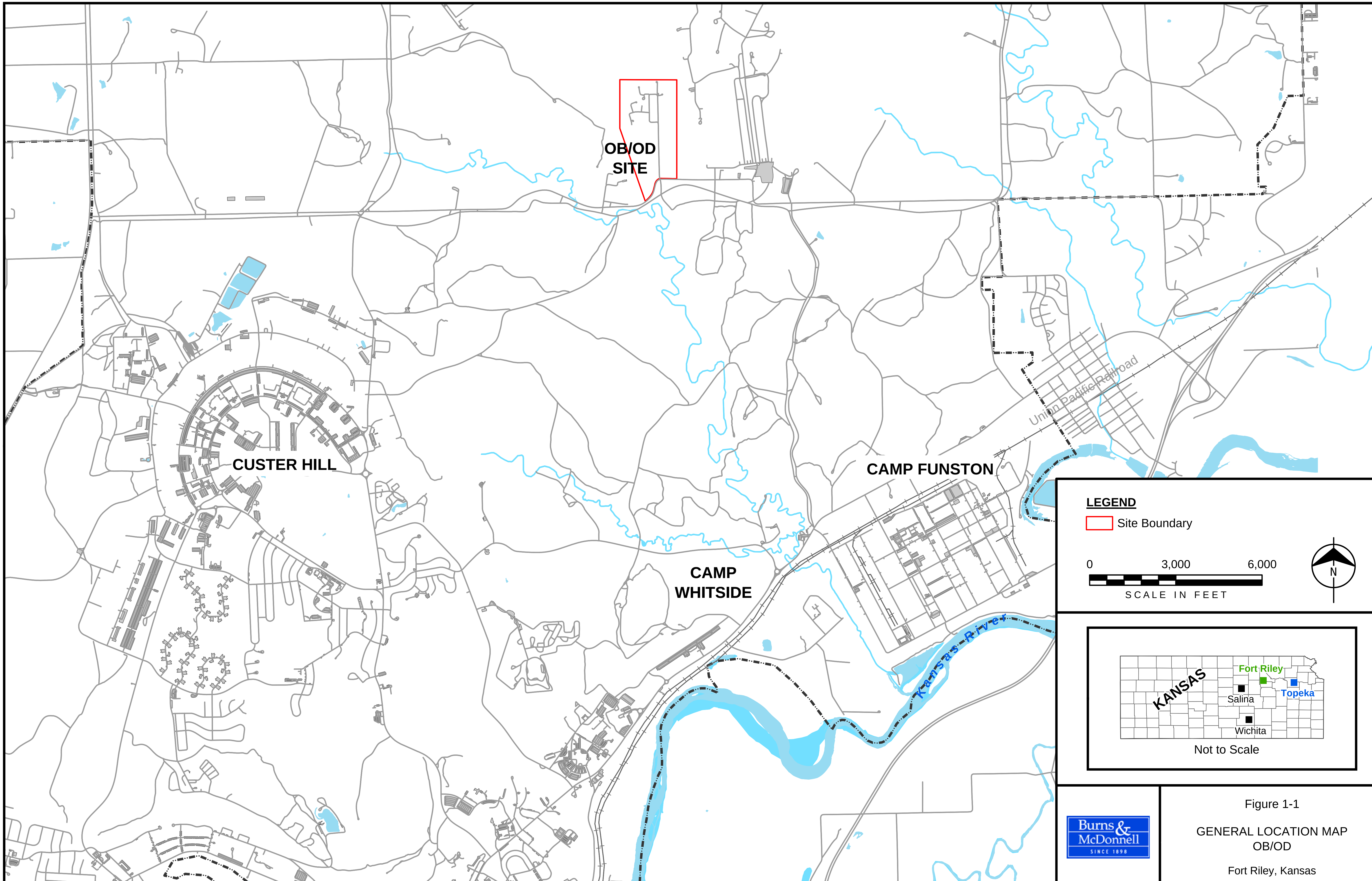


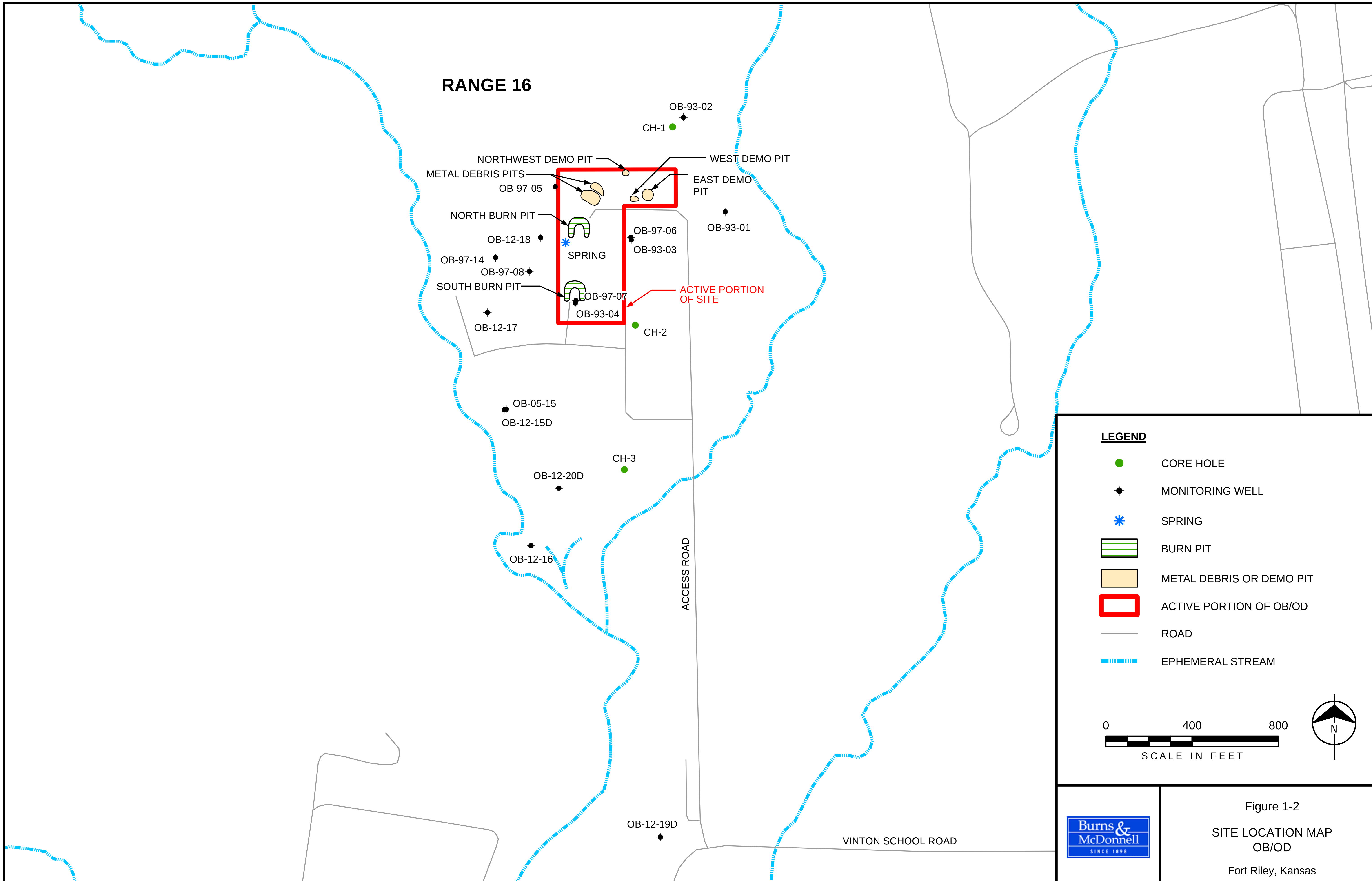

Figure 1-1

GENERAL LOCATION MAP
OB/OD

Fort Riley, Kansas



Name: Fig1-1_General_Location_Map_OBOD_REV1

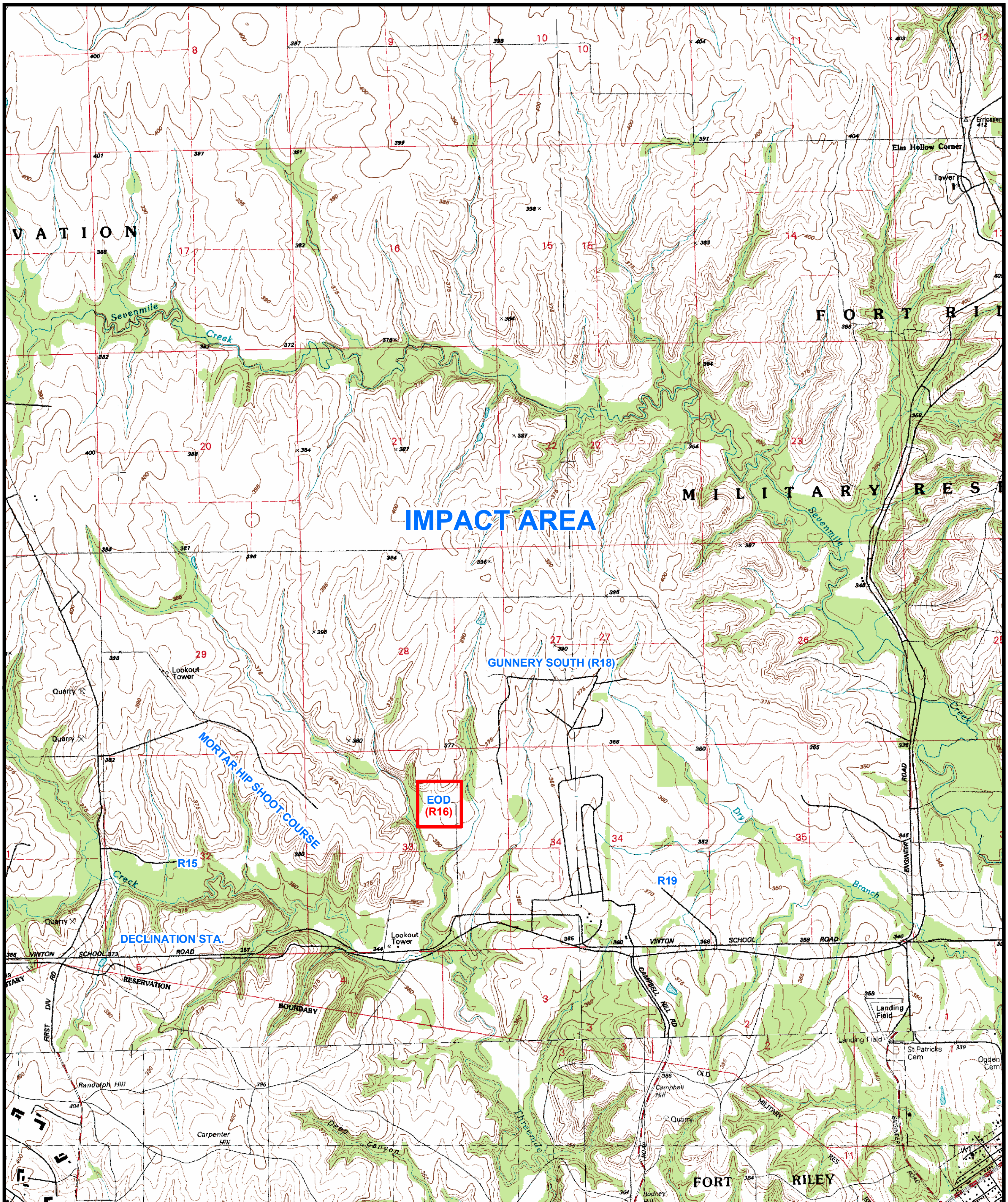



Burns & McDonnell SINCE 1898

Figure 1-2

SITE LOCATION MAP
OB/OD

Fort Riley, Kansas




**LEGEND**

OB/OD SITE BOUNDARY

0 3,500 7,000

SCALE IN FEET

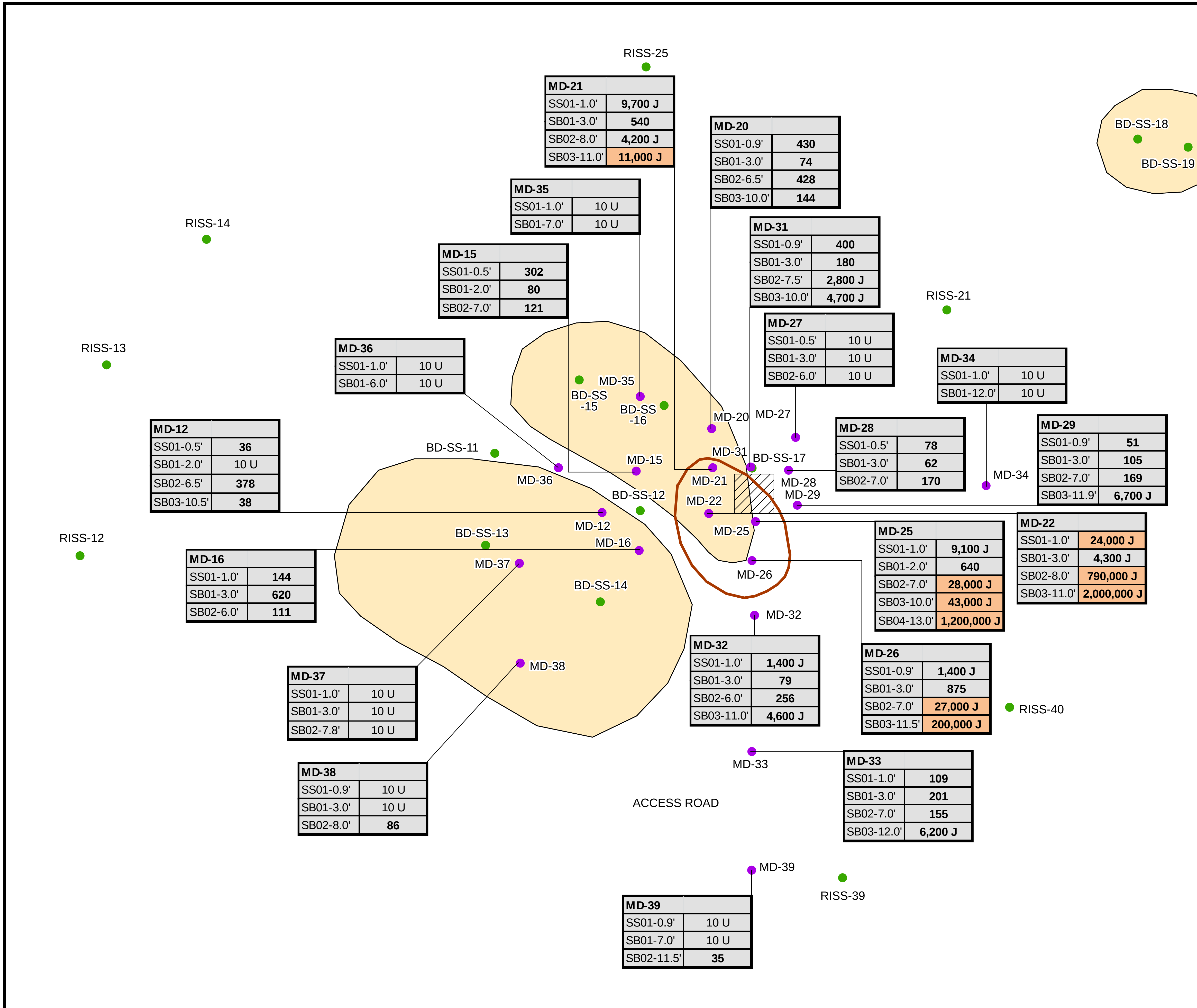
N

Burns & McDonnell SINCE 1898

Figure 1-3

IMPACT AREA
OB/OD

Fort Riley, Kansas




| MD-21 | |
|---|---|
| SS01-1.0' | **9,700 J** |
| SB01-3.0' | **540** |
| SB02-8.0' | **4,200 J** |
| SB03-11.0' | **11,000 J** |

| MD-20 | |
|---|---|
| SS01-0.9' | **430** |
| SB01-3.0' | **74** |
| SB02-6.5' | **428** |
| SB03-10.0' | **144** |

| MD-35 | |
|---|---|
| SS01-1.0' | 10 U |
| SB01-7.0' | 10 U |

| MD-15 | |
|---|---|
| SS01-0.5' | **302** |
| SB01-2.0' | **80** |
| SB02-7.0' | **121** |

| MD-31 | |
|---|---|
| SS01-0.9' | **400** |
| SB01-3.0' | **180** |
| SB02-7.5' | **2,800 J** |
| SB03-10.0' | **4,700 J** |

| MD-27 | |
|---|---|
| SS01-0.5' | 10 U |
| SB01-3.0' | 10 U |
| SB02-6.0' | 10 U |

| MD-36 | |
|---|---|
| SS01-1.0' | 10 U |
| SB01-6.0' | 10 U |

| MD-34 | |
|---|---|
| SS01-1.0' | 10 U |
| SB01-12.0' | 10 U |

| MD-12 | |
|---|---|
| SS01-0.5' | **36** |
| SB01-2.0' | 10 U |
| SB02-6.5' | **378** |
| SB03-10.5' | **38** |

| MD-28 | |
|---|---|
| SS01-0.5' | **78** |
| SB01-3.0' | **62** |
| SB02-7.0' | **170** |

| MD-29 | |
|---|---|
| SS01-0.9' | **51** |
| SB01-3.0' | **105** |
| SB02-7.0' | **169** |
| SB03-11.9' | **6,700 J** |

| MD-25 | |
|---|---|
| SS01-1.0' | **9,100 J** |
| SB01-2.0' | **640** |
| SB02-7.0' | **28,000 J** |
| SB03-10.0' | **43,000 J** |
| SB04-13.0' | **1,200,000 J** |

| MD-22 | |
|---|---|
| SS01-1.0' | **24,000 J** |
| SB01-3.0' | **4,300 J** |
| SB02-8.0' | **790,000 J** |
| SB03-11.0' | **2,000,000 J** |

| MD-16 | |
|---|---|
| SS01-1.0' | **144** |
| SB01-3.0' | **620** |
| SB02-6.0' | **111** |

| MD-32 | |
|---|---|
| SS01-1.0' | **1,400 J** |
| SB01-3.0' | **79** |
| SB02-6.0' | **256** |
| SB03-11.0' | **4,600 J** |

| MD-26 | |
|---|---|
| SS01-0.9' | **1,400 J** |
| SB01-3.0' | **875** |
| SB02-7.0' | **27,000 J** |
| SB03-11.5' | **200,000 J** |

| MD-37 | |
|---|---|
| SS01-1.0' | 10 U |
| SB01-3.0' | 10 U |
| SB02-7.8' | 10 U |

| MD-38 | |
|---|---|
| SS01-0.9' | 10 U |
| SB01-3.0' | 10 U |
| SB02-8.0' | **86** |

| MD-33 | |
|---|---|
| SS01-1.0' | **109** |
| SB01-3.0' | **201** |
| SB02-7.0' | **155** |
| SB03-12.0' | **6,200 J** |

| MD-39 | |
|---|---|
| SS01-0.9' | 10 U |
| SB01-7.0' | 10 U |
| SB02-11.5' | **35** |

**LEGEND**

- 2011 SOIL SAMPLE LOCATION
- 2013 SOIL SAMPLE LOCATION
- AREA WHERE TCE FIELD GC RESULTS > PRG OF 10,720 ug/kg
- AREA WITH METALLIC SIGNATURE
- METAL DEBRIS OR DEMO PIT
- ROAD

| Monitoring Well | |
|---|---|
| Quarter | <PRG |
| | >PRG |

**NOTES:**

1. ALL RESULTS IN ug/kg. DETECTIONS ARE BOLDED.
2. THE PRELIMINARY REMEDIAL GOAL (PRG) FOR TCE IN SOIL IS 10,720 ug/kg.

0 25 50
SCALE IN FEET

N

Burns & McDonnell SINCE 1898

Figure 1-4

TCE SOIL RESULTS
FIELD GC
METAL DEBRIS PITS
OB/OD

Fort Riley, Kansas

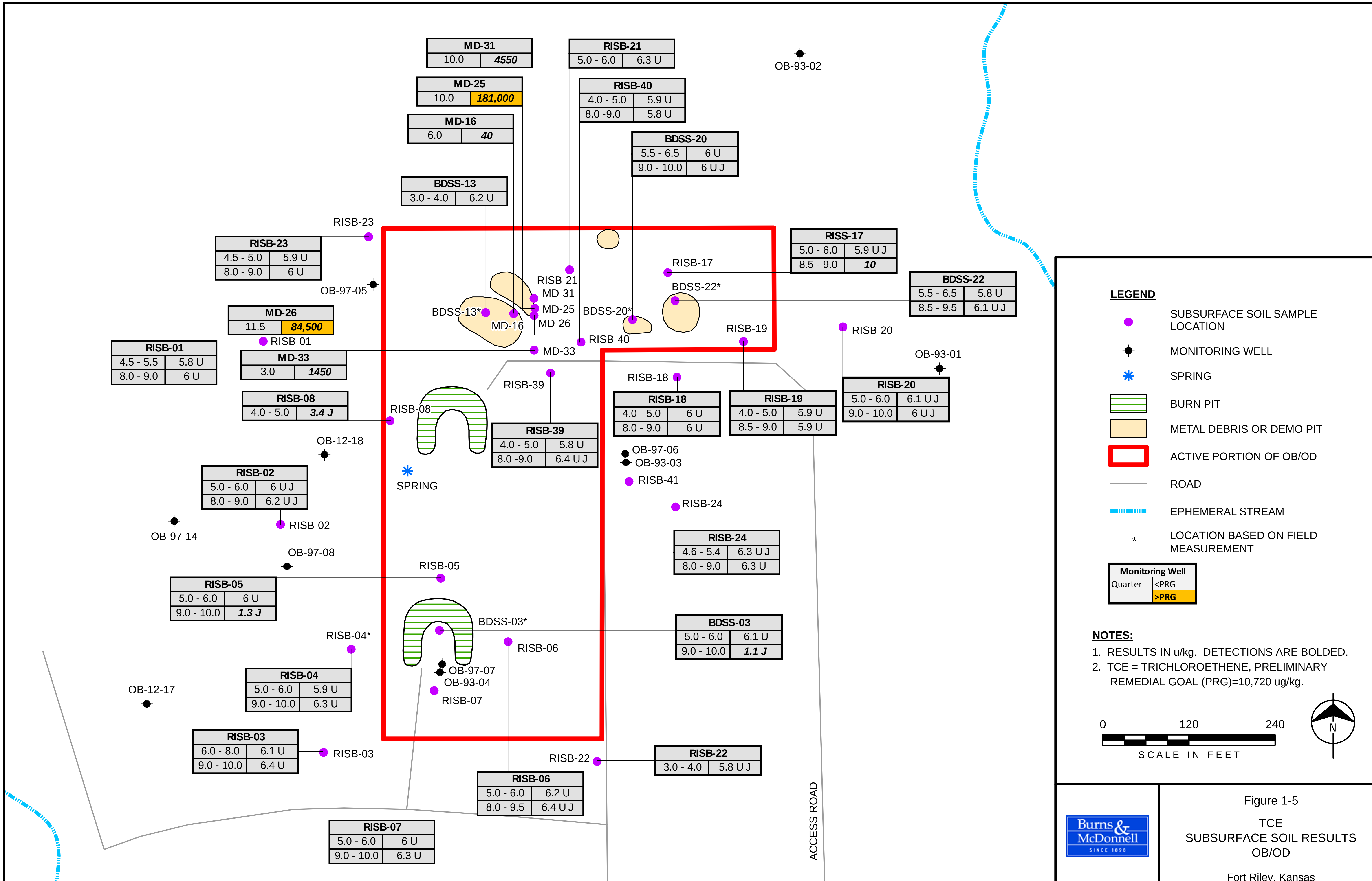



Figure 1-5

TCE SUBSURFACE SOIL RESULTS OB/OD

Fort Riley, Kansas



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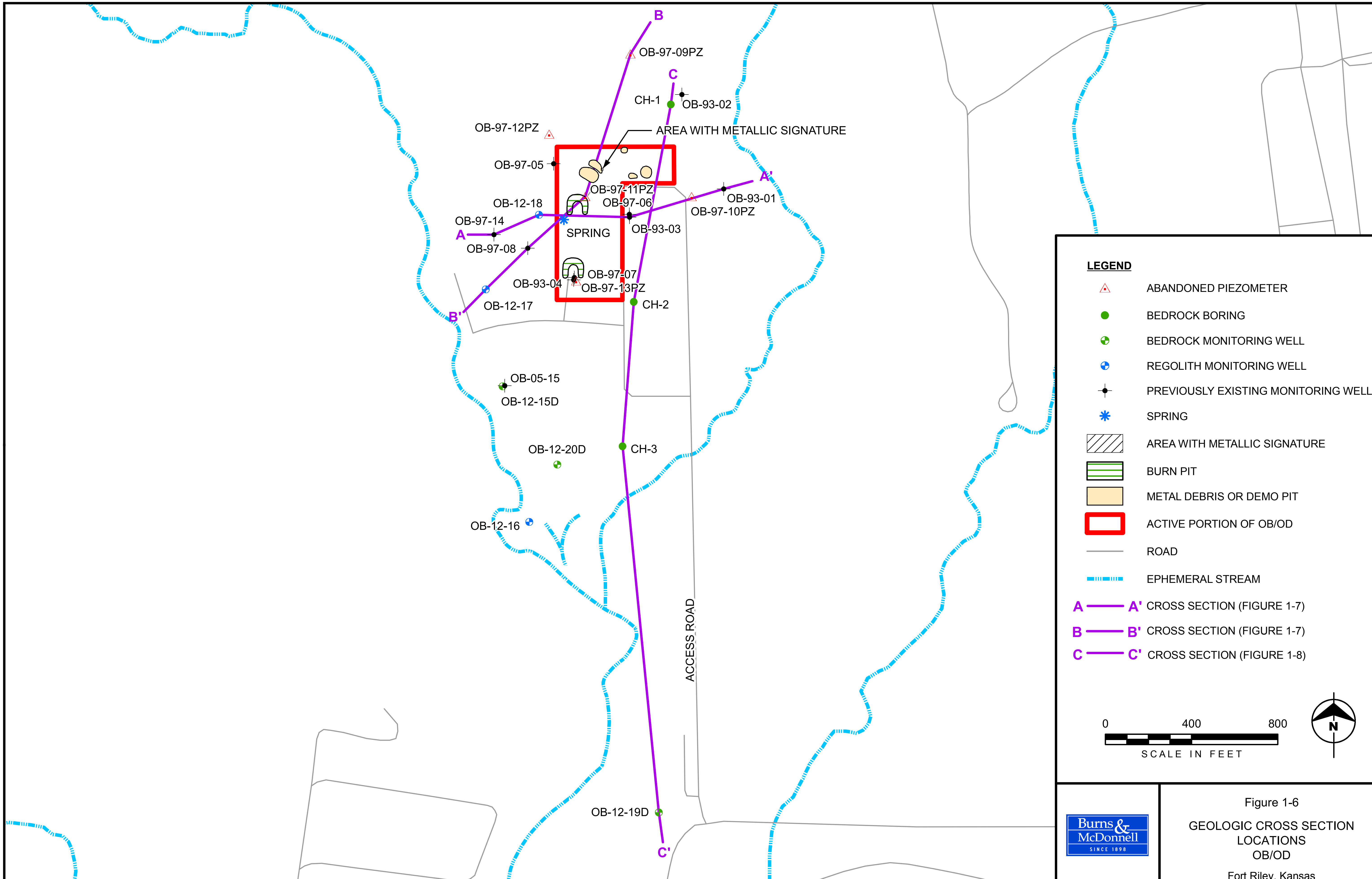


Figure 1-6

GEOLOGIC CROSS SECTION LOCATIONS OB/OD

Fort Riley, Kansas



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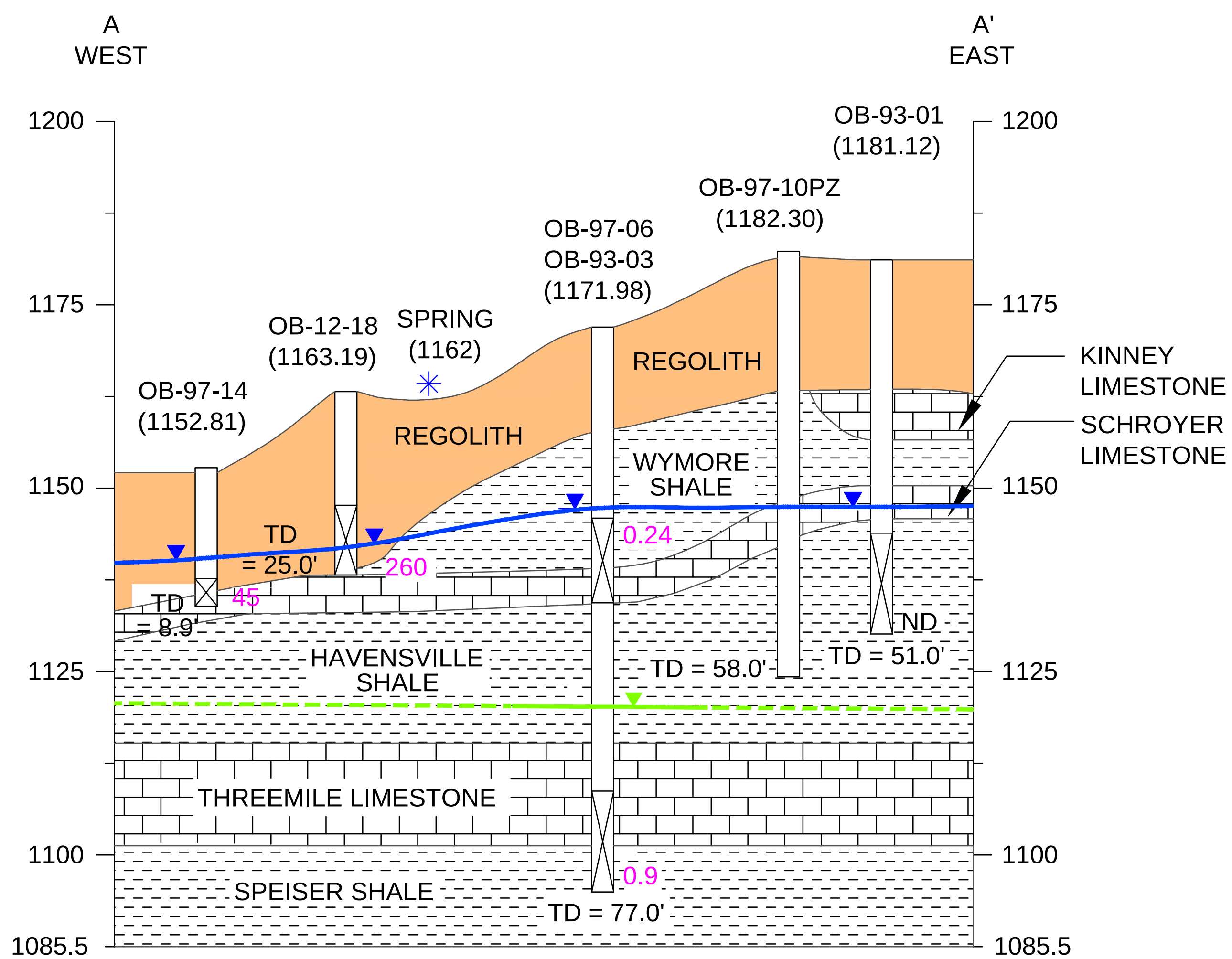
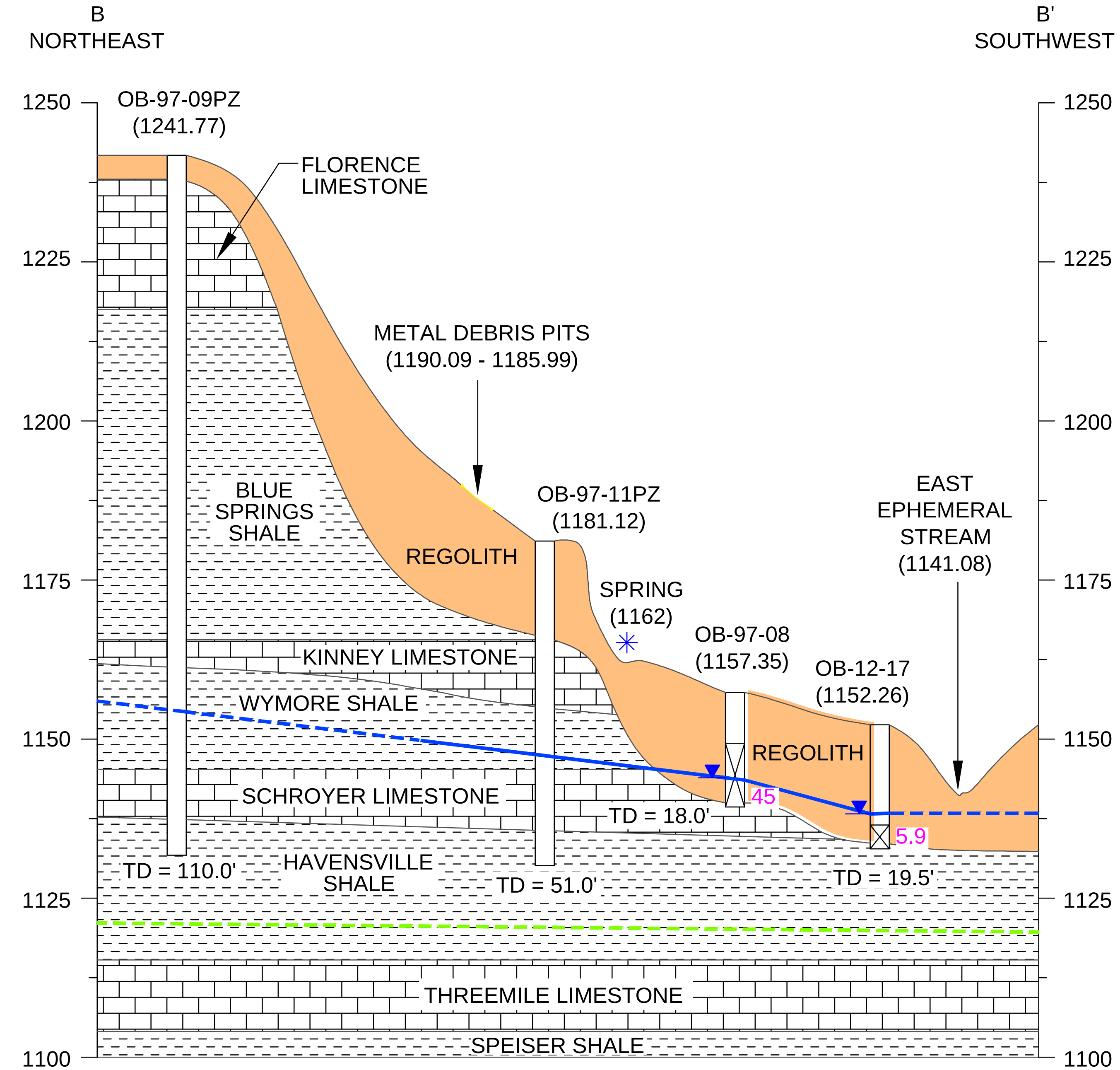



**LEGEND:**

| | |
|---|---|
| □ | WELL OR BORING |
| ☒ | SCREEN INTERVAL |
| 45 | TCE IN µg/L, JUNE 2012 |
| (orange fill) | REGOLITH |
| (brick pattern) | LIMESTONE |
| (dashed pattern) | SHALE |
| OB-93-03 (1171.98) | GROUND SURFACE ELEVATION IN FT ABOVE MEAN SEA LEVEL (MSL) |
| (blue line) | PIEZOMETRIC SURFACE - REGOLITH/WEATHERED BEDROCK (DASHED WHERE INFERRED) |
| (green line) | PIEZOMETRIC SURFACE - THREEMILE LIMESTONE (DASHED WHERE INFERRED) |

**NOTE:**

1. WATER LEVELS OBSERVED FOR JUNE 2012.

HORIZONTAL 0 300' 600' SCALE IN FEET

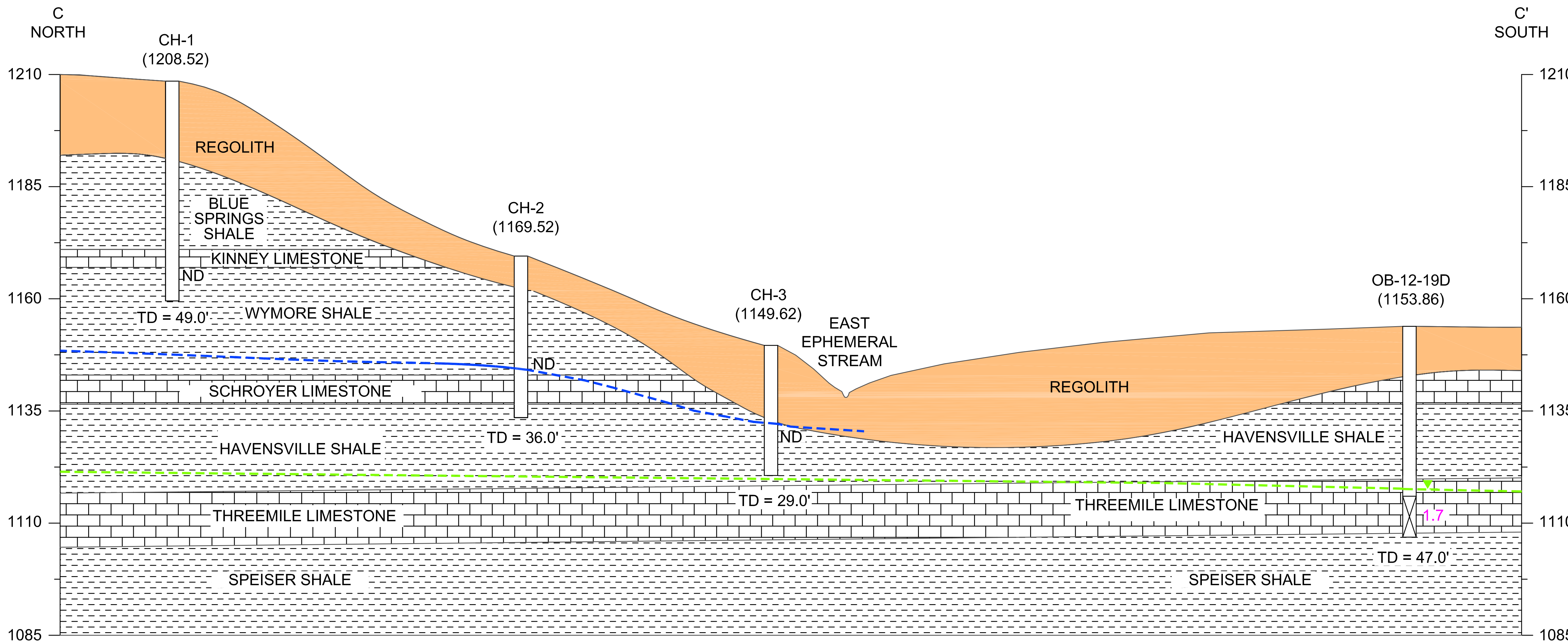
VERTICAL 0 25' 50' SCALE IN FEET

Burns & McDonnell SINCE 1898

Figure 1-7

GEOLOGIC CROSS SECTIONS
A - A' AND B - B'
OB/OD

Fort Riley, Kansas




**LEGEND:**

WELL OR BORING

SCREEN INTERVAL

45 TCE IN µg/L, JUNE 2012

REGOLITH

LIMESTONE

SHALE

CH-1 (1208.52) GROUND SURFACE ELEVATION IN FT ABOVE MEAN SEA LEVEL (MSL)

PIEZOMETRIC SURFACE - REGOLITH/WEATHERED BEDROCK (DASHED WHERE INFERRED)

PIEZOMETRIC SURFACE - THREEMILE LIMESTONE (DASHED WHERE INFERRED)

**NOTE:**

1. WATER LEVLELS OBSERVED FOR JUNE 2012.

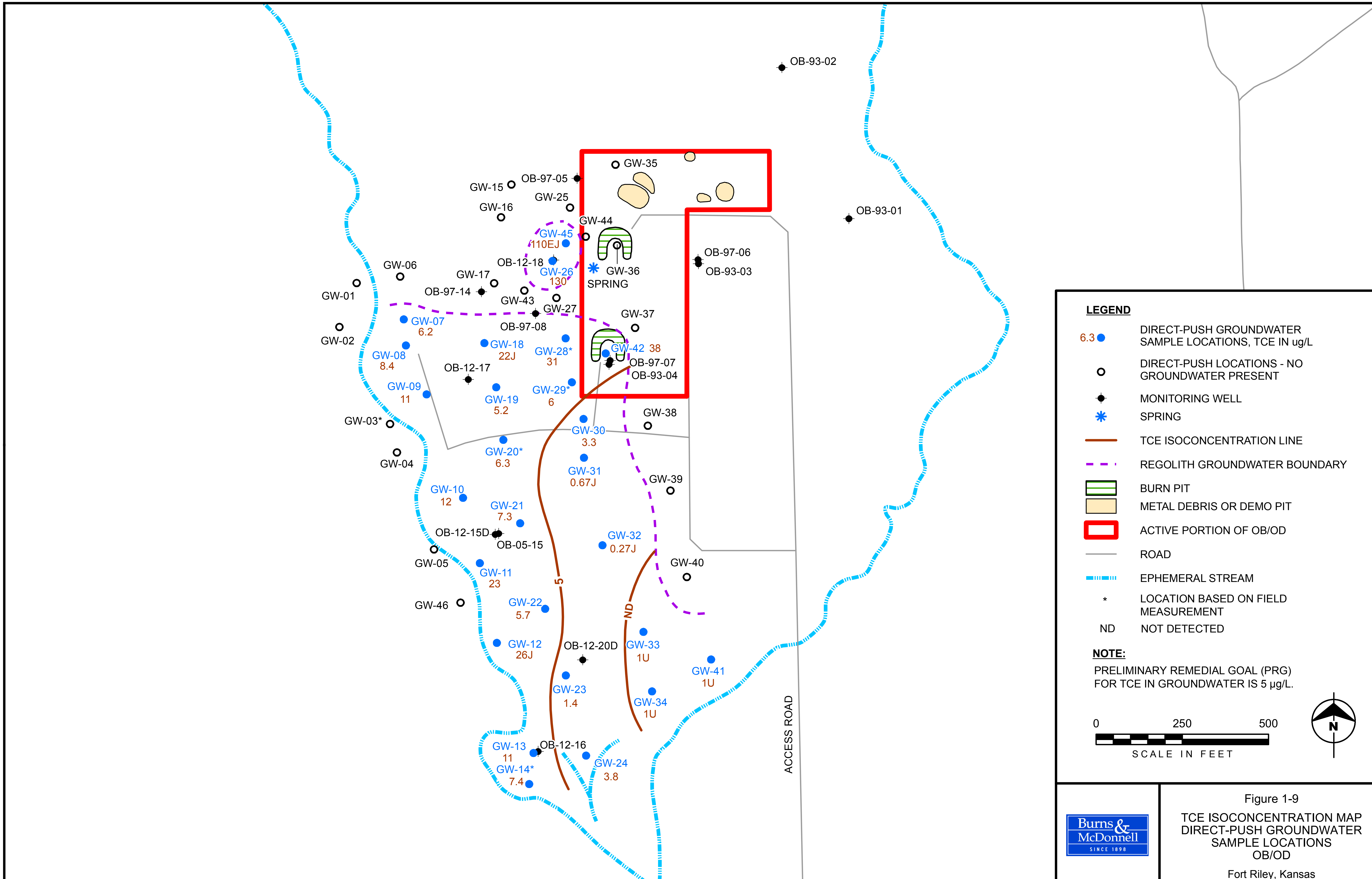
**HORIZONTAL** 0 300' 600' SCALE IN FEET

**VERTICAL** 0 25' 50' SCALE IN FEET

Burns & McDonnell SINCE 1898

Figure 1-8

GEOLOGIC CROSS SECTION
C - C'
OB/OD
Fort Riley, Kansas



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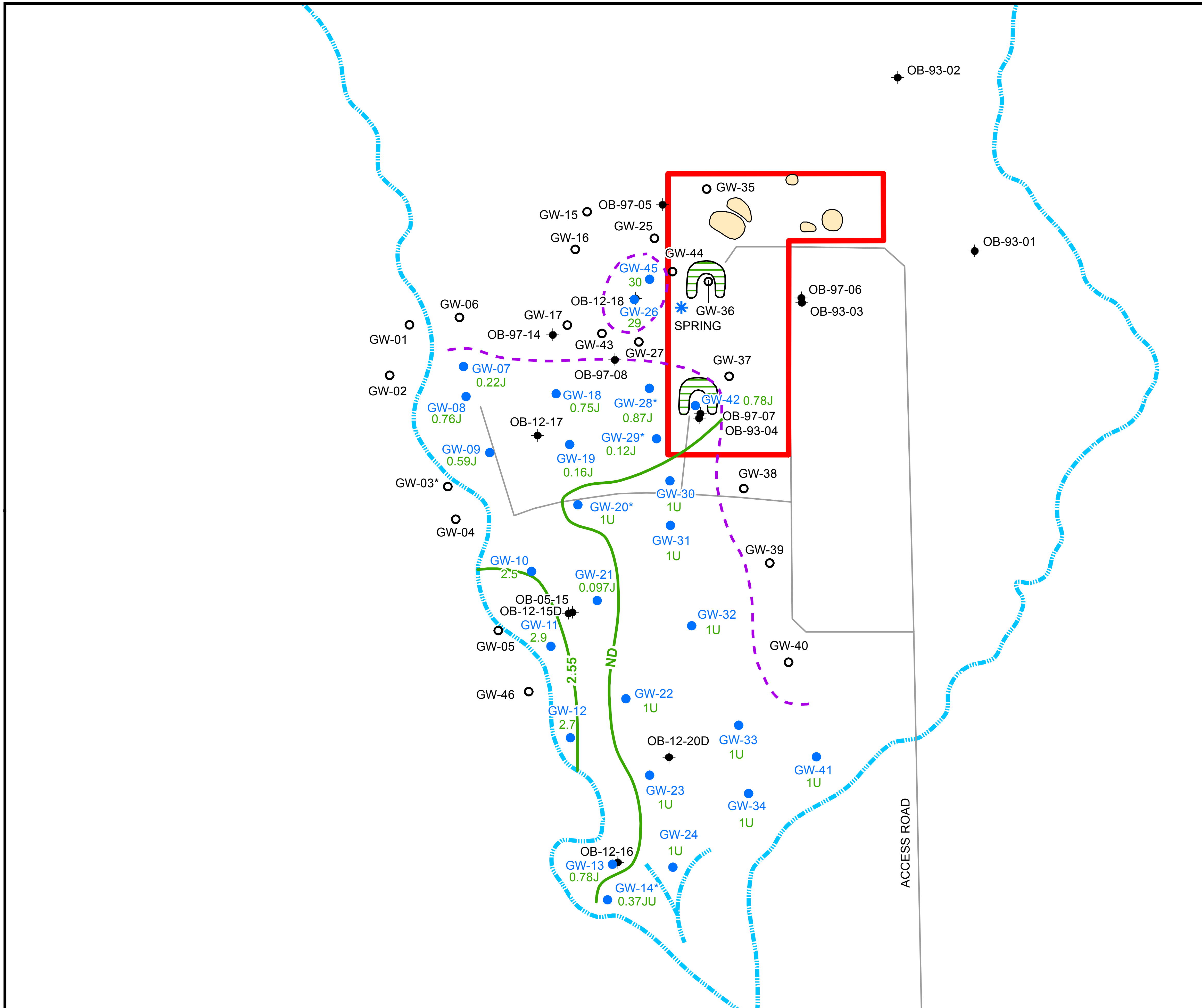



**LEGEND**

| | |
|---|---|
| 2.5 ● | DIRECT-PUSH GROUNDWATER SAMPLE LOCATIONS, PCA IN ug/L |
| ○ | DIRECT-PUSH LOCATIONS - NO GROUNDWATER PRESENT |
| | MONITORING WELL |
| ✱ | SPRING |
| | PCA ISOCONCENTRATION LINE |
| | REGOLITH GROUNDWATER BOUNDARY |
| | BURN PIT |
| | METAL DEBRIS OR DEMO PIT |
| | ACTIVE PORTION OF OB/OD |
| | ROAD |
| | EPHEMERAL STREAM |
| * | LOCATION BASED ON FIELD MEASUREMENT |
| ND | NOT DETECTED |

**NOTE:**

1. PRELIMINARY REMEDIAL GOAL (PRG) FOR PCA IN GROUNDWATER IS 2.55 μg/L.

0 250 500

SCALE IN FEET

N

Burns & McDonnell SINCE 1898

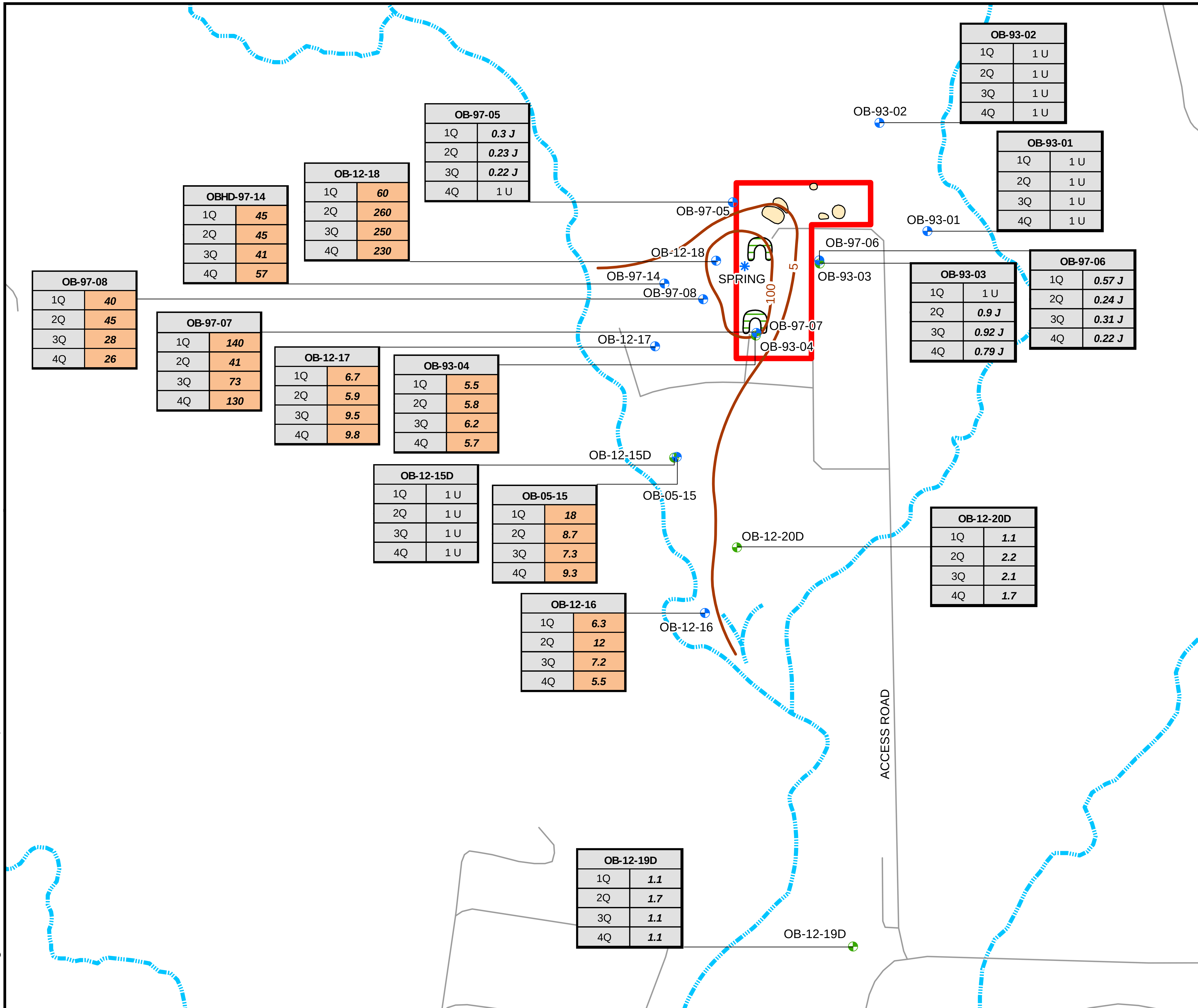
Figure 1-10

PCA ISOCONCENTRATION MAP
DIRECT-PUSH GROUNDWATER
SAMPLE LOCATIONS
OB/OD

Fort Riley, Kansas



Path: K:\ENV\LOUIS BERGER GROUP INC\site\63598\Deliver\GIS\2013\FS\Fig1-10_PCA_Isoconcentration_in_Direct-Push_GW_OBOD.mxd




| OB-93-02 | |
|---|---|
| 1Q | 1 U |
| 2Q | 1 U |
| 3Q | 1 U |
| 4Q | 1 U |

| OB-93-01 | |
|---|---|
| 1Q | 1 U |
| 2Q | 1 U |
| 3Q | 1 U |
| 4Q | 1 U |

| OB-97-05 | |
|---|---|
| 1Q | **0.3 J** |
| 2Q | **0.23 J** |
| 3Q | **0.22 J** |
| 4Q | 1 U |

| OB-12-18 | |
|---|---|
| 1Q | **60** |
| 2Q | **260** |
| 3Q | **250** |
| 4Q | **230** |

| OBHD-97-14 | |
|---|---|
| 1Q | **45** |
| 2Q | **45** |
| 3Q | **41** |
| 4Q | **57** |

| OB-97-08 | |
|---|---|
| 1Q | **40** |
| 2Q | **45** |
| 3Q | **28** |
| 4Q | **26** |

| OB-97-07 | |
|---|---|
| 1Q | **140** |
| 2Q | **41** |
| 3Q | **73** |
| 4Q | **130** |

| OB-12-17 | |
|---|---|
| 1Q | **6.7** |
| 2Q | **5.9** |
| 3Q | **9.5** |
| 4Q | **9.8** |

| OB-93-04 | |
|---|---|
| 1Q | **5.5** |
| 2Q | **5.8** |
| 3Q | **6.2** |
| 4Q | **5.7** |

| OB-93-03 | |
|---|---|
| 1Q | 1 U |
| 2Q | **0.9 J** |
| 3Q | **0.92 J** |
| 4Q | **0.79 J** |

| OB-97-06 | |
|---|---|
| 1Q | **0.57 J** |
| 2Q | **0.24 J** |
| 3Q | **0.31 J** |
| 4Q | **0.22 J** |

| OB-12-15D | |
|---|---|
| 1Q | 1 U |
| 2Q | 1 U |
| 3Q | 1 U |
| 4Q | 1 U |

| OB-05-15 | |
|---|---|
| 1Q | **18** |
| 2Q | **8.7** |
| 3Q | **7.3** |
| 4Q | **9.3** |

| OB-12-20D | |
|---|---|
| 1Q | **1.1** |
| 2Q | **2.2** |
| 3Q | **2.1** |
| 4Q | **1.7** |

| OB-12-16 | |
|---|---|
| 1Q | **6.3** |
| 2Q | **12** |
| 3Q | **7.2** |
| 4Q | **5.5** |

| OB-12-19D | |
|---|---|
| 1Q | **1.1** |
| 2Q | **1.7** |
| 3Q | **1.1** |
| 4Q | **1.1** |

**LEGEND**

- REGOLITH/WEATHERED BEDROCK MONITORING WELL
- BEDROCK MONITORING WELL
- SPRING
- TCE ISOCONCENTRATION LINES
- BURN PIT
- METAL DEBRIS OR DEMO PIT
- ACTIVE PORTION OF OB/OD
- ROAD
- EPHEMERAL STREAM

| Monitoring Well | |
|---|---|
| Quarter | <PRG |
| | >PRG |

**NOTES:**

1. ALL RESULTS IN u/L. DETECTIONS ARE BOLD.
2. THE PRELIMINARY REMEDIATION GOAL (PRG) FOR TCE IS 5.0 ug/L.
3. ISOCONCENTRATION CONTOURS BASED ON AVERAGE RESULT FOR FOUR QUARTERS FOR THE REGOLITH/WEATHERED BEDROCK AQUIFER.

0 400 800
SCALE IN FEET

N

Burns & McDonnell SINCE 1898

Figure 1-11

QUARTERLY TCE DETECTIONS GROUNDWATER OB/OD

Fort Riley, Kansas



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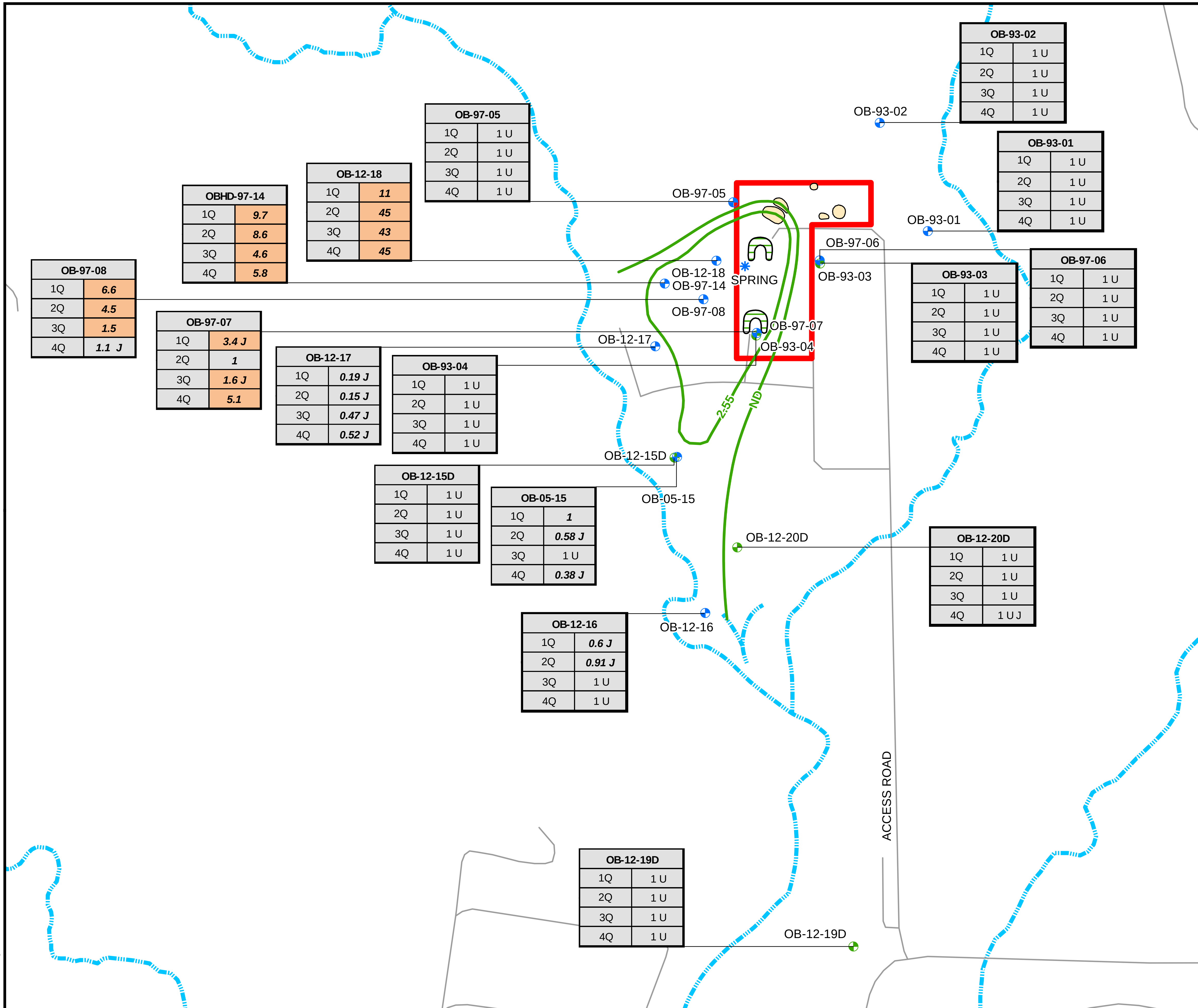


| OB-93-02 | |
|---|---|
| 1Q | 1 U |
| 2Q | 1 U |
| 3Q | 1 U |
| 4Q | 1 U |

| OB-97-05 | |
|---|---|
| 1Q | 1 U |
| 2Q | 1 U |
| 3Q | 1 U |
| 4Q | 1 U |

| OB-93-01 | |
|---|---|
| 1Q | 1 U |
| 2Q | 1 U |
| 3Q | 1 U |
| 4Q | 1 U |

| OB-12-18 | |
|---|---|
| 1Q | ***11*** |
| 2Q | ***45*** |
| 3Q | ***43*** |
| 4Q | ***45*** |

| OBHD-97-14 | |
|---|---|
| 1Q | ***9.7*** |
| 2Q | ***8.6*** |
| 3Q | ***4.6*** |
| 4Q | ***5.8*** |

| OB-97-08 | |
|---|---|
| 1Q | ***6.6*** |
| 2Q | ***4.5*** |
| 3Q | ***1.5*** |
| 4Q | ***1.1 J*** |

| OB-97-06 | |
|---|---|
| 1Q | 1 U |
| 2Q | 1 U |
| 3Q | 1 U |
| 4Q | 1 U |

| OB-93-03 | |
|---|---|
| 1Q | 1 U |
| 2Q | 1 U |
| 3Q | 1 U |
| 4Q | 1 U |

| OB-97-07 | |
|---|---|
| 1Q | ***3.4 J*** |
| 2Q | ***1*** |
| 3Q | ***1.6 J*** |
| 4Q | ***5.1*** |

| OB-12-17 | |
|---|---|
| 1Q | ***0.19 J*** |
| 2Q | ***0.15 J*** |
| 3Q | ***0.47 J*** |
| 4Q | ***0.52 J*** |

| OB-93-04 | |
|---|---|
| 1Q | 1 U |
| 2Q | 1 U |
| 3Q | 1 U |
| 4Q | 1 U |

| OB-12-15D | |
|---|---|
| 1Q | 1 U |
| 2Q | 1 U |
| 3Q | 1 U |
| 4Q | 1 U |

| OB-05-15 | |
|---|---|
| 1Q | ***1*** |
| 2Q | ***0.58 J*** |
| 3Q | 1 U |
| 4Q | ***0.38 J*** |

| OB-12-20D | |
|---|---|
| 1Q | 1 U |
| 2Q | 1 U |
| 3Q | 1 U |
| 4Q | 1 U J |

| OB-12-16 | |
|---|---|
| 1Q | ***0.6 J*** |
| 2Q | ***0.91 J*** |
| 3Q | 1 U |
| 4Q | 1 U |

| OB-12-19D | |
|---|---|
| 1Q | 1 U |
| 2Q | 1 U |
| 3Q | 1 U |
| 4Q | 1 U |

**LEGEND**

- REGOLITH/WEATHERED BEDROCK MONITORING WELL
- BEDROCK MONITORING WELL
- SPRING
- PCA ISOCONCENTRATION LINE
- BURN PIT
- METAL DEBRIS OR DEMO PIT
- ACTIVE PORTION OF OB/OD
- ROAD
- EPHEMERAL STREAM
- ND NOT DETECTED

| Monitoring Well | |
|---|---|
| Quarter | <PRG |
| | **>PRG** |

**NOTES:**

1. ALL RESULTS IN ug/L. DETECTIONS ARE BOLD.
2. THE PRELIMINARY REMEDIAL GOAL (PRG) FOR PCA IS 2.55 ug/L.
3. ISOCONCENTRATION CONTOURS BASED ON AVERAGE RESULT FOR FOUR QUARTERS FOR THE REGOLITH/WEATHERED BEDROCK AQUIFER.

0 400 800
SCALE IN FEET

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Figure 1-12

QUARTERLY PCA DETECTIONS GROUNDWATER OB/OD

Fort Riley, Kansas



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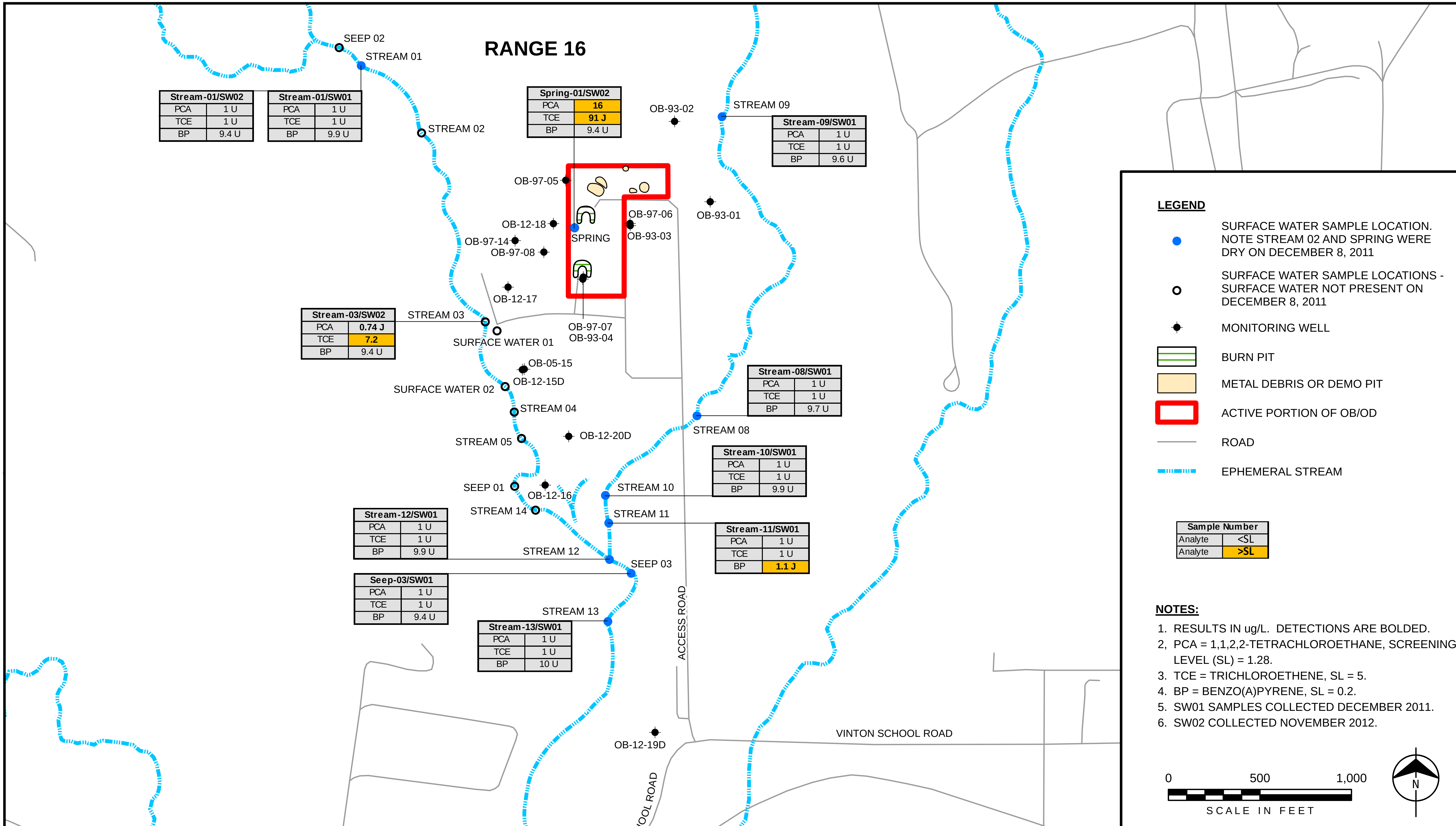


Figure 1-13
SURFACE WATER SAMPLE EXCEEDANCES
DECEMBER 2011 AND MARCH 2012
OB/OD
Fort Riley, Kansas



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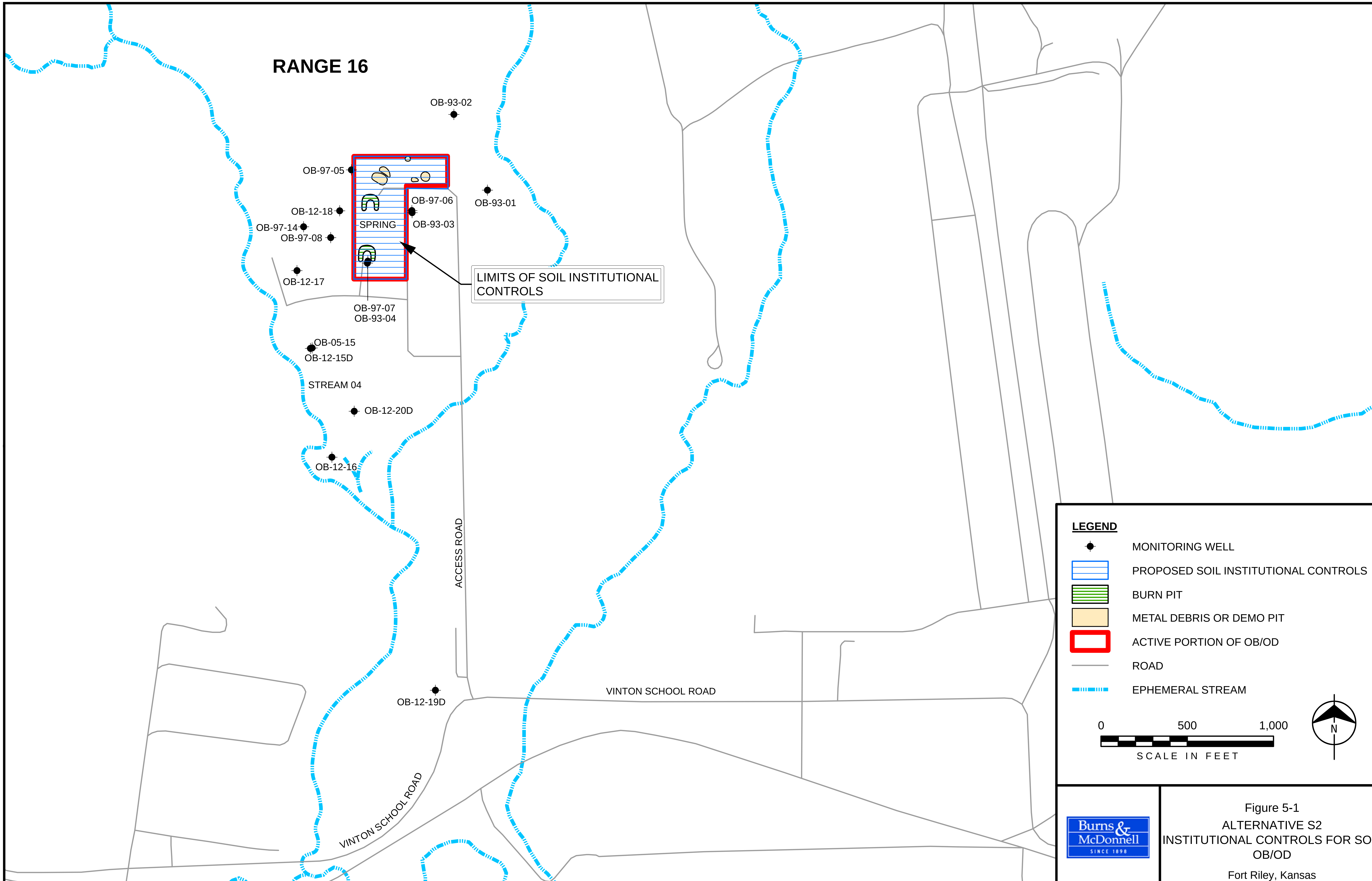


Figure 5-1
ALTERNATIVE S2
INSTITUTIONAL CONTROLS FOR SOIL
OB/OD
Fort Riley, Kansas



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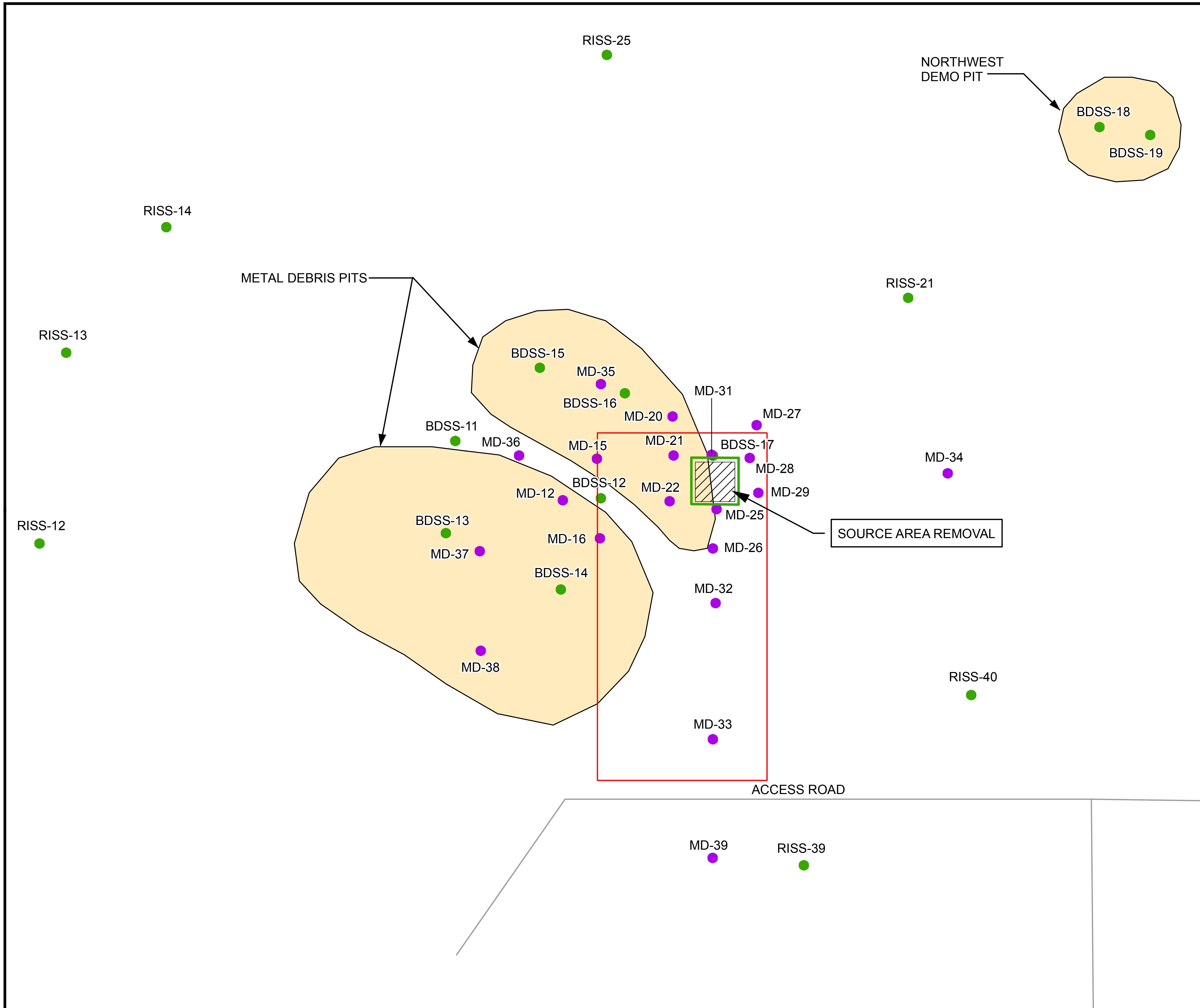


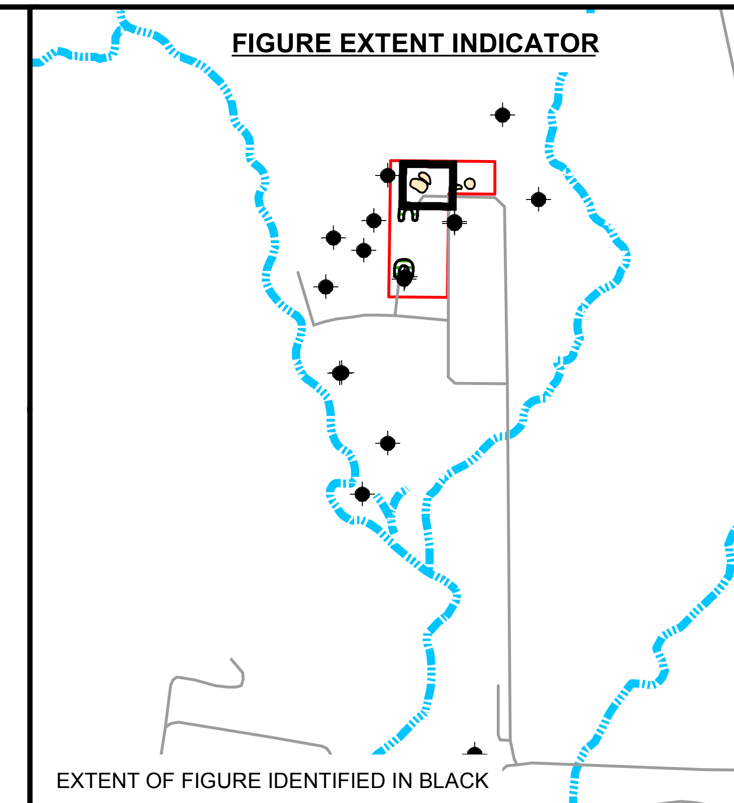


**LEGEND**

- SOURCE AREA REMOVAL
- SOIL EXCAVATION (GENERAL)
- 2011 SOIL SAMPLE LOCATION
- 2013 SOIL SAMPLE LOCATION
- AREA WITH METALLIC SIGNATURE
- METAL DEBRIS OR DEMO PIT
- ROAD

**NOTE:**

METAL DEBRIS AND DEMO PIT LOCATIONS PROVIDED BY THE INSTALLATION.

0 25 50
SCALE IN FEET

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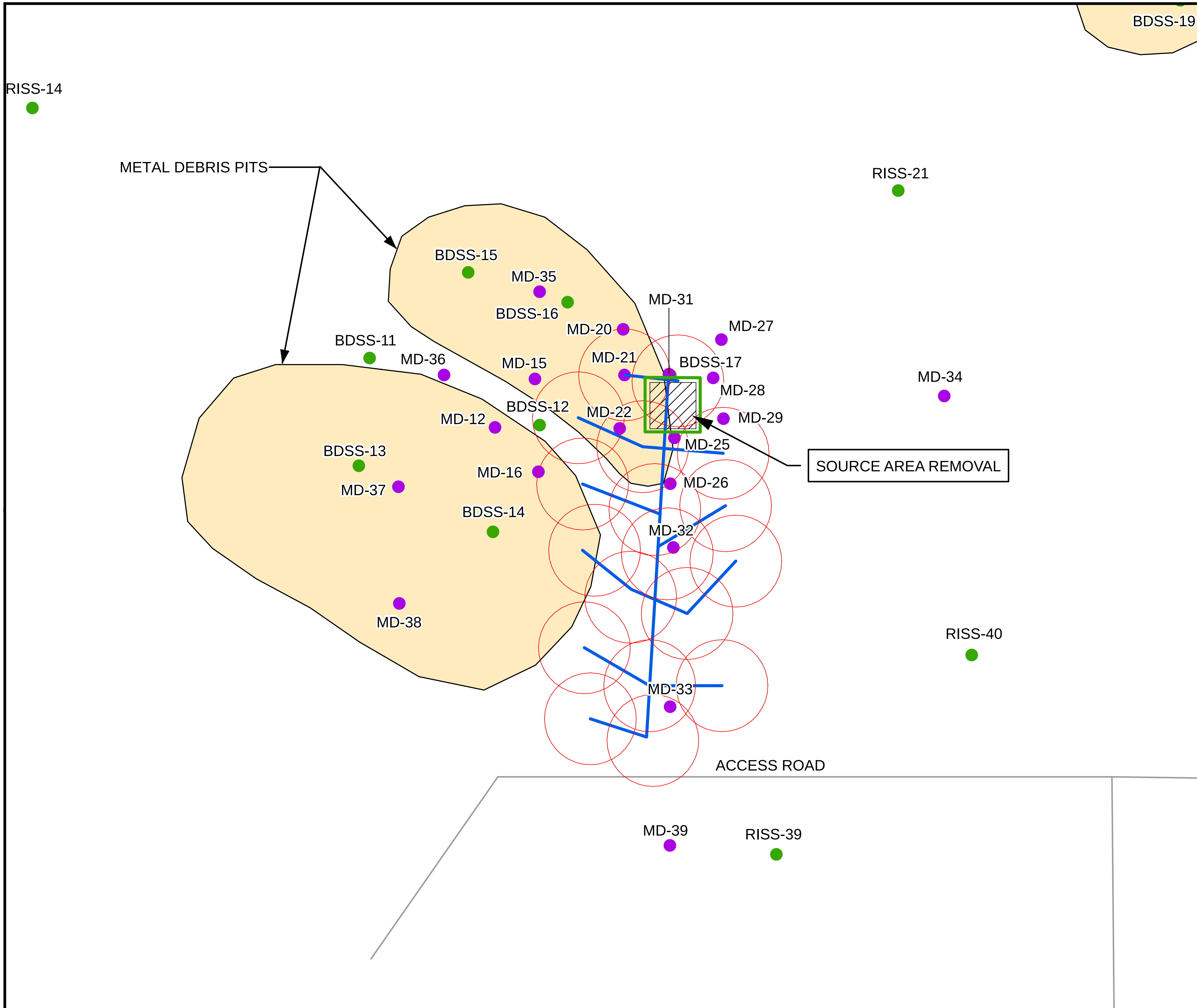
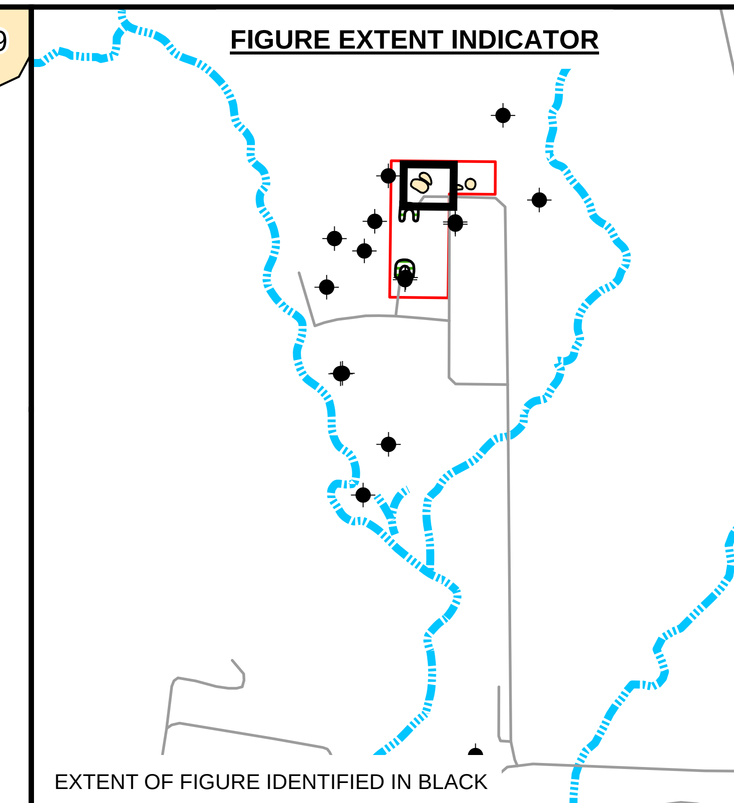
SINCE 1898

Figure 5-2
ALTERNATIVE S3
EX-SITU PHYSICAL TREATMENT
FOR SOIL
OB/OD
Fort Riley, Kansas



Path: K:\ENV\LOUIS BERGER GROUP INC\site\63598\Deliver\GIS\2013\FS\Fig5-2_Alt 3 - Ex Situ Soil Removal.mxd




**LEGEND**

- SOURCE AREA REMOVAL
- PROPOSED RADIUS OF INFLUENCE
- SVE PIPING
- 2011 SOIL SAMPLE LOCATION
- 2013 SOIL SAMPLE LOCATION
- AREA WITH METALLIC SIGNATURE
- METAL DEBRIS OR DEMO PIT
- ROAD

**NOTE:**

METAL DEBRIS AND DEMO PIT LOCATIONS PROVIDED BY THE INSTALLATION.

0 25 0

SCALE IN FEET

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Figure 5-3
ALTERNATIVE S4
IN-SITU TREATMENT FOR SOIL
SOILVAPOR EXTRACTION
OB/OD
Fort Riley, Kansas



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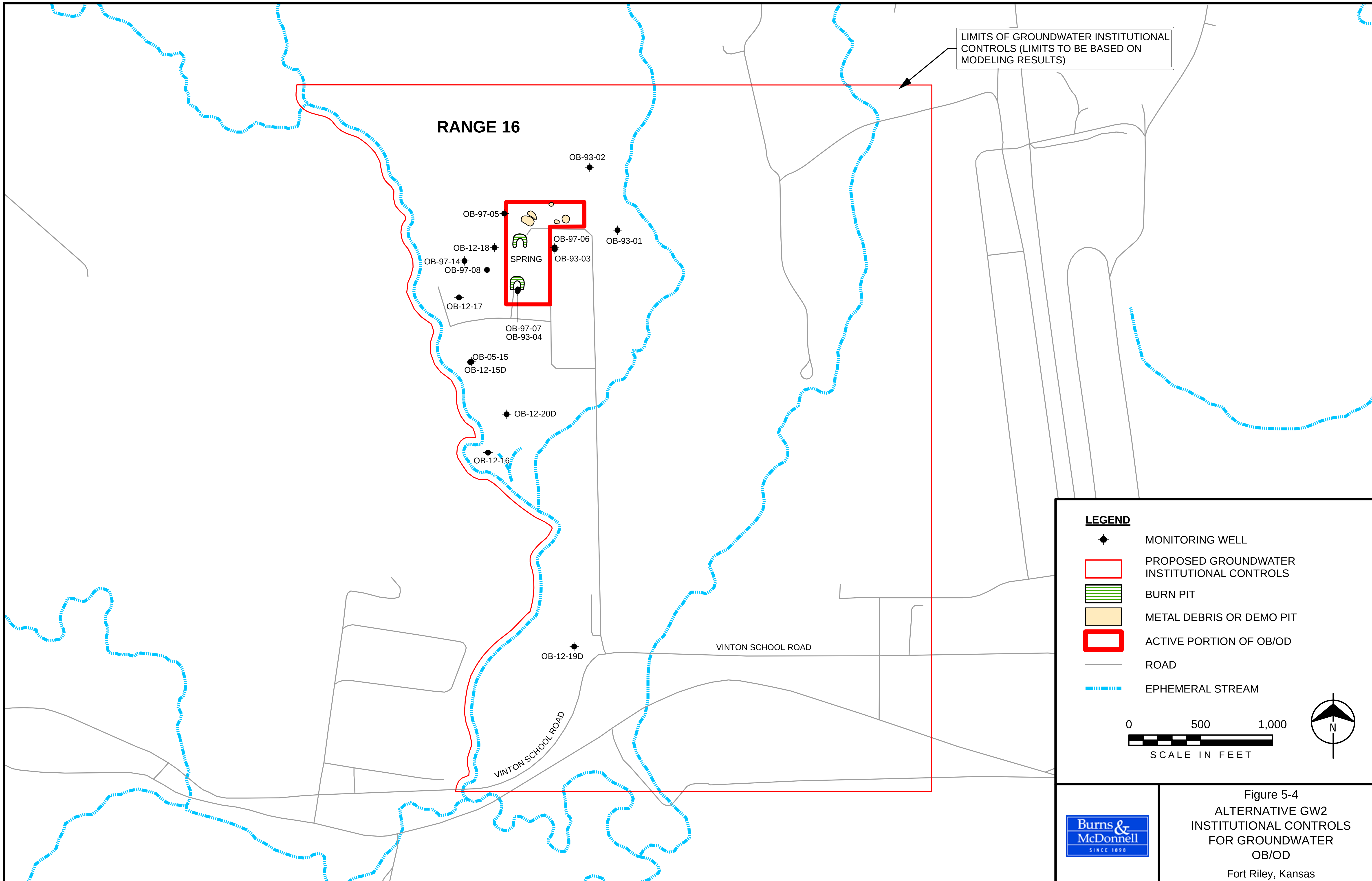


Figure 5-4
ALTERNATIVE GW2 INSTITUTIONAL CONTROLS FOR GROUNDWATER OB/OD
Fort Riley, Kansas



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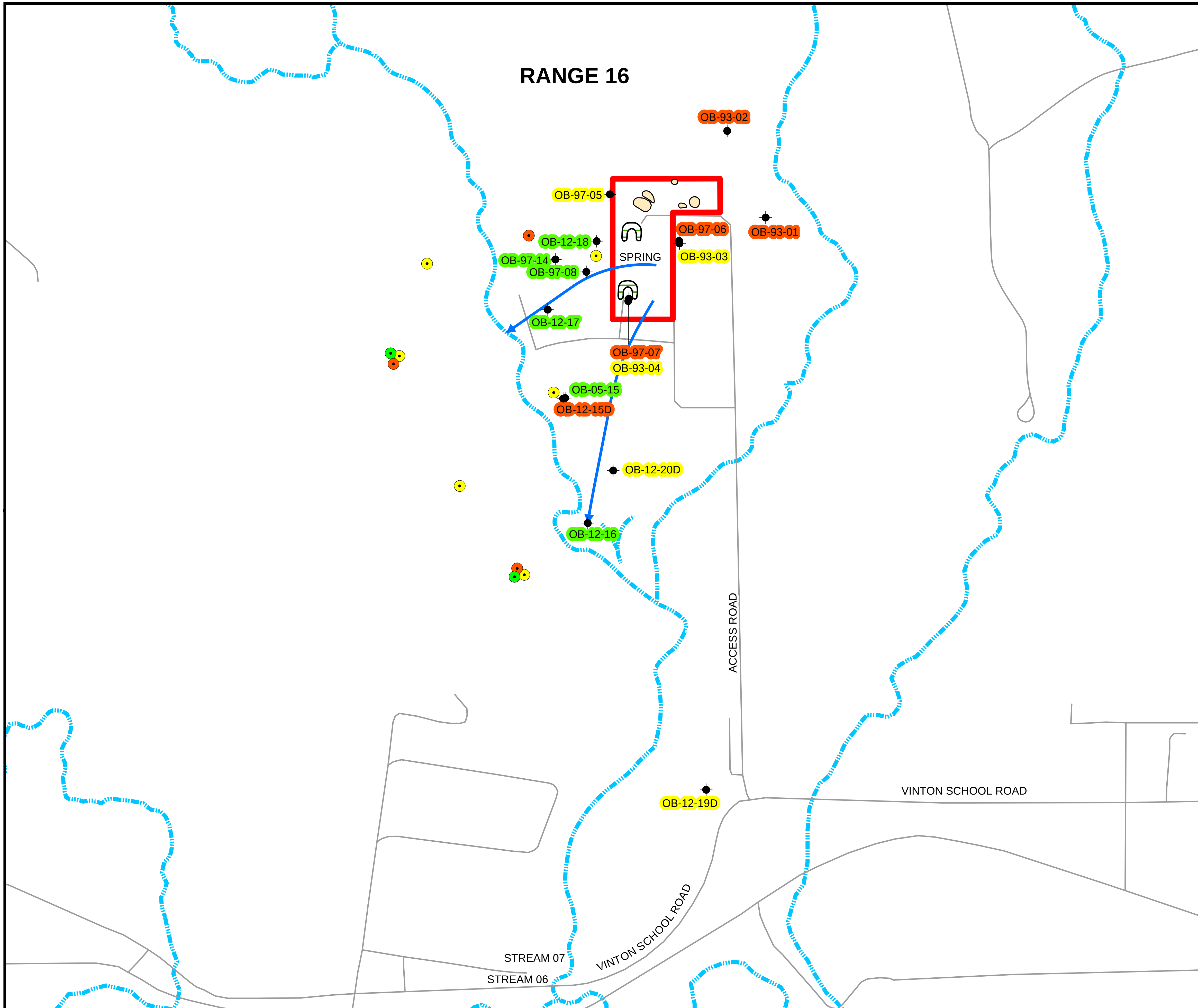


| Monitoring Well Network | | |
|---|---|---|
| Formation | Existing | Proposed |
| Regolith | 6 | 2 |
| Weathered Bedrock | 6 | 3 |
| Deep Bedrock | 5 | 6 |

**LEGEND**

- PROPOSED DEEP BEDROCK WELL
- PROPOSED REGOLITH WELL
- PROPOSED WEATHERED BEDROCK WELL
- MONITORING WELL
- APPROXIMATE DIRECTION OF GROUNDWATER FLOW
- BURN PIT
- METAL DEBRIS OR DEMO PIT
- ACTIVE PORTION OF OB/OD
- ROAD
- EPHEMERAL STREAM

**NOTES**

1. LOCATION OF PROPOSED MONITORING WELLS ARE APPROXIMATE AND MAY BE ADJUSTED TO ACCOUNT FOR FIELD CONDITIONS.
2. EXISTING MONITORING WELL LABELS ARE SHADED TO IDENTIFY SCREENED INTERVAL.

0 500 1,000

SCALE IN FEET

N

Burns & McDonnell SINCE 1898

Figure 5-5

ALTERNATIVE GW3
GROUNDWATER MONITORING
OB/OD

Fort Riley, Kansas



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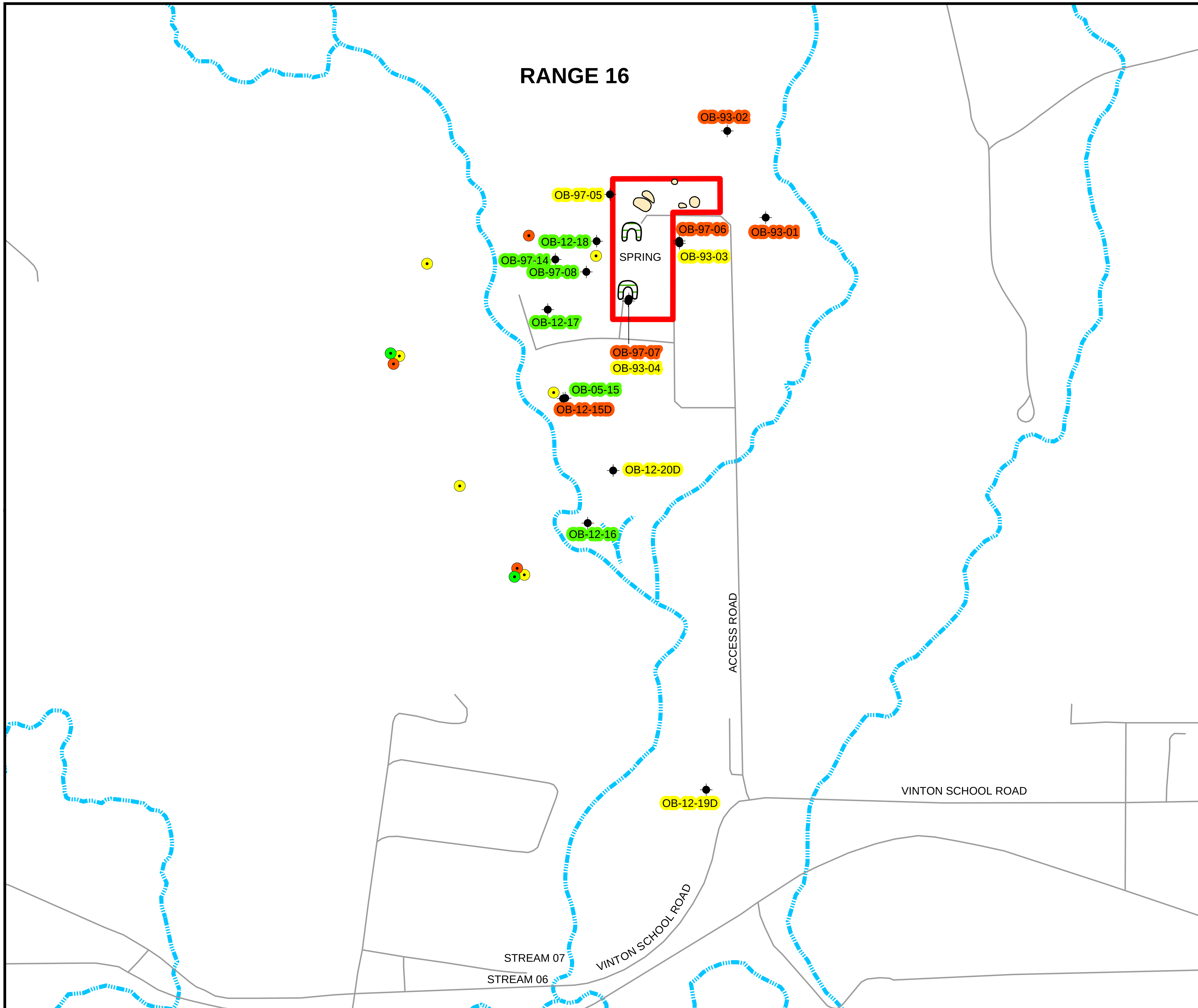


| Monitoring Well Network | | |
|---|---|---|
| Formation | Existing | Proposed |
| Regolith | 6 | 2 |
| Weathered Bedrock | 6 | 3 |
| Deep Bedrock | 5 | 6 |

**LEGEND**

- PROPOSED DEEP BEDROCK WELL
- PROPOSED REGOLITH WELL
- PROPOSED WEATHERED BEDROCK WELL
- MONITORING WELL
- BURN PIT
- METAL DEBRIS OR DEMO PIT
- ACTIVE PORTION OF OB/OD
- ROAD
- EPHEMERAL STREAM

**NOTES**

1. LOCATION OF PROPOSED MONITORING WELLS ARE APPROXIMATE AND MAY BE ADJUSTED TO ACCOUNT FOR FIELD CONDITIONS.
2. EXISTING MONITORING WELL LABELS ARE SHADED TO IDENTIFY SCREENED INTERVAL.

0 500 1,000

SCALE IN FEET

N

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Figure 5-6
ALTERNATIVE GW4
MONITORING NATURAL ATTENUATION
OB/OD
Fort Riley, Kansas



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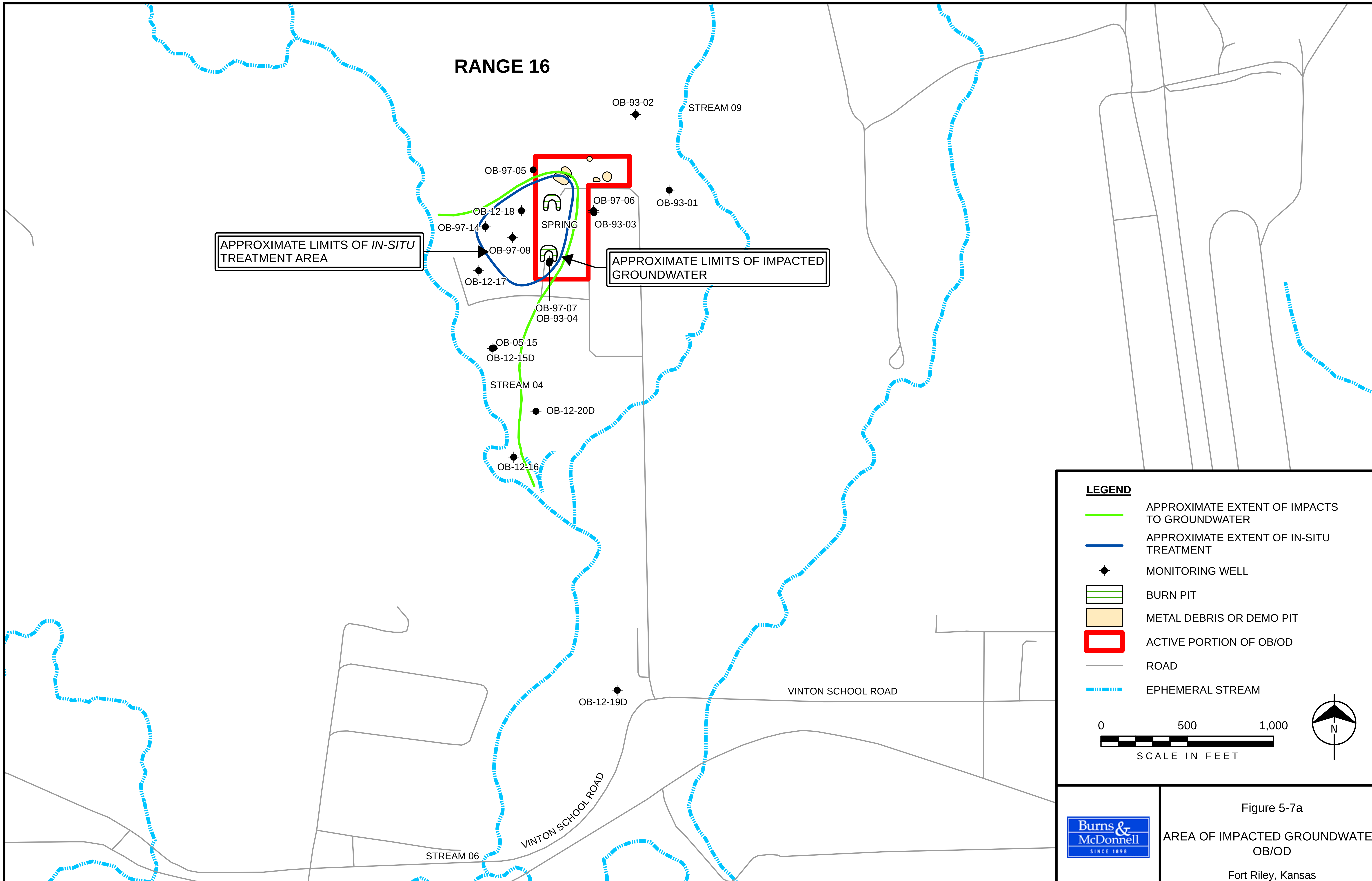


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Figure 5-7a

AREA OF IMPACTED GROUNDWATER OB/OD

Fort Riley, Kansas



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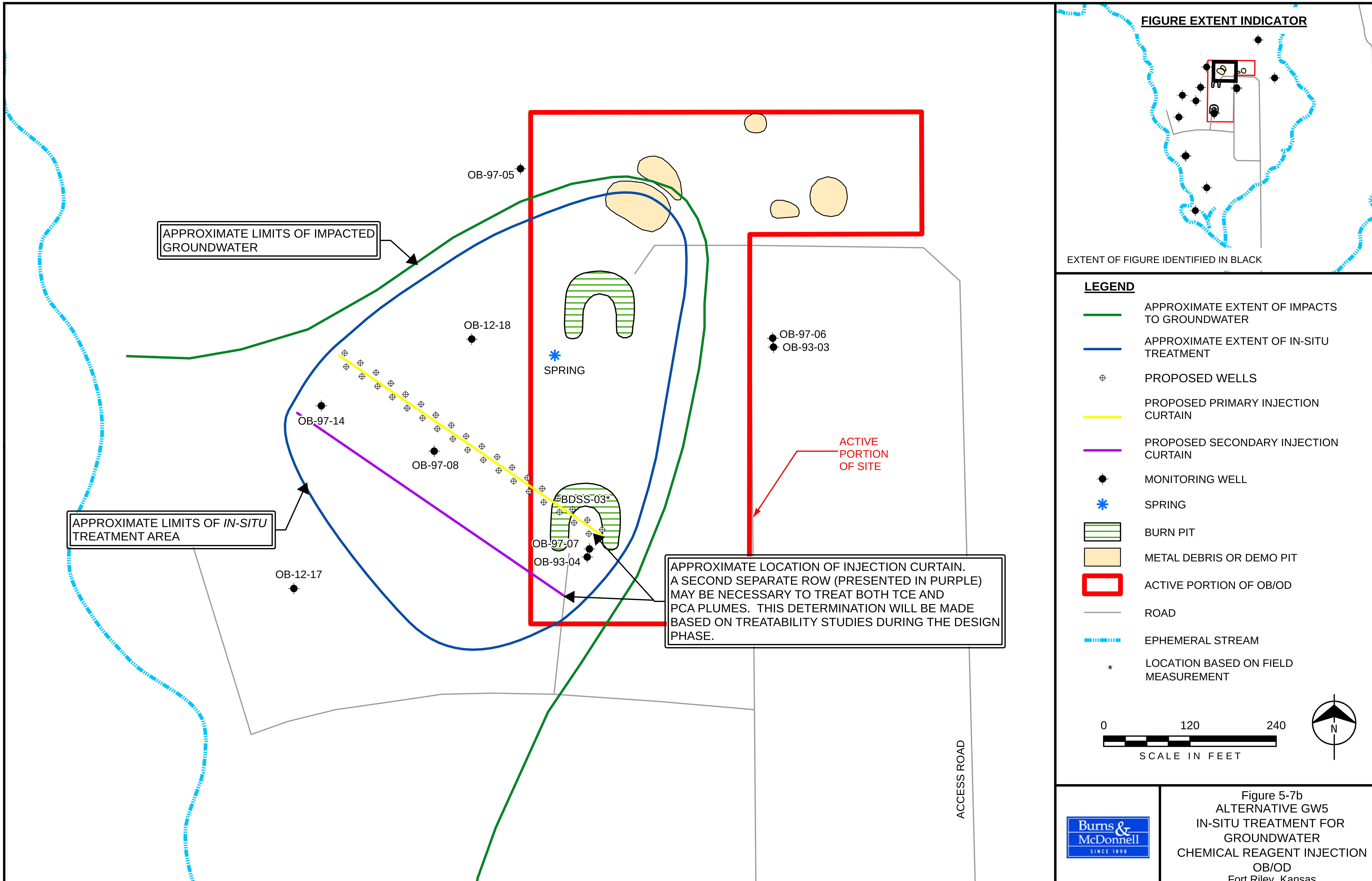




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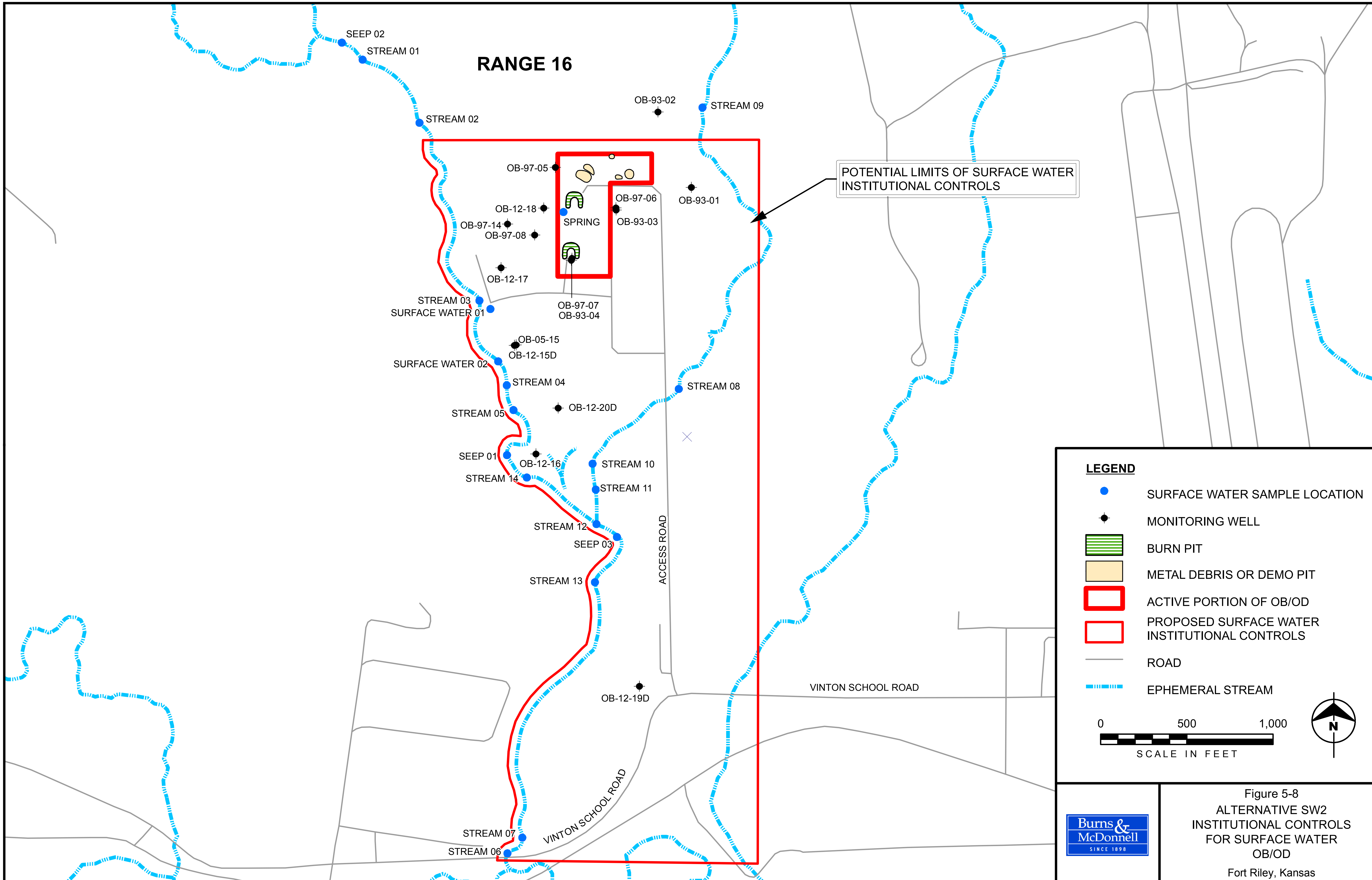


Figure 5-8
ALTERNATIVE SW2
INSTITUTIONAL CONTROLS
FOR SURFACE WATER
OB/OD
Fort Riley, Kansas

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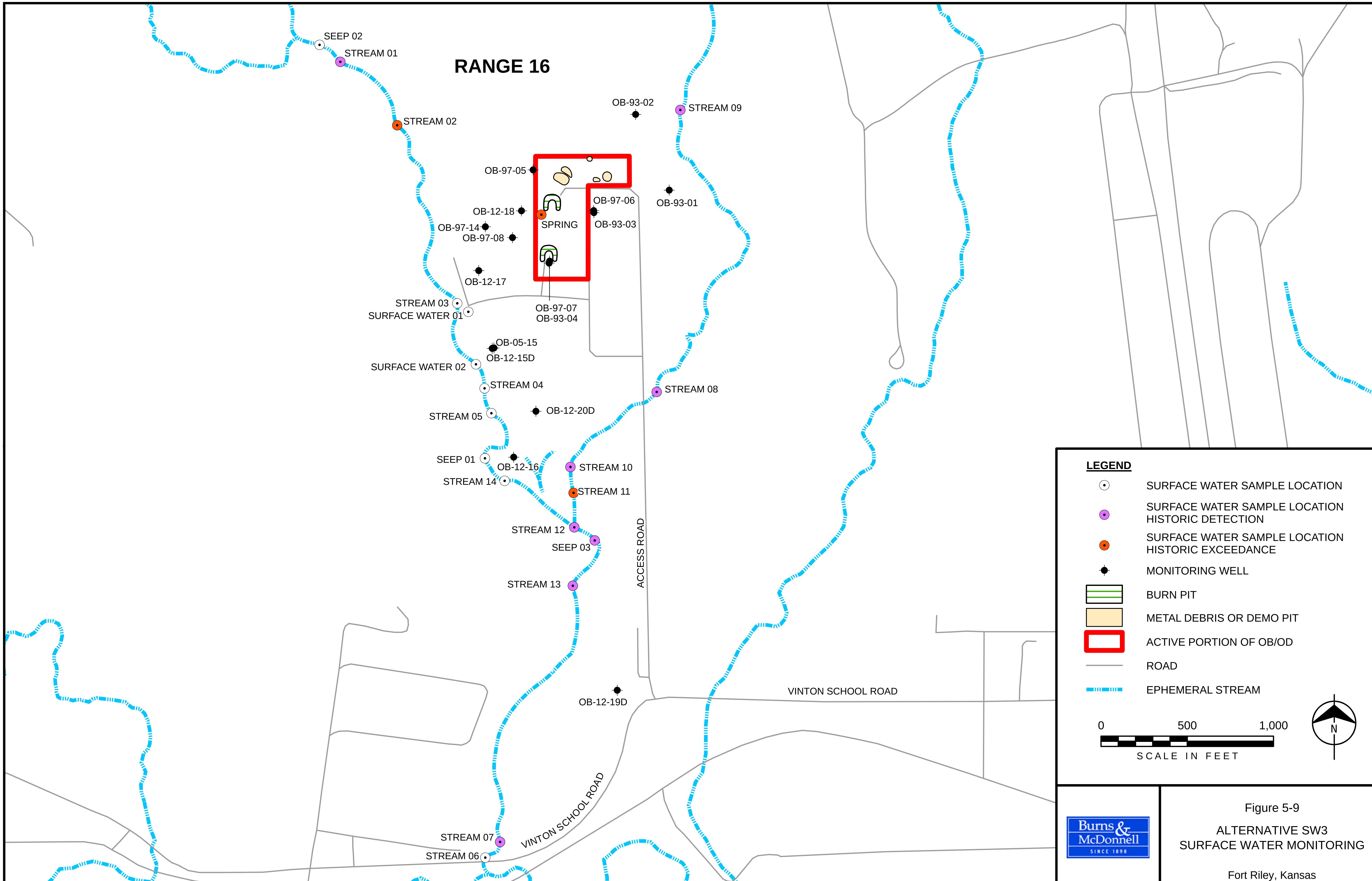


Burns & McDonnell SINCE 1898

Figure 5-9

ALTERNATIVE SW3
SURFACE WATER MONITORING

Fort Riley, Kansas



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# APPENDICES

## APPENDIX 2A

## Summary of ARARs and TBCs

# Appendix 2A
# Summary of ARARs and TBCs
*Feasibility Study Report*
*Open Burning / Open Detonation Ground (Range 16)*
*Fort Riley, Kansas*

| Citation | Description | Category | Summary |
|---|---|---|---|
| **Chemical-Specific ARARs** | | | |
| 42 USC § 300f et seq. as amended in 1986 | **Safe Drinking Water Act of 1974** | Relevant and Appropriate | Established to protect the quality of drinking water in the United 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 standards. |
| 40 CFR § 141, and 142 | National Primary Drinking Water Regulations and Standards (i.e. Maximum Contaminant Levels) | | Establishes maximum contaminant levels which are health risk based standards for public water systems. Federally promulgated drinking water regulations designed to protect human health from the potential adverse effects of drinking water contaminants. The regulation establishes maximum contaminant levels for water. |
| 40 CFR § 143 | National Secondary Drinking Water Standards | | Establishes welfare-based secondary standards for public water systems. |
| 40 CFR § 144-148 | Underground Injection Control Program | | 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. |
| K.A.R. 28-15a-1 to 28-15a-571 | **Kansas Drinking Water Standards** | Relevant and Appropriate | 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. |
| **Location-Specific ARARs** | | | |
| K.S.A. 65-1,221 to 65-1,235 | **Environmental Use Controls** | Applicable | Legal mechanism and associated application process for imposing restrictions, prohibitions and conditions on land use for property with residual contamination at levels prohibiting unrestricted use. |
| 16 USC § 469 et seq. | **Archaeological and Historic Preservation Act of 1974** | Applicable | 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. |
| 7 USC § 136 and 16 USC § 460 et seq. | **Endangered Species Act of 1973** | Applicable | Provides a program for conservation of threatened and endangered plants and animals and the habitats in which they are found. |
| 16 USC § 2901-2911 | **Fish and Wildlife Conservation Act** | Applicable | 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. |

# Appendix 2A
## Summary of ARARs and TBCs
*Feasibility Study Report*
*Open Burning / Open Detonation Ground (Range 16)*
*Fort Riley, Kansas*

| Citation | Description | Category | Summary |
|---|---|---|---|
| **Location-Specific ARARs (continued)** | | | |
| 16 USC § 661-667e | **Fish and Wildlife Coordination Act** | Applicable | Action to conserve fish and wildlife, particularly those species which are indigenous to the |
| 16 USC § 470 et seq. | **National Historic Preservation Act of 1966** | Applicable | Establishes a national registry of historic sites. Provides for preservation of historic or prehistoric resources. |
| K.A.R. 118-3-1 to 118-3-16 | **Kansas Historic Preservation Act** | Applicable | Provides for the protection and preservation of sites and buildings listed on state or federal historic registries. |
| K.A.R. 115-15-1 to 115-15-4 | **Non-Game, Threatened or Endangered Species** | Applicable | Identifies Threatened and Endangered Species. |
| **Action-Specific ARARs** | | | |
| 42 USC § 7401 et seq. as amended in 1977 and 1990 | **Clean Air Act of 1970** | Applicable | Regulates air emissions from area, stationary, and mobile sources. Authorizes EPA to establish National Ambient Air Quality Standards. |
| 40 CFR § 60 | Standards of Performance for New Stationary Sources | | Identifies standards of performance for new stationary sources of air emissions. Provides emission guidelines and compliance times. |
| 40 CFR § 61 | National Emission Standard for Hazardous Air Pollution | | Identifies emission standards for specific hazardous air pollutants. |
| 40 CFR § 62 | National Emission Standards for Hazardous Air Pollutants for Source Categories including Site Remediation | | Identifies emission standards for hazardous air pollutants that originate from specific categories of sources. |
| 33 USC § 1251 et seq. as amended in 1977 and 1987 | **Clean Water Act of 1972** | Applicable | 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. |
| 40 CFR § 122 | National Pollutant Discharge Elimination System (NPDES) | | Regulates discharges of pollutants from any point source into waters of the United States. |
| 40 CFR § 122.26 | Storm Water Discharge Requirements NPDES | | Provide requirements to obtain a permit to discharge to the storm water sewer system under the NPDES program. |
| 40 CFR § 131 | Federal Water Quality Standards | | 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. |
| 40 CFR § 403 | General Pre-Treatment Regulations for Existing and New Sources of Pollution for Publically Owned Treatment Works | | Provides effluent limitations and guidelines for existing sources, standards of performance for new sources, and pre-treatment standards for new and existing sources. |
| 40 CFR § 22, 230-233 and 33 CFR 320-330 | Wetlands Protection | | 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. |

# Appendix 2A
# Summary of ARARs and TBCs
*Feasibility Study Report*
*Open Burning / Open Detonation Ground (Range 16)*
*Fort Riley, Kansas*

| Citation | Description | Category | Summary |
|---|---|---|---|
| **Action-Specific ARARs (continued)** | | | |
| 42 USC § 9601 et seq. as amended by the Superfund Amendments and Reauthorization Act of 1986 | **CERCLA of 1980** | Applicable | 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. |
| 40 CFR § 300 | NCP | | Federal government's blueprint for responding to spills or releases of oil and hazardous substances. |
| 42 USC § 6901 et seq. as amended by the Hazardous and Solid Waste Amendments (HSWA) of 1984 and 1986, the Federal Facilities Compliance Act of 1992, and the Land Disposal Program Flexibility Act of 1996 | **RCRA of 1979** | | 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 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. |
| 40 CFR § 257 and 258 | Solid Waste Disposal Facility Criteria | | Provides criteria for identification of hazardous and solid wastes. |
| 40 CFR § 261 | Standards for Identification and Listing of Hazardous Waste | Applicable | Regulates the manifesting, pre-transport requirements, and record keeping and reporting for hazardous waste generators. |
| 40 CFR § 262 | Standards Applicable to Generators of Hazardous Waste | | Establishes standards which apply to persons transporting hazardous waste within the United States if the transportation requires a manifest under RCRA. |
| 40 CFR § 263 | Standards Applicable to Transporters of Hazardous Waste | | 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. |
| 40 CFR § 264 | Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities | | These standards apply to owners and operators of all facilities which treat, store or dispose of hazardous wastes. |
| 40 CFR § 264.70-264.77 | Manifesting, Record Keeping, and Reporting Requirements | | Regulations apply to owners or operators of hazardous waste treatment, storage or disposal facilities. |

## Appendix 2A
## Summary of ARARs and TBCs
*Feasibility Study Report*
*Open Burning / Open Detonation Ground (Range 16)*
*Fort Riley, Kansas*

| Citation | Description | Category | Summary |
|---|---|---|---|
| **Action-Specific ARARs (continued)** | | | |
| | **RCRA of 1979 (continued)** | | |
| 40 CFR § 265 | Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities | Applicable | Regulations apply to owners and operators of facilities that treat, store, or dispose of hazardous waste. |
| 42 USC § 11001 et seq. | **Emergency Planning and Community Right-to Know Act of 1986** | Applicable | 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. |
| 49 USC § 5101 et seq. | **Federal Hazardous Materials Transportation Law** | Applicable | Regulates the transportation of hazardous wastes and hazardous substances by aircraft, railcar, vessels, and motor vehicles. Requires employers to train, test, and maintain training records for all hazmat employees. |
| 29 USC § 651 et seq. | **OSHA of 1970** | Applicable | 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. |
| 29 CFR § 1910 | OSHA Safety and Health Standards for Workplace | | 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. |
| 29 CFR § 1926 | OSHA Safety and Health Standards for Construction | | 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. |
| KAR 28-19-1 to 28-19-801 | **Ambient Air Quality Standards and Air Pollution Control** | Applicable | 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. |

| Citation | Description | Category | Summary |
|---|---|---|---|
| **Action-Specific ARARs (continued)** | | | |
| K.A.R. 28-31-1 to 28-31-16 | **Hazardous Waste Management Standards and Regulations** | Applicable | 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. |
| K.A.R. 28-29-1 to 28-29-121 and 28-29-2101 to 28-29-2113 | **Solid Waste Management** | Applicable | Provides standards for management of solid wastes. Establishes administrative procedures. Establishes the requirement for development and submittal of Solid Waste Management Plans. |
| K.A.R. 28-46-1 to 28-46-44 | **Spill Reporting** | Applicable | 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. |
| K.A.R. 28-30-1 to 28-30-10 | **Water Well Contractor's License; Water Well Construction and Abandonment** | Applicable | Establishes the requirements for licensing of drillers. Regulates drilling activities including the construction of wells. |
| K.A.R. 28-46-1 to 28-46-44 | **Underground Injection Control Regulations** | Applicable | 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. |
| KAR 28-65-1 to 28-65-4 | **Emergency Planning and Right-to Know** | Applicable | 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. |
| K.A.R. 66-6-1 to 66-14-12 | **Kansas Board of Technical Professions** | Applicable | Establishes the requirements for licensing of engineers, land surveyors, geologists and architects. |
| **TBCs** | | | |
| RSK Manual - 5th Version | **Risk-Based Standards for Kansas** | TBC | Compiles risk-based cleanup screening goals for contaminants in soil and groundwater. |
| EPA Regional Screening Level Table, November 2012 | **Regional Screening Levels** | TBC | Compiles risk-based cleanup screening goals for soil contaminants and to address groundwater contaminants not included in the MCL list.. |
| OSWER Directive 9355.7-04 | **Land Use in the CERCLA Remedy Selection Process Memorandum** | TBC | Future land use influences the types and frequencies of exposures that may occur to any residual contamination remaining on the site and therefore must be considered in making corrective action decisions. |
| KDHE BER Policy # BER-RS-005 | **Evaluating Future Land Use** | TBC | Future land use influences the types and frequencies of exposures that may occur to any residual contamination remaining on the site and therefore must be considered in making corrective action decisions. |

| Citation | Description | Category | Summary |
|---|---|---|---|
| | **TBCs (continued)** | | |
| KDHE BER Policy # BER-RS-033 | **Consideration for Remedial Standards** | TBC | Identifies remedial standards and situations where they should be used. |
| NTIS Order Number PB88-112107 | **Groundwater Protection Strategy** | TBC | Identifies the EPA's strategy for protecting groundwater resources. |
| KDHE BER Policy # BER-RS-045 | **Considerations for Groundwater Use and Applying RSK Standards to Contaminated Groundwater,** | TBC | Establishes a mechanism for consistency across BER programs in protecting public health and the environment, in addition to protection of groundwater resources of the State. |
| KDHE BER Policy # BER-RS-028 | **Consideration for Hydraulic Containment** | TBC | Specifies requirements for hydraulic containment of groundwater contamination. |
| OSWER Directive 9200.4-17P EPA/540/R-99/009 | **Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tanks** | TBC | Clarifies EPA's policy regarding the use of monitored natural attenuation for the cleanup of contaminated soil and groundwater in the Superfund, RCRA Corrective Action, and Underground Storage Tank programs. |
| KDHE BER Policy # BER-RS-042 | **Monitored Natural Attenuation of Volatile Organic Compounds in Groundwater** | TBC | Provides further clarification of additional KDHE-BER requirements to the guidance on monitored natural attenuation provided by EPA. |
| OSWER Directive 9355.3-01 EPA/540/G-89/004 | **Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA** | TBC | Provides the methodology that the Superfund program uses to characterize the nature and extent of risk posed by uncontrolled hazardous wastes sites and for evaluating potential remedial alternatives. |
| EPA/240/R-02/009 | **Guidance for Quality Assurance Project Plans** | TBC | Describes the Quality Assurance Project Plan as four basic element groups covering project management, data generation, and acquisition, assessment and oversight, and data validation and usability. |
| EPA/240/B-06/001 | **Guidance on the Systematic Planning Using the Data Quality Objectives Process** | TBC | Provides a systematic planning process to develop acceptance or performance criteria for collection, evaluation, or use of environmental data. |
| OSWER Directive 9285.7-45<br>EPA-540-R-89-002<br>OSWER Directive 9285.7-02EP<br>EPA-540-R-99-005<br>OSWER Directive 9285.7-82<br>EPA-540-R-70-002 | **RAGS, Volume I;**<br>RAGS Part A<br>RAGS Part E<br>RAGS Part F | TBC | Provides guidelines for conducting a baseline risk assessment. |
| EPA/630/R-03/003F | **Supplemental Guidance for Assessing Susceptibility from Early-Life Exposure to Carcinogens** | TBC | Provides guidance on calculating risk from exposure to chemicals with a mutagenic mode of action. |
| OSWER Directive 92857.7-53 | **Human Health Toxicity Values in Superfund Risk Assessments** | TBC | Identifies OSWER toxicity value hierarchy for use in risk assessments. |
| EPA/542/S-02/001 | **Groundwater Sampling Guidelines for Superfund and RCRA Project Managers** | TBC | Identifies methods for sampling groundwater. |
| OSWER Directive 9355.0-04B EPA/540/R-95/056 | **Remedial Design/Remedial Action Handbook** | TBC | Provides an overview of the remedial design and remedial action process. |
| EPA/530/R-97/007 | **Best Management Practices for Soils Treatment Technologies** | TBC | Describes various best management practices to be implemented during remedy implementation. |

**Appendix 2A**
**Summary of ARARs and TBCs**
*Feasibility Study Report*
*Open Burning / Open Detonation Ground (Range 16)*
*Fort Riley, Kansas*

| Citation | Description | Category | Summary |
|---|---|---|---|
| **TBCs (continued)** | | | |
| EPA/832/R-92/005 | **Storm Water Management for Construction Activities.** | TBC | Describes storm water pollution prevention measures. |
| USACE Engineer Manual 385-1-1 | **Safety and Health Requirements** | TBC | Describes safety and health requirements for USACE activities and operations. |
| USACE Engineer Pamphlet 75-1-2 | **Unexploded Ordnance Support during Hazardous, Toxic, and Radioactive Waste and Construction Activities** | TBC | Provides supplemental safety and health standards for sites where UXOs are known to be present or likely to be found. |
| DoD Directive 6055.9E | **Explosives Safety Management and the DoD ESB** | TBC | Provides explosives safety management at DoD facilities. |

Notes:

ARAR - Applicable or Relevant and Appropriate Requirements
BER - Bureau of Environmental Remediation
CERCAL - Comprehensive Environmental Response, Compensation, and Liability Act
CFR - Code of Federal Regulation
DoD - Department of Defense
EPA - Environmental Protection Agency
ESB - Explosives Safety Board
K.A.R - Kansas Administrative Record
KDHE - Kansas Department of Health and Environment
K.S.A. - Kansas Statutes Annotated
NCP - National Oil and Hazardous Substances Pollution Contingency Plan
NTIS - National Technical Information Service
OSHA - Occupational Safety and Health Administration
OSWER - Office of Solid Waste and Emergency Response
RAGS - Risk Assessment Guidance for Superfund
RCRA - Resource Conservation and Recovery Act
RSK - Risk-Based Standards for Kansas
TBC - To Be Considered
USACE - United States Army Corps of Engineers
USC - United Stated Code
UXO - Unexploded Ordnance

# APPENDIX 3A

## Range 16 Use Logs

# Appendix 3A
# Range 16 Use Logs
*Feasibility Study Report*
*Open Burning / Open Detonation Ground (Range 16)*
*Fort Riley, Kansas*

| Incident Type | FY13 Total | Estimated % on Range 16 | TOTAL | Manhours on Range 16 |
|---|---|---|---|---|
| **774** | | | | |
| Conventional Munitions Cache | 1 | 0% | 0 | 0 |
| Dismounted - Pick Up and/or Disposal UXO | 1 | 100% | 1 | 1.5 |
| VIP Support Mission | 11 | 0% | 0 | 0 |
| Pick Up and/or Disposal (UXO) | 26 | 80% | 20.8 | 31.2 |
| Post Blast Analysis | 1 | 0% | 0 | 0 |
| Request of EOD Evaluation of Possible Hazardouse/Damaged Munition (UXO) | 57 | 0% | 0 | 0 |
| Disposal of Unserviceable/Excess Munitions | 3 | 100% | 3 | 4.5 |
| | | | | |
| **630th** | | | | |
| Disposal of Unserviceable/Excess Munitions | 1 | 100% | 1 | 1.5 |
| VIP Support Mission | 3 | 0% | 0 | 0 |
| Other (Specify in Narrative) | 4 | 50% | 2 | 3 |
| Pick Up and/or Disposal (UXO) | 11 | 80% | 8.8 | 13.2 |
| IED Incident | 4 | 0% | 0 | 0 |
| | | Totals | 36.6 | 54.9 |

| **Notes** |
|---|
| Manhours based on 3 man teams (30 min per Soldier/Total 1.5 hours per incident) |

# APPENDIX 5A-1

## Alternative S1 – No Action for Soil

**Appendix 5A-1**
**Alternative S1 - No Action for Soil**
*Feasibility Study Report*
*Open Burning / Open Detonation Ground (Range 16)*
*Fort Riley, Kansas*

## Capital Costs

| No. | Description | Quantity | Unit | Material, Equipment, Labor, and OHP Unit Cost | Material, Equipment, Labor, and OHP Total | Total Cost (rounded) | General Requirements 5% | 2013 CONSTRUCTION COST TOTAL |
|---|---|---|---|---|---|---|---|---|
| 1 | **PREDESIGN INVESTIGATIONS** | | | | | | | |
| 2 | **GENERAL REQUIREMENTS** | | | | | | | |
| 3 | **SITE WORK** | | | | | | | |
| | | | | | | | | |
| Subtotal Project | | | | | $ - | $ - | $ - | $ - |
| Design (10%) | | | | | | | | $ - |
| Project Management (10%) | | | | | | | | $ - |
| Construction Management (0%) | | | | | | | | $ - |
| Scope Contingency (15%) | | | | | | | | $ - |
| Bid Contingency (10%) | | | | | | | | $ - |
| **OPINION OF PROBABLE CONSTRUCTION COST (Point Estimate)** | | | | | | | | **$ -** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - Low (-30%)** | | | | | | | | **$ -** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - High (+50%)** | | | | | | | | **$ -** |

## Annual Costs

| Item No. | Description | Quantity | Unit | Material, Equipment, Labor, and OHP Unit Cost | Material, Equipment, Labor, and OHP Total | Total Cost (rounded) | General Requirements 5% | 2013 O&M COST TOTAL |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| Subtotal | | | | | $ - | $ - | $ - | $ - |
| Project Management, Engineering and Technical Assistance (20%) | | | | | | | | $ - |
| Contingency (Bid and Scope) (20%) | | | | | | | | $ - |
| **OPINION OF PROBABLE CONSTRUCTION COST (Point Estimate)** | | | | | | | | **$ -** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - Low (-30%)** | | | | | | | | **$ -** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - High (+50%)** | | | | | | | | **$ -** |

## Periodic Costs

| Item No. | Description | Quantity | Unit | Material, Equipment, Labor, and OHP Unit Cost | Material, Equipment, Labor, and OHP Total | Total Cost (rounded) | General Requirements 5% | 2013 PERIODIC COST TOTAL |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| | | | | | | | | $ - |
| | | | | | | | | |
| Subtotal | | | | | $ - | $ - | $ - | $ - |
| Project Management, Engineering and Technical Assistance (20%) | | | | | | | | $ - |
| Contingency (Bid and Scope) (20%) | | | | | | | | $ - |
| **OPINION OF PROBABLE CONSTRUCTION COST (Point Estimate)** | | | | | | | | **$ -** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - Low (-30%)** | | | | | | | | **$ -** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - High (+50%)** | | | | | | | | **$ -** |

**Item No.**

### Basis of Cost

Costs based on a variety of sources including published and unpublished sources such as RS Means, communications with vendors (written and verbal), and internal databases of cost based on previous experience. Costs FOB Topeka, Kansas where applicable.

Potential source area in the metal debris area will not be remediated under the No Action Alternative. It is assumed it will continue to act as a contaminant source through the 30-year period.

***Capital Costs***

***O&M Costs***

***Periodic Costs***

# APPENDIX 5A-2

## Alternative S2 – Institutional Controls for Soil

**Appendix 5A-2**
**Alternative S2 - Institutional Controls for Soil**
*Feasibility Study Report*
*Open Burning / Open Detonation Ground (Range 16)*
*Fort Riley, Kansas*

## Capital Costs

| No. | Description | Quantity | Unit | Material, Equipment, Labor, and OHP Unit Cost | Material, Equipment, Labor, and OHP Total | Total Cost (rounded) | General Requirements 5% | 2013 CONSTRUCTION COST TOTAL |
|---|---|---|---|---|---|---|---|---|
| 1 | **PREDESIGN INVESTIGATIONS** | | | | | | | |
| 2 | **GENERAL REQUIREMENTS** | | | | | | | |
| 3 | **SITE WORK** | | | | | | | |
| 4 | **INSTITUTIONAL CONTROLS** | | | | | | | |
| | Development of Institutional Controls | 1 | LS | $ 2,500 | $ 2,500 | $ 2,500 | $ 125 | $2,625 |
| | | | | | | | | |
| Subtotal Project | | | | | $ 2,500 | $ 2,500 | $ 125 | $ 2,625 |
| Design (10%) | | | | | | | | $ 263 |
| Project Management (10%) | | | | | | | | $ 263 |
| Construction Management (0%) | | | | | | | | $ - |
| Scope Contingency (15%) | | | | | | | | $ 394 |
| Bid Contingency (10%) | | | | | | | | $ 263 |
| **OPINION OF PROBABLE CONSTRUCTION COST (Point Estimate)** | | | | | | | | **$ 4,000** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - Low (-30%)** | | | | | | | | **$ 3,000** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - High (+50%)** | | | | | | | | **$ 10,000** |

## Annual Costs

| Item No. | Description | Quantity | Unit | Material, Equipment, Labor, and OHP Unit Cost | Material, Equipment, Labor, and OHP Total | Total Cost (rounded) | General Requirements 5% | 2013 O&M COST TOTAL |
|---|---|---|---|---|---|---|---|---|
| 1 | **ENFORCEMENT** | 1 | YR | $2,500 | $2,500 | $ 2,500 | 125 | $ 2,625 |
| | | | | | | | | |
| | | | | | | | | |
| Subtotal | | | | | $ 2,500 | $ 2,500 | $ 125 | $ 2,625 |
| Project Management, Engineering and Technical Assistance (20%) | | | | | | | | $ 525 |
| Contingency (Bid and Scope) (20%) | | | | | | | | $ 525 |
| **OPINION OF PROBABLE CONSTRUCTION COST (Point Estimate)** | | | | | | | | **$ 4,000** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - Low (-30%)** | | | | | | | | **$ 3,000** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - High (+50%)** | | | | | | | | **$ 10,000** |

## Periodic Costs

| Item No. | Description | Quantity | Unit | Material, Equipment, Labor, and OHP Unit Cost | Material, Equipment, Labor, and OHP Total | Total Cost (rounded) | General Requirements 5% | 2013 PERIODIC COST TOTAL |
|---|---|---|---|---|---|---|---|---|
| 1 | **5-YEAR REPORTING** | | | | | | | |
| | 5- Year Report | 1 | LS | 30,000 | $ 30,000 | $ 30,000 | $ 1,500 | $ 31,500 |
| | | | | | | | | |
| Subtotal | | | | | $ 30,000 | $ 30,000 | $ 1,500 | $ 31,500 |
| Project Management, Engineering and Technical Assistance (20%) | | | | | | | | $ 6,300 |
| Contingency (Bid and Scope) (20%) | | | | | | | | $ 6,300 |
| **OPINION OF PROBABLE CONSTRUCTION COST (Point Estimate)** | | | | | | | | **$ 44,000** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - Low (-30%)** | | | | | | | | **$ 30,000** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - High (+50%)** | | | | | | | | **$ 70,000** |

**Item No.** **Basis of Cost**

Costs based on a variety of sources including published and unpublished sources such as RS Means, communications with vendors (written and verbal), and internal databases of cost based on previous experience. Costs FOB Topeka, Kansas where applicable.

Potential source area in the metal debris area will not be remediated under the this alternative. It is assumed it will continue to act as a contaminant source through the 30-year period.

Site to be checked for explosives prior to sampling event and MEC technician would be on-site during the sampling event.

***Capital Costs***

Development costs include preparation of language for IC and distribution as necessary.

***O&M Costs***

Enforcement costs involves periodic plan reviews as necessary and periodic site inspections to ensure compliance.

***Periodic costs***

5- year report prepared to assess condition of contaminants in OU6 soil.

No sampling costs on current conditions at the site prior to the 5-year report have been included in the cost estimate.

Cost is based on the assumption that Soils Report is prepared separately from GW or SW reports. Combined reports would result in savings. Six reporting events anticipated over 30-year operating period.

# APPENDIX 5A-3A

## Alternative S3b – Soil Removal and Disposal or Treatment: Off-Site Disposal in a Landfill

**Appendix 5A-3A**
**Alternative S3B - Soil Removal and Disposal or Treatment: Off-Site Disposal in a Landfill**
*Feasibility Study Report*
*Open Burning / Open Detonation Ground (Range 16)*
*Fort Riley, Kansas*

## Capital Costs

| Item No. | Description | Quantity | Unit | Material, Equipment, Labor, and OHP | | Total Cost | General Requirements | 2013 CONSTRUCTION COST TOTAL |
|---|---|---|---|---|---|---|---|---|
| | | | | Unit Cost | Total | (rounded) | 5% | |
| 1 | **PREDESIGN INVESTIGATIONS** | | | | | | | |
| | Site clearance for investigation | 1 | LS | $ 10,000 | $ 10,000 | $ 10,000 | $500 | $10,500 |
| | MEC Tech during predesign investigation | 25 | DAY | $ 1,500 | $ 37,500 | $ 37,500 | $1,875 | $39,375 |
| | Geophysical Testing | 2 | DAY | $ 3,000 | $ 6,000 | $ 6,000 | $300 | $6,300 |
| | Test pits | 1 | DAY | $ 2,000 | $ 2,000 | $ 2,000 | $100 | $2,100 |
| | Soil sampling (collection and analysis) | 50 | SAMPLE | $ 600 | $ 30,000 | $ 30,000 | $1,500 | $31,500 |
| | Backfill sampling and analysis | 1 | LS | $ 5,000 | $ 5,000 | $ 5,000 | $250 | $5,250 |
| | Pilot testing for removal rates | 1 | LS | $ 25,000 | $ 25,000 | $ 25,000 | $1,250 | $26,250 |
| 2 | **GENERAL REQUIREMENTS** | | | | | | | |
| | Performance and Payment Bond | 1% | LS | | $ - | $ 19,400 | $0 | $19,400 |
| | Insurance | 2% | LS | | $ - | $ 38,800 | $0 | $38,800 |
| | Mobilization | | | | | | | |
| | General Mobilization | 5% | LS | | $ - | $ 96,900 | $0 | $96,900 |
| | General labor (not including equipment operators/truck drivers) | | | | | | | |
| | Program Management/Corporate Oversight/ QA | 520 | HR | $ 200 | $ 104,000 | $ 104,000 | $5,200 | $109,200 |
| | Project Manager | 1,040 | HR | $ 150 | $ 156,000 | $ 156,000 | $7,800 | $163,800 |
| | Administrative assistance | 520 | HR | $ 75 | $ 39,000 | $ 39,000 | $1,950 | $40,950 |
| | Job Superintendent | 1,040 | HR | $ 125 | $ 130,000 | $ 130,000 | $6,500 | $136,500 |
| | MEC/MEC | 1,040 | HR | $ 125 | $ 130,000 | $ 130,000 | $6,500 | $136,500 |
| | SSHS Officer | 1,040 | HR | $ 75 | $ 78,000 | $ 78,000 | $3,900 | $81,900 |
| | Foreman (1) | 1,040 | HR | $ 75 | $ 78,000 | $ 78,000 | $3,900 | $81,900 |
| | General laborers | 3,120 | HR | $ 25 | $ 78,000 | $ 78,000 | $3,900 | $81,900 |
| | General Mobile Equipment and Operators | | | | | | | |
| | Water truck | 260 | HR | $ 85 | $ 22,100 | $ 22,100 | $1,105 | $23,205 |
| 3 | **SITE WORK** | | | | | | | |
| | Silt fence | 2,500 | LF | $ 1.5 | $ 3,750 | $ 3,800 | $190 | $3,990 |
| | Temporary fencing | 2,500 | LF | $ 5 | $ 12,500 | $ 12,500 | $625 | $13,125 |
| | Vegetation clearing | 2 | ACRE | $ 1,500 | $ 3,000 | $ 3,000 | $150 | $3,150 |
| | Confimatory sampling | | | | | | | |
| | Confimatory sampling in source area | 10 | SAMPLE | $ 1,500 | $ 15,000 | $ 15,000 | $750 | $15,750 |
| | Confirmatory sampling-base/sidewalls of main excavation | 20 | SAMPLE | $ 1,500 | $ 30,000 | $ 30,000 | $1,500 | $31,500 |
| | Topographic surveys | | | | | | | |
| | Pre excavation | 1 | EA | $ 5,000 | $ 5,000 | $ 5,000 | $250 | $5,250 |
| | Post excavation | 1 | EA | $ 5,000 | $ 5,000 | $ 5,000 | $250 | $5,250 |
| | Post backfill | 1 | EA | $ 5,000 | $ 5,000 | $ 5,000 | $250 | $5,250 |
| 4 | **SOURCE AREA INVESTIGATION/REMOVAL** | | | | | | | |
| | Setup drum staging areas | | | | | | | |
| | 2- 50 by 50 foot areas - graded and bermed, lined | 2 | EA | $ 20,000 | $ 40,000 | $ 40,000 | $2,000 | $42,000 |
| | Contact water tank (delivery, rental, pickup) | 3 | MON | $ 1,500 | $ 4,500 | $ 4,500 | $225 | $4,725 |
| | Contact water treatment sytem (del, rent, pickup | 3 | MON | $ 10,000 | $ 30,000 | $ 30,000 | $1,500 | $31,500 |
| | Excavation | | | | | | | |
| | Remove overburden/surrounding area/additional in base area | 460 | CY | $ 15 | $ 6,900 | $ 6,900 | $345 | $ 7,245 |
| | Backfill | | | | | | | |
| | Backfill source area - bank run purchase (onsite, excavate, haul) | 575 | CY | $ 5 | $ 2,875 | $ 2,900 | $145 | $3,045 |
| | Backfill placement and compaction | 575 | CY | $ 10 | $ 5,750 | $ 5,800 | $290 | $6,090 |
| | Liquid disposal | | | | | | | |
| | Sample collection for waste characterization | 10 | SAMPLE | $ 2,000 | $ 20,000 | $ 20,000 | $1,000 | $21,000 |
| | Transfer liquid to 55 gal drums, haul, off-site disposal | 25 | DRUM | $ 1,000 | $ 25,000 | $ 25,000 | $1,250 | $26,250 |
| | Metal debris disposal (triple rinsed, recycled) | 1 | TON | | | | | |
| 5 | **SOIL EXCAVATION** | | | | | | | |
| | Excavation - 0-15 ft | 3,500 | CY | $ 10 | $ 35,000 | $ 35,000 | $1,750 | $36,750 |
| | Excavation 15-25 ft | 3,500 | CY | $ 20 | $ 70,000 | $ 70,000 | $3,500 | $73,500 |
| | Endloader -building windrow | 1 | MON | $ 10,000 | $ 10,000 | $ 10,000 | $500 | $10,500 |
| | Lined Dump trucks - 6 trucks | 1 | MON | $ 99,000 | $ 99,000 | $ 99,000 | $4,950 | $103,950 |
| | Backfill | | | | | | | |
| | Backfill - bank run excavation and hauling | 4,375 | CY | $ 5 | $ 21,875 | $ 21,900 | $1,095 | $22,995 |
| | Backfill placement and compaction | 4,950 | CY | $ 10 | $ 49,500 | $ 49,500 | $2,475 | $51,975 |
| | Air quality monitoring during construction | 3 | MON | $ 5,000 | $ 15,000 | $ 15,000 | $750 | $15,750 |
| 6 | **HAULING AND DISPOSAL** | | | | | | | |
| | Haul source area material to Incinerator (Kimball NE) | 690 | TON | $ 75 | $ 51,750 | $ 52,000 | $2,600 | $54,600 |
| | Tipping fee incinerator | 690 | TON | $ 400 | $ 276,000 | $ 276,000 | $13,800 | $289,800 |
| | Haul excavated soil to Subtitle D landfill | 10,500 | TON | $ 50 | $ 525,000 | $ 525,000 | $26,250 | $551,250 |
| | Tipping fee at Subtitle D landfill | 10,500 | TON | $ 40 | $ 420,000 | $ 420,000 | $21,000 | $441,000 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **7** | **SITE RESTORATION** | | | | | | | |
| | Regrading/seed | 2 | ACRE | $ 2,500 | $ 5,000 | $ 5,000 | $250 | $5,250 |
| | Remove and dispose of drum containment systems | 1 | LS | $ 10,000 | $ 10,000 | $ 10,000 | $500 | $10,500 |
| | Remove and dispose of silt fence and silt barrier | 1 | LS | $ 2,500 | $ 2,500 | $ 2,500 | $125 | $2,625 |
| | Remove and dispose of landfarming pad | 1 | LS | $ 35,000 | $ 35,000 | $ 35,000 | $1,750 | $36,750 |
| | Decon and remove all equipment | 1 | LS | $ 5,000 | $ 5,000 | $ 5,000 | $250 | $5,250 |
| Subtotal Project | | | | | $ 2,660,000 | $ 2,815,500 | $ 133,020 | $ 3,069,795 |
| Design (10%) | | | | | | | | $ 306,980 |
| Project Management (10%) | | | | | | | | $ 306,980 |
| Construction Management (6%) | | | | | | | | $ 184,188 |
| Scope Contingency (15%) | | | | | | | | $ 460,469 |
| Bid Contingency (10%) | | | | | | | | $ 306,980 |
| **OPINION OF PROBABLE CONSTRUCTION COST (Point Estimate)** | | | | | | | | **$ 4,640,000** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - Low (-30%)** | | | | | | | | **$ 3,250,000** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - High (+50%)** | | | | | | | | **$ 6,960,000** |

## Annual Costs

| Item No. | Description | Quantity | Unit | Material, Equipment, Labor, and OHP | | Total Cost | General Requirements | 2013 O&M COST TOTAL |
|---|---|---|---|---|---|---|---|---|
| | | | | Unit Cost | Total | (rounded) | 5% | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| Subtotal | | | | | $ - | $ - | $ - | $ - |
| Project Management, Engineering and Technical Assistance (20%) | | | | | | | | $ - |
| Contingency (Bid and Scope) (20%) | | | | | | | | $ - |
| **OPINION OF PROBABLE CONSTRUCTION COST (Point Estimate)** | | | | | | | | **$ -** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - Low (-30%)** | | | | | | | | **$ -** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - High (+50%)** | | | | | | | | **$ -** |

## Periodic Costs

| Item No. | Description | Quantity | Unit | Material, Equipment, Labor, and OHP | | Total Cost | General Requirements | 2013 PERIODIC COST TOTAL |
|---|---|---|---|---|---|---|---|---|
| | | | | Unit Cost | Total | (rounded) | 5% | |
| **1** | **5-YEAR REPORTING** | | | | | | | |
| | 5- Year Report | 1 | LS | 30,000 | $ 30,000 | $ 30,000 | $ 1,500 | $ 31,500 |
| | | | | | | | | |
| Subtotal | | | | | $ 30,000 | $ 30,000 | $ 1,500 | $ 31,500 |
| Project Management, Engineering and Technical Assistance (20%) | | | | | | | | $ 6,300 |
| Contingency (Bid and Scope) (20%) | | | | | | | | $ 6,300 |
| **OPINION OF PROBABLE CONSTRUCTION COST (Point Estimate)** | | | | | | | | **$ 44,000** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - Low (-30%)** | | | | | | | | **$ 30,000** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - High (+50%)** | | | | | | | | **$ 70,000** |

| Item No. | Basis of Cost |
|---|---|
| | Costs based on a variety of sources including published and unpublished sources such as RS Means, communications with vendors (written and verbal), and internal databases of cost based on previous experience. Costs FOB Topeka, Kansas where applicable. |
| | Site to be checked for explosives prior to any field investigation. MEC technician would be on-site during all sampling events. |
| | For this analysis, it was assumed that the metalic anomaly is a number of buried 55-gal drums placed in an area approximately 10 ft by 10 ft. The total depth of drums is unknown but is assumed to be 10 feet. One layer of drums is assumed. |
| | Costs based on an estimated construction period of 6 months. |
| | ***Capital Costs*** |
| 1 | Predesign investigations will be conducted prior to the Remedial Design to more thoroughly investigate metalic anomaly, delineate contaminan limits, profile waste for disposal, determine wastewater treatment requirements. |
| | Geophyscal testing to assess additional information on metalic anomaly. |
| | Test pits dug in source area to ground truth geophysical testing results and to gain additional information on depth of burial, horizontal (and potentially vertical) extent of the drums and other information to assist in identifying and planning for removal of drums if necessary. |
| | Soil sampling will be conducted on excavated soil generated from test pit operations to confirm characterization and to identify limits of excavation at OU6. Geoprobe soil sampling will be conducted within OU6 to establish limits of excavation. Samples analyzed for VOCs as primary COC. |
| | Backfil lmaterials will be sampled and analyzed to ensure material complies with state regulations . One sample per 2500 cy, a minimum of 5 tests. |
| | Pilot testing to be conducted on a contaminated soil to evaluate effectiveness of landfarming and timing on stripping the chlorinated solvents (TCE and PCA). |
| 2 | General requirements consist of overhead costs borne by the general contractor not directly related to specific remediation activities including QA and H&S requirements, temporary site facilites (trailers, power, water, sanitary, etc. ), site supervision, general supplies, general labor for operations. |
| 3 | Site work includes general preparation activities prior to construction as well as other site wide activities conducted throughout the construction period. |
| | Silt fencing installed downgradient of excavation. |
| | Termporary fencing installed around excavation work area for safety. |
| | Confirmatory sampling will be conducted to verify the in-place soil (in source area and in general excavation) meets regulatory limits following excavation. |
| | Topographic surveys will be conducted and drawings prepared pre excavation, post excavation, and post backfill to document remediation. |
| 4 | Source removal will address the metalic anomaly identfied during the RI. Additional investigation would be conducted during predesign investigation to obtain more information and develop plans for removal, if necessary. |
| | If the condition and content of drums can be determined in place, it may be possible to remove the contents of the drums in place. However, if contents cannot be easily verified, it may necessary to relocate the drums to allow access for sampling and removal of contents. |
| | Staging area to be established for drum removal process. Area will be graded level and surrounded by a small berm to prevent surface water entering area. Area will be lined to contain spills. Two 50x50 ft staging areas will constructed to allow drums to be sampled and contents removed for disposal. Estimate assumes excavation and removal required. |
| | Overburden soil will be removed by backhoe to allow access to drums. Assume 10 feet overburden on drums. In addition, soil around drums will be removed to allow access - an area 5 feet on all sides of drum stack will be removed. Following drum removal, additional soil will be removed from the base of the excavation (assume 5 ft depth) until soil meets regulatory limits. Total size of excavation is approximately 20- x 20- x 25-ft with 1:1 sideslopes. |
| | Following confirmation samplng, source area to be backfilled. On-Post source assumed. Backfill will be compacted and the area seeded with native grasses. |
| | Liquids handling procedures will vary based on results of sampling. For this estimate it was assumed that the liquid is limited to chlorinated solvents and can be pumped from drums and combined in tanks or placed in overpacks without additional processing. Liquids in drums will be characterized for disposal at the hazardous waste incinerator in Kimball, NE (approximately 650 miles from site). Samples of the liquid will be characterized for disposal based on the volume of material/number of drums and in accordance with the requirements of the disposal facility. |
| 5 | Soil excavation will address contaminated soil exceeding regulatory limits and backfilling once excavation is complete for areas outside the source area (addressed separately). |
| | Contaminated soil exceeding regulatory limits will be excavated and hauled to a Subtitle D landfill for disposal. Depth of excavation will be established during predesign investigation but is anticipated to extend to a depth beyond that identified during RI sampling depths in some locations. Excavated soil will be placed in lined dump trucks for transport to the disposal site. Up to 10 percent of the material is assumed to require moisture conditioning prior to transport. Assumed area of excavation is shown in Figure 5-2 and is approximately 80 by 50 feet in size with depths of 15 to 25 feet. |
| | Following confirmation samplng, area to be backfilled. On-Post source for backfill assumed. Backfill will be compacted and the area seeded with native grasses. |
| | Air monitoring will be conducted during excavation for fugitive dust, metals. |
| 6 | Excavated soil [(outside of source area (Item 4)] would be hauled to a Subtitle D landfill (Clean Harbors) in Wayoka, OK, approximately 350 miles from the Post. |
| | Estimated tipping fee is $40 per ton although this could vary based on final waste characterization. |
| | Estimated tipping fee for source area material will vary based on waste characterization. Vendors will not quote without chemical characteristics but average Subtitle D landfill costs in OK/KS is $40 per ton. |
| | Tranportation to facility based on OTR haul vehicles at an estimated cost per ton-mile of $50. If rail transport could be arranged, costs would be less. |
| 7 | Following completion of the source area excavation, disturbed portions of the site will be restored to pre construction conditions. Materials and equipment will be removed from the site and decontaminated or disposed in accordance with regulations. |
| | ***O&M Costs*** |
| | ***Periodic costs*** |
| | 5- year report prepared to assess condition of contaminants in OU6 soil. |
| | No sampling costs on current conditions at the site prior to the 5-year report have been included in the cost estimate. |
| | Cost is based on the assumption that Soils Report is prepared separately from GW or SW reports. Combined reports would result in savings. Six reporting events anticipated over 30-year operating period. |

# APPENDIX 5A-3B

## Alternative S3b – Soil Removal and Disposal or Treatment: On-Site Land Farming

## Capital Costs

| | Description | Quantity | Unit | Material, Equipment, Labor, and OHP | | Total Cost | General Requirements | 2013 CONSTRUCTION COST TOTAL |
|---|---|---|---|---|---|---|---|---|
| | | | | Unit Cost | Total | (rounded) | 5% | |
| 1 | **PREDESIGN INVESTIGATIONS** | | | | | | | |
| | Site clearance for investigation | 1 | LS | $ 10,000 | $ 10,000 | $ 10,000 | $500 | $10,500 |
| | MEC Tech during predesign investigation | 25 | DAY | $ 1,500 | $ 37,500 | $ 37,500 | $1,875 | $39,375 |
| | Geophysical Testing | 2 | DAY | $ 3,000 | $ 6,000 | $ 6,000 | $300 | $6,300 |
| | Test pits | 1 | DAY | $ 2,000 | $ 2,000 | $ 2,000 | $100 | $2,100 |
| | Soil sampling (collection and analysis) | 50 | SAMPLE | $ 600 | $ 30,000 | $ 30,000 | $1,500 | $31,500 |
| | Backfill sampling and analysis | 1 | LS | $ 5,000 | $ 5,000 | $ 5,000 | $250 | $5,250 |
| | Pilot testing for removal rates | 1 | LS | $ 25,000 | $ 25,000 | $ 25,000 | $1,250 | $26,250 |
| 2 | **GENERAL REQUIREMENTS** | | | | | | | |
| | Performance and Payment Bond | 1% | LS | | $ - | $ 15,300 | $0 | $15,300 |
| | Insurance | 2% | LS | | $ - | $ 30,500 | $0 | $30,500 |
| | Mobilization | | | | | | | |
| | General Mobilization | 5% | LS | | $ - | $ 76,100 | $0 | $76,100 |
| | General labor (not including equipment operators/truck drivers) | | | | | | | |
| | Program Management/Corporate Oversight/ QA | 520 | HR | $ 200 | $ 104,000 | $ 104,000 | $5,200 | $109,200 |
| | Project Manager | 1,040 | HR | $ 150 | $ 156,000 | $ 156,000 | $7,800 | $163,800 |
| | Administrative assistance | 520 | HR | $ 75 | $ 39,000 | $ 39,000 | $1,950 | $40,950 |
| | Job Superintendent | 1,040 | HR | $ 125 | $ 130,000 | $ 130,000 | $6,500 | $136,500 |
| | MEC/MEC | 1,040 | HR | $ 125 | $ 130,000 | $ 130,000 | $6,500 | $136,500 |
| | SSHS Officer | 1,040 | HR | $ 75 | $ 78,000 | $ 78,000 | $3,900 | $81,900 |
| | Foreman (1) | 1,040 | HR | $ 75 | $ 78,000 | $ 78,000 | $3,900 | $81,900 |
| | General laborers | 3,120 | HR | $ 25 | $ 78,000 | $ 78,000 | $3,900 | $81,900 |
| | General Mobile Equipment and Operators | | | | | | | |
| | Water truck | 260 | HR | $ 85 | $ 22,100 | $ 22,100 | $1,105 | $23,205 |
| 3 | **SITE WORK** | | | | | | | |
| | Silt fence | 2,500 | LF | $ 1.5 | $ 3,750 | $ 3,800 | $190 | $3,990 |
| | Temporary fencing | 2,500 | LF | $ 5 | $ 12,500 | $ 12,500 | $625 | $13,125 |
| | Vegetation clearing | 2 | ACRE | $ 1,500 | $ 3,000 | $ 3,000 | $150 | $3,150 |
| | Confimatory sampling | | | | | | | |
| | Confimatory sampling in source area | 10 | SAMPLE | $ 1,500 | $ 15,000 | $ 15,000 | $750 | $15,750 |
| | Confirmatory sampling-base/sidewalls of main excavation | 20 | SAMPLE | $ 1,500 | $ 30,000 | $ 30,000 | $1,500 | $31,500 |
| | Topographic surveys | | | | | | | |
| | Pre excavation | 1 | EA | $ 5,000 | $ 5,000 | $ 5,000 | $250 | $5,250 |
| | Post excavation | 1 | EA | $ 5,000 | $ 5,000 | $ 5,000 | $250 | $5,250 |
| | Post backfill | 1 | EA | $ 5,000 | $ 5,000 | $ 5,000 | $250 | $5,250 |
| 4 | **SOURCE AREA INVESTIGATION/REMOVAL** | | | | | | | |
| | Setup drum staging areas | | | | | | | |
| | 2- 50 by 50 foot areas - graded and bermed, lined | 2 | EA | $ 20,000 | $ 40,000 | $ 40,000 | $2,000 | $42,000 |
| | Contact water tank (delivery, rental, pickup) | 3 | MON | $ 1,500 | $ 4,500 | $ 4,500 | $225 | $4,725 |
| | Contact water treatment sytem (del, rent, pickup | 3 | MON | $ 10,000 | $ 30,000 | $ 30,000 | $1,500 | $31,500 |
| | Excavation | | | | | | | |
| | Remove overburden/surrounding area/additional in base area | 460 | CY | $ 15 | $ 6,900 | $ 6,900 | $345 | $ 7,245 |
| | Backfill | | | | | | | |
| | Backfill source area - bank run purchase (onsite, excavate, haul) | 575 | CY | $ 5 | $ 2,875 | $ 2,900 | $145 | $3,045 |
| | Backfill placement and compaction | 575 | CY | $ 10 | $ 5,750 | $ 5,800 | $290 | $6,090 |
| | Liquid disposal | | | | | | | |
| | Sample collection for waste characterization | 10 | SAMPLE | $ 2,000 | $ 20,000 | $ 20,000 | $1,000 | $21,000 |
| | Transfer liquid to 55 gal drums, haul, off-site disposal | 25 | DRUM | $ 1,000 | $ 25,000 | $ 25,000 | $1,250 | $26,250 |
| | Metal debris disposal (triple rinsed, recycled) | 1 | TON | | | | | |
| 5 | **SOIL EXCAVATION** | | | | | | | |
| | Excavation - 0-15 ft | 3,500 | CY | $ 10 | $ 35,000 | $ 35,000 | $1,750 | $36,750 |
| | Excavation 15-25 ft | 3,500 | CY | $ 20 | $ 70,000 | $ 70,000 | $3,500 | $73,500 |
| | Endloader -building windrow | 1 | MON | $ 10,000 | $ 10,000 | $ 10,000 | $500 | $10,500 |
| | Lined Dump trucks - 6 trucks | 1 | MON | $ 99,000 | $ 99,000 | $ 99,000 | $4,950 | $103,950 |
| | Backfill | | | | | | | |
| | Backfill - bank run excavation and hauling | 4,375 | CY | $ 5 | $ 21,875 | $ 21,900 | $1,095 | $22,995 |
| | Backfill placement and compaction | 4,950 | CY | $ 10 | $ 49,500 | $ 49,500 | $2,475 | $51,975 |
| | Air quality monitoring during construction | 3 | MON | $ 5,000 | $ 15,000 | $ 15,000 | $750 | $15,750 |
| 6 | **LAND FARMING** | | | | | | | |
| | Treatment Pad | | | | | | | |
| | Grading/Berm Construction, liner, paving | 23,958 | SF | $ 10 | $ 239,580 | $ 239,600 | $11,980 | $251,580 |
| | SW piping | 475 | CY | $ 100 | $ 47,500 | $ 47,500 | $2,375 | $49,875 |
| | SW collection basin (lined) | 1 | LS | $ 7,000 | $ 7,000 | $ 7,000 | $350 | $7,350 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Water treatment | 12 | MON | $ 10,000 | $ 120,000 | $ 120,000 | $6,000 | $126,000 |
| | Water treatment mob/demob | 1 | LS | $ 10,000 | $ 10,000 | $ 10,000 | $500 | $10,500 |
| | Transport /Disposal - on post | | | | | | | |
| | Hauling | 7,460 | CY | $ 5 | $ 37,300 | $ 37,300 | $1,865 | $39,165 |
| | Grading | 7,460 | CY | $ 5 | $ 37,300 | $ 37,300 | $1,865 | $39,165 |
| | Turning equipment (rental) | 12 | MON | $ 5,000 | $ 60,000 | $ 60,000 | $3,000 | $63,000 |
| | Labor (Turning piles) | 720 | HR | $ 125 | $ 90,000 | $ 90,000 | $4,500 | $94,500 |
| | Sampling windrows | 12 | MON | $ 16,500 | $ 198,000 | $ 198,000 | $9,900 | $207,900 |
| | Air monitoring (at landfarming site) | 12 | MON | $ 2,500 | $ 30,000 | $ 30,000 | $1,500 | $31,500 |
| **7** | **SITE RESTORATION** | | | | | | | |
| | Regrading/seed | 2 | ACRE | $ 2,500 | $ 5,000 | $ 5,000 | $250 | $5,250 |
| | Remove and dispose of drum containment systems | 1 | LS | $ 10,000 | $ 10,000 | $ 10,000 | $500 | $10,500 |
| | Remove and dispose of silt fence and silt barrier | 1 | LS | $ 2,500 | $ 2,500 | $ 2,500 | $125 | $2,625 |
| | Remove and dispose of landfarming pad | 1 | LS | $ 35,000 | $ 35,000 | $ 35,000 | $1,750 | $36,750 |
| | Decon and remove all equipment | 1 | LS | $ 5,000 | $ 5,000 | $ 5,000 | $250 | $5,250 |
| Subtotal Project | | | | | $ 2,263,930 | $ 2,386,000 | $ 113,205 | $ 2,620,480 |
| Design (10%) | | | | | | | | $ 262,048 |
| Project Management (10%) | | | | | | | | $ 262,048 |
| Construction Management (6%) | | | | | | | | $ 157,229 |
| Scope Contingency (15%) | | | | | | | | $ 393,072 |
| Bid Contingency (10%) | | | | | | | | $ 262,048 |
| **OPINION OF PROBABLE CONSTRUCTION COST (Point Estimate)** | | | | | | | | **$ 3,960,000** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - Low (-30%)** | | | | | | | | **$ 2,770,000** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - High (+50%)** | | | | | | | | **$ 5,940,000** |

## Annual Costs

| Item No. | Description | Quantity | Unit | Material, Equipment, Labor, and OHP | | Total Cost | General Requirements | 2013 O&M COST TOTAL |
|---|---|---|---|---|---|---|---|---|
| | | | | Unit Cost | Total | (rounded) | 5% | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| Subtotal | | | | | $ - | $ - | $ - | $ - |
| Project Management, Engineering and Technical Assistance (20%) | | | | | | | | $ - |
| Contingency (Bid and Scope) (20%) | | | | | | | | $ - |
| **OPINION OF PROBABLE CONSTRUCTION COST (Point Estimate)** | | | | | | | | **$ -** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - Low (-30%)** | | | | | | | | **$ -** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - High (+50%)** | | | | | | | | **$ -** |

## Periodic Costs

| Item No. | Description | Quantity | Unit | Material, Equipment, Labor, and OHP | | Total Cost | General Requirements | 2013 PERIODIC COST TOTAL |
|---|---|---|---|---|---|---|---|---|
| | | | | Unit Cost | Total | (rounded) | 5% | |
| **1** | **5-YEAR REPORTING** | | | | | | | |
| | 5- Year Report | 1 | LS | 30,000 | $ 30,000 | $ 30,000 | $ 1,500 | $ 31,500 |
| | | | | | | | | |
| Subtotal | | | | | $ 30,000 | $ 30,000 | $ 1,500 | $ 31,500.00 |
| Project Management, Engineering and Technical Assistance (20%) | | | | | | | | $ 6,300.00 |
| Contingency (Bid and Scope) (20%) | | | | | | | | $ 6,300.00 |
| **OPINION OF PROBABLE CONSTRUCTION COST (Point Estimate)** | | | | | | | | **$ 44,000** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - Low (-30%)** | | | | | | | | **$ 30,000** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - High (+50%)** | | | | | | | | **$ 70,000** |

**Item No.** **Basis of Cost**

Costs based on a variety of sources including published and unpublished sources such as RS Means, communications with vendors (written and verbal), and internal databases of cost based on previous experience. Costs FOB Topeka, Kansas where applicable.

Site to be checked for explosives prior to any field investigation. MEC technician would be on-site during all sampling events.

For this analysis, it was assumed that the metalic anomaly is a number of buried 55-gal drums placed in an area approximately 10 ft by 10 ft. The total depth of drums is unknown but is assumed to be 10 feet. One layer of drums is assumed.

Costs based on an estimated construction period of 6 months.

***Capital Costs***

**1** Predesign investigations will be conducted prior to the Remedial Design to more thoroughly investigate metalic anomaly, delineate contaminan limits, profile waste for disposal, determine wastewater treatment requirements.

Geophyscal testing to assess additional information on metalic anomaly.

Test pits dug in source area to ground truth geophysical testing results and to gain additional information on depth of burial, horizontal (and potentially vertical) extent of the drums and other information to assist in identifying and planning for removal of drums if necessary.

Soil sampling will be conducted on excavated soil generated from test pit operations to confirm characterization and to identify limits of excavation at OU6. Geoprobe soil sampling will be conducted within OU6 to establish limits of excavation. Samples analyzed for VOCs as primary COC.

Backfil lmaterials will be sampled and analyzed to ensure material complies with state regulations . One sample per 2500 cy, a minimum of 5 tests.

Pilot testing to be conducted on a contaminated soil to evaluate effectiveness of landfarming and timing on stripping the chlorinated solvents (TCE and PCA).

**2** General requirements consist of overhead costs borne by the general contractor not directly related to specific remediation activities including QA and H&S requirements, temporary site facilites (trailers, power, water, sanitary, etc. ), site supervision, general supplies, general labor for operations.

**3** Site work includes general preparation activities prior to construction as well as other site wide activities conducted throughout the construction period.

Silt fencing installed downgradient of excavation.

Termporary fencing installed around excavation work area for safety.

Confirmatory sampling will be conducted to verify the in-place soil (in source area and in general excavation) meets regulatory limits following excavation.

Topographic surveys will be conducted and drawings prepared pre excavation, post excavation, and post backfill to document remediation.

**4** Source removal will address the metalic anomaly identfied during the RI. Additional investigation would be conducted during predesign investigation to obtain more information and develop plans for removal, if necessary.

If the condition and content of drums can be determined in place, it may be possible to remove the contents of the drums in place. However, if contents cannot be easily verified, it may necessary to relocate the drums to allow access for sampling and removal of contents.

Staging area to be established for drum removal process. Area will be graded level and surrounded by a small berm to prevent surface water entering area. Area will be lined to contain spills. Two 50x50 ft staging areas will constructed to allow drums to be sampled and contents removed for disposal. Estimate assumes excavation and removal required.

Overburden soil will be removed by backhoe to allow access to drums. Assume 10 feet overburden on drums. In addition, soil around drums will be removed to allow access - an area 5 feet on all sides of drum stack will be removed. Following drum removal, additional soil will be removed from the base of the excavation (assume 5 ft depth) until soil meets regulatory limits. Total size of excavation is approximately 20- x 20- x 25-ft with 1:1 sideslopes.

Following confirmation samplng, source area to be backfilled. On-Post source assumed. Backfill will be compacted and the area seeded with native grasses.

Liquids handling procedures will vary based on results of sampling. For this estimate it was assumed that the liquid is limited to chlorinated solvents and can be pumped from drums and combined in tanks or placed in overpacks without additional processing. Liquids in drums will be characterized for disposal at the hazardous waste incinerator in Kimball, NE (approximately 650 miles from site). Samples of the liquid will be characterized for disposal based on the volume of material/number of drums and in accordance with the requirements of the disposal facility.

**5** Soil excavation will address contaminated soil exceeding regulatory limits and backfilling once excavation is complete for areas outside the source area (addressed separately).

Contaminated soil exceeding regulatory limits will be excavated and hauled to an on-Post landfarming operation. Depth of excavation will be established during predesign investigation but is anticipated to extend to a depth beyond that identified during RI sampling depths in some locations. Excavated soil will be placed in lined dump trucks and hauled to the landfarming area where it will be placed in windrows. B164

Following confirmation samplng, area to be backfilled. On-Post source for backfill assumed. Backfill will be compacted and the area seeded with native grasses.

Air monitoring will be conducted during excavation for fugitive dust, metals.

**6** An on-Post area remote from OU6 will be developed for landfarming activities. Area will be approximately 1 acre in size, graded and paved to prevent contaminants leaching into soil.

A treatment pad will be constructed approximately 1 acre in size. The area will be graded and small berms constructed around the perimeter to control surface water runoff. The area would be paved to minimize infiltration of leachate /contact water into the soil at the landfarming site. Surface water collected within the landfarming area will collected in tanks and treated prior to release under an NPDES permit. The contact water is anticipated to contain low concentrations of VOCs, metals, and other contaminants detected at OU6. If approved, contact water may be used for dust control at the landfarming operation or excavation site.

Following treatment and confirmatory sampling, the treated soil would be used for general fill at an approved location on-Post. The proposed use of the material will be dependent on the characteristics of the final material. If no approved use is available, the material will be used for cover and disposed in the on-Post C&D landfill.

Costs include rental for equipment (monthly rates) for turning windrows, labor for windrow turning (10 hours per week)

Air monitoring will be conducted during landfarming operations for fugitive dust, metals. Assumes no APC required.

Windrows will be sampled at least monthly to determine when material meets regulatory limits and can be removed for disposal. At least one sample per month per 2500 in-place cy of material. It is assumed an average of 11 tests per month at a cost of $1500 per sample. The analytical program will be based on the contaminants detected during the predesign investigation and may vary over time.

**7** Following completion of the source area excavation, disturbed portions of the site will be restored to pre construction conditions. Materials and equipment will be removed from the site and decontaminated or disposed in accordance with regulations.

***O&M Costs***

Land farming operation costs are included in capital costs.

***Periodic costs***

5- year report prepared to assess condition of contaminants in OU6 soil.

No sampling costs on current conditions at the site prior to the 5-year report have been included in the cost estimate.

Cost is based on the assumption that Soils Report is prepared separately from GW or SW reports. Combined reports would result in savings. Six reporting events anticipated over 30-year operating period.

# APPENDIX 5A-3C

## Alternative S3c – Soil Removal and Disposal or Treatment: Off-Site Thermal Incineration and Disposal

## Appendix 5A-3C
## Alternative S3C - Soil Removal and Disposal or Treatment: Off-Site Thermal Incineration and Disposal
## Feasibility Study Report
## Open Burning / Open Detonation Ground (Range 16)
## Fort Riley, Kansas

# Capital Costs

| | Description | Quantity | Unit | Material, Equipment, Labor, and OHP | | Total Cost | General Requirements | 2013 CONSTRUCTION COST TOTAL |
|---|---|---|---|---|---|---|---|---|
| | | | | Unit Cost | Total | (rounded) | 5% | |
| 1 | **PREDESIGN INVESTIGATIONS** | | | | | | | |
| | Site clearance for investigation | 1 | LS | $ 10,000 | $ 10,000 | $ 10,000 | $500 | $10,500 |
| | MEC Tech during predesign investigation | 25 | DAY | $ 1,500 | $ 37,500 | $ 37,500 | $1,875 | $39,375 |
| | Geophysical Testing | 2 | DAY | $ 3,000 | $ 6,000 | $ 6,000 | $300 | $6,300 |
| | Test pits | 1 | DAY | $ 2,000 | $ 2,000 | $ 2,000 | $100 | $2,100 |
| | Soil sampling (collection and analysis) | 50 | SAMPLE | $ 600 | $ 30,000 | $ 30,000 | $1,500 | $31,500 |
| | Backfill sampling and analysis | 1 | LS | $ 5,000 | $ 5,000 | $ 5,000 | $250 | $5,250 |
| | Pilot testing for removal rates | 1 | LS | $ 25,000 | $ 25,000 | $ 25,000 | $1,250 | $26,250 |
| 2 | **GENERAL REQUIREMENTS** | | | | | | | |
| | Performance and Payment Bond | 1% | LS | | $ - | $ 61,900 | $0 | $61,900 |
| | Insurance | 2% | LS | | $ - | $ 123,700 | $0 | $123,700 |
| | Mobilization | | | | | | | |
| | General Mobilization | 10% | LS | | $ - | $ 618,200 | $0 | $618,200 |
| | General labor (not including equipment operators/truck drivers) | | | | | | | |
| | Program Management/Corporate Oversight/ QA | 520 | HR | $ 200 | $ 104,000 | $ 104,000 | $5,200 | $109,200 |
| | Project Manager | 1,040 | HR | $ 150 | $ 156,000 | $ 156,000 | $7,800 | $163,800 |
| | Administrative assistance | 520 | HR | $ 75 | $ 39,000 | $ 39,000 | $1,950 | $40,950 |
| | Job Superintendent | 1,040 | HR | $ 125 | $ 130,000 | $ 130,000 | $6,500 | $136,500 |
| | MEC/MEC | 1,040 | HR | $ 125 | $ 130,000 | $ 130,000 | $6,500 | $136,500 |
| | SSHS Officer | 1,040 | HR | $ 75 | $ 78,000 | $ 78,000 | $3,900 | $81,900 |
| | Foreman (1) | 1,040 | HR | $ 75 | $ 78,000 | $ 78,000 | $3,900 | $81,900 |
| | General laborers | 3,120 | HR | $ 25 | $ 78,000 | $ 78,000 | $3,900 | $81,900 |
| | General Mobile Equipment and Operators | | | | | | | |
| | Water truck | 260 | HR | $ 85 | $ 22,100 | $ 22,100 | $1,105 | $23,205 |
| 3 | **SITE WORK** | | | | | | | |
| | Silt fence | 2,500 | LF | $ 1.5 | $ 3,750 | $ 3,800 | $190 | $3,990 |
| | Temporary fencing | 2,500 | LF | $ 5 | $ 12,500 | $ 12,500 | $625 | $13,125 |
| | Vegetation clearing | 2 | ACRE | $ 1,500 | $ 3,000 | $ 3,000 | $150 | $3,150 |
| | Confimatory sampling | | | | | | | |
| | Confimatory sampling in source area | 10 | SAMPLE | $ 1,500 | $ 15,000 | $ 15,000 | $750 | $15,750 |
| | Confirmatory sampling-base/sidewalls of main excavation | 20 | SAMPLE | $ 1,500 | $ 30,000 | $ 30,000 | $1,500 | $31,500 |
| | Topographic surveys | | | | | | | |
| | Pre excavation | 1 | EA | $ 5,000 | $ 5,000 | $ 5,000 | $250 | $5,250 |
| | Post excavation | 1 | EA | $ 5,000 | $ 5,000 | $ 5,000 | $250 | $5,250 |
| | Post backfill | 1 | EA | $ 5,000 | $ 5,000 | $ 5,000 | $250 | $5,250 |
| 4 | **SOURCE AREA INVESTIGATION/REMOVAL** | | | | | | | |
| | Setup drum staging areas | | | | | | | |
| | 2- 50 by 50 foot areas - graded and bermed, lined | 2 | EA | $ 20,000 | $ 40,000 | $ 40,000 | $2,000 | $42,000 |
| | Contact water tank (delivery, rental, pickup) | 3 | MON | $ 1,500 | $ 4,500 | $ 4,500 | $225 | $4,725 |
| | Contact water treatment sytem (del, rent, pickup | 3 | MON | $ 10,000 | $ 30,000 | $ 30,000 | $1,500 | $31,500 |
| | Excavation | | | | | | | |
| | Remove overburden/surrounding area/additional in base area | 460 | CY | $ 15 | $ 6,900 | $ 6,900 | $345 | $ 7,245 |
| | Backfill | | | | | | | |
| | Backfill source area - bank run purchase (onsite, excavate, haul) | 575 | CY | $ 5 | $ 2,875 | $ 2,900 | $145 | $3,045 |
| | Backfill placement and compaction | 575 | CY | $ 10 | $ 5,750 | $ 5,800 | $290 | $6,090 |
| | Liquid disposal | | | | | | | |
| | Sample collection for waste characterization | 10 | SAMPLE | $ 2,000 | $ 20,000 | $ 20,000 | $1,000 | $21,000 |
| | Transfer liquid to 55 gal drums, haul, off-site disposal | 25 | DRUM | $ 1,000 | $ 25,000 | $ 25,000 | $1,250 | $26,250 |
| | Metal debris disposal (triple rinsed, recycled) | 1 | TON | | | | | |
| 5 | **SOIL EXCAVATION** | | | | | | | |
| | Excavation - 0-15 ft | 3,500 | CY | $ 10 | $ 35,000 | $ 35,000 | $1,750 | $36,750 |
| | Excavation 15-25 ft | 3,500 | CY | $ 20 | $ 70,000 | $ 70,000 | $3,500 | $73,500 |
| | Endloader -building windrow | 1 | MON | $ 10,000 | $ 10,000 | $ 10,000 | $500 | $10,500 |
| | Lined Dump trucks - 6 trucks | 1 | MON | $ 99,000 | $ 99,000 | $ 99,000 | $4,950 | $103,950 |
| | Backfill | | | | | | | |
| | Backfill - bank run excavation and hauling | 4,375 | CY | $ 5 | $ 21,875 | $ 21,900 | $1,095 | $22,995 |
| | Backfill placement and compaction | 4,950 | CY | $ 10 | $ 49,500 | $ 49,500 | $2,475 | $51,975 |
| | Air quality monitoring during construction | 3 | MON | $ 5,000 | $ 15,000 | $ 15,000 | $750 | $15,750 |
| 6 | **INCINERATRION/ASH DISPOSAL** | | | | | | | |
| | Haul to Kimball NE incinerator | 11,190 | TON | $ 75 | $ 839,250 | $ 839,300 | $41,965 | $881,265 |
| | Tipping fee at Kimball NE incinerator | 11,190 | TON | $ 400 | $ 4,476,000 | $ 4,476,000 | $223,800 | $4,699,800 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **7** | **SITE RESTORATION** | | | | | | | |
| | Regrading/seed | 2 | ACRE | $ 2,500 | $ 5,000 | $ 5,000 | $250 | $5,250 |
| | Remove and dispose of drum containment systems | 1 | LS | $ 10,000 | $ 10,000 | $ 10,000 | $500 | $10,500 |
| | Remove and dispose of silt fence and silt barrier | 1 | LS | $ 2,500 | $ 2,500 | $ 2,500 | $125 | $2,625 |
| | Remove and dispose of landfarming pad | 1 | LS | $ 35,000 | $ 35,000 | $ 35,000 | $1,750 | $36,750 |
| | Decon and remove all equipment | 1 | LS | $ 5,000 | $ 5,000 | $ 5,000 | $250 | $5,250 |
| Subtotal Project | | | | | $ 6,702,500 | $ 7,506,500 | $ 335,135 | $ 7,962,910 |
| Design (10%) | | | | | | | | $ 796,291 |
| Project Management (10%) | | | | | | | | $ 796,291 |
| Construction Management (6%) | | | | | | | | $ 477,775 |
| Scope Contingency (15%) | | | | | | | | $ 1,194,437 |
| Bid Contingency (10%) | | | | | | | | $ 796,291 |
| **OPINION OF PROBABLE CONSTRUCTION COST (Point Estimate)** | | | | | | | | **$ 12,020,000** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - Low (-30%)** | | | | | | | | **$ 8,410,000** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - High (+50%)** | | | | | | | | **$ 18,030,000** |

## Annual Costs

| Item No. | Description | Quantity | Unit | Material, Equipment, Labor, and OHP | | Total Cost | General Requirements | 2013 O&M COST TOTAL |
|---|---|---|---|---|---|---|---|---|
| | | | | Unit Cost | Total | (rounded) | 5% | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| Subtotal | | | | | $ - | $ - | $ - | $ - |
| Project Management, Engineering and Technical Assistance (20%) | | | | | | | | $ - |
| Contingency (Bid and Scope) (20%) | | | | | | | | $ - |
| **OPINION OF PROBABLE CONSTRUCTION COST (Point Estimate)** | | | | | | | | **$ -** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - Low (-30%)** | | | | | | | | **$ -** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - High (+50%)** | | | | | | | | **$ -** |

## Periodic Costs

| Item No. | Description | Quantity | Unit | Material, Equipment, Labor, and OHP | | Total Cost | General Requirements | 2013 PERIODIC COST TOTAL |
|---|---|---|---|---|---|---|---|---|
| | | | | Unit Cost | Total | (rounded) | 5% | |
| **1** | **5-YEAR REPORTING** | | | | | | | |
| | 5- Year Report | 1 | LS | 30,000 | $ 30,000 | $ 30,000 | $ 1,500 | $ 31,500 |
| | | | | | | | | |
| Subtotal | | | | | $ 30,000 | $ 30,000 | $ 1,500 | $ 31,500 |
| Project Management, Engineering and Technical Assistance (20%) | | | | | | | | $ 6,300 |
| Contingency (Bid and Scope) (20%) | | | | | | | | $ 6,300 |
| **OPINION OF PROBABLE CONSTRUCTION COST (Point Estimate)** | | | | | | | | **$ 44,000** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - Low (-30%)** | | | | | | | | **$ 30,000** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - High (+50%)** | | | | | | | | **$ 70,000** |

**Item No.** **Basis of Cost**

Costs based on a variety of sources including published and unpublished sources such as RS Means, communications with vendors (written and verbal), and internal databases of cost based on previous experience. Costs FOB Topeka, Kansas where applicable.

Site to be checked for explosives prior to any field investigation. MEC technician would be on-site during all sampling events.

For this analysis, it was assumed that the metalic anomaly is a number of buried 55-gal drums placed in an area approximately 10 ft by 10 ft. The total depth of drums is unknown but is assumed to be 10 feet. One layer of drums is assumed.

Costs based on an estimated construction period of 6 months.

***Capital Costs***

1 Predesign investigations will be conducted prior to the Remedial Design to more thoroughly investigate metalic anomaly, delineate contaminan limits, profile waste for disposal, determine wastewater treatment requirements.

Geophyscal testing to assess additional information on metalic anomaly.

Test pits dug in source area to ground truth geophysical testing results and to gain additional information on depth of burial, horizontal (and potentially vertical) extent of the drums and other information to assist in identifying and planning for removal of drums if necessary.

Soil sampling will be conducted on excavated soil generated from test pit operations to confirm characterization and to identify limits of excavation at OU6. Geoprobe soil sampling will be conducted within OU6 to establish limits of excavation. Samples analyzed for VOCs as primary COC.

Backfil lmaterials will be sampled and analyzed to ensure material complies with state regulations . One sample per 2500 cy, a minimum of 5 tests.

Pilot testing to be conducted on a contaminated soil to evaluate effectiveness of landfarming and timing on stripping the chlorinated solvents (TCE and PCA).

2 General requirements consist of overhead costs borne by the general contractor not directly related to specific remediation activities including QA and H&S requirements, temporary site facilites (trailers, power, water, sanitary, etc. ), site supervision, general supplies, general labor for operations.

3 Site work includes general preparation activities prior to construction as well as other site wide activities conducted throughout the construction period.

Silt fencing installed downgradient of excavation.

Termporary fencing installed around excavation work area for safety.

Confirmatory sampling will be conducted to verify the in-place soil (in source area and in general excavation) meets regulatory limits following excavation.

Topographic surveys will be conducted and drawings prepared pre excavation, post excavation, and post backfill to document remediation.

4 Source removal will address the metalic anomaly identfied during the RI. Additional investigation would be conducted during predesign investigation to obtain more information and develop plans for removal, if necessary.

If the condition and content of drums can be determined in place, it may be possible to remove the contents of the drums in place. However, if contents cannot be easily verified, it ma necessary to relocate the drums to allow access for sampling and removal of contents.

Staging area to be established for drum removal process. Area will be graded level and surrounded by a small berm to prevent surface water entering area. Area will be lined to contain spills. Two 50x50 ft staging areas will constructed to allow drums to be sampled and contents removed for disposal. Estimate assumes excavation and removal required.

Overburden soil will be removed by backhoe to allow access to drums. Assume 10 feet overburden on drums. In addition, soil around drums will be removed to allow access - an area 5 feet on all sides of drum stack will be removed. Following drum removal, additional soil will be removed from the base of the excavation (assume 5 ft depth) until soil meets regulatory limits. Total size of excavation is approximately 20- x 20- x 25-ft with 1:1 sideslopes.

Following confirmation samplng, source area to be backfilled. On-Post source assumed. Backfill will be compacted and the area seeded with native grasses.

Liquids handling procedures will vary based on results of sampling. For this estimate it was assumed that the liquid is limited to chlorinated solvents and can be pumped from drums and combined in tanks or placed in overpacks without additional processing. Liquids in drums will be characterized for disposal at the hazardous waste incinerator in Kimball, NE (approximately 650 miles from site). Samples of the liquid will be characterized for disposal based on the volume of material/number of drums and in accordance with the requirements of the disposal facility.

5 Soil excavation will address contaminated soil exceeding regulatory limits and backfilling once excavation is complete for areas outside the source area (addressed separately).

Contaminated soil exceeding regulatory limits will be excavated and hauled to an incinerator for thermal treatment and disposal. Depth of excavation will be established during predesign investigation but is anticipated to extend to a depth beyond that identified during RI sampling depths in some locations. Excavated soil will be placed in lined dump trucks for transport to the disposal site. Up to 10 percent of the material is assumed to require moisture conditioning prior to transport. Assumed area of excavation is shown in Figure 5-2 and is approximately 80 by 50 feet in size with depths of 15 to 25 feet.

Following confirmation samplng, area to be backfilled. On-Post source for backfill assumed. Backfill will be compacted and the area seeded with native grasses.

Air monitoring will be conducted during excavation for fugitive dust, metals.

6 Excavated soil would be hauled to a Incinerator for thermal destruction (Clean Harbors) in Kimball NE, approximately 650 miles from the Post. Estimated tipping fee is $400 per ton although this could vary based on final waste characterization.

Estimated tipping fee will vary based on waste characterization. Vendors will not quote without chemical characteristics but a typical rate for incineration would be approximately $400 to $500 per ton.

Tranportation to facility based on OTR haul vehicles at an estimated cost of $75 per ton. If rail transport could be arranged, costs would be less.

7 Following completion of the source area excavation, disturbed portions of the site will be restored to pre construction conditions. Materials and equipment will be removed from the site and decontaminated or disposed in accordance with regulations.

***O&M Costs***

***Periodic costs***

5- year report prepared to assess condition of contaminants in OU6 soil.

No sampling costs on current conditions at the site prior to the 5-year report have been included in the cost estimate.

Cost is based on the assumption that Soils Report is prepared separately from GW or SW reports. Combined reports would result in savings. Six reporting events anticipated over 30-year operating period.

# APPENDIX 5A-4

## Alternative S4 – In-Situ Treatment for Soil: Soil Vapor Extraction

**Appendix 5A-4**
**Alternative S4 - In- Situ Treatment for Soil: Soil Vapor Extraction**
*Feasibility Study Report*
*Open Burning / Open Detonation Ground (Range 16)*
*Fort Riley, Kansas*

## Capital Costs

| No. | Description | Quantity | Unit | Material, Equipment, Labor, and OHP Unit Cost | Material, Equipment, Labor, and OHP Total | Total Cost (rounded) | General Requirements 5% | |
|---|---|---|---|---|---|---|---|---|
| 1 | **PREDESIGN INVESTIGATIONS** | | | | | | | |
| | Site clearance for investigation | 1 | LS | $ 10,000 | $ 10,000 | $ 10,000 | $500 | $10,500 |
| | MEC tech during predesign investigation | 25 | DAY | $ 1,500 | $ 37,500 | $ 37,500 | $1,875 | $39,375 |
| | Geophysical Testing | 2 | DAY | $ 3,000 | $ 6,000 | $ 6,000 | $300 | $6,300 |
| | Test pits (source area) | 2 | DAY | $ 2,000 | $ 4,000 | $ 4,000 | $200 | $4,200 |
| | Soil sampling and analysis | 50 | SAMPLE | $ 600 | $ 30,000 | $ 30,000 | $1,500 | $31,500 |
| | Backfill sampling and analysis | 1 | LS | $ 1,500 | $ 1,500 | $ 1,500 | $75 | $1,575 |
| | SVE well vacumm testing for ROI | 1 | LS | $ 50,000 | $ 50,000 | $ 50,000 | $2,500 | $52,500 |
| 2 | **GENERAL REQUIREMENTS** | | | | | | | |
| | Performance and Payment Bond | 1% | LS | | $ - | $ 20,800 | $0 | $20,800 |
| | Insurance | 2% | LS | | $ - | $ 41,500 | $0 | $41,500 |
| | Mobilization | | | | | | | |
| | General Mobilization | 5% | LS | | $ - | $ 103,600 | $0 | $103,600 |
| | General labor (not including equipment operators/truck drivers) | | | | | | | |
| | Program Management/Corporate Oversight/ QA | 520 | HR | $ 200 | $ 104,000 | $ 104,000 | $5,200 | $109,200 |
| | Project Manager | 1,040 | HR | $ 150 | $ 156,000 | $ 156,000 | $7,800 | $163,800 |
| | Administrative assistance | 520 | HR | $ 75 | $ 39,000 | $ 39,000 | $1,950 | $40,950 |
| | Job Superintendent | 1,040 | HR | $ 125 | $ 130,000 | $ 130,000 | $6,500 | $136,500 |
| | MEC Specialist | 1,040 | HR | $ 125 | $ 130,000 | $ 130,000 | $6,500 | $136,500 |
| | SSHS Officer | 1,040 | HR | $ 75 | $ 78,000 | $ 78,000 | $3,900 | $81,900 |
| | Foreman (1) | 1,040 | HR | $ 75 | $ 78,000 | $ 78,000 | $3,900 | $81,900 |
| | General laborers | 1,040 | HR | $ 25 | $ 26,000 | $ 26,000 | $1,300 | $27,300 |
| | General Mobile Equipment and Operators | | | | | | | |
| | Water truck | 260 | HR | $ 85 | $ 22,100 | $ 22,100 | $1,105 | $23,205 |
| 3 | **SITE WORK** | | | | | | | |
| | Silt fence | 2,500 | LF | $ 1.5 | $ 3,750 | $ 3,800 | $190 | $3,990 |
| | Temporary fencing | 2,500 | LF | $ 5 | $ 12,500 | $ 12,500 | $625 | $13,125 |
| | Vegetation clearing | 2 | ACRE | $ 1,500 | $ 3,000 | $ 3,000 | $150 | $3,150 |
| | Air quality monitoring during construction | 4 | MON | $ 15,000 | $ 60,000 | $ 60,000 | $3,000 | $63,000 |
| | Confimatory sampling collection | | | | | | | |
| | Source area pit | 10 | SAMPLE | $ 1,500 | $ 15,000 | $ 15,000 | $750 | $15,750 |
| | Topographic surveys | | | | | | | |
| | Pre excavation | 1 | EA | $ 5,000 | $ 5,000 | $ 5,000 | $250 | $5,250 |
| | Post excavation | 1 | EA | $ 5,000 | $ 5,000 | $ 5,000 | $250 | $5,250 |
| | Post SVE network construction | 1 | EA | $ 5,000 | $ 5,000 | $ 5,000 | $250 | $5,250 |
| | Underground power to OU6 | 1 | LS | $ 270,000 | $ 270,000 | $ 270,000 | $13,500 | $283,500 |
| | Communication lines for control system | 1 | Mile | $ 25,000 | $ 25,000 | $ 25,000 | $1,250 | $26,250 |
| 4 | **SOURCE AREA INVESTIGATION/REMOVAL** | | | | | | | |
| | Setup drum staging areas | | | | | | | |
| | 2- 50 by 50 foot areas - graded and bermed, lined | 2 | EA | $ 20,000 | $ 40,000 | $ 40,000 | $2,000 | $42,000 |
| | Contact water tank (delivery, rental, pickup) | 2 | MON | $ 1,500 | $ 3,000 | $ 3,000 | $150 | $3,150 |
| | Excavation | | | | | | | |
| | Remove overburden/surrounding area/additional in base area | 1,100 | CY | $ 15 | $ 16,500 | $ 16,500 | $825 | $17,325 |
| | Backfill | | | | | | | |
| | Backfill source area - bank run purchase (onsite, excavate, haul) | 1,375 | CY | $ 5 | $ 6,875 | $ 6,900 | $345 | $7,245 |
| | Backfill placement and compaction | 1,375 | CY | $ 10 | $ 13,750 | $ 13,800 | $690 | $14,490 |
| | Grade/seed | 1 | ACRE | $ 1,500 | $ 1,500 | $ 1,500 | $75 | $1,575 |
| | Sample collection for waste characterization | 10 | SAMPLE | $ 2,000 | $ 20,000 | $ 20,000 | $1,000 | $21,000 |
| | Transfer liquid to 55 gal drums, haul, off-site disposal | 25 | DRUM | $ 1,000 | $ 25,000 | $ 25,000 | $1,250 | $26,250 |
| | Offsite disposal of soil | | | | | | | |
| | Haul to Kimball NE | 1,782 | Ton | $ 75 | $ 133,650 | $ 133,700 | $6,685 | $140,385 |
| | Disposal in incinerator | 1,782 | Ton | $ 400 | $ 712,800 | $ 712,800 | $35,640 | $748,440 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **5** | **SVE SYSTEM** | | | | | | | |
| | Extraction wells | 20 | EA | $ 10,000 | $ 200,000 | $ 200,000 | $10,000 | $210,000 |
| | Wellhead structures and cover | 20 | EA | $ 5,000 | $ 100,000 | $ 100,000 | $5,000 | $105,000 |
| | Wellhead piping and valves | 20 | EA | $ 500 | $ 10,000 | $ 10,000 | $500 | $10,500 |
| | Piping legs | 400 | LF | $ 15 | $ 6,000 | $ 6,000 | $300 | $6,300 |
| | Piping mains | 1,000 | LF | $ 25 | $ 25,000 | $ 25,000 | $1,250 | $26,250 |
| | Piping manifolds - 4 | 4 | EA | $ 1,500 | $ 6,000 | $ 6,000 | $300 | $6,300 |
| | Concrete pad | 15 | CY | $ 750 | $ 11,111 | $ 11,200 | $560 | $11,760 |
| | Protective berm (around equipment trailer) | 400 | CY | $ 15 | $ 6,000 | $ 6,000 | $300 | $6,300 |
| | Pumps and blowers, controls, trailer mounted | 1 | LS | $ 75,000 | $ 75,000 | $ 75,000 | $3,750 | $78,750 |
| | GAC canisters | 8 | EA | $ 5,000 | $ 40,000 | $ 40,000 | $2,000 | $42,000 |
| | Shelter for canisters | 1 | LS | $ 5,000 | $ 5,000 | $ 5,000 | $250 | $5,250 |
| | Remote readout of controls system | 1 | LS | $ 10,000 | $ 10,000 | $ 10,000 | $500 | $10,500 |
| **6** | **SITE RESTORATION** | | | | | | | |
| | Regrading | 2 | ACRE | $ 2,500 | $ 5,000 | $ 5,000 | $250 | $5,250 |
| | Abandon SVE wells | 1 | LS | $ 50,000 | $ 50,000 | $ 50,000 | $2,500 | $52,500 |
| | Remove and dispose of drum containment systems | 1 | LS | $ 25,000 | $ 25,000 | $ 25,000 | $1,250 | $26,250 |
| | Remove and dispose of silt fence and silt barrier | 1 | LS | $ 5,000 | $ 5,000 | $ 5,000 | $250 | $5,250 |
| | Decon and remove all equipment | 1 | LS | $ 15,000 | $ 15,000 | $ 15,000 | $750 | $15,750 |
| Subtotal Project | | | | | $ 2,873,536 | $ 3,039,700 | $ 143,690 | $ 3,183,390 |
| Design (10%) | | | | | | | | $ 318,339 |
| Project Management (10%) | | | | | | | | $ 318,339 |
| Construction Management (6%) | | | | | | | | $ 191,003 |
| Scope Contingency (15%) | | | | | | | | $ 477,509 |
| Bid Contingency (10%) | | | | | | | | $ 318,339 |
| **OPINION OF PROBABLE CONSTRUCTION COST (Point Estimate)** | | | | | | | | **$ 4,810,000** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - Low (-30%)** | | | | | | | | **$ 3,370,000** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - High (+50%)** | | | | | | | | **$ 7,220,000** |

## Annual Costs

| Item No. | Description | Quantity | Unit | Material, Equipment, Labor, and OHP | | Total Cost | General Requirements | 2013 O&M COST TOTAL |
|---|---|---|---|---|---|---|---|---|
| | | | | Unit Cost | Total | (rounded) | 5% | |
| **1** | **SYSTEM MAINTENANCE** | | | | | | | |
| | Labor (average 10 hours per week) | 572 | EA | $ 125 | $ 71,500 | $ 71,500 | $ 3,575 | $ 75,075 |
| | Parts and Supplies | 10% | Captial Costs | | $ 51,891 | $ 51,900 | $ 2,595 | $ 54,495 |
| | Monitoring | 1 | LS | $ 10,000 | $ 10,000 | $ 10,000 | $ 500 | $ 10,500 |
| | Utilities | 12 | MON | $ 2,500 | $ 30,000 | $ 30,000 | $ 1,500 | $ 31,500 |
| | GAC disposal and replacement | 12 | CANNISTER | $ 6,500 | $ 78,000 | $ 78,000 | $ 3,900 | $ 81,900 |
| | Reporting | 12 | MON | $ 1,500 | $ 18,000 | $ 18,000 | $ 900 | $ 18,900 |
| Subtotal | | | | | $ 259,391 | $ 259,400 | $ 1,686,100,000 | $ 272,370 |
| Project Management, Engineering and Technical Assistance (20%) | | | | | | | | $ 54,474.00 |
| Contingency (Bid and Scope) (20%) | | | | | | | | $ 54,474.00 |
| **OPINION OF PROBABLE CONSTRUCTION COST (Point Estimate)** | | | | | | | | **$ 380,000** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - Low (-30%)** | | | | | | | | **$ 270,000** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - High (+50%)** | | | | | | | | **$ 570,000** |

## Periodic Costs

| Item No. | Description | Quantity | Unit | Material, Equipment, Labor, and OHP Unit Cost | Material, Equipment, Labor, and OHP Total | Total Cost (rounded) | General Requirements 5% | 2013 PERIODIC COST TOTAL |
|---|---|---|---|---|---|---|---|---|
| 1 | **5-YEAR REPORTING** | | | | | | | |
| | 5- Year Report | 1 | LS | 30,000 | $ 30,000 | $ 30,000 | $ 1,500 | $ 31,500 |
| | | | | | | | | |
| Subtotal | | | | | $ 30,000 | $ 30,000 | $ 1,500 | $ 31,500.00 |
| Project Management, Engineering and Technical Assistance (20%) | | | | | | | | $ 6,300.00 |
| Contingency (Bid and Scope) (20%) | | | | | | | | $ 6,300.00 |
| **OPINION OF PROBABLE CONSTRUCTION COST (Point Estimate)** | | | | | | | | **$ 44,000** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - Low (-30%)** | | | | | | | | **$ 30,000** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - High (+50%)** | | | | | | | | **$ 70,000** |

**Item No.** **Basis of Cost**

Costs based on a variety of sources including published and unpublished sources such as RS Means, communications with vendors (written and verbal), and internal databases of cost based on previous experience. Costs FOB Topeka, Kansas where applicable.

Site to be checked for explosives prior to any field investigation. MEC technician would be on-site during all sampling events.

For this analysis, it was assumed that the metalic anomaly is a number of buried 55-gal drums placed in an area approximately 10 ft by 10 ft. The total depth of drums is unknown but is assumed to be 10 feet. One layer of drums is assumed.

***Capital Costs***

1 Predesign investigations will be conducted prior to the Remedial Design to more thoroughly investigate metalic anomaly, delineate contaminan limits, profile waste for disposal, determine wastewater treatment requirements.

Geophyscal testing to assess additional information on metalic anomaly.

Test pits dug in source area to ground truth geophysical testing results and to gain additional information on depth of burial, horizontal (and potentially vertical) extent of the drums and other information to assist in identifying and planning for removal of drums if necessary.

Soil sampling will be conducted on excavated soil generated from test pit operations to confirm characterization and to identify limits of excavation at OU6. Geoprobe soil sampling will be conducted within OU6 to establish limits of excavation. Samples analyzed for VOCs as primary COC.

Backfill lmaterials will be sampled and analyzed to ensure material complies with state regulations . One sample per 2500 cy, a minimum of 5 tests.

Well vacuum testing to be conducted to evaluate ROI for SVE wells .

2 General requirements consist of overhead costs borne by the general contractor not directly related to specific remediation activities including QA and H&S requirements, temporary site facilites (trailers, power, water, sanitary, etc. ), site supervision, general supplies, general labor for operations.

3 Site work includes general preparation activities prior to construction as well as other site wide activities conducted throughout the construction period

Silt fencing installed downgradient of excavation.

Termporary fencing installed around excavation work area for safety.

Confirmatory sampling will be conducted to verify the in-place soil meets regulatory limits following excavation.

Air monitoring will be conducted during construction for fugitive dust, metals.

Topographic surveys will be conducted and drawings prepared pre excavation, post excavation, and post backfill to document remediation.

Power will be supplied to the site through a buried underground line extending from a point on Vinton School Road. Estimated distance - 4000 feet.

To allow remote access to monitor the SVE system, a fiber optic line or phone line will be run to the site. No information is currently available on these utilities but it was assumed that the connection point would be on Vinton School Road, south of OU6. Estimated distance - 1 mile.

4 Source removal will address the metalic anomaly identfied during the RI. Additional investigation would be conducted during predesign investigation to obtain more information and develop plans for removal, if necessary.

If the condition and content of drums can be determined in place, it may be possible to remove the contents of the drums in place. However, if contents cannot be easily verified, it may necessary to relocate the drums to allow access for sampling and removal of contents.

Staging area to be established for drum removal process. Area will be graded level and surrounded by a small berm to prevent surface water entering area. Area will be lined to contain spills. Two 50x50 ft staging areas will constructed to allow drums to be sampled and contents removed for disposal. Estimate assumes excavation and removal required.

Overburden soil will be removed by backhoe to allow access to drums. Assume 10 feet overburden on drums. In addition, soil around drums will be removed to allow access - an area 5 feet on all sides of drum stack will be removed. Following drum removal, additional soil will be removed from the base of the excavation (assume 5 ft depth) until soil meets regulatory limits.

Following confirmation samplng, source area to be backfilled. On-Post source assumed. Backfill will be compacted and the area seeded with native grasses.

Liquids handling procedures will vary based on results of sampling. For this estimate it was assumed that the liquid is limited to chlorinated solvents and can be pumped from drums and combined in tanks or placed in overpacks without additional processing. Liquids in drums will be characterized for disposal at the hazardous waste incinerator in Kimball, NE (approximately 650 miles from site). Samples of the liquid will be characterized for disposal based on the volume of material/number of drums and in accordance with the requirements of the disposal facility.

Soil removed during the source area remediation would be characterized. It is anticipated that this material will require disposal at a hazardous waste incinerator in accordance with federal Land Disposal Regulation. The material would be shipped in over-the-road trailers to the incinerator in Kimball, NE.

**5** Soil vapor extraction system construction .

Extraction wells will be constructed in areas where VOC concentrations exceed regulatory limits. Assumed ROI of wells is 10 to 15 feet based on soil conditions in the area. Wells will be placed in an overlapping pattern such that several wells may treat each area. Well depth will be based on the predesign investigation but are assumed to extend through the regolith and potentially into the weathered bedrock. Wells will be screened through the depth of contamination starting at least 5 feet below the ground surface. An estimated 20 wells will be installed.

A piping system will be constructed to collect the gases from the well and tranfer it to the treatment system. Four collection loops will be constructed with 5 to 7 wells per loop. Each loop will be connected to a central valving manifold which will be used to control the flow from each well. The manifold will be conntected to extraction pumps used to create a vacuum in the wells and draw VOCs out of the soil.

A central treatment system will remove VOC from off-gases prior to release to the atmosphere. For this analysis, it is assumed that the treatment system will consist of a series of cannisters containing granular activated carbon (GAC). Other treatment alternatives may be evaluated during the design phase.

The air treatment system will be trailer mounted or located in a small building constructed at or near OU6 on a concrete pad constructed on grade. The treatment system will be surrounded by an earthen berm to protect the equipment from explosions in the area.

**6** Following completion of the source area excavation, disturbed portions of the site will be restored to pre construction conditions. Materials and equipment will be removed from the site and decontaminated or disposed in accordance with regulations.

***O&M Costs***

Monitoring costs for air pollution control system emissions, in-line air testing for systems operation, periodic rebound testing to assess overall performance of removal action

GAC canisters for APC assumed. Assume contractor to remove spent cannisters and replace with canister containing fresh GAC. GAC will require recycle or incineration for disposing impacting costs.

O&M based on a operating life of 10 years for the SVE system costs. Groundwater monitoring would be performed quarterly for 5 years and semiannually for 25 years.

***Periodic costs***

5- year report prepared to assess condition of contaminants in OU6 soil.

No sampling costs on current conditions at the site prior to the 5-year report have been included in the cost estimate.

Cost is based on the assumption that Soils Report is prepared separately from GW or SW reports. Combined reports would result in savings. Six reporting events anticipated over 30-year operating period.

# APPENDIX 5B-1

## Alternative GW1 – No Action for Groundwater

**Appendix 5B-1**
**Alternative GW1 - No Action for Groundwater**
*Feasibility Study Report*
*Open Burning / Open Detonation Ground (Range 16)*
*Fort Riley, Kansas*

## Capital Costs

| Item No. | Description | Quantity | Unit | Material, Equipment, Labor, and OHP Unit Cost | Material, Equipment, Labor, and OHP Total | Total Cost (rounded) | General Requirements 5% | 2013 CONSTRUCTION COST TOTAL |
|---|---|---|---|---|---|---|---|---|
| 1 | **PREDESIGN INVESTIGATIONS** | | | | | | | |
| 2 | **GENERAL REQUIREMENTS** | | | | | | | |
| 3 | **SITE WORK** | | | | | | | |
| | | | | | | | | |
| Subtotal Project | | | | | $ - | $ - | $ - | $ - |
| Design (10%) | | | | | | | | $ - |
| Project Management (10%) | | | | | | | | $ - |
| Construction Management (0%) | | | | | | | | $ - |
| Scope Contingency (15%) | | | | | | | | $ - |
| Bid Contingency (10%) | | | | | | | | $ - |
| **OPINION OF PROBABLE CONSTRUCTION COST (Point Estimate)** | | | | | | | | **$ -** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - Low (-30%)** | | | | | | | | **$ -** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - High (+50%)** | | | | | | | | **$ -** |

## Annual Costs

| Item No. | Description | Quantity | Unit | Material, Equipment, Labor, and OHP Unit Cost | Material, Equipment, Labor, and OHP Total | Total Cost (rounded) | General Requirements 5% | 2013 O&M COST TOTAL |
|---|---|---|---|---|---|---|---|---|
| | **ANNUAL OPERATING AND MAINTENANCE COSTS** | | | | | | | |
| | | | | | | | | |
| Subtotal | | | | | $ - | $ - | $ - | $ - |
| Project Management, Engineering and Technical Assistance (20%) | | | | | | | | $ - |
| Contingency (Bid and Scope) (20%) | | | | | | | | $ - |
| **OPINION OF PROBABLE CONSTRUCTION COST (Point Estimate)** | | | | | | | | **$ -** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - Low (-30%)** | | | | | | | | **$ -** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - High (+50%)** | | | | | | | | **$ -** |

## Periodic Costs

| Item No. | Description | Quantity | Unit | Material, Equipment, Labor, and OHP Unit Cost | Material, Equipment, Labor, and OHP Total | Total Cost (rounded) | General Requirements 5% | 2013 PERIODIC COST TOTAL |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| | | | | | | | | $ - |
| Subtotal | | | | | $ - | $ - | $ - | $ - |
| Project Management, Engineering and Technical Assistance (20%) | | | | | | | | $ - |
| Contingency (Bid and Scope) (20%) | | | | | | | | $ - |
| **OPINION OF PROBABLE CONSTRUCTION COST (Point Estimate)** | | | | | | | | **$ -** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - Low (-30%)** | | | | | | | | **$ -** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - High (+50%)** | | | | | | | | **$ -** |

**Item No.** **Basis of Cost**

Costs based on a variety of sources including published and unpublished sources such as RS Means, communications with vendors (written and verbal), and internal databases of cost based on previous experience. Costs FOB Topeka, Kansas where applicable.

Site to be checked for explosives prior to sampling event and MEC technician would be on-site during the sampling event

***Capital Costs***

***O&M Costs***

***Periodic Costs***

# APPENDIX 5B-2

## Alternative GW2 – Institutional Controls for Groundwater

**Appendix 5B-2**
**Alternative GW2 - Institutional Controls for Groundwater**
*Feasibility Study Report*
*Open Burning / Open Detonation Ground (Range 16)*
*Fort Riley, Kansas*

## Capital Costs

| Item No. | Description | Quantity | Unit | Material, Equipment, Labor, and OHP Unit Cost | Material, Equipment, Labor, and OHP Total | Total Cost (rounded) | General Requirements 5% | |
|---|---|---|---|---|---|---|---|---|
| 1 | **PREDESIGN INVESTIGATIONS** | | | | | | | |
| 2 | **GENERAL REQUIREMENTS** | | | | | | | |
| 3 | **SITE WORK** | | | | | | | |
| 4 | **INSTITUTIONAL CONTROLS** | | | | | | | |
| | Development of IC | 1 | LS | 250,000 | $ 250,000 | $ 250,000 | $ 12,500 | $ 262,500 |
| 5 | **MONITORING** | | | | | | | |
| | | | | | | | | |
| Subtotal Project | | | | | | $ 250,000 | $ 12,500 | $ 262,500 |
| Design (10%) | | | | | | | | $ 26,000 |
| Project Management (10%) | | | | | | | | $ 26,000 |
| Construction Management (0%) | | | | | | | | $ - |
| Scope Contingency (15%) | | | | | | | | $ 39,000 |
| Bid Contingency (10%) | | | | | | | | $ 26,000 |
| **OPINION OF PROBABLE CONSTRUCTION COST (Point Estimate)** | | | | | | | | **$ 380,000** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - Low (-30%)** | | | | | | | | **$ 270,000** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - High (+50%)** | | | | | | | | **$ 570,000** |

## Annual Costs

| Item No. | Description | Quantity | Unit | Material, Equipment, Labor, and OHP Unit Cost | Material, Equipment, Labor, and OHP Total | Total Cost (rounded) | General Requirements 5% | 2013 O&M COST TOTAL |
|---|---|---|---|---|---|---|---|---|
| 1 | **ENFORCEMENT OF INSTITUTIONAL CONTROLS** | 1 | LS | $ 2,500 | $ 2,500 | $ 2,500 | $ 100 | $ 2,600 |
| | | | | | | | | |
| | | | | | | | | |
| Subtotal | | | | | $ 2,500 | $ 2,500 | $ 100 | $ 2,600 |
| Project Management, Engineering and Technical Assistance (20%) | | | | | | | | $ 520 |
| Contingency (Bid and Scope) (20%) | | | | | | | | $ 520 |
| **OPINION OF PROBABLE CONSTRUCTION COST (Point Estimate)** | | | | | | | | **$ 4,000** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - Low (-30%)** | | | | | | | | **$ 3,000** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - High (+50%)** | | | | | | | | **$ 10,000** |

## Periodic Costs

| Item No. | Description | Quantity | Unit | Material, Equipment, Labor, and OHP | | Total Cost | General Requirements | 2013 PERIODIC COST TOTAL |
|---|---|---|---|---|---|---|---|---|
| | | | | Unit Cost | Total | (rounded) | 5% | |
| 1 | **5-YEAR REPORTING** | | | | | | | |
| | 5- Year Report | 1 | LS | 45,000 | $ 45,000 | $ 45,000 | $ 2,300 | $ 47,300 |
| | | | | | | | | |
| Subtotal | | | | | $ 45,000 | $ 45,000 | $ 2,300 | $ 47,300 |
| Project Management, Engineering and Technical Assistance (20%) | | | | | | | | $ 9,000 |
| Contingency (Bid and Scope) (20%) | | | | | | | | $ 9,000 |
| **OPINION OF PROBABLE CONSTRUCTION COST (Point Estimate)** | | | | | | | | **$ 65,000** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - Low (-30%)** | | | | | | | | **$ 50,000** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - High (+50%)** | | | | | | | | **$ 100,000** |

**Item No.** **Basis of Cost**

Costs based on a variety of sources including published and unpublished sources such as RS Means, communications with vendors (written and verbal), and internal databases of cost based on previous experience. Costs FOB Topeka, Kansas where applicable.

Site to be checked for explosives prior to sampling event and MEC technician would be on-site during the sampling event

***Capital Costs***

Development costs include preparation of language for IC and distribution as necessary. Limited modeling or analysis to assess the potential limits of the zone such that future water supply wells do not impact groundwater flow at OU6.

***O&M Costs***

Enforcement costs involve plan reviews as necessary and periodic site inspections to ensure compliance.

***Periodic costs***

5- year report prepared to assess condition of contaminants in OU6 groundwater.

No sampling costs on current conditions at the site prior to the 5-year report have been included in the cost estimate.

Cost is based on the assumption that GW Report is prepared separately from soil or SW reports. Combined reports would result in savings. Six reporting events anticipated over 30-year operating period.

# APPENDIX 5B-3

## Alternative GW3 – Groundwater Monitoring

**Appendix 5B-3**
**Alternative GW3 - Groundwater Monitoring**
*Feasibility Study Report*
*Open Burning / Open Detonation Ground (Range 16)*
*Fort Riley, Kansas*

## Capital Costs

| Item No. | Description | Quantity | Unit | Material, Equipment, Labor, and OHP Unit Cost | Material, Equipment, Labor, and OHP Total | Total Cost (rounded) | General Requirements 5% | |
|---|---|---|---|---|---|---|---|---|
| 1 | **PREDESIGN INVESTIGATIONS** | | | | | | | |
| | Monitoriing well location selection | 1 | LS | $ 10,000 | $ 10,000 | $ 10,000 | $ 500 | $ 10,500 |
| 2 | **GENERAL REQUIREMENTS** | | | | | | | |
| | Work planning documents | 1 | LS | $ 25,000 | $ 25,000 | $ 25,000 | $ 1,300 | $ 26,300 |
| | Clear site for access | 1 | LS | $ 10,000 | $ 10,000 | $ 10,000 | $ 500 | $ 10,500 |
| | MEC specialist during well install & develop, baseline sampling | 50 | DAY | $ 1,500 | $ 75,000 | $ 75,000 | $ 3,800 | $ 78,800 |
| 3 | **SITE WORK** | | | | | | | |
| | Well installation | 1 | LS | $ 201,000 | $ 201,000 | $ 201,000 | $ 10,100 | $ 211,100 |
| | Well development | 5 | DAY | $ 7,500 | $ 37,500 | $ 38,000 | $ 1,900 | $ 39,900 |
| | Baseline sampling - 2 rounds | 11 | WELL | $ 8,500 | $ 93,500 | $ 94,000 | $ 4,700 | $ 98,700 |
| | Reporting/Documentation | 1 | LS | $ 25,000 | $ 25,000 | $ 25,000 | $ 1,300 | $ 26,300 |
| | | | | | | | | |
| Subtotal Project | | | | | $ 477,000 | $ 478,000 | $ 24,100 | $ 502,100 |
| Design (10%) | | | | | | | | $ 50,000 |
| Project Management (10%) | | | | | | | | $ 50,000 |
| Construction Management (0%) | | | | | | | | $ - |
| Scope Contingency (15%) | | | | | | | | $ 75,000 |
| Bid Contingency (10%) | | | | | | | | $ 50,000 |
| **OPINION OF PROBABLE CONSTRUCTION COST (Point Estimate)** | | | | | | | | **$ 727,000** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - Low (-30%)** | | | | | | | | **$ 510,000** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - High (+50%)** | | | | | | | | **$ 1,090,000** |

## Annual Costs

| Item No. | Description | Quantity | Unit | Material, Equipment, Labor, and OHP Unit Cost | Material, Equipment, Labor, and OHP Total | Total Cost (rounded) | General Requirements 5% | 2013 O&M COST TOTAL |
|---|---|---|---|---|---|---|---|---|
| 1 | **QUARTERLY GROUNDWATER MONITORING** | | | | | | | |
| | Clear site for access | 1 | LS | $ 10,000 | $ 10,000 | $ 10,000 | $ 500 | $ 10,500 |
| | MEC specialist during sampling | 10 | DAY | $ 1,500 | $ 15,000 | $ 15,000 | $ 800 | $ 15,800 |
| | Groundwater sampling event | 4 | EVENT | $ 85,000 | $ 340,000 | $ 340,000 | $ 17,000 | $ 357,000 |
| | Quarterly Reporting | 4 | QTR | $ 25,000 | $ 100,000 | $ 100,000 | $ 5,000 | $ 105,000 |
| | Annual Reporting | 1 | YR | $ 30,000 | $ 30,000 | $ 30,000 | $ 1,500 | $ 31,500 |
| | | | | | | | | |
| Subtotal | | | | | $ 495,000 | $ 495,000 | $ 495,000 | $ 519,800 |
| Project Management, Engineering and Technical Assistance (20%) | | | | | | | | $ 103,960 |
| Contingency (Bid and Scope) (20%) | | | | | | | | $ 103,960 |
| **OPINION OF PROBABLE CONSTRUCTION COST (Point Estimate)** | | | | | | | | **$ 728,000** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - Low (-30%)** | | | | | | | | **$ 510,000** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - High (+50%)** | | | | | | | | **$ 1,090,000** |

## Periodic Costs

| Item No. | Description | Quantity | Unit | Material, Equipment, Labor, and OHP Unit Cost | Material, Equipment, Labor, and OHP Total | Total Cost (rounded) | General Requirements 5% | 2013 PERIODIC COST TOTAL |
|---|---|---|---|---|---|---|---|---|
| 1 | **5-YEAR REPORTING** | | | | | | | |
| | 5- Year Report | 1 | LS | 35,000 | $ 35,000 | $ 35,000 | $ 1,800 | $ 36,800 |
| Subtotal | | | | | $ 35,000 | $ 35,000 | $ 1,800 | $ 36,800 |
| Project Management, Engineering and Technical Assistance (20%) | | | | | | | | $ 7,000 |
| Contingency (Bid and Scope) (20%) | | | | | | | | $ 7,000 |
| **OPINION OF PROBABLE CONSTRUCTION COST (Point Estimate)** | | | | | | | | **$ 51,000** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - Low (-30%)** | | | | | | | | **$ 40,000** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - High (+50%)** | | | | | | | | **$ 80,000** |

**Item No.** **Basis of Cost**

Costs based on a variety of sources including published and unpublished sources such as RS Means, communications with vendors (written and verbal), and internal databases of cost based on previous experience. Costs FOB Topeka, Kansas where applicable.

Site to be checked for explosives prior to sampling event and MEC technician would be on-site during on-site work.

***Capital Costs***

Monitoring well location selection based on current known contaminant locations and estimated path of contaminants related to groundwater flow. An additional 11 monitoring wells would be installaed to 1) track vertical and horizontal path of plume and 2) serve as sentinel wells to determine if plume migration is occurring.

Additional wells proposed: 2 in regolith, 3 in weathered bedrock, and 6 in deeper bedrock.

Documentation report on well location selection, well installation and development, and baseline sampling results will be prepared for submittal to appriopriate regulatoary agencies.

***O&M Costs***

Groundwater will be sampled quarterly for approximately 5 years and then semi-annually. This schedule is reflected in the present value calculations.

During sampling events, samples will be analyzed for selected SVOCs, VOCs, metals, and explosive.

***Periodic costs***

The 5- year report prepared to assess condition of contaminants in OU6 groundwater.

No sampling costs on current conditions at the site prior to the 5-year report have been included in the cost estimate.

Cost is based on the assumption that Groundwater Report is prepared separately from Soil or SW reports. Combined reports would result in savings. Six reporting events anticipated over 30-year operating period.

# APPENDIX 5B-4

## Alternative GW4 – Monitored Natural Attenuation

**Appendix 5B-4**
**Alternative GW4 - Monitored Natural Attenuation**
*Feasibility Study Report*
*Open Burning / Open Detonation Ground (Range 16)*
*Fort Riley, Kansas*

## Capital Costs

| | Description | Quantity | Unit | Material, Equipment, Labor, and OHP Unit Cost | Material, Equipment, Labor, and OHP Total | Total Cost (rounded) | General Requirements 5% | 2013 CONSTRUCTION COST TOTAL |
|---|---|---|---|---|---|---|---|---|
| 1 | **PREDESIGN INVESTIGATIONS** | | | | | | | |
| | Monitorng well location selection | 1 | LS | $ 10,000 | $ 10,000 | $ 10,000 | $ 500 | $ 10,500 |
| | Background assessment of MNA conditions | 1 | LS | $ 25,000 | $ 25,000 | $ 25,000 | $ 25,000 | $ 25,000 |
| 2 | **GENERAL REQUIREMENTS** | | | | | | | |
| | Work Planning Documents | 1 | LS | $ 25,000 | $ 25,000 | $ 25,000 | $ 1,300 | $ 26,300 |
| | Clear site for access | 1 | LS | $ 10,000 | $ 10,000 | $ 10,000 | $ 500 | $ 10,500 |
| | MEC specialist during well install & develop, baseline sampling | 50 | DAY | $ 1,500 | $ 75,000 | $ 75,000 | $ 3,800 | $ 78,800 |
| 3 | **SITE WORK** | | | | | | | |
| | Well installation | 1 | LS | $ 201,000 | $ 201,000 | $ 201,000 | $ 10,100 | $ 211,100 |
| | Well development | 5 | DAY | $ 7,500 | $ 37,500 | $ 38,000 | $ 1,900 | $ 39,900 |
| | Baseline sampling - 2 rounds | 11 | WELL | $ 9,600 | $ 105,600 | $ 106,000 | $ 5,300 | $ 111,300 |
| | Reporting/Documentation | 1 | LS | $ 25,000 | $ 25,000 | $ 25,000 | $ 1,300 | $ 26,300 |
| | | | | | | | | |
| Subtotal Project | | | | | $ 514,100 | $ 515,000 | $ 49,700 | $ 539,700 |
| Design (10%) | | | | | | | | $ 54,000 |
| Project Management (10%) | | | | | | | | $ 54,000 |
| Construction Management (0%) | | | | | | | | $ - |
| Scope Contingency (15%) | | | | | | | | $ 81,000 |
| Bid Contingency (10%) | | | | | | | | $ 54,000 |
| **OPINION OF PROBABLE CONSTRUCTION COST (Point Estimate)** | | | | | | | | **$ 783,000** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - Low (-30%)** | | | | | | | | **$ 550,000** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - High (+50%)** | | | | | | | | **$ 1,170,000** |

## Annual Costs

| Item No. | Description | Quantity | Unit | Material, Equipment, Labor, and OHP Unit Cost | Material, Equipment, Labor, and OHP Total | Total Cost (rounded) | General Requirements 5% | 2013 O&M COST TOTAL |
|---|---|---|---|---|---|---|---|---|
| 1 | **QUARTERLY GROUNDWATER MONITORING** | | | | | | | |
| | Clear site for access | 1 | LS | $ 10,000 | $ 10,000 | $ 10,000 | $ 500 | $ 10,500 |
| | MEC specialist during sampling | 10 | DAY | $ 1,500 | $ 15,000 | $ 15,000 | $ 800 | $ 15,800 |
| | Groundwater sampling event | 4 | WELL | $ 96,000 | $ 384,000 | $ 384,000 | $ 19,200 | $ 403,200 |
| | IDW | 25 | DRUM | $ 500 | $ 12,500 | $ 12,500 | $ 600 | $ 13,100 |
| | Quarterly Reporting | 4 | QTR | $ 30,000 | $ 120,000 | $ 120,000 | $ 6,000 | $ 126,000 |
| | Annual Reporting | 1 | YR | $ 50,000 | $ 50,000 | $ 50,000 | $ 2,500 | $ 52,500 |
| | | | | | | | | |
| Subtotal | | | | | $ 591,500 | $ 591,500 | $ 591,500 | $ 621,100 |
| Project Management, Engineering and Technical Assistance (20%) | | | | | | | | $ 124,220 |
| Contingency (Bid and Scope) (20%) | | | | | | | | $ 124,220 |
| **OPINION OF PROBABLE CONSTRUCTION COST (Point Estimate)** | | | | | | | | **$ 870,000** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - Low (-30%)** | | | | | | | | **$ 609,000** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - High (+50%)** | | | | | | | | **$ 1,310,000** |

## Periodic Costs

| Item No. | Description | Quantity | Unit | Material, Equipment, Labor, and OHP Unit Cost | Material, Equipment, Labor, and OHP Total | Total Cost (rounded) | General Requirements 5% | 2013 PERIODIC COST TOTAL |
|---|---|---|---|---|---|---|---|---|
| 1 | **5-YEAR REPORTING** | | | | | | | |
| | 5- Year Report | 1 | LS | 50,000 | $ 50,000 | $ 50,000 | $ 2,500 | $ 52,500 |
| Subtotal | | | | | $ 50,000 | $ 50,000 | $ 2,500 | $ 52,500 |
| Project Management, Engineering and Technical Assistance (20%) | | | | | | | | $ 11,000 |
| Contingency (Bid and Scope) (20%) | | | | | | | | $ 11,000 |
| **OPINION OF PROBABLE CONSTRUCTION COST (Point Estimate)** | | | | | | | | **$ 75,000** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - Low (-30%)** | | | | | | | | **$ 50,000** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - High (+50%)** | | | | | | | | **$ 110,000** |

**Item No.** **Basis of Cost**

Costs based on a variety of sources including published and unpublished sources such as RS Means, communications with vendors (written and verbal), and internal databases of cost based on previous experience. Costs FOB Topeka, Kansas where applicable.

Site to be checked for explosives prior to sampling event and MEC technician would be on-site during the sampling event

***Capital Costs***

Monitoring well location selection based on current known contaminant locations and estimated path of contaminants related to groundwater flow. Additional wells proposed to 1) track vertical and horizontal path of plume and 2) serve as sentinel wells to determine if plume migration is occurring.

Additional wells proposed: 2 in regolith, 3 in weathered bedrock, and 6 in deeper bedrock.

Documentation report on well location selection, well installation and development, and baseline sampling results will be prepared for submittal to appriopriate regulatoary agencies.

***O&M Costs***

Groundwater will be sampled quarterly for approximately 5 years and then semi-annually. This schedule is reflected in the present value calculations.

During sampling events, samples will be analyzed for selected SVOCs, VOCs, metals, and explosive.

During sampling events, samples will be analyzed for MNA parameters to assess the ability of groundwater in each of the three formations to naturally attenuation the contaminants in the formation. The results of the MNA analysis and the impact on remediation of the plume will be evaluate annually.

***Periodic costs***

The 5- year report prepared to assess condition of contaminants in OU6 groundwater.

No sampling costs on current conditions at the site prior to the 5-year report have been included in the cost estimate.

Cost is based on the assumption that Groundwater Report is prepared separately from Soil or SW reports. Combined reports would result in savings. Six reporting events anticipated over 30-year operating period.

# APPENDIX 5B-5

## Alternative GW5 – In-Situ Treatment for Groundwater: Chemical Reagent Injection

**Appendix 5B-5**
**Alternative GW5 - In-Situ Treatment for Groundwater: Chemical Reagent Injection**
*Feasibility Study Report*
*Open Burning / Open Detonation Ground (Range 16)*
*Fort Riley, Kansas*

## Captial Costs

| Item No. | Description | Quantity | Unit | Material, Equipment, Labor, and OHP Unit Cost | Material, Equipment, Labor, and OHP Total | Total Cost (rounded) | General Requirements 5% | 2013 CONSTRUCTION COST TOTAL |
|---|---|---|---|---|---|---|---|---|
| 1 | **PREDESIGN INVESTIGATIONS** | | | | | | | |
| | MEC clearance for predesign investigation | 1 | LS | $ 10,000 | $ 10,000 | $ 10,000 | $ 500 | $ 10,500 |
| | MEC specialist on-site during pilot study | 15 | DAY | $ 1,500 | $ 22,500 | $ 22,500 | $ 1,100 | $ 23,600 |
| | Monitoriing well location selection | 1 | LS | $ 10,000 | $ 10,000 | $ 10,000 | $ 500 | $ 10,500 |
| | Treatability testing for reagents | 1 | LS | $ 25,000 | $ 25,000 | $ 25,000 | $ 1,300 | $ 26,300 |
| | Formation assessment - field activities | 1 | LS | $ 100,000 | $ 100,000 | $ 100,000 | $ 5,000 | $ 105,000 |
| | Formation assessment - reporting | 1 | LS | $ 25,000 | $ 25,000 | $ 25,000 | $ 1,300 | $ 26,300 |
| 2 | **GENERAL REQUIREMENTS** | | | | | | | |
| | General mobilization | 5% | LS | | $ 72,000 | $ 72,000 | $ 3,600 | $ 75,600 |
| | MEC clearance for well installation | 1 | LS | $ 10,000 | $ 10,000 | $ 10,000 | $ 500 | $ 10,500 |
| | MEC technican during field activities | 65 | DAY | $ 1,500 | $ 98,000 | $ 98,000 | $ 4,900 | $ 102,900 |
| 3 | **SITE WORK** | | | | | | | |
| | Monitoring well installation | 1 | LS | $ 201,000 | $ 201,000 | $ 201,000 | $ 10,100 | $ 211,100 |
| | Well development | 5 | DAY | $ 7,500 | $ 37,500 | $ 38,000 | $ 1,900 | $ 39,900 |
| | Baseline sampling - 2 rounds | 11 | WELL | $ 8,500 | $ 93,500 | $ 94,000 | $ 4,700 | $ 98,700 |
| | Injection wells installation - shallow wells | 30 | EA | $ 8,000 | $ 240,000 | $ 240,000 | $ 12,000 | $ 252,000 |
| | Injection wells installation - intermediate wells | 10 | EA | $ 12,000 | $ 120,000 | $ 120,000 | $ 6,000 | $ 126,000 |
| | IDW | 4 | Rolloff | $ 4,000 | $ 16,000 | $ 16,000 | $ 800 | $ 16,800 |
| | Parts and supplies | 1 | LS | $ 20,000 | $ 20,000 | $ 20,000 | $ 1,000 | $ 21,000 |
| | Well construction oversight | 60 | DAY | $ 1,500 | $ 90,000 | $ 90,000 | $ 4,500 | $ 94,500 |
| | Injection and monitoring installation documentation | 1 | LS | $ 25,000 | $ 25,000 | $ 25,000 | $ 1,300 | $ 26,300 |
| 4 | **INSITU INJECTION** | | | | | | | |
| | Injection process | | | | | | | |
| | Injection contractor | 50 | DAY | $ 3,000 | $ 150,000 | $ 150,000 | $ 7,500 | $ 157,500 |
| | Chemicals | 1 | EVENT | $ 20,000 | $ 20,000 | $ 20,000 | $ 1,000 | $ 21,000 |
| | Parts and supplies | 40 | WELL | $ 2,500 | $ 100,000 | $ 100,000 | $ 5,000 | $ 105,000 |
| | Shipping | 1 | LS | $ 1,500 | $ 1,500 | $ 1,500 | $ 100 | $ 1,600 |
| | Construction oversight | 50 | DAY | $ 3,000 | $ 150,000 | $ 150,000 | $ 7,500 | $ 157,500 |
| 5 | **SITE RESTORATION** | 1 | LS | $ 20,000 | $ 20,000 | $ 20,000 | $ 1,000 | $ 21,000 |
| | | | | | | | | |
| Subtotal Project | | | | | | $ 1,658,000 | $ 83,100 | $ 1,741,100 |
| Design (10%) | | | | | | | | $ 174,110 |
| Project Management (10%) | | | | | | | | $ 174,110 |
| Construction Management (6%) | | | | | | | | $ 104,466 |
| Scope Contingency (15%) | | | | | | | | $ 261,165 |
| Bid Contingency (10%) | | | | | | | | $ 174,110 |
| | | | | | | | | **$ 2,630,000** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - Low (-30%)** | | | | | | | | **$ 1,840,000** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - High (+50%)** | | | | | | | | **$ 3,950,000** |

**Appendix 5B-5**
**Alternative GW5 - In-Situ Treatment for Groundwater: Chemical Reagent Injection**
*Feasibility Study Report*
*Open Burning / Open Detonation Ground (Range 16)*
*Fort Riley, Kansas*

## Annual Costs

| Item No. | Description | Quantity | Unit | Material, Equipment, Labor, and OHP Unit Cost | Material, Equipment, Labor, and OHP Total | Total Cost (rounded) | General Requirements 5% | 2013 O&M COST TOTAL |
|---|---|---|---|---|---|---|---|---|
| 1 | **QUARTERLY GROUNDWATER MONITORING** | | | | | | | |
| | Clear site for access | 1 | LS | $ 10,000 | $ 10,000 | $ 10,000 | $ 500 | $ 10,500 |
| | MEC specialist during sampling | 10 | DAY | $ 1,500 | $ 15,000 | $ 15,000 | $ 800 | $ 15,800 |
| | Groundwater sampling event | 27 | WELL | $ 1,500 | $ 40,500 | $ 41,000 | $ 2,100 | $ 43,100 |
| | IDW | 25 | DRUM | $ 500 | $ 12,500 | $ 12,500 | $ 600 | $ 13,100 |
| | Quarterly Reporting | 4 | QTR | $ 30,000 | $ 120,000 | $ 120,000 | $ 6,000 | $ 126,000 |
| | Annual Reporting | 1 | YR | $ 40,000 | $ 40,000 | $ 40,000 | $ 2,000 | $ 42,000 |
| | | | | | | | | |
| Subtotal | | | | | $ 238,000 | $ 238,000 | $ 238,000 | $ 250,500 |
| Project Management, Engineering and Technical Assistance (20%) | | | | | | | | $ 50,100.00 |
| Contingency (Bid and Scope) (20%) | | | | | | | | $ 50,100.00 |
| **OPINION OF PROBABLE CONSTRUCTION COST (Point Estimate)** | | | | | | | | **$ 351,000** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - Low (-30%)** | | | | | | | | **$ 246,000** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - High (+50%)** | | | | | | | | **$ 530,000** |

## Periodic Costs

| Item No. | Description | Quantity | Unit | Material, Equipment, Labor, and OHP Unit Cost | Material, Equipment, Labor, and OHP Total | Total Cost (rounded) | General Requirements 5% | 2013 PERIODIC COST TOTAL |
|---|---|---|---|---|---|---|---|---|
| 1 | **ADDITIONAL ROUNDS OF INJECTIONS (Every 10 Years)** | | | | | | | |
| | Clear site for access | 1 | LS | $ 10,000 | $ 10,000 | $ 10,000 | $ 500 | $ 10,500 |
| | MEC specialist during sampling | 50 | DAY | $ 1,500 | $ 75,000 | $ 75,000 | $ 3,800 | $ 78,800 |
| | Injection process | | | | | | | |
| | Injection contractor | 50 | DAY | $ 3,000 | $ 150,000 | $ 150,000 | $ 7,500 | $ 157,500 |
| | Chemicals | 1 | EVENT | $ 20,000 | $ 20,000 | $ 20,000 | $ 1,000 | $ 21,000 |
| | Parts and supplies | 40 | WELL | $ 2,500 | $ 100,000 | $ 100,000 | $ 5,000 | $ 105,000 |
| | Shipping | 1 | LS | $ 1,500 | $ 1,500 | $ 1,500 | $ 75 | $ 1,575 |
| | Construction oversight | 50 | DAY | $ 3,000 | $ 150,000 | $ 150,000 | $ 7,500 | $ 157,500 |
| 2 | **5-YEAR REPORTING** | | | | | | | |
| | 5- Year Report | 1 | LS | $ 50,000 | $ 50,000 | $ 50,000 | $ 2,500 | $ 52,500 |
| Subtotal | | | | | $ 471,500 | $ 471,500 | $ 23,575 | $ 495,075 |
| Project Management, Engineering and Technical Assistance (20%) | | | | | | | | $ 99,015 |
| Contingency (Bid and Scope) (20%) | | | | | | | | $ 99,015 |
| **OPINION OF PROBABLE CONSTRUCTION COST (Point Estimate)** | | | | | | | | **$ 693,000** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - Low (-30%)** | | | | | | | | **$ 490,000** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - High (+50%)** | | | | | | | | **$ 1,040,000** |

**Item No.** **Basis of Cost**

Costs based on a variety of sources including published and unpublished sources such as RS Means, communications with vendors (written and verbal), and internal databases of cost based on previous experience. Costs FOB Topeka, Kansas where applicable.

Site to be checked for explosives prior to sampling event and MEC technician would be on-site during the sampling event.

***Capital Costs***

**1** Predesign investigations will be conducted prior to the Remedial Design to more thoroughly delineate limits, profile waste for disposal, determine wastewater treatment requirements.

Bench scale treatability testing of potential reagents for use in treating both TCE and PCA in situ.

Formation testing will include tests to assess the ability of the formation(s) to accept the reagent, rate of injection, ROI of injection and other parameters to be used in designing the injection program. Testing will also include in-field testing of one or more reagent for its ability to treat both PCA and TCE in situ within this formation.

Following the field program, a report will be prepared for regulatory submittal summarizing the basis of the design that will be used in the remainder of the injection program.

**2** General requirements consist of overhead costs borne by the general contractor not directly related to specific remediation activities including QA and H&S requirements, temporary site facilites (trailers, power, water, sanitary, etc. ), site supervision, general supplies, general labor for operations.

**3** Site work related to upgrades to monitoring well network and installation of permanent injection wells downgradient of the source area to treat the TCE and PCA plume. For this analysis, it was 2 rows of off-set wells were assumed to provide adequate coverage. Due to formation, assume ROI 10 to 15 feet. Depth of wells to be based on formation testing.

Monitoring well location selection based on current known contaminant locations and estimated path of contaminants. Additional wells proposed to 1) track vertical and horizontal path of plume and 2) serve as sentinel wells to determine if plume migration is occurring. Based on placement of injection wells, some existing monitoring wells may be abandoned.

Additional wells proposed: 2 in regolith, 3 in weathered bedrock, and 6 in deeper bedrock.

Documentation report on well location selection, well installation and development, and baseline sampling results will be prepared for submittal to appriopriate regulatoary agencies.

**4** Insitu injection program will be conducted to inject a reagent into one or more formations to treat the chlorinated solvent plume.

Injection wells will be installed to allow multiple rounds of injections as necessary to address contaminants in the groundwater. Shallow injections will be constructed in the regolith; intermediate injection wells into the weathered bedrock if supported by injection testing. Wells will be constructed at an estimated rate of 1 well per day.

IDW will be placed in a lined rolloff container and covered. Following the completion of the well construction program, the IDW will be characterized for disposal. For this estimate it was assumed that the IDW would require incineration at the facility in Kimball, NE.

A report will be prepared for submittal to the appropriate regulatory agencies on monitoring well and injection well installation.

A contractor will be retained to assist in the injection well process and to supply pumps, tanks and other equipment required.

Insitu injection is assumed to take one day per well based on the formation; actual rates will vary. Infield time includes time for setup and decontamination/restoration of the site following the injection process.

Parts and supplies include forklift for handling reagent bins, water truck for use in mixing reagent, tanks, hoses and tubing, PPE and other miscellaneous items.

**5** Site cleanup activities will include the removal of all equipment, cleaning and testing of paved surface, and restoration of paving to preconstruction conditions.

***O&M Costs***

Groundwater will be sampled quarterly for approximately 5 years and then semi-annually. This schedule is reflected in the present value calculations.

During sampling events, samples will be analyzed for selected SVOCs, VOCs, metals, and explosive.

During sampling events, samples will be analyzed for MNA parameters to assess the impact of injections on groundwater in each of the three formations toattenuation the contaminants.

***Periodic costs***

Reagent will be reinjected into the formation as necessary to treat the plume. Timing will be vary based on the selected reagent. For this analysis, it was assumed that the reagent would be injected approximately every 5 years over the 30 year operating period. A contractor would be retained for this work and construction oversight provided at a cost of $1500 per person per day. This rate includes labor, travel and per diem, vehicles, equipment, supplies.

The 5-year report prepared to assess condition of contaminants in OU6 groundwater.

No sampling costs on current conditions at the site prior to the 5-year report have been included in the cost estimate.

Cost is based on the assumption that Groundwater Report is prepared separately from Soil or SW reports. Combined reports would result in savings. Six reporting events anticipated over 30-year operating period.

# APPENDIX 5C-1

## Alternative SW1 – No Action for Surface Water

**Appendix 5C-1**
**Alternative SW1 - No Action for Surface Water**
*Feasibility Study Report*
*Open Burning / Open Detonation Ground (Range 16)*
*Fort Riley, Kansas*

## Capital Costs

| No. | Description | Quantity | Unit | Material, Equipment, Labor, and OHP Unit Cost | Material, Equipment, Labor, and OHP Total | Total Cost (rounded) | General Requirements 5% | 2013 CONSTRUCTION COST TOTAL |
|---|---|---|---|---|---|---|---|---|
| 1 | **PREDESIGN INVESTIGATIONS** | | | | | | | |
| 2 | **GENERAL REQUIREMENTS** | | | | | | | |
| 3 | **SITE WORK** | | | | | | | |
| 4 | **INSTITUTIONAL CONTROLS** | | | | | | | |
| | | | | | | | | |
| Subtotal Project | | | | | | $ - | $ - | $ - |
| Design (10%) | | | | | | | | $ - |
| Project Management (10%) | | | | | | | | $ - |
| Construction Management (0%) | | | | | | | | $ - |
| Scope Contingency (15%) | | | | | | | | $ - |
| Bid Contingency (10%) | | | | | | | | $ - |
| **OPINION OF PROBABLE CONSTRUCTION COST (Point Estimate)** | | | | | | | | **$ -** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - Low (-30%)** | | | | | | | | **$ -** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - High (+50%)** | | | | | | | | **$ -** |

## Annual Costs

| Item No. | Description | Quantity | Unit | Material, Equipment, Labor, and OHP Unit Cost | Material, Equipment, Labor, and OHP Total | Total Cost (rounded) | General Requirements 5% | 2013 O&M COST TOTAL |
|---|---|---|---|---|---|---|---|---|
| | **ANNUAL OPERATING AND MAINTENANCE COSTS** | | | | | | | |
| | | | | | | | | |
| Subtotal | | | | | $ - | $ - | $ - | $ - |
| Project Management, Engineering and Technical Assistance (20%) | | | | | | | | $ - |
| Contingency (Bid and Scope) (20%) | | | | | | | | $ - |
| **OPINION OF PROBABLE CONSTRUCTION COST (Point Estimate)** | | | | | | | | **$ -** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - Low (-30%)** | | | | | | | | **$ -** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - High (+50%)** | | | | | | | | **$ -** |

## Periodic Costs

| Item No. | Description | Quantity | Unit | Material, Equipment, Labor, and OHP Unit Cost | Material, Equipment, Labor, and OHP Total | Total Cost (rounded) | General Requirements 5% | 2013 PERIODIC COST TOTAL |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| | | | | | | | | $ - |
| | | | | | | | | $ - |
| Subtotal | | | | | $ - | $ - | $ - | $ - |
| Project Management, Engineering and Technical Assistance (20%) | | | | | | | | $ - |
| Contingency (Bid and Scope) (20%) | | | | | | | | $ - |
| **OPINION OF PROBABLE CONSTRUCTION COST (Point Estimate)** | | | | | | | | **$ -** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - Low (-30%)** | | | | | | | | **$ -** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - High (+50%)** | | | | | | | | **$ -** |

**Item No.** **Basis of Cost**

Costs based on a variety of sources including published and unpublished sources such as RS Means, communications with vendors (written and verbal), and internal databases of cost based on previous experience. Costs FOB Topeka, Kansas where applicable.

Site to be checked for explosives prior to sampling event and MEC technician would be on-site during the sampling event

***Capital Costs***

***O&M Costs***

***Periodic Costs***

# APPENDIX 5C-2

## Alternative SW2 – Institutional Controls for Surface Water

**Appendix 5C-2**
**Alternative SW2 - Institutional Controls for Surface Water**
*Feasibility Study Report*
*Open Burning / Open Detonation Ground (Range 16)*
*Fort Riley, Kansas*

## Capital Costs

| No. | Description | Quantity | Unit | Material, Equipment, Labor, and OHP Unit Cost | Material, Equipment, Labor, and OHP Total | Total Cost (rounded) | General Requirements 5% | 2013 CONSTRUCTION COST TOTAL |
|---|---|---|---|---|---|---|---|---|
| **1** | **PREDESIGN INVESTIGATIONS** | | | | | | | |
| **2** | **GENERAL REQUIREMENTS** | | | | | | | |
| **3** | **SITE WORK** | | | | | | | |
| **4** | **INSTITUTIONAL CONTROLS** | | | | | | | |
| | Develop Institutional Controls | 1 | LS | $ 2,500 | $ 2,500 | $ 2,500 | $100 | $2,600 |
| | | | | | | | | |
| Subtotal Project | | | | | $ 2,500 | $ 2,500 | $ 100 | $ 2,600 |
| Design (10%) | | | | | | | | $ 300 |
| Project Management (10%) | | | | | | | | $ 300 |
| Construction Management (0%) | | | | | | | | $ - |
| Scope Contingency (15%) | | | | | | | | $ 400 |
| Bid Contingency (10%) | | | | | | | | $ 300 |
| | | | | | | | | **$ 4,000** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - Low (-30%)** | | | | | | | | **$ 3,000** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - High (+50%)** | | | | | | | | **$ 6,000** |

## Annual Costs

| Item No. | Description | Quantity | Unit | Material, Equipment, Labor, and OHP Unit Cost | Material, Equipment, Labor, and OHP Total | Total Cost (rounded) | General Requirements 5% | 2013 O&M COST TOTAL |
|---|---|---|---|---|---|---|---|---|
| **1** | **ENFORCEMENT** | 1 | YR | $ 1,500 | $ 1,500 | $ 2,000 | $ 100 | $ 2,100 |
| | | | | | | | | |
| | | | | | | | | |
| Subtotal | | | | | $ 1,500 | $ 2,000 | $ 100 | $ 2,100 |
| Project Management, Engineering and Technical Assistance (20%) | | | | | | | | $ 400 |
| Contingency (Bid and Scope) (20%) | | | | | | | | $ 400 |
| **OPINION OF PROBABLE CONSTRUCTION COST (Point Estimate)** | | | | | | | | **$ 3,000** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - Low (-30%)** | | | | | | | | **$ 2,000** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - High (+50%)** | | | | | | | | **$ 5,000** |

## Periodic Costs

| Item No. | Description | Quantity | Unit | Material, Equipment, Labor, and OHP | | Total Cost | General Requirements | 2013 PERIODIC COST TOTAL |
|---|---|---|---|---|---|---|---|---|
| | | | | Unit Cost | Total | (rounded) | 5% | |
| 1 | **5-YEAR REPORTING** | | | | | | | |
| | 5- Year Report | 1 | LS | $ 15,000 | $ 15,000 | $ 15,000 | $ 800 | $ 15,800 |
| | | | | | | | | |
| Subtotal | | | | | $ 15,000 | $ 15,000 | $ 800 | $ 15,800 |
| Project Management, Engineering and Technical Assistance (20%) | | | | | | | | $ 3,000 |
| Contingency (Bid and Scope) (20%) | | | | | | | | $ 3,000 |
| **OPINION OF PROBABLE CONSTRUCTION COST (Point Estimate)** | | | | | | | | **$ 22,000** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - Low (-30%)** | | | | | | | | **$ 15,000** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - High (+50%)** | | | | | | | | **$ 33,000** |

**Item No.**

### Basis of Cost

Costs based on a variety of sources including published and unpublished sources such as RS Means, communications with vendors (written and verbal), and internal databases of cost based on previous experience. Costs FOB Topeka, Kansas where applicable.

Site to be checked for explosives prior to sampling event and MEC technician would be on-site during the sampling event

***Capital Costs***

Development costs include preparation of language for IC and distribution as necessary

***O&M Costs***

Enforcement costs involves periodic plan reviews as necessary and periodic site inspections to ensure compliance

***Periodic costs***

The 5- year report prepared to assess condition of contaminants in OU6 surface water.

No sampling costs on current conditions at the site prior to the 5-year report have been included in the cost estimate.

Cost is based on the assumption that Surface Water Report is prepared separately from Soil or SW reports. Combined reports would result in savings. Six reporting events anticipated over 30-year operating period.

# APPENDIX 5C-3

## Alternative SW3 – Surface Water Monitoring

**Appendix 5C-3**
**Alternative SW3 - Surface Water Monitoring**
*Feasibility Study Report*
*Open Burning / Open Detonation Ground (Range 16)*
*Fort Riley, Kansas*

## Capital Costs

| No. | Description | Quantity | Unit | Material, Equipment, Labor, and OHP Unit Cost | Material, Equipment, Labor, and OHP Total | Total Cost (rounded) | General Requirements 5% | 2013 CONSTRUCTION COST TOTAL |
|---|---|---|---|---|---|---|---|---|
| **1** | **PREDESIGN INVESTIGATIONS** | | | | | | | |
| | Workplan for sampling program | 1 | LS | $25,000 | $25,000 | $25,000 | $ 1,300 | $26,300 |
| **2** | **GENERAL REQUIREMENTS** | | | | | | | |
| **3** | **SITE WORK** | | | | | | | |
| | | | | | | | | |
| Subtotal Project | | | | | $ 25,000 | $ 25,000 | $ 1,300 | $ 26,300 |
| Design (10%) | | | | | | | | $ 2,600 |
| Project Management (10%) | | | | | | | | $ 2,600 |
| Construction Management (0%) | | | | | | | | $ - |
| Scope Contingency (15%) | | | | | | | | $ 3,900 |
| Bid Contingency (10%) | | | | | | | | $ 2,600 |
| **OPINION OF PROBABLE CONSTRUCTION COST (Point Estimate)** | | | | | | | | **$ 38,000** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - Low (-30%)** | | | | | | | | **$ 27,000** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - High (+50%)** | | | | | | | | **$ 57,000** |

## Annual Costs

| Item No. | Description | Quantity | Unit | Material, Equipment, Labor, and OHP Unit Cost | Material, Equipment, Labor, and OHP Total | Total Cost (rounded) | General Requirements 5% | |
|---|---|---|---|---|---|---|---|---|
| **1** | **SURFACE WATER MONITORING** | | | | | | | |
| | Clear site for access | 2 | LS | 5,000 | $ 10,000 | $ 10,000 | $ 500 | $ 10,500 |
| | MEC specialist during sampling | 4 | DAY | 1,500 | $ 6,000 | $ 6,000 | $ 300 | $ 6,300 |
| | Semi-annual surface water monitoring | 2 | EVENT | 45,000 | $ 90,000 | $ 90,000 | $ 4,500 | $ 94,500 |
| | Annual report | 1 | RPT | 12,000 | $ 12,000 | $ 12,000 | $ 600 | $ 12,600 |
| | | | | | | | | |
| Subtotal | | | | | $ 118,000 | $ 118,000 | $ 5,900 | $ 123,900 |
| Project Management, Engineering and Technical Assistance (20%) | | | | | | | | $ 25,000 |
| Contingency (Bid and Scope) (20%) | | | | | | | | $ 25,000 |
| **OPINION OF PROBABLE CONSTRUCTION COST (Point Estimate)** | | | | | | | | **$ 174,000** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - Low (-30%)** | | | | | | | | **$ 122,000** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - High (+50%)** | | | | | | | | **$ 261,000** |

**Appendix 5C-3**
**Alternative SW3 - Surface Water Monitoring**
*Feasibility Study Report*
*Open Burning / Open Detonation Ground (Range 16)*
*Fort Riley, Kansas*

## Periodic Costs

| Item No. | Description | Quantity | Unit | Material, Equipment, Labor, and OHP | | Total Cost | General Requirements | 2013 PERIODIC COST TOTAL |
|---|---|---|---|---|---|---|---|---|
| | | | | Unit Cost | Total | (rounded) | 5% | |
| 1 | **5-YEAR REPORTING** | | | | | | | |
| | 5- Year Report | 1 | LS | 15,000 | $ 15,000 | $ 15,000 | $ 800 | $ 15,800 |
| | | | | | | | | |
| Subtotal | | | | | $ 15,000 | $ 15,000 | $ 800 | $ 15,800 |
| Project Management, Engineering and Technical Assistance (20%) | | | | | | | | $ 3,000 |
| Contingency (Bid and Scope) (20%) | | | | | | | | $ 3,000 |
| **OPINION OF PROBABLE CONSTRUCTION COST (Point Estimate)** | | | | | | | | **$ 22,000** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - Low (-30%)** | | | | | | | | **$ 15,000** |
| **OPINION OF PROBABLE CONSTRUCTION COST (Range Estimate - High (+50%)** | | | | | | | | **$ 33,000** |

**Item No.**

### Basis of Cost

Costs based on a variety of sources including published and unpublished sources such as RS Means, communications with vendors (written and verbal), and internal databases of cost based on previous experience. Costs FOB Topeka, Kansas where applicable.

Site to be checked for explosives prior to sampling event and MEC technician would be on-site during the sampling event

***Capital Costs***

Development or workplan for semi-annual groundwater monitoring program, identification of monitoring points, H&S Plan

***O&M Costs***

Semi-annual surface water monitoring at OU6 - 15 to 20 points, timing based on flow in streams and seeps

Existing monitoring where be used as feasible although some points may be combined or not sampled during the same period

Samples analyzed for VOCs, SVOCs, metals, perchlorate, explosives

Data report prepared based on sampling program

***Periodic costs***

The 5- year report prepared to assess condition of contaminants in OU6 surface water.

No sampling costs on current conditions at the site prior to the 5-year report have been included in the cost estimate.

Cost is based on the assumption that Surface Water Report is prepared separately from Soil or SW reports. Combined reports would result in savings. Six reporting events anticipated over 30-year operating period.