REMEDIAL INVESTIGATION REPORT

FORMER FORBES ATLAS MISSILE SITE S-5
LYON COUNTY, KANSAS

FUDS B07KS0204-01

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FINAL

Prepared for:

U.S. Army Corps of Engineers – Kansas City District

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Acronyms and Abbreviations

ABS_{GI}	fraction of a COPC that is absorbed in the gastrointestinal tract
ADAF	age-dependent adjustment factor
ADD	average daily dose
AF	adherence factor
AMSL	above mean sea level
AQTESOLV	AQuifer Test SOLVer
AT	averaging time
BER	Bureau of Environmental Remediation
bgs	below ground surface
BTOC	below top of casing
BW	body weight
C_2HCl_3	chlorinated hydrocarbon
CalEPA	California Environmental Protection Agency
CENWK	U.S. Army Corps of Engineers-Kansas City District
CERCLA	Comprehensive Environmental Response, Compensation, & Liability Act
cis-1,2-DCE	cis-1,2-dichloroethene
CLPNFG	Contract Laboratory Program National Functional Guidelines
cm/sec	centimeters per second
CO_2	carbon dioxide
COC	Contaminant of Concern
COPC	Contaminant of Potential Concern
CS	Confirmation Study
CSF	Cancer slope factor
CSF	Dermal cancer slope factor
CSM	Conceptual Site Model
DERP	Defense Environmental Restoration Program
DL	Detection limit
DO	dissolved oxygen
DoD	Department of Defense
ED	exposure duration
EF	exposure frequency
EO	Executive Order
EPC	Exposure Point Concentration
EUC	environmental use control
EV	Event frequency
FAFB	Former Forbes Air Force Base
^oF	Fahrenheit

Acronyms and Abbreviations

Fe(III)	Ferric iron
FI	fraction ingested
Forbes S-5	Former Forbes Atlas Missile Site S-5
ft	feet
ft/ft	feet/foot
ft/yr	feet/year
FS	Feasibility Study
FUDS	Formerly Used Defense Site
gpm	gallons per minute
H_2	molecular hydrogen
HHE	human health and the environment
HHRA	Human Health Risk Assessment
HI	Hazard index
HQ	Hazard quotient
ICBM	Intercontinental Ballistic Missile
IDW	investigation-derived waste
IRA	Interim Remedial Action
IRIS	Integrated Risk Information Systems
IRW	water ingestion rate
IR-SD	sediment ingestion rate
KDHE	Kansas Department of Health and Environment
kg	kilogram
KGS	Kansas Geological Survey
KM	Kaplan Meier
L/day	Liters/day
LADD	Lifetime average daily dose
LOX	Liquid oxygen
MCL	maximum contaminant level
µg/L	microgram per liter
mg/kg	milligram per kilogram
mg/L	milligram per liter
MOA	mode of action
mV	millivolt
NAPL	non-aqueous phase liquid

Acronyms and Abbreviations

NCP	National Oil and Hazardous Substances Pollution Contingency Plan
ND	nondetect
NHLymphoma	non-Hodgkin lymphomaNRCS
Natural Resources Conservation Service	
NPL	National Priorities List
ORP	oxidation-reduction potential
PA	Preliminary Assessment
PAH	polynuclear aromatic hydrocarbon
PCB	polychlorinated biphenyls
PCE	tetrachloroethylene
PID	photoionization detector
QAPP	Quality Assurance Project Plan
QA/QC	quality assurance/quality control
QCSR	Quality Control Summary Report
QSM	quality systems manual
RAGS	Risk Assessment Guidance for Superfund
RCRA	Resource Conservation and Recovery Act
RfC	Reference Concentration
RfD	Reference Dose
RfD_o	Oral Reference Dose
RI	Remedial Investigation
RME	reasonable maximum exposure
RSK	Risk-Based Standards for Kansas
RSL	regional screening levels
SA	surface area
SARA	Superfund Amendments and Reauthorization Act
SLERA	screening-level ecological risk assessment
SMS	Strategic Missile Squadron
START	Superfund Technical Assessment and Response Team
SVOC	semivolatile organic compound
TCE	trichloroethene
TCLP	toxicity characteristic leaching procedure
THQ	target hazard quotient
TOC	total organic carbon
TPH	total petroleum hydrocarbons
TR	target risk

trans-1,2-DCE	trans-1,2-dichloroethene
UCL	upper-confidence limit
UFP-QAPP	Uniform Federal Policy – Quality Assurance Project Plan
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
UST	underground storage tank
URF	Unit Risk Factor
VC	vinyl chloride
VI	vapor intrusion
VISL	vapor intrusion screening level
VOC	volatile organic compound
WWC5	water well completion forms

1. INTRODUCTION

This Remedial Investigation (RI) Report was prepared by Avatar Environmental, LLC and Burns & McDonnell Engineering Company, Inc. for the Former Forbes Atlas Missile Site S-5 (Forbes S-5), an Atlas E Missile Facility, located in Lyon County, Kansas. The work was performed for the U.S. Army Corps of Engineers (USACE), Kansas City District (CENWK) under Contract No. W912DQ-12-D-3003. The Forbes S-5 Site is a Formerly Used Defense Site (FUDS), B07KS0204-01.

1.1 REGULATORY REQUIREMENTS AND AGENCY COORDINATION

Activities at the Forbes S-5 Site are being administered by the USACE under the Defense Environmental Restoration Program (DERP)/FUDS program. The Army is the executive agent on behalf of the Department of Defense (DoD) charged with meeting all applicable environmental restoration requirements at FUDS, regardless of which DoD component previously owned or used the property. The Secretary of the Army further delegated the program management and execution responsibility for FUDS to the USACE.

In carrying out its responsibilities, USACE must comply with the DERP statute (10 USC 2701 et seq.), the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) (42 USC § 9601 *et seq.*), Executive Orders (EOs) 12580 and 13016, the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), and all applicable DoD (e.g., DoD Management Guidance for the DERP) and Army policies in managing and executing the FUDS program.

For FUDS properties not included on the National Priorities List (NPL), such as the Forbes S-5 Site, the DERP statute requires that response actions addressing DoD hazardous substances, pollutants, and contaminants be conducted in accordance with CERCLA. States or tribes are generally the lead regulator for environmental investigations and responses at non-NPL FUDS. As such, the Kansas Department of Health and Environment (KDHE) is the lead regulatory agency. DoD maintains lead agency authority at the Forbes S-5 Site, coordinates project

activities with KDHE, and provides notice and opportunity for comment to KDHE. Under the DERP-FUDS program, only known or potential contamination or hazards on the Forbes S-5 Site attributable to former DoD activities (prior to October 17, 1986) can be addressed.

This report was prepared in accordance with CERCLA. It is consistent with the requirements of CERCLA, as amended by the Superfund Amendments and Reauthorization Act (SARA) of 1986, and the NCP.

1.2 PURPOSE OF REPORT

This report presents the RI results and data evaluation conducted for the Forbes S-5 Site. It was prepared based on historical data and data developed during the investigations detailed herein. The overall objectives of the RI are;

- Characterize the nature and extent of contamination;
- Evaluate the environmental fate and transport of site-related contamination; and
- Assess the potential risks to human health and the environment (HHE) posed by contamination at the Forbes S-5 Site.

To meet these objectives, the RI:

- Compiled and evaluated available historic Forbes S-5 Site data;
- Obtained additional data required to characterize the source and the nature and extent of contamination in the soil and groundwater;
- Assessed the environmental fate and transport conditions of contaminants of potential concern at the Site; and
- Prepared a risk assessment of the potential threats to HHE posed by site-related contamination.

1.3 REPORT ORGANIZATION

The RI report contains the following sections:

- Section 1 describes the purpose and objectives of the RI, and provides a description of the site history and the previous environmental investigations;
- Section 2 presents a description of the site characteristics including site features, meteorology, hydrology, geology, land use, and ecology;
- Section 3 discusses the nature and extent of contamination which includes the RI sampling;
- Section 4 addresses the fate and transport of site-related contaminants;
- Section 5 presents the human health and ecological risk assessments.
- Section 6 presents the RI summary and conclusions.
- Section 7 presents the report references.

Tables and figures that are referenced in the document are contained in separate tables and figures sections at the end of the report text. There are also twelve appendices to this report, as follows:

- Appendix A Precipitation Graph
- Appendix B Boring Logs, Well Construction Diagrams, and Kansas WWC-5 Forms
- Appendix C Shallow and Deep Groundwater Elevation Graphs
- Appendix D Groundwater Elevation Maps
- Appendix E Slug Test Field Forms
- Appendix F Slug Test Analysis
- Appendix G Field Log Book
- Appendix H Quality Control Summary Reports (QCSRs) including Laboratory Analytical Data Reports
- Appendix I Historical Analytical Result Tables
- Appendix J Well Development Forms
- Appendix K Survey Data

- Appendix L Photograph Log
- Appendix M Field Quality Control Checklists
- Appendix N Groundwater Sampling Forms
- Appendix O TCE and cis-1,2 dichloroethene (DCE) Trend Graphs
- Appendix P Human Health Risk Assessment ProUCL Input and Output

1.4 SITE BACKGROUND

The former Forbes S-5 Site is one of nine Atlas E missile launch facilities constructed near the former Forbes Air Force Base (FAFB) between 1959 and 1965 to house Intercontinental Ballistic Missiles (ICBM). The Forbes S-5 Site is located in Lyon County, Kansas, approximately 8 miles west of Allen, Kansas and approximately 45 miles southwest of Topeka, Kansas (see Figure 1-1). The Forbes S-5 Site consists of approximately 25 acres within a general rectangular area and is surrounded by agricultural grazing lands (see Figure 1-2).

1.4.1 Site Description

Each of the Atlas E missile facilities, including the Forbes S-5 Site, consisted of a buried, horizontal concrete vault, with launch doors located at ground surface. Additional features included a launch operations building, a missile maintenance building, a cooling tower, a launch and services building, a water supply building, a septic system, a fuel storage system, former sewage lagoons, and a tunnel. Structures remaining at the facility include the horizontal concrete vault (missile coffin), underground launch operation rooms, underground storage tanks (UST), concrete pads, and sewage lagoons (see Figure 1-3).

1.4.2 Site History

Construction started on the nine Forbes Atlas E missile facilities in 1959. Operation of the Forbes S-5 Site was the responsibility of the 548th Strategic Missile Squadron (SMS) assigned to the Former Forbes Air Force Base in Topeka, Kansas. The 548th SMS was activated in 1960 and missiles first started arriving at the SMS sites in January 1961. The 548th SMS was declared “Operationally Ready” in October of 1961.

The Atlas E type missiles were composed of the SM-65 variant and were housed in a "coffin launcher" style complex. The missile was kept in a horizontal position and in order to launch, a 400-ton hardened concrete overhead roof was rolled back after which the missile was elevated to a vertical launch position. Once upright, the rocket was fueled with RP-1 (kerosene) and liquid oxygen (LOX). The Atlas E missiles were equipped with a Mark IV re-entry vehicle and carried a type W-38 warhead which had a yield of approximately 4 megatons of trinitrotoluene. The Atlas E missile had a range of approximately 6,000 miles.

The Forbes S-5 facility operated from 1961 until 1965, when it was decommissioned. In 1965, the facility was reported as excess and was subsequently sold (USACE, 1993). The facility is currently privately owned and is not being used.

A typical facility deactivation plan for Atlas missile facilities involved four phases:

- Removal/transportation/storage of missiles;
- Preservation of sites/complexes;
- Screening and re-utilization; and
- Disposition of real property and installed equipment.

Real property normally removed and disposed of at Atlas missile facilities included:

- Administrative building quonset hut with lighting and electrical;
- Maintenance building quonset hut with lighting and electrical;
- Underground fuel oil tank and fuel storage tank;
- Underground water storage reservoir tanks;
- Facility infrastructure including cooling tower, radar antenna, LOX tank, etc.;
- Street lights and poles; and
- All site designation signs.

Property allowed to remain on Site include the concrete foundations and pads, concrete missile silo housing and control structure, and perimeter fencing.

1.4.3 Previous Investigations

This section describes the field sampling activities that have been performed during previous environmental investigations at the Forbes S-5 Site. Much of the information presented in this section was obtained from the Preliminary Assessment (PA) conducted in 2007 (USEPA, 2007). Figure 1-4 presents the locations of the on-site and off-site samples collected during the previous investigations. The original USACE site visit to Forbes S-5 occurred in May 1987. Subsequent to the May 1987 visit, a preliminary site investigation was completed.

1.4.3.1 1988 Preliminary Site Investigation

A preliminary site investigation was performed for USACE by O'Brien and Gere at the Forbes S-5 Site in October 1988. This investigation determined the current status and general information in regard to the Site including geographic location, site layout, site geology and shallow hydrogeology, and remaining infrastructure. The results of the preliminary site investigation are included in the Confirmation Study (CS) (USACE, 1991).

According to information obtained from USACE boring logs for the Site, the geology was described as four to nine feet (ft) of lean, fat, and organic fat clays, some very gravelly with cobbles overlying bedrock material consisting of limestone with alternating shales of the Chase and Council Grove Groups of Permian Age. Shallow ground water was approximately three to ten ft below existing grade.

1.4.3.2 1991 Confirmation Study

O'Brien and Gere conducted a CS for the Site in May-August 1990 (USACE, 1991). The objective of the CS was to provide a preliminary determination of the presence or absence of chemical contamination which may have resulted from DoD activities at the Site. Below is a results summary of contaminants of concern (COCs) by media for the 1991 Confirmation Study. Historical data tables are provided in Appendix I.

Confirmation Study COCs		
Analyte	**Soil Range of Detections (mg/kg)**	**Groundwater Range of Detections (ug/l)**
Acetone	0.002 - 0.01	4
Bromodichloromethane	---	2
Chloroform	0.002	40 - 54
Methylene Chloride	0.008 - 0.036	---
Toluene	0.001	---
Trans-1,2-Dichloroethene	---	98 - 104
Trichloroethene	0.01	2 - 85
Naphthalene	0.071	---
Arsenic	3.2 - 6.7	---
Barium	129 - 2180	134 - 235
Cadmium	1.3 - 1.4	---
Chromium	11.7 - 20.8	19 - 21
Lead	12.0 - 63.8	45

Notes:
If only one result reported, analyte was only detected in one sample.
--- Indicates analyte was not a COC for this media.

Soil

Shallow soil samples were collected for chemical analysis at six locations. One of the locations was reported to represent background conditions. Soil samples were analyzed for volatile organic compounds (VOCs), polynuclear aromatic hydrocarbons (PAHs), and total metals.

Five VOCs were detected in the soil samples: acetone, chloroform, methylene chloride, toluene, and trichloroethene (TCE). TCE, the compound most likely to be associated with DoD operations, was detected in one sample located in the vicinity of the sediment trap. The TCE concentration of 0.01 milligram per kilogram (mg/kg) was less than the current U.S. Environmental Protection Agency (USEPA) Regional Screening Level (RSL) for residential soil of 0.94 mg/kg (USEPA, 2017a). Acetone, chloroform and methylene chloride were detected in laboratory method blanks at concentrations similar to reported soil concentrations and were considered to be related to laboratory contamination. Toluene was only detected in a rinsate blank but not detected in any soil sample. Naphthalene, a semivolatile organic compound

(SVOC), was detected in the same sample as TCE. Five metals were detected in the soil samples (arsenic, barium, cadmium, chromium, and lead).

Groundwater

Two shallow Monitoring Wells GMW#501 and GMW #502 were installed to assess specific subsurface areas at the Site. Monitoring Well GMW#501 was installed west of the missile housing structure. The well was located to assess shallow groundwater in the vicinity of the underground diesel fuel storage tank. Monitoring Well GMW#502 was installed east of the missile structure to assess shallow groundwater in the vicinity of the LOX tank and the area east of the missile structure.

At Monitoring Well GMW#502, trans-l,2-dichloroethene (trans-1,2-DCE) was detected in the primary sample and field duplicate. TCE was also detected in Monitoring Well GMW#502 in the primary and duplicate samples at concentrations of 76 microgram per Liter (µg/L) and 85 µg/L, respectively. TCE was also detected in Monitoring Well GMW#501 at 2 µg/L. Figure 1-4 shows the CS investigation locations. Please note, at the time the samples were collected it was standard practice to report DCE as the trans-isomer. Based on data collected to date, it is more likely that the detection was actually from the cis-isomer.

1.4.3.3 2007 Preliminary Assessment (PA)

A PA was conducted by Tetra Tech in 2007 (USEPA, 2007) for USEPA Region 7 under the Superfund Technical Assessment and Response Team (START) program. The general objective of the PA was to determine whether any threats to HHE existed as a result of releases to soil and groundwater. Figure 1-4 and 1-5 shows the PA on-site and off-site investigation locations. Analytical results by media can be found in Section 1.4.3.3.2. Historical data tables are provided in Appendix I. Below is a brief summary of COC detections and ranges for the 2007 PA.

Preliminary Assessment COCs			
Analyte	**Sediment Range of Detections (mg/kg)**	**Soil Range of Detections (mg/kg)**	**Groundwater Range of Detections (µg/l)**
2-Butanone	---	0.015 – 0.046	---
Acetone	0.026	0.015 - 0.17	---
Benzene	---	0.0064	---
cis-1,2-Dichloroethene	---	---	57
m,p-xylene	0.019	0.0063 - 0.019	---
Methylcyclohexane		0.018	---
Thallium	---	---	3.21
Trichloroethene	---	---	87
Antimony	---	---	12.7
Arsenic	4.72 - 8.71	1.93 - 22.1	5.32
Beryllium	1.11	---	---
Chromium	20.7 – 23.5	---	6.33
Copper	15.0 - 65.3	---	28.1
Lead	24.5 – 71.3	---	7.96
Mercury	0.416	---	---
Extractable TPH	0.306	---	---

Notes:
If only one result reported, analyte was only detected in one sample.
--- Indicates analyte was not a COC for this specified medium.

1.4.3.3.1 Sampling Activities

Field activities included collection of soil, sediment, and groundwater samples on the facility and groundwater samples from nearby private wells. Based on previous investigations, site reconnaissance observations, and background information about the facility, a biased sampling scheme was followed to select source sampling locations at the Site.

Eleven boreholes were advanced using direct-push methodology (Figures 1-4 and 1-5). One soil sample was collected by hand from a soil stockpile located on the facility. A background sample was collected from a borehole located upgradient of the Site to the north of the facility at the end of Road D. At each boring, soil samples were collected from a shallow interval ranging from 0 to 4 ft below ground surface (bgs) and, except when shallow probe refusal was encountered, from a second, deeper interval ranging from 4 to 18 ft bgs. Nineteen soil samples were submitted to the

laboratory to be analyzed for metals, perchlorate, polychlorinated biphenyls (PCBs), total petroleum hydrocarbons (TPH), SVOCs, and VOCs.

Three sediment samples were collected from drainage features that appeared to receive stormwater runoff from the facility. In addition, one background sediment sample was collected from a tributary of Bluff Creek at a location upgradient of the Site (see Figure 1-5). The sediment samples were collected using hand tools from a shallow interval of approximately 0 to 6 inches bgs. At the time of sampling, no surface water was present in the drainage features; therefore, no surface water samples were collected. Three groundwater samples were collected, two from private wells and one sample from GMW#502 located east of the missile structure (Figures 1-4 and 1-5). Four sediment samples and the groundwater samples were submitted to the laboratory to be analyzed for metals, perchlorate, PCBs, TPH, SVOCs, and VOCs.

1.4.3.3.2 Analytical Results

Soil

Perchlorate, PCBs, and TPH were not detected in the soil samples. Several metals were detected in the soil samples but the levels were within the range of naturally-occurring levels for Kansas. Further, there is no evidence to suggest that any metals would have been released as a result of DoD activities at the Site.

Except arsenic, no metals were detected at concentrations exceeding their respective risk screening concentrations. Arsenic was detected in all but one of the soil samples collected, including the background sample at concentrations ranging from 1.93 to 22.1 mg/kg, which exceed its RSL concentration of 0.67 mg/kg. The highest arsenic concentration detected was in the background soil sample. Therefore, the concentrations of arsenic, like other metals detected in the soil samples at the facility, are believed to be representative of naturally occurring levels and not DoD releases. Several SVOCs and VOCs were detected in the soil samples; however, none of these constituents were detected at concentrations exceeding their respective health-based benchmarks, at the time of the 2007 PA (USEPA, 2007).

Sediment

Perchlorate, PCBs, and SVOCs were not detected in any of the sediment samples. Except for arsenic, no metals were detected in the sediment samples at concentrations exceeding their respective health-based benchmarks, at the time of the 2007 PA (USEPA, 2007). Arsenic was detected in each of the sediment samples collected, including the background sample, at concentrations ranging from 4.72 to 8.71 mg/kg. The background sediment sample exhibited the highest arsenic concentration of 8.71 mg/kg. Therefore, the concentrations of arsenic detected in the sediment samples at the facility are believed to be representative of naturally occurring levels. Several organic constituents were detected in the sediment samples; however, none of these constituents were reported at concentrations exceeding their respective health-based benchmarks, at the time of the 2007 PA (USEPA, 2007).

Groundwater

Perchlorate, PCBs, SVOCs, and TPH were not detected in the groundwater samples collected from the private wells or the monitoring wells. Antimony, arsenic, and thallium were detected in the downgradient private well sample at concentrations exceeding their respective health-based benchmarks, at the time of the 2007 PA (USEPA, 2007). These metals were not detected in groundwater collected from the upgradient background private well or from the monitoring well located on the Forbes S-5 Site (GMW #502). Several organic constituents were detected in the groundwater samples. TCE and cis-1,2-dichloroethene (cis-1,2-DCE) was detected in Monitoring Well GMW#502 with concentrations of 87 µg/L and 57 µg/L, respectively (USEPA, 2007).

2. SITE CHARACTERISTICS

General site characteristics and ownership history are discussed in Section 1.3 and are not repeated in this section.

2.1 TOPOGRAPHY AND SURFACE WATER HYDROLOGY

The Forbes S-5 Site is located within the eastern portion of the Flint Hills Upland Region of the Osage Plains physiographic province. From the Flint Hills Upland Region eastward in Kansas, outcropping Pennsylvanian and the overlying Permian rocks dip gently to the west and northwest with an average dip of 20 to 25 ft per mile. The topography at the Site is slightly undulated with an elevation difference of approximately 20 ft across the former DoD property boundary. Elevation at the Site above mean sea level (AMSL) ranges from approximately 1,404 ft AMSL at the northeastern corner of the Site; to 1,425 ft AMSL at the missile structure located in the middle of the Site; back down to 1,410 ft AMSL at the southwestern corner of the Site. The greatest elevation change is located northeast of the missile structure where elevation drops approximately 21 ft to the northeast. Surface drainage generally flows from west to east/southeast following surface topography. The drainage empties into an unnamed tributary that parallels Road D and which eventually discharges to Bluff Creek. Surface water bodies in the immediate area include numerous farm ponds constructed from agricultural earthen dams.

2.2 CLIMATE

The climate at the Forbes S-5 Site is dominated by typical continental interior conditions, with hot summers and cold, dry winters. The following discussion is based on climate data collected from Council Grove, Kansas, which is located approximately 11 miles to the west of the Site (U.S. Climate Data, 2016).

Average temperatures at the Site range from 18 to 89 degrees Fahrenheit (^{o}F). July and August are typically the hottest months, with daily maximum and minimum temperatures of 89 and 67 ^{o}F, respectively. January is usually the coldest month, with daily maximum and minimum temperatures of 39 and 18 ^{o}F, respectively. The mean annual precipitation is 34 inches, with approximately half of this falling in the months of May, June, July, and August. Approximately

13 inches of snow falls in an average year, with most snowfall occurring in December, January, and February. Monthly precipitation data from the Council Grove station from January 2015 to the present is shown on the precipitation graph in Appendix A. Severe thunderstorms, with high rainfall and the possibility of tornados, are common in late spring and early summer.

2.3 GEOLOGY

This section summarizes the geology of the Site, to include both the bedrock geology and the geology of overburden material and soil. This discussion is based on information provided in previous investigations and data collected during the RI.

2.3.1 Regional Geology

Regionally, Lyon County lies within the Forest City basin, which is located in the northeastern part of the state. The Forest City basin lies east of the southwest to northeast trending Nemaha Uplift, an ancient granite range that was uplifted following the Mississippian Period (Merriam, 1963), and north of the Cherokee basin.

2.3.2 Soil and Overburden Geology

Unconsolidated overburden deposits within Lyon County include but are not limited to soil that has been formed from residuum or colluvium derived from Permian age shale and limestone. These soils are found on nearly level to moderately sloping areas on interfluves and hillslopes of uplands. Soils in the vicinity of the Site are dominated by several mapped soil units. These include the Labette silty clay loam and the Florence-Labette complex (Natural Resource Conservation Service [NRCS], 2013). A brief description of these soil types follows:

- The Labette silty clay loam develops on upland hills with slopes of 1 to 3 percent and is classified as a *Mollisol*. Soil depths can range from moderately deep to very deep (1.5 ft to 6.5 ft). These soils are found in elevations between 980 and 1,650 ft AMSL. These soils have good structure, are moderately well to well drained, low permeability, a low to high available water capacity, and can have high amounts of calcium carbonate. This soil type is found generally in the western portion of the Site.
- The Florence-Labette Complex is also a silty clay loam which develops on upland hills with slopes of 2 to 12 percent, which are steeper that the Labette. This complex is composed primarily of the Florence soil (50 percent) followed by the Labette soil

(35 percent) and the Tully soil (5 percent) with four other soil types composing the rest. This soil is also classified as a *Mollisol.* Soil depths can range from moderately deep to very deep (1.5 ft to 6.5 ft). These soil types, found in elevations between 980 and 1,650 ft AMSL, are from limestone residuum and generally have high amounts of chert fragments. Due to the presence of chert in the subsoil, these soils have a very low to low available water capacity. This soil type is found generally in the eastern portion of the Site.

The evaluation of soil in the vicinity of the Forbes S-5 Site is complicated by the historical DoD construction activities for the Atlas Missile Program. These anthropogenic activities have excavated, removed, stockpiled, and reshaped the area which probably mixed the soil types to some degree. Additionally, a portion of the Site was excavated into bedrock to enable construction of underground facilities for the Atlas site. Within this area, it is expected that the backfill consists of excavated material that was then replaced as engineered fill and bears little resemblance to pre-construction conditions.

A description of the soils found at the Site can be found in the boring logs developed during the RI in Appendix B.

2.3.3 Bedrock Geology

The subsurface geology at the Site is composed of alternating sequences of Permian Age shale and limestone. The bedrock stratigraphy includes rocks from the Wolfcampian Series which includes the Chase and Council Grove Groups (see Figure 2-1). Site-specific Formations that are of interest for this RI include the Matfield Shale and the Wreford Limestone of the Chase Group and the Speiser Shale of the Council Grove Group.

Bedrock encountered in the subsurface from the Matfield Shale Formation include the Kinney Limestone Member and Wymore Shale Member. This formation is approximately 55 to 60 ft thick (Kansas Geologic Survey [KGS], 1953). A general description for these two members are provided below (Zeller, 1986):

- *Kinney Limestone Member* – Generally includes two gray fossiliferous limestone beds separated by a gray fossiliferous shale bed. Fossils include bryozoans, brachiopods, echinoids, crinoids, pelecypods, and ostracodes. The thickness of this member ranges from 1 to 24 ft. The member is observed as the upper bedrock member in the boring

logs for the Site showing the distinct limestone beds divided by a small shale bed. This configuration thins out traveling from the north to the south due to erosion.

- *Wymore Shale Member* – Is a multicolored shale with beds of gray, red, green, tan, and purple. Limestone and fossiliferous shale beds are included in the lower part of the member in the southeastern part of the state. The thickness of the member ranges from 9 to 25 ft. The member is observed in boring logs developed for the Site and appears as a dusky yellow to dark gray slightly fossiliferous shale.

Bedrock encountered in the subsurface from the Wreford Limestone Formation include the Schroyer Limestone Member, Havensville Shale Member, and the Threemile Limestone Member. A general description for these three members are provided below (Zeller, 1986; KGS, 1953):

- *Schroyer Limestone Member* – Is a light gray to nearly white chert bearing limestone. Member does contain a three-foot-thick non-chert bed approximately 3-foot-thick in the upper part of the member. Thickness of the Schroyer Limestone Member ranges from 6 to 13 ft. The member is observed in boring logs developed for the Site and appears as a yellowish-brown limestone with bluish gray chert. A thin shale can be present in the middle of the member. A four-foot section in the upper part of the member is non-cherty with oxidation, solution cavities, and vugs.

- *Havensville Shale Member* – Is a gray, calcareous shale that contains thin beds of limestone. The member thins considerably in the southeastern part of the state. Thickness of the Havensville Shale Member ranges from 1.5 to 27 ft. The lower half can be fossiliferous including brachiopods. The member can contain thin limestone beds. The member is observed in boring logs developed for the Site and appears greyish green to red with interbedded mudstone.

- *Threemile Limestone Member* – Is a light gray to nearly white limestone with chert in some parts, but contains massive and non-cherty beds in the middle and lower parts. Thickness of the Threemile Limestone Member ranges from 6 to 33 ft. The limestone unit does contain fossils including brachiopods, bryozoans, and echinoderms. The member is observed in boring logs developed for the Site and appears as a light to medium gray, somewhat fossiliferous limestone with thin bands of chert nodules.

Bedrock encountered in the subsurface below the Wreford Limestone Formation includes the Speiser Shale Formation. A general description is provided below (Zeller, 1986):

- *Speiser Shale Formation* – Consists of a gray fossiliferous shale underlain by a fairly persistence 1 ft limestone bed that occurs about three ft below the base of the Wreford Limestone Formation. The thickness of the Speiser Shale Formation is approximately

18 ft in northern and central Kansas. The member is observed in boring logs developed for the Site and appears as a medium dark gray shale.

Boring logs for the Forbes S-5 RI are provided in Appendix B. Geologic cross sections for the Site are shown in Figures 2-2 through 2-4. Figure 2-2 provides a cross section location map; Figure 2-3 provides a cross section from north to south (A to A'); and Figure 2-4 provides a cross section from west to east (B to B').

2.4 HYDROGEOLOGY

The groundwater resources for the Lyon County area are determined based on bedrock, geology, and the structure of the area. The groundwater resources are classified based on five regions (Region A through Region E). These regions are briefly summarized below (KGS, 1953).

- ***Region A*** – Most groundwater is derived from alluvium in river valleys and streams.
- ***Region B*** - Most groundwater is derived from Pleistocene terrace deposits.
- ***Region C*** – Includes groundwater collected from Permian rocks of the Chase and Council Grove groups between the Florence Limestone Member (Barneston ls) of the Chase group and the Americus Limestone Member (Foraker ls) of the Council Grove Group. This is the primary groundwater region for the Forbes S-5 Site.
- ***Region D*** – Includes bedrock of the Admire and Wabaunsee groups which are lower in the stratigraphic sequence.
- ***Region E*** – Includes Pennsylvanian rocks of the Shawnee Group, which underlies the Wabaunsee Group.

2.4.1 Overburden Hydrogeology

The overburden at the Site is thin with a maximum thickness of less than ten ft. The overburden is typically dry and is not considered an aquifer at the Forbes S-5 Site.

2.4.2 Bedrock Hydrogeology

The bedrock aquifers underlying the Site are classified as the Region C aquifers as described above. Wells installed in these aquifer units derive water primarily from jointed and fractured limestones and from open joints and fractures in calcareous shales (KGS 1953). The general hydrogeological characteristics for the formations underlying the Site are as follows:

- *Matfield Shale Formation* – This formation is not utilized and is of little importance as an aquifer (KGS, 1953).
- *Wreford Limestone* – Small supplies of groundwater are obtained from this aquifer on a localized basis (KGS, 1953).
- *Speiser Shale Formation* - This formation is not utilized and is of little importance as an aquifer (KGS, 1953).

2.4.2.1 Site-Specific Bedrock Hydrogeology

The primary aquifer formation at the Site is the Wreford Limestone which contains the Schroyer and Threemile Limestone Members. The Havensville Shale Member is situated between the two limestone members and serves as an aquitard. Groundwater yields in these limestone units is highly variable, depending primarily on the amount of secondary permeability such as fractures and solution-enlarged features present. During the RI, 17 monitoring wells were installed at the Site in these limestone members. Water level data collected during the RI indicate that the Threemile Limestone Member is a confined aquifer as the water levels for monitoring wells screened in both members rises above the base of the confining unit which overlies it. The Schroyer Limestone Member at the site during the period monitored for the RI is an unconfined aquifer; the groundwater elevation in one of the five shallow monitoring wells screened within the Schroyer Limestone Member illustrated on Figures 2-3 and 2-4 rises above the base of the unit which overlies it. Eleven wells were classified as shallow bedrock monitoring wells and were screened in the Schroyer Limestone Member. Six monitoring wells were classified as deep bedrock wells and were screened in the Threemile Limestone Member. Monitoring well construction details are provided in Section 3.1.2.

2.4.2.2 Groundwater Flow

Water levels were collected from each shallow and deep monitoring well on a quarterly basis for two years. Water level measurements and groundwater elevations collected from site monitoring wells during the RI are presented on Table 2-1. Graphs of groundwater elevations for the shallow and deep monitoring wells are located in Appendix C. Depth to water for the shallow bedrock wells generally ranged from 11 to 29 ft bgs, with a seasonal variance between 2.38 ft and 5.86 ft. Depth to water for the deep bedrock wells generally ranged from 40 to 51 ft bgs,

with seasonal variances between 1.84 ft and 3.67 ft. Based on the collected data, groundwater across the northern and western half of the Site generally flows from the south to the north for both shallow (wells screened in the Schroyer Limestone Member) and deep (wells screened in the Threemile Limestone Member) wells. After the installation of Monitoring Wells MW-12S and MW-13S, groundwater flow in the southeastern portion of the Site has exhibited indications of a potential groundwater divide. However, based on limited water level observations collected and lack of off-site monitoring wells, groundwater flow direction in this portion of the Site is uncertain. A typical groundwater elevation map for the period of the RI of the deep and shallow monitoring wells can be found in Figures 2-5 and 2-6, respectively. Please note that these figures may not be representative of normal groundwater elevations, due to the Site experiencing drought conditions during the course of the RI. Groundwater elevation maps for each of the eight rounds for the deep and shallow wells are provided in Appendix D.

2.4.2.3 Groundwater Gradient

The horizontal and vertical hydraulic gradients and estimated linear groundwater velocities discussed in this section were calculated based on the typical groundwater elevation maps, Figures 2-5 and 2-6, for the deep and shallow monitoring wells and hydraulic conductivities calculated using the Bouwer and Rice (1976) solution method. Discussion of hydraulic conductivities is presented below in Section 2.4.2.4. The horizontal hydraulic gradients for the deep monitoring wells screened in the Threemile Limestone Member ranged from a maximum of 0.025 feet per foot (ft/ft) to a minimum of 0.01 ft/ft. The estimated linear groundwater velocities for the deep monitoring wells screened in the Threemile Limestone Member ranged from a maximum of 0.381 feet per year (ft/yr) to a minimum of 0.07 ft/yr. The location of maximum and minimum horizontal hydraulic gradients and estimated linear groundwater velocities were calculated are illustrated on Figure 2-5. The maximum and minimum calculations of the horizontal hydraulic gradients and estimated linear groundwater velocities of the deep monitoring wells is presented on Tables 2-2 and 2-3, respectively.

The horizontal hydraulic gradients for the shallow monitoring wells screened in the Schroyer Limestone Member ranged from a maximum of 0.026 ft/ft to a minimum of 0.002 ft/ft. The

estimated linear groundwater velocities for the shallow monitoring wells screened in the Schroyer Limestone Member ranged from a maximum of 91.59 ft/yr to a minimum of 0.29 ft/yr. The location of maximum and minimum horizontal hydraulic gradients and estimated linear groundwater velocity calculations are illustrated on Figure 2-6. The maximum and minimum calculations of the horizontal hydraulic gradients and estimated linear groundwater velocities of the shallow monitoring wells is presented on Tables 2-4 and 2-5, respectively.

The vertical hydraulic gradient was determined for each nested well pair present at the Site (MW-02S/MW-02D, MW-03S/MW-03D, MW-04S/MW-04D, MW-06S/MW-06D) based on the mid-point of the saturated screen for each well cluster. The vertical hydraulic gradients at each nested well pair was determined to be downward, with gradients that ranged from a maximum of 0.78 ft/ft to a minimum of 0.54 ft/ft (see Table 2-6).

2.4.2.4 Hydraulic Conductivity Testing

Hydraulic conductivity testing (slug testing) was performed on each monitoring well installed using the slug-out or rising head test procedure. Slug testing was performed using the following procedure:

1. Measure and record static water level using an electronic water level indicator.
2. Using a nondedicated disposable bailer, remove a volume of water causing a water level decline.
3. Immediately after the last slug of water is removed, measure and record the water level response at set intervals during the test using either a transducer or manually with an electronic water level indicator.
4. Stop measuring water level response after water level has recovered to 90 percent of the static water level.

For the shallow wells, slug tests were performed on Monitoring Wells MW-2S, MW-3S, MW-4S, MW-6S, MW-7S, MW-8S, MW-9S, MW-10S, MW-11S, MW-12S, and MW-13S. For the deep wells, slug tests were performed for Monitoring Wells MW-1D, MW-2D, MW-3D, MW-

4D, MW-5D, and MW-6D. Monitoring Wells MW-2D and MW-3D were both tested but not analyzed due to errors in the downhole pressure transducer. Slug testing forms for the RI are presented in Appendix E.

Slug Test Results – Shallow Bedrock Wells

The slug tests were performed in the field for the Phase I shallow wells on July 27th and 28th, 2015, and Phase II shallow wells were performed on July 11th and 12th, 2016. The performance criteria for these tests are illustrated on Table 2-7. All shallow wells recovered to at least 90 percent static. The data from each shallow slug test was uploaded into the AQTESOLV Aquifer Test Analysis Software (version 4.50 Pro) and analyzed using Springer and Gelhar (Springer and Gelhar, 1991) and Bouwer and Rice (Bouwer and Rice, 1976), solution methods. The hydraulic conductivities as determined by the Springer and Gelhar (1991) and Bouwer and Rice (1976) solution methods are summarized on Table 2-8 and the analysis results are presented in Appendix F.

Analysis of slug test data for the shallow bedrock wells using the Springer and Gelhar (1991) solution method resulted in hydraulic conductivity values ranging from 4.983 E^{-5} to 5.593 E^{-4} centimeters per second (cm/sec). The Bouwer and Rice (1976) solution method resulted in hydraulic conductivity values ranging from 1.65 E^{-5} to 4.71 E^{-4} cm/sec.

Slug Test Results – Deep Bedrock Wells

The slug tests were performed in the field for the Phase I deep wells in July and August of 2015. The performance criteria for these tests are illustrated on Table 2-7. All six of the deep wells tested recovered to 90 percent static with the exception of MW-06D. The data from each deep slug test was uploaded into the AQTESOLV program and analyzed using the Hvorslev (1951), and Bouwer and Rice (1976) solution methods. The hydraulic conductivities as determined by the Hvorslev (1951) and Bouwer and Rice (1976) solution methods are summarized on Table 2-8 and the analysis results are presented in Appendix F.

Analysis of slug test data for the deep bedrock wells using the Hvorslev solution method resulted in hydraulic conductivity values ranging from 9.406 E^{-7} to 2.52 E^{-5} cm/sec. The Bouwer and

Rice (1976) solution method resulted in hydraulic conductivity values ranging from 9.406 E^{-7} to 2.06 E^{-6} cm/sec.

2.4.2.5 Water Well Inventory

According to the KGS Water Well Completion Records database (KGS, 2017), two wells are located within one mile of the Site (Figure 2-7). The first well (KS Record #488048) is located approximately 0.8 miles northwest of the Site; is a domestic well; well depth of 45 ft; and has a yield of 15 gallons per minute (gpm). Based on the ground surface elevation and well depth, this well is probably screened across a portion of the Schroyer Limestone Member. This well was sampled during the 2007 PA. The second well (KS Record # 36518) is 0.74 miles to the east/southeast; is classified as a domestic and livestock well, and is 50 ft deep. This well is screened in a limestone unit below the limestone units screened at the Forbes S-5 Site. This well was not sampled during the 2007 PA.

2.5 DEMOGRAPHY AND LAND USE

Lyon County, where the Site is located, is primarily rural, with several small towns. The KDHE classifies Lyon County as a Densely-settled Rural County. According to the 2010 Census data (U.S. Census Bureau, 2010), the county had a population of about 34,000 people and a population density of approximately 39 persons per square mile. The communities closest to the Forbes S-5 Site are Council Grove, Bushong, Allen, and Admire. Council Grove, located in Morris County, Kansas, is approximately 11 miles west of the Site and has a population of approximately 2,200. Bushong, located in Lyon County, Kansas is approximately four miles southeast of the Site and has a population of approximately 34. Allen is located in Lyon County, approximately seven miles east of the Site, and has a population of approximately 536. Admire, located in Lyon County, Kansas is about 11 miles east of the Site and has a population of approximately 262. The area in the immediate vicinity of the Site is sparsely populated, with most people living on farms and small ranches.

Most land in Lyon County, including in the immediate vicinity of the Site, is devoted to agriculture. The site proper is mowed for grass (for use as cattle feed) and the land immediately surrounding the Site is pasture for cattle grazing.

3. NATURE AND EXTENT OF CONTAMINATION

3.1 INTRODUCTION

Field activities conducted for this RI were performed in two phases and are listed in Table 3-1. Activities included soil and sediment sampling, surface water sampling, shallow and deep bedrock well installation, and eight rounds of groundwater sampling. A description of these field activities follows in the text below. Refer to Appendix G - Field Log Book for details. All data reported in this RI Report have been reviewed and validated. All laboratory data and validation results were reported in QCSRs (included in Appendix H) reviewed by the USACE Project Chemist.

Phase I field activities conducted to support the RI at the Forbes S-5 Site included:

- Collection of surface and subsurface soils samples from ten locations;
- Collection of sediment samples from seven locations;
- Collection of surface water samples from ten locations;
- Installation and development of five shallow and six deep monitoring wells;
- Hydraulic conductivity testing to characterize the aquifer from eleven monitoring wells;
- Investigation-derived waste (IDW) characterization sampling; and
- Eight quarterly groundwater sampling events.

Samples collected during Phase I field activities were analyzed for the following parameters per the prescribed procedures in the Work Plan:

Analytical Group	Analytical Method	Matrix Sampled
VOCs	8260C	Surface Water, Sediment Samples
VOCs	8260C	Soil Boring, Soil Samples
TOC	9060A	
VOCs	8260C	Quarterly Groundwater Samples
Anions	9056A	
Sulfide	EPA 376.1	
Alkalinity	SM-2320B	
Methane/Ethane/Ethene	RSK-175	
VOCs	8260C	IDW Samples - Liquid
pH	9045	IDW Samples – Solid
TCLP-RCRA 8 Metals	1311 & 6020	
PCBs	8082	
Flash Point	1010	

Phase II field activities conducted to support the RI at the Forbes S-5 Site included:

- Collection of surface and subsurface soils samples from two locations;
- Installation and development of five shallow monitoring wells;
- Hydraulic conductivity testing to characterize the aquifer from five monitoring wells;
- IDW characterization sampling; and
- Four quarterly groundwater sampling events.

Samples collected during Phase II field activities were analyzed for the following parameters per the prescribed procedures in the Work Plan:

Analytical Group	Analytical Method	Matrix Sampled
VOCs	8260C	Soil Samples
TOC	9060A	
VOCs	8260C	IDW Samples - Liquid
pH	9045	IDW Samples – Solid
Flash point	1010	
VOCs	8260C	Quarterly Groundwater Samples
Anions	9056A	
Sulfide	EPA 376.1	
Alkalinity	SM-2320B	
Methane/Ethane/Ethene	RSK-175	

Analytical results were compared to screening levels per the procedures set forth in the regulatory agency-approved Uniform Federal Policy – Quality Assurance Project Plan (UFP-QAPP). Analytical results were compared to the September 2015 KDHE Risk-Based Standards for Kansas (RSK) Tables and USEPA June 2017 RSL Tables.

Surface and Subsurface Soil Samples

- KDHE RSKs Residential Soil
- USEPA RSL Residential Soil

Sediment Samples

- KDHE RSK Non-Residential Soil
- USEPA RSL Industrial Soil

Surface and Groundwater Samples

- USEPA Maximum Contaminant Level (MCL)
- USEPA RSL Tapwater

3.2 RI FIELD ACTIVITIES

3.2.1 Soil Sampling

Fifty-one soil samples were collected from 10 soil boring sample locations (SB-01 through SB-10) from May 12 through June 2, 2015. Two additional soil borings (SB-11 and SB-12) were advanced and soil samples were collected from May 24 through June 5, 2016. A total of six samples were collected from these two locations. Soil samples were submitted to an off-site laboratory for analysis of VOCs and total organic carbon (TOC), sample results are presented in Table 3-2. The rationale for the soil boring locations were advanced and sampled (see Figure 3-1 for locations) is as follows:

- SB-01 was located adjacent to former Monitoring Well GMW#502, which was abandoned during the first phase of investigation field activities. This soil boring was completed as shallow Monitoring Well MW-02S. This boring was advanced and soil samples were collected to a depth of 40 ft bgs.
- SB-02 was located at the approximate location of the underground LOX tank to the east of the missile erection structure. This boring was advanced and soil samples were collected to a depth of 30 ft bgs.
- SB-03 was located to the east of the flame exit pit. This boring was advanced and soil samples were collected to a depth of 30 ft bgs.
- SB-04 was located to the west of the flame exit pit, within presumed backfill, and completed as shallow Monitoring Well MW-07S. This boring was advanced and soil samples were collected to a depth of 40 ft bgs.
- SB-05 was located adjacent to the manhole to the west of the primary sump (west of the missile erection structure). This boring was advanced and soil samples were collected to a depth of 30 ft bgs.
- SB-06 was located within presumed backfill to the west of the missile erection structure. This boring was advanced and soil samples were collected to a depth of 21 ft bgs.
- SB-07 was located immediately adjacent to the sediment trap along the south perimeter fence. This boring was advanced and soil samples were collected to a depth of 30 ft bgs.

- SB-08 was located downslope of the sediment trap and was completed as shallow Monitoring Well MW-06S. This boring was advanced and soil samples were collected to a depth of 30 ft bgs.

- SB-09 was located to the north of the missile erection structure, in the vicinity of the former maintenance building concrete slab, and completed as deep Monitoring Well MW-03D. This boring was advanced and soil samples were collected to a depth of 60 ft bgs.

- SB-10 was located west of the former cooling tower concrete slab, near the west perimeter fence, and completed as shallow Monitoring Well MW-04S. This boring was advanced and soil samples were collected to a depth of 40 ft bgs.

- SB-11 was located southeast of the missile complex, east of the MW-06S/D pair, and between the inner and outer south perimeter fences. This boring was completed as Monitoring Well MW-12S. This boring was advanced and soil samples were collected to a depth of 25 ft bgs.

- SB-12 was located southwest of the missile complex, west of the MW-06S/D pair, and between the inner and outer south perimeter fences. This boring was completed as Monitoring Well MW-13S. This boring was advanced and soil sampled were collected to a depth of 20 ft bgs.

All borings were advanced and sampled using sonic drilling equipment. Continuous soil samples were collected throughout the entire depth of the boring and were logged by the project geologist. Soil samples for VOCs were collected using Terracore samplers while TOC samples were obtained using a decontaminated sample knife. Samples were submitted to a to an off-site laboratory for analysis of VOCs by USEPA Method 8260C, and samples for TOC analysis by USEPA Method 9060A. Samples were collected from the center of the core to minimize any impact from the sonic technology on the soil samples. The project geologist screened the soil cores using a photoionization detector (PID) and visually inspected soil cores for indications of possible contamination in the soil. Selection of soil samples was based primarily on PID readings. In the absence of elevated PID readings or other evidence of contamination, the sampling approach was biased towards fine grained material within the soil core. Elevated PID were not observed in any of the borings. Only one boring (MW-12S) had PID readings above 10 ppm. PID field results are reported in Table 3-3. Bedrock was encountered at shallow depths at each of the boring locations (ranging from 2 to 9 ft bgs), limiting the amount of unconsolidated

material from which samples could be collected. Soft shales and claystones were the only bedrock units that were able to be sampled. Surface soil samples were collected at each boring location from 0 to 1 ft bgs. Soil borings were advanced and samples collected from May 12 through June 2, 2015 and May 26 through June 1, 2016. Soil Borings SB-01, SB-04, SB-08, SB-09, SB-10, SB-11, and SB-12 were completed as Monitoring Wells MW-02S, MW-07S, MW-06S, MW-03D, MW-04S, MW-12S, and MW-13S, respectively. The remaining five soil borings (SB-02, SB-03, SB-05, SB-06, and SB-07) were plugged and abandoned following the completion of sampling activities. Copies of the boring logs and field notes are included in Appendix B and H, respectively.

3.2.2 Sediment Sampling

Seven sediment samples were collected from seven locations from May 14 through May 20, 2015, and were submitted to an off-site laboratory for analysis of VOCs. Sediment sampling results are presented in Table 3-4. Sediment samples were collected from the following locations (see Figure 3-2 for locations):

- SD-01 was collected from the sediment trap near the south perimeter fence.
- SD-02 was collected from a manhole located to the west of the primary sump.
- SD-04 was collected from the flame pit within the missile erection structure.
- SD-06 was collected from a sump pit in the northwest room adjacent to the missile erection structure.
- SD-07 was collected from a sump pit in the southeast room adjacent to the missile erection structure.
- SD-10 was collected from the west former sewage lagoon.
- SD-11 was collected from the east former sewage lagoon.

Sediment samples from locations SD-10 and SD-11 were collected using a decontaminated shovel. Sediment samples from the remaining five locations were collected using a decontaminated stainless-steel bottom dredge sampler. Eleven sediment sample locations were originally planned for this investigation, however, at sample locations SD-3, SD-5, and SD-8,

debris was present at the bottom of the pit and prevented the sampler from reaching sediment (if present). No sediment was recovered in the dredge sampler from sample location SD-9, despite multiple attempts.

3.2.3 Surface Water Sampling

Ten surface water samples were collected from ten locations from May 14 through May 20, 2015. Samples were submitted to an off-site laboratory for analysis of VOCs, sample results are presented in Table 3-5. Surface water samples were collected from the following locations (see Figure 3-2 for locations):

- SW-01 was collected from the sediment trap near the south perimeter fence.
- SW-03 was collected from the deep sump located near the southwest end of the missile erection area.
- SW-04 was collected from the flame pit within the missile erection structure.
- SW-05 was collected from a sump pit within the missile erection structure.
- SW-06 was collected from a sump pit in the northwest room adjacent to the missile erection area.
- SW-07 was collected from a sump pit in the southeast room adjacent to the missile erection area.
- SW-08 was collected from the flame exit pit outside the missile erection structure.
- SW-09 was collected from the radar antenna pit.
- SW-10 was collected from the west former sewage lagoon.
- SW-11 was collected from the east former sewage lagoon.

Surface water samples were collected at the SW-10 and SW-11 locations directly from the shore of the lagoon ponds. Surface water samples from the remaining eight sample locations were collected with the use of a disposable plastic bailer and rope, with a new bailer and rope being used at each location. Eleven surface water sample locations were planned, however there was no surface water present at SW-02, the manhole located west of the primary sump.

3.2.4 Monitoring Well Installation and Development

A total of 11 monitoring wells, five shallow (MW-02S, MW-03S, MW-04S, MW-06S, and MW-07S) and six deep (MW-01D, MW-02D, MW-03D, MW-04D, MW-05D, and MW-06D) were installed and developed at the Forbes S-5 Site from May 12 through June 17, 2015 (see Figure 3-3 for locations). Following the first four rounds of groundwater sampling and evaluation of analytical results, the determination was made to install eight additional shallow monitoring wells to further delineate the extent of shallow groundwater contamination at the Site. This included several wells planned for south of the site boundary to determine groundwater flow south of the Site and delineate TCE and cis-1,2-DCE plumes that may extend off-site. A right of entry to gain access to the off-site areas could not be obtained and so only six wells were installed, all on Site. The impact of not installing the off-site wells is discussed in Section 6. The final sampling plan implemented was determined to be sufficient to meet the objectives of the RI. The additional monitoring wells were installed and developed from May 24 through June 5, 2016 and included Monitoring Wells MW-08S, MW-09S, MW-10S, MW-11S, MW-12S, and MW-13S (see Figure 3-3 for locations). Monitoring well construction details are presented on Table 3-6. The borings for these wells were advanced using sonic drilling equipment. Boring logs, monitoring well construction diagrams, and Kansas water well completion forms (WWC5) for all monitoring wells can be found in Appendix B.

Monitoring Wells MW-1D, MW-2D, MW-2S, MW-3D, MW-3S, MW-4D, MW-4S, MW-5D, MW-6D, MW-6S, and MW-7S, were constructed of flush-threaded Schedule 40 2-inch diameter PVC screen and riser. Ten ft of 10 slot (0.010 inch) mill slot screen was installed in MW-01D. Five ft of 10 slot (0.010 inch) mill slot screen was installed in the remaining 10 monitoring wells due to the shorter than anticipated thickness of the target limestone units encountered at these locations. The filter pack consisted of 20/40 grade silica sand. A three to five-foot bentonite seal was placed immediately above the filter pack and a high-solids bentonite grout was then placed to approximately three ft bgs. Surface completions were above grade completions. The above grade completions also included the installation of four bollards.

Monitoring Wells MW-08S, MW-09S, MW-10S, MW-11S, MW-12S, and MW-13S, were constructed of flush-threaded Schedule 40 2-inch diameter PVC screen and riser. Ten ft of 20 slot (0.020 inch) mill slot screen was installed in MW-12S and MW-13S. Five ft of 20 slot (0.020 inch) mill slot screen was installed in the remaining monitoring wells due to the shorter than anticipated thickness of the target limestone unit encountered at these locations. The filter pack consisted of 20/40 grade silica sand. A three to five-foot bentonite seal was placed immediately above the filter pack and a high-solids bentonite grout was then placed to approximately three ft bgs. Surface completions were above grade completions. The above grade completions also included the installation of four bollards.

Well development was performed using a combination of surging and pumping. Due to the low hydraulic conductivity of the screened units (limestone), sixteen of the seventeen installed wells purged dry after pumping approximately one well volume. These wells were purged dry and allowed to recharge to 90 percent of static water level before being purged dry an additional two times. After being purged dry a total of three times, these monitoring wells were considered developed. Monitoring Well MW-02S did not purge dry and approximately 1.5 times the volume of water lost during drilling and well installation was recovered. Development was considered complete after consulting with the USACE Project Manager. This well was considered developed once the following criteria were met:

- Turbidity: < 50 nephelometric turbidity units;
- Specific conductance: ± 1 percent of full-scale reading (instrument repeatability) or default ± 20 millimhos/ centimeter;
- pH: ± 0.1 unit;
- Temperature: ± 0.5 degrees Celsius; and
- Water level had stabilized.

Upon completion of the well construction, a horizontal and vertical survey of the monitoring well location, top of casing, and ground surface was performed by a licensed Kansas Surveyor. Copies of boring logs and well construction diagrams, field log book, well development forms,

survey data, photograph log, and field quality control checklists are included in Appendices A, E, G, H, I, and J, respectively.

The following is a brief summary of the monitoring wells installed during field activities including their location and top of screened depth (see Figure 3-3 for monitoring well locations):

- MW-01D was installed as a deep down-gradient well and located to the north of the missile complex. Ten ft of screen was installed, with the top of the screen at a depth of 58.00 ft below top of casing (BTOC).
- MW-02S was installed as a shallow well adjacent to the former MW-502 (abandoned during this phase of field activities) and located down-gradient of the former LOX tank. Five ft of screen was installed, with the top of the screen at a depth of 29.14 ft BTOC.
- MW-02D was installed as a deep well adjacent to MW-02S and located down-gradient of the former LOX tank. Five ft of screen was installed, with the top of the screen at a depth of 53.40 ft BTOC.
- MW-03S was installed as a shallow down-gradient well, located adjacent to the former maintenance building concrete slab. Five ft of screen was installed, with the top of the screen at a depth of 25.23 ft BTOC.
- MW-03D was installed as a deep down-gradient well and is located adjacent to MW-03S. Five ft of screen was installed, with the top of the screen at a depth of 52.09 ft BTOC.
- MW-04S was installed as a shallow side-gradient well and located west of the cooling tower concrete slab near the west perimeter fence. Five ft of screen was installed, with the top of the screen at a depth of 31.82 ft BTOC.
- MW-04D was installed as a deep side-gradient well and located adjacent to MW-04S. Five ft of screen was installed, with the top of the screen at a depth of 61.20 ft BTOC.
- MW-05D was installed as a deep side-gradient well and is located south of the MW-04S/D pair near the west perimeter fence. Five ft of screen was installed, with the top of the screen at a depth of 59.14 ft BTOC.
- MW-06S was installed as a shallow monitoring well, downslope of the sediment trap and located between the inner and outer south perimeter fences. Five ft of screen was installed, with the top of the screen at a depth of 18.35 ft BTOC.

- MW-06D was installed as a deep monitoring well, downslope of the sediment trap, adjacent to MW-06S. Five ft of screen was installed, with the top of the screen at a depth of 46.23 ft BTOC.

- MW-07S was installed as a shallow monitoring well, west of the flame exit pit. Five ft of screen was installed, with the top of the screen at a depth of 30.07 ft BTOC.

- MW-08S was installed as a shallow down-gradient well located at the northeast corner of the site property. Five ft of screen was installed, with the top of the screen at a depth of 17.80 ft BTOC.

- MW-09S was installed as a shallow well located down-gradient of the MW-03S/D well pair at the north end of the Site, between the inner and outer north perimeter fences. Five ft of screen was installed, with the top of the screen at a depth of 20.27 ft BTOC.

- MW-10S was installed as a shallow side-gradient well, located east of the MW-03S/D well pair, near the outer east perimeter fence. Five ft of screen was installed, with the top of the screen at a depth of 19.68 ft BTOC.

- MW-11S was installed as a shallow side-gradient well and is located east of the MW-02S/D pair, near the outer east perimeter fence. Five ft of screen was installed, with the top of the screen at a depth of 19.72 ft BTOC.

- MW-12S was installed southeast of the missile complex, east of the MW-06S/D well pair, between the inner and outer south perimeter fences. Ten ft of screen was installed, with the top of the screen at a depth of 16.94 ft BTOC.

- MW-13S was installed southwest of the missile complex, west of the MW-06S/D well pair, between the inner and outer south perimeter fences. Ten ft of screen was installed, with the top of the screen at a depth of 9.51 ft BTOC.

3.2.5 Groundwater Sampling

Eight rounds of low-flow groundwater sampling were performed at the Site during the RI field activities for monitoring wells that were installed in 2015, and 4 rounds of sampling for monitoring wells installed in 2016. All monitoring wells were sampled using low-flow purging and sampling protocol with a non-dedicated bladder pump. During purging, stabilization parameters measured included temperature, conductivity, pH, oxidation-reduction potential (ORP), dissolved oxygen (DO), and turbidity. All parameters, with the exception of turbidity, were measured using a YSI 556 multi probe system and a flow-through cell. Turbidity was measured using a Hach Model 2100Q portable turbidimeter. Following the stabilization of

parameters, groundwater samples were collected for the analysis of selected VOCs (Method 8260C), anions (Method 9056), methane, ethane, and ethene (Method RSK 175), sulfide (Method 376.1), and alkalinity (Method SM-2320B). Groundwater samples also were collected for the field determination of ferrous iron using a CHEMmetrics ferrous iron kit, which performs the evaluation using a colorimetric method. Results are discussed in Section 3.4.1. Groundwater sampling forms are presented in Appendix N.

3.2.6 Investigation Derived Waste

Soil cuttings and sediment generated during boring and well installation activities were containerized in 27, 55-gallon steel drums. Samples were collected and analyzed for pH, flashpoint, toxicity characteristic leaching procedure (TCLP) 8 Resource Conservation and Recovery Act (RCRA) metals, PCBs, and percent moisture (note, only phase II IDW-soil tested for TCLP and PCBs). These drums were staged on-site during activities and hauled off-site for proper disposal. Refer to Table 3-7 for the soil drum inventory list and analytical data reports. IDW soil sample analytical data reports are provided in Appendix H.

Purge water and drilling water generated during RI field activities were stored in 11, 55-gallon steel drums, one frac tank, and two poly large capacity tanks and were staged on-site during activities. Representative samples were collected and analyzed for VOC from the waste streams present in these containers (see Table 3-7). Based on the analytical results from the frac tank and the poly tanks, discharging of the liquid IDW to the sewage lagoon was approved by the USACE and KDHE/Bureau of Environmental Remediation (BER) project managers. The liquid IDW in the 11, 55-gallon steel drums was transported and disposed off site. Refer to Table 3-7 for the IDW inventory list and analytical data reports. IDW water sample analytical data reports are provided in Appendix H.

3.3 SOILS AND SEDIMENTS RESULTS

This section presents the analytical results for the sampling of surface and subsurface soil and sediment at the Site, beginning with the RI field effort. Historical analytical result tables from the 1991 Confirmation Study and the 2007 Preliminary Assessment can be found in Appendix I.

3.3.1 2015 RI Results – Soil

Soil samples were collected from Soil Borings SB-01, SB-02, SB-03, SB-04, SB-05, SB-06, SB-07, SB-08, SB-09, SB-10, SB-11, and SB-12. Section 3.1.1 of this report discusses the rationale for the boring locations and the depths at which soil samples were collected (see Figure 3-1).

Analytical data were subject to USEPA Stage 2B validation in accordance with the UFP-QAPP, Former Forbes Atlas Missile Site S-5, Lyon County, KS (April 2015) and UFP-QAPP Addendum (May 2016). The analytical data were evaluated for quality assurance and quality control (QA/QC) based on the DoD Quality Systems Manual (QSM) for Environmental Laboratories, Version 5.0 (July 2013), the USEPA Contract Laboratory Program National Functional Guidelines (CLPNFG) for Superfund Organic Methods Data Review (June 2008) and the USEPA CLPNFG for Inorganic Superfund Data Review (January 2010). Eight QCSRs were written to summarize the data validation from the eight events and are included in Appendix H. No results were rejected during the data validation process. The usefulness of the data in terms of completeness is summarized within each 2015 RI Results section.

Percent analytical completeness (project goal of 98 percent) and percent quality completeness (project goal of 80 percent) within the first (May 2015 samples) and fifth QCSR (May/June 2016 samples) was calculated for soil boring samples (SB designation) and all completeness goals were met for the VOC (8260 analysis) (see Table 3-8).

cis-1,2-DCE was detected in soil boring samples SB-01-17-18 and SB-07-12-13 with concentrations below both USEPA and KDHE screening criteria. TCE was detected in soil boring samples SB-01-11-12, SB-01-17-18, and SB-07-12-13 with concentrations below both USEPA and KDHE screening criteria. Vinyl chloride (VC) was detected in soil boring SB-07-12-13 with concentration below both USEPA and KDHE screening criteria. Soil sample results are presented in Table 3-2. Analytical data reports are included in Appendix H as part of the QCSRs.

3.3.2 2007 Preliminary Assessment – Soil

Perchlorate, PCBs, and TPH were not detected in the soil samples. Several metals were detected in the soil samples but the levels were within the range of naturally-occurring levels for Kansas. Further, there is no evidence to suggest that any metals would have been released as a result of DoD activities at the Site.

Except arsenic, no metals were detected at concentrations exceeding their respective risk screening concentrations. Arsenic was detected in all but one of the soil samples collected, including the background sample at concentrations ranging from 1.93 to 22.1 mg/kg. These concentrations exceed arsenic's RSL concentration of 0.67 mg/kg. The highest arsenic concentration detected was in the background soil sample. Therefore, the concentrations of arsenic, like other metals detected in the soil samples at the facility, are probably representative of naturally occurring levels and not DoD releases. Several SVOCs and VOCs were detected in the soil samples; however, none of these constituents were detected at concentrations exceeding their respective health-based benchmarks. Historical data tables are provided in Appendix I.

3.3.3 1991 Confirmation Study Results – Soil

Shallow soil samples were collected for chemical analysis at six locations. One of the locations was reported to represent background conditions. Soil samples were analyzed for VOCs, PAHs, and total metals.

Five VOCs were detected in the soil samples: acetone, chloroform, methylene chloride, toluene, and TCE. TCE, the compound most likely to be associated with DoD operations, was detected in one sample located in the vicinity of the sediment trap. The TCE concentration of 0.01 mg/kg was less than the current USEPA RSL for residential soil of 0.94 mg/kg (USEPA, 2014a). Naphthalene, a SVOC, was detected in the same sample as TCE. Five metals were detected in the soil samples (arsenic, barium, cadmium, chromium, and lead). Historical data tables are provided in Appendix I.

3.3.4 2015 RI Results – Sediment

Sediment samples were collected from seven locations. Section 3.1.2 of this report discusses the sample locations. The percent analytical completeness goal for VOCs (8260 analysis) was met (100 percent) but not the percent quality completeness goal (86 percent of SD VOC samples) (Table 3-8). TCE and cis-1,2-DCE were both detected below their respective USEPA and KDHE screening criteria in sediment samples SD-01 and SD-06. VC was detected above both USEPA and KDHE human health screening criteria in sediment sample SD-01. Surface water and sediment pathways were not evaluated in a screening level ecological risk assessment. This is discussed in Section 5-2. Sediment sample results are presented in Table 3-4 and illustrated on Figure 3-2. Analytical data reports are included in Appendix H.

An interim remedial action (IRA) is planned to remediate contaminated sediment. The Decision Document for this action was finalized in June 2017.

3.3.5 2007 Preliminary Assessment – Sediment

Perchlorate, PCBs, and SVOCs were not detected in the sediment samples. Except arsenic, no metals were detected in the sediment samples at concentrations exceeding their respective health-based benchmarks. Arsenic was detected in each of the sediment samples collected, including the background sample at concentrations ranging from 4.72 to 8.71 mg/kg. The background sediment sample exhibited the highest arsenic concentration of 8.71 mg/kg. Therefore, the concentrations of arsenic detected in the sediment samples at the facility are representative of naturally occurring levels. Several organic constituents were detected in the sediment samples; however, none of these constituents were reported at concentrations exceeding their respective health-based benchmarks. Historical data tables are provided in Appendix I.

3.4 SURFACE WATER AND GROUNDWATER RESULTS

This section presents the analytical results for the sampling of surface water and groundwater at the Site, beginning with the RI field effort. Historical analytical result tables from the 1991 Confirmation Study and the 2007 Preliminary Assessment can be found in Appendix I.

3.4.1 2015 RI – Surface Water

As discussed previously in Sections 3.1.3 of this report, 10 surface water samples were collected from sump pits and the former sewage lagoons for the Phase 1 RI field effort. Both the percent analytical and percent quality completeness goals for VOCs (8260 analysis) were met (Table 3-8). Of the 10 samples, cis-1,2-DCE, TCE, and VC were detected above the USEPA RSL tapwater screening level. Additional analytical detections are presented on Table 3-5.

TCE and cis-1,2-DCE were detected in the flame pit above their respective screening levels at concentrations of 50 µg/L and 45 µg/L, respectively. VC was detected above the screening level (0.19 µg/L) in the sediment trap (15 µg/L), deep sump (23 µg/L), and flame pit (24 µg/L).

Although surface water sampling results were compared to USEPA RSL tapwater screening levels, this surface water was collected from sediment traps and the former sewage lagoon. The quantity of water available from these sources is not likely to be sufficient to serve as a potable water supply. An IRA is planned to remediate contaminated surface water from the sediment traps. The Decision Document for this action was finalized in June 2017.

3.4.2 2015 - 2017 RI – Groundwater

As discussed previously in Sections 3.1.3 of this report, eight quarterly rounds of samples were collected for the RI field effort between July 2015 and March 2017. The percent analytical completeness goal for VOCs (8260 analysis) was met for five of the events and the percent quality completeness goal was met for all eight events.

During the first four sampling events, a total of 44 samples were collected from 11 monitoring wells. Of the 44 samples that were collected, TCE was detected in twenty samples and exceeded the USEPA MCL (5 µg/L) screening level in 11 samples (Table 3-9 through 3-11).

TCE was detected above the screening level in Monitoring Well MW-2S during the first four quarterly sampling events with analytical results ranging from 65 µg/L to 120 µg/L. TCE was detected above the screening level in downgradient Monitoring Well MW-3S during the second and third quarter sampling events with analytical results of 5.4 µg/L and 5.9 µg/L, respectively.

TCE was detected above the screening level in upgradient Monitoring Well MW-6S in the first four quarterly sampling events ranging from 16 µg/L to 25 µg/L. TCE was detected above the screening level in Monitoring Well MW-7S during the fourth quarter sampling event with an analytical result of 5.1 µg/L. Additional analytical detections and exceedances are presented on Tables 3-9 through Table 3-12.

During the last four sampling events, a total of 68 samples were collected from 17 monitoring wells. Of the 68 samples that were collected, TCE was detected in 28 samples and exceeded the USEPA MCL (5 µg/L) screening level in 19 samples (Table 3-13 through 3-16). TCE concentrations across the Site are detected above the USEPA MCL (5 µg/L) screening level within Monitoring Wells MW-2S, MW-6S, MW-7S, MW-11S, and MW-13S. Shallow groundwater flow across the Site is predominantly from south to north with groundwater near the southeast corner of the Site flow towards the east (see Figure 2-6). The highest concentrations of TCE within the operations area was detected in Monitoring Well MW-2S with exceedances ranging from 77 J µg/L to 120 J µg/L (See Section 5.1.3.3 for description of J qualifiers). Exceedances within Monitoring Well MW-11S ranged from 61 µg/L to 69 µg/L, which is downgradient from the presumed source area near Monitoring Well MW-2S. Exceedances within Monitoring Well MW-7S ranged from 1.9 J µg/L to 8.5 µg/L, which is downgradient from the source area associated with the sediment trap. A source plume southwest of the facility boundary from the sediment trap is likely the cause for detections within Monitoring Wells MW-6S, MW-7S, and MW-13S. When comparing concentration trends of TCE to cis-1,2-DCE through the eight rounds of sampling, no noticeable trends of biodegradation were observed in Monitoring Wells MW-2S, MW-6S, MW-7S, MW-11S, and MW-13S. Trend graphs comparing the TCE to cis-1,2-DCE concentration through the course of the RI can be found in Appendix O. As shown on these graphs, TCE and cis-1,2-DCE concentrations have remain relatively unchanged during the RI. Historical TCE results from groundwater samples collected from GMW#502 (located adjacent to the location of MW-02S) during the 1991 CS and 2007 PA were within the range of the TCE concentrations detected at MW-02S. This indicates that the long-term TCE concentration trend at this location has been consistent long-term, as well as the short-term during the RI.

Additional analytical detections and exceedances are presented on Tables 3-12 through Table 3-16. A typical TCE isoconcentration map for the RI of the Site can be found in Figure 3-4. A typical groundwater elevation map for the period of the RI of the deep and shallow monitoring wells can be found in Figures 2-5 and 2-6, respectively. Please note that Figures 2-5 and 2-6 may not be representative of normal groundwater elevations and Figure 3-4 may not represent normal TCE distribution, since during the RI investigation period, the annual precipitation was consistently below average and therefore there is potential for variation under different, prolonged conditions.

3.4.3 2007 Preliminary Assessment – Groundwater

Perchlorate, PCBs, SVOCs, and TPH were not detected in the groundwater samples collected from the private wells or the monitoring wells. Antimony, arsenic, and thallium were detected in the downgradient private well sample at concentrations exceeding their respective health-based benchmarks. These metals were not detected in groundwater collected from the upgradient background private well or from the monitoring well located on the facility (GMW #502). Several organic constituents were detected in the groundwater samples. TCE and cis-1,2-DCE was detected in Monitoring Well GMW#502 at concentrations of 87 µg/L and 57 µg/L, respectively.

3.4.4 1991 Confirmation Study Results – Groundwater

Two shallow monitoring wells (GMW#501 and GMW #502) were installed to assess specific subsurface areas at the Site. Monitoring Well GMW#501 was installed west of the missile housing structure. The well was located to assess shallow groundwater in the vicinity of the underground diesel fuel storage tank. Monitoring Well GMW#502 was installed east of the missile structure to assess shallow groundwater in the vicinity of the LOX tank and the area east of the missile structure.

trans-l,2-dichloroethene was detected in samples from GMW#502 (primary sample and field duplicate). TCE was also detected in the primary and duplicate groundwater sample from

GMW#502 at concentrations of 76 µg/L and 85 µg/L, respectively. TCE was also detected in GMW#501 at 2 µg/L. Figure 1-4 shows the CS investigation locations.

3.5 CONTAMINANT SOURCES

The primary contaminant sources at the Site are believed to be contributed from historical operational activities associated with the use of degreasing and cleaning solvents. Detections of TCE and daughter products in soil, sediment, and surface water samples during RI field activities and past investigations indicate that the likely contaminant sources are associated with the main sumps, the sediment trap along the south perimeter fence, and the flame pit. The contaminated surface water and sediments within the sediment trap represent an ongoing release of contaminants to groundwater.

The presence of surface water and sediment contamination within the structure presents an ongoing risk to Site workers and potential future residents; therefore, the USACE decided to perform the IRA on the contaminated surface water and sediments.

4. FATE AND TRANSPORT

This section provides a discussion of contaminant fate and transport at the Forbes S-5 Site and consists of the following subsections:

- Subsection 4.1 discusses the characteristics of contaminants, with emphasis on the behavior of chlorinated solvents in groundwater.
- Subsection 4.2 describes potential routes of migration.
- Subsection 4.3 discusses the various fate and transport processes.
- Subsection 4.4 describes contaminant migration at the Forbes S-5 Site, set within the framework of a conceptual site model.

4.1 CONTAMINANT CHARACTERISTICS

TCE is the primary contaminant present at the Forbes S-5 Site. TCE is a chlorinated hydrocarbon (C_2HCl_3) commonly used as an industrial solvent. It is a clear, non-flammable liquid with a sweet odor. TCE is an effective solvent for a variety of organic materials and has been used as a dry-cleaning solvent and as a degreaser for metal parts. Another application was use by the military to clean kerosene-fueled rocket engines. Much of the knowledge regarding the human health effects of TCE is based on occupational exposures. TCE exposure in humans can result in toxic effects to the nervous system, liver, and kidneys, and may cause fetal cardiac effects. Human exposure typically occurs through the ingestion of TCE-contaminated drinking water. TCE can also readily volatilize out of hot water, such as during showering, which could result in the inhalation of TCE.

TCE and the other chlorinated solvents are subject to microbial degradation, a destructive process that physically changes the chemical structure of the compound. The chlorinated solvents can be used by microorganisms as either electron donors or electron acceptors, depending upon the redox conditions in the aquifer. These compounds can also be degraded by cometabolic processes (Weidemeier & Chapelle, 1998). Chlorinated solvents can be reductively dechlorinated under anoxic conditions. For the common chlorinated ethenes such as

tetrachloroethylene (PCE), TCE, cis-1,2-DCE, and VC, the process occurs in the following sequence:

$$PCE > TCE + Cl^- > cis\text{-}1,2\text{-}DCE + Cl^- > VC + Cl^- > ethene + Cl^-$$

The efficiency of dechlorination differs for particular compounds and for particular geochemical conditions. The dechlorination of PCE and TCE to cis-1,2-DCE occurs under both mild and strongly reducing conditions, whereas the transformation of cis-1,2-DCE to VC, and the transformation of VC to ethene, require the more strongly reducing conditions characteristic of methanogenesis.

Reductive dechlorination is driven by molecular hydrogen (H_2). This suggests why the efficiency of reductive dechlorination is sensitive to redox conditions. Hydrogen is continuously produced in anoxic systems by fermentation of organic matter. This is represented by the general relationship:

$$3CH_2O + H_2O > CH_3COOH + CO_2 + 2H_2$$

The hydrogen produced by fermentation is then used by microorganisms such as methanogens:

$$CO_2 + 4H_2 > CH_4 + 2H_2O$$

Hydrogen concentrations are progressively lower under sulfate-reducing, ferric iron [Fe(III)]-reducing, and denitrifying conditions, which support successively more efficient hydrogen users than methanogens. The efficiency of reductive dechlorination is directly linked to the availability of H_2. Under denitrifying conditions, relatively little hydrogen is available, and reductive dechlorination is relatively inefficient. Conversely, significantly more hydrogen is available under methanogenic conditions and reductive dechlorination is generally more efficient. However, under conditions of excess H_2 availability, methanogenesis becomes favored over dechlorination as a sink for H_2.

PCE and TCE contaminants are most commonly degraded by reductive dechlorination. Their daughter products cis-1,2-DCE, VC, and ethene can be directly oxidized. For example, under

oxic conditions, cis-1,2-DCE, VC, and ethene can be oxidized to carbon dioxide (CO_2) according to the following equations:

For cis-1,2-DCE $Cl_2C_2H_2 + 2O_2 > 2CO_2 + 2H^+ + 2Cl^-$

For VC $ClC_2H_3 + 5/2O_2 > 2CO_2 + H_2O + H^+ + Cl^-$

The complete degradation of chlorinated solvents is favored by sequential anoxic/oxic conditions:

Anoxic (reductive dechlorination)		Oxic (direct oxidation, co-metabolism)
PCE, TCE > cis-1,2-DCE and VC	>	cis-1,2-DCE, VC > $2CO_2$ + Cl-

An accurate delineation of redox conditions within the groundwater system is the key to assessing the biodegradation of chlorinated solvents.

Biodegradation of organic compounds, whether natural or anthropogenic, creates measurable changes in the groundwater chemistry. By measuring these changes, it is possible to document and qualitatively evaluate biodegradation in an aquifer. The following are those geochemical indicators typically evaluated (USEPA, 1998):

- ORP: The ORP of groundwater is a measure of electron activity and is an indicator of the relative tendency of a solution to accept or transfer electrons.
- DO: DO is the most thermodynamically favored electron acceptor used by microbes for the biodegradation of organic carbon, whether natural or anthropogenic.
- Nitrate: Nitrate provides a substrate for microbial respiration if oxygen is depleted.
- Iron: Fe(III) is reduced to ferrous [Fe(II)] during biodegradation of organics; therefore, Fe(II) concentrations can be used as an indicator of anaerobic degradation of chlorinated solvents.
- Sulfate: Sulfate may be used as an electron acceptor for anaerobic degradation, resulting in the formation of sulfide.

- Methane: During methanogenesis, organics and CO_2 are used as electron acceptors and are reduced to methane.
- Chloride: During biodegradation of chlorinated hydrocarbons, chloride is released to the environment.
- Alkalinity: For chlorinated solvents, increases in alkalinity result from interaction of CO_2 with aquifer minerals as a result of degradation.
- TOC: Reductive dechlorination tends to occur more easily in aquifers with higher TOC values.

An application of several of these geochemical indicators to the Forbes S-5 Site can be made based on field data collected during the quarterly sampling conducted at the Site from July 2015 through March 2017. Specifically, data is available for ORP, DO, ferrous iron, sulfate, sulfide, chloride, sulfate, methane, and ethene which is presented in Tables 3-8 through 3-15. This site-specific data is discussed in the following paragraphs.

Based on USEPA guidelines (USEPA, 1998), conditions are considered favorable for reductive dechlorination at ORPs of less than 50 millivolts (mV). At ORPs less than -100 mV, reductive dechlorination is likely to occur. Data collected during the eight quarterly sampling events indicated that ORP conditions within the shallow and deep monitoring wells in most cases were within the favorable range of between 50 and -100 mV for reductive dechlorination in 82 of the 112 samples collected. However, measured ORPs was above the favorable range of between 50 and -100 mV in 24 of the 64 samples collected in the shallow monitoring wells, and 1 of the 48 samples in collected in the deep monitoring wells. Measured ORPs at MW-03D, MW-04D, MW-05D, and MW-06D were less than -100 mV, putting them in a range where reductive dechlorination is likely to occur.

The DO is the most thermodynamically favored electron acceptor used by microbes for the biodegradation of organic carbon, whether natural or anthropogenic. In the case of chlorinated solvents, anaerobic bacteria optimally function at DO concentrations less than 0.5 milligram per liter (mg/L) (USEPA, 1998). None of the DO field measurements taken during the eight

quarterly sampling events were less than 0.5 mg/L (the lowest DO measured was 0.54 mg/L at MW-02S in round six), which indicates that conditions at the Site are not favorable.

Ferrous iron concentration at or greater than 1.0 mg/L can provide evidence that reductive dechlorination is occurring in the aquifer (USEPA, 1998). Ferrous iron was detected in 73 of 101 samples during the seven rounds of sampling events. Ferrous iron samples were not collected during the third quarter sampling event. Data indicates that favorable conditions for reductive dechlorination is not present.

Sulfate may be used as an electron acceptor for anaerobic degradation, resulting in the formation of sulfide. In the case of chlorinated solvents, concentrations of sulfate greater than 20 mg/L may cause competitive exclusion of dechlorination, while the presence of sulfide at concentrations greater than 1 mg/L indicates that dechlorination may be occurring (USEPA, 1998). The sulfate data collected from the monitoring wells ranged from 0.5 U to 557 mg/L (See Section 5.1.3.3 for description of U qualifiers) with only 8 detections below 20 mg/L. Based on the data collected, sulfate concentrations are well above what is considered favorable for biodegradation of chlorinated solvents. Sulfide was detected in approximately 50 percent or 66 samples of the samples collected during the eight groundwater monitoring events evaluated. Five of the detections were below 1 mg/L and 61 were above. Based on the data collected, approximately half of the samples were above what is considered favorable for biodegradation of chlorinated solvents. Sulfate and sulfide results indicate that conditions are not favorable for biodegradation of chlorinated solvents.

During biodegradation of chlorinated hydrocarbons, chloride is released to the environment, and chloride concentrations in the plume will be elevated compared to background concentrations. Chloride can serve as a conservative tracer for reductive dechlorination (USEPA, 1998). For the chlorinated solvents plume, the background chloride concentration value was determined to be 19.9 mg/L (twice the background as calculated based upon Monitoring Wells MW-08S and MW-09S). Chloride was detected in 110 samples during eight groundwater monitoring events with 56 samples above 19.9 mg/L. Chloride concentrations at most monitoring wells indicated that reductive dechlorination conditions are favorable.

During methanogenesis, organics are used as electron acceptors and are reduced to methane. For chlorinated solvents, the presence of methane in the groundwater is indicative of strongly reducing conditions. Methane concentrations greater than 500 µg/L indicate methanogenic conditions favorable to degradation of chlorinated solvents (USEPA, 1998). Methane was detected in 85 samples and below 5 µg/L in 56 samples. No wells had methane greater than 500 µg/L. The low methane levels detected suggest that methane reduction is not occurring.

In conclusion, the data support that aerobic conditions are present in the majority of the shallow and deep monitoring wells. However, the data also supports the presence of areas of reducing conditions, with conditions appearing to become more anaerobic and therefore more conducive to reductive dechlorination as the groundwater flows downgradient and also within the deeper part of the aquifer. The increase in reducing conditions with depth and downgradient distance indicate a potential natural limiting effect on the extent of TCE migration.

4.2 POTENTIAL ROUTES OF MIGRATION

Figure 4-1 presents the identified and presumed sources and identified routes of migration for contaminants at the Site. Potential contaminant sources at the Site were discussed previously in Section 3.5 and shown in Figure 4-1. Original releases of TCE at the Site would initially impact the soil and then leach into the groundwater. In addition, contaminated groundwater could release vapors which may migrate above ground through the vapor intrusion (VI) pathway. Exposure media at the Site include the soil, water, and air. Potentially exposed receptors include future on- and off-site residents.

- Future on-site residents could potentially be exposed to contaminated surface water, sediment, and groundwater from the ingestion and dermal contact routes of exposure and possibly inhalation of vapors from groundwater.
- Future off-site residents could be exposed to contaminated groundwater from the ingestion and dermal contact routes of exposure and possibly inhalation of vapors from groundwater used to supply the residence.

Based on the results of soil, sediment, surface water, and groundwater sampling at the Site, significant exposures and risk are present at the Site. Because of this the USACE decided to

perform the IRA on the contaminated surface water and sediments within the structure at the Site.

4.3 CONTAMINANT MIGRATION

The migration of TCE contamination at the Forbes S-5 Site can be best described within the framework of a conceptual site model. This model incorporates elements of the site geology, hydrogeology, contaminant release history, and exposure pathways, to provide a unified picture of the movement of contamination.

Based on the site investigations performed, the site geology is fairly simple, with a fine-grained lithology of clay, silt, and mudstone overlying the Schroyer Limestone Member, Havensville Shale Member, and the Threemile Limestone Member. The primary aquifer formation at the Site is the Wreford Limestone which contains the Schroyer and Threemile Limestone members. The Havensville Shale Member is situated between the two limestone members and serves as an aquitard. Groundwater flow direction of the shallow monitoring wells in the Schroyer Limestone Member flows in a radial direction away from the groundwater high at MW-06S (see Figure 2-6). The direction of groundwater flow across the Site is from south to north within the Threemile Limestone Member (see Figure 2-5).

The extent of TCE contamination in the southwest portion of the Site down gradient of the sediment trap near the southwest corner of the facility is likely attributed to the following:

- Leaking of TCE-contaminated water into the subsurface from the vitrified clay pipe line that connects the main sump to the sediment trap;
- Discharge of TCE-contaminated water from the sediment trap to the ground surface and subsurface after accumulation via the sediment trap discharge line;
- TCE-contaminated water slowly seeping through the floor of the sediment trap into the subsurface.

During the RI, the location of the line that connects the main sump to the sediment trap was unable to be located. The discharge pipe from the sediment trap was located on the south side of the sediment trap, however; the exact distance from the sediment trap and the location where it daylighted are unknown.

Once TCE-contaminated water leaked or seeped into the subsurface, the TCE-contaminated water entered the groundwater through a process of infiltration and percolation and migrated through the unsaturated zone into the groundwater. When TCE-contaminated water was discharged to the ground surface, it flowed overland, downhill, following the surface topography toward the drainage swale located southwest of the facility that drains to the south. As the TCE-contaminated water flowed downhill it was absorbed in the ground through the processes of infiltration and percolation, and then migrated through the unsaturated zone into the groundwater. Once in groundwater, the TCE was transported down-gradient, primarily through the process of advection. The extent of the overflow migration is dependent on the amount of TCE-contaminated water released from the sediment trap and precipitation events that contributed to additional migration of the impacted water.

TCE contamination associated with the main sump and flame pit is attributed to TCE slowly seeping through the floor into the subsurface. TCE impacted water is believed to have entered the groundwater through a process of infiltration and percolation and migrated through the unsaturated zone to the groundwater.

Contaminants, primarily TCE, in both source areas were released to the soil and, through the processes of infiltration and percolation, migrated through the unsaturated zone to the groundwater. Once in groundwater, the TCE is transported down-gradient, primarily through the process of advection. Other processes, including sorption, volatilization, biodegradation, advection, and dispersion, probably act to reduce the contaminant mass as the groundwater flows down gradient. The little evidence provided above in Subsection 4.1 suggests that biodegradation is taking place down the flow gradient. During the RI, low concentrations of TCE (below 1 µg/L) were detected in all of the deep wells except Monitoring Well MW-04D,

indicating trace amounts of contamination are leaking from shallow aquifer in the Schroyer Limestone to the deep aquifer in the Threemile Limestone.

5. RISK ASSESSMENT

5.1 HUMAN HEALTH RISK ASSESSMENT

5.1.1 Introduction and Objectives

A CERCLA baseline risk assessment provides an evaluation of the potential threat to human health and the environment in the absence of any remedial action. It provides the basis for determining whether or not remedial actions are necessary and the justification for performing those actions. The results of the risk assessment are used to determine if a feasibility study is needed to evaluate remedial options.

This section presents the human health risk assessment (HHRA) that was performed for the Former Forbes Atlas Missile Site S-5. The HHRA was performed following the approach presented in the approved Work Plan (USACE, 2015). The HHRA evaluated the contamination present in the soil and groundwater to determine the potential risks (cancer and noncancer) associated with human contact with these media based on the current and reasonably anticipated future uses of the Site. The HHRA was conducted in general accordance with guidance under CERCLA and input from KDHE. It was based on the following guidance and methods including:

- USACE Risk Assessment Handbook, Volume I: Human Health Evaluation (EM 200-1-4) (USACE, 1999)
- USEPA Risk Assessment Guidance for Superfund (RAGS), Volume I: Human Health Evaluation Manual – Part A (1989), Part E (Supplemental Guidance for Dermal Risk Assessment, 2004), and Part F (Supplemental Guidance for Inhalation Risk Assessment, 2009)
- USEPA Human Health Evaluation Manual, Supplemental Guidance: Standard Default Exposure Factors (USEPA, 1991)
- USEPA Exposure Factors Handbook (USEPA, 2011)

- USEPA Supplemental Guidance for Developing Soil Screening Levels (USEPA, 2002a)
- USEPA Child Exposure Factors Handbook (USEPA, 2008)
- USEPA Regional Screening Level Table (USEPA, 2017a)
- USEPA Guidelines for Carcinogen Risk Assessment (USEPA, 2005a)
- USEPA OSWER Directive 9200.1-120 Memorandum (USEPA, 2014b)
- USEPA Supplemental Guidance for Assessing Susceptibility from Early-Life Exposure to Carcinogens (USEPA, 2005b) as presented at https://www.epa.gov/risk/supplemental-guidance-assessing-susceptibility-early-life-exposure-carcinogens
- USEPA Technical Guide for Assessing and Mitigating the Vapor Intrusion Pathway from Subsurface Vapor Sources to Indoor Air (USEPA, 2015c)
- KDHE's Risk-Based Standards for Kansas (KDHE, 2015)

5.1.2 Report Overview

There are five major components of the HHRA process for the Site:

- Hazard Identification – Describes the available site data, the data usability and validation, and the guidelines for data reduction for risk assessment purposes; outlines the data evaluation approach; and identifies the contaminants of potential concern (COPCs) (Section 5.1.3);
- Exposure Assessment – Describes the exposure setting and local land and water uses. Presents a conceptual site model (CSM) for human exposures that describes the source of contamination, the affected media, and the exposure scenarios and their associated exposure pathways. Methods for estimating the exposure point concentrations (EPCs) are also presented along with the scenario-specific exposure parameters (Section 5.1.4);

- Toxicity Assessment – Describes and identifies the cancer and noncancer toxicity factors that were used to evaluate the risks associated with exposure to COPCs (Section 5.1.5);

- Risk Characterization – Integrates the toxicity assessment and the exposure assessment to characterize potential cancer risks and noncancer health effects and presents an overall summary of the potential risks based on exposure to the affected media (Section 5.1.6); and

- Uncertainty Analysis – Identifies the important uncertainties in the risk assessment process and describes the potential impact of these uncertainties on the overall estimate of risk (Section 5.1.7).

5.1.3 Hazard Identification

The hazard identification presents the data available to assess site risks, evaluates the usability of the data, outlines the approach used to summarize the data, and identifies the COPCs. The hazard identification process involves the following tasks:

- Describe the available site data that were used to calculate site risks;

- Identify the media of potential concern;

- Establish the guidelines for data reduction;

- Evaluate the data for use in the risk assessment; and

- Select the COPCs.

The following subsections describe each of these tasks in greater detail.

5.1.3.1 Available Site Data

5.1.3.1.1 Groundwater

The groundwater data used in the risk assessment included data collected during the current RI. A total of eight rounds of low-flow groundwater sampling were performed for wells installed in

2015 and four rounds of sampling for monitoring wells installed in 2016. All samples were analyzed for cis-1,2-DCE, TCE and VC. The data collected during the current RI field activities reflect current conditions and are appropriate to use for calculating risk associated with the future use of the groundwater. There is no current use of the site groundwater. Table 5-1 presents a general summary of the analytical results for the groundwater samples.

5.1.3.1.2 Soil Data

Soil samples for this RI were collected from the Site between May 12 and June 2, 2015 and May 24 and June 5, 2016. A total of 57 soil samples were collected from 12 soil boring locations. Table 3-2 presents the analytical results for the soil samples. All samples were analyzed for cis-1,2-DCE, TCE and VC. Only a few samples had detected values and those samples were outside the zone of potential human contact (> 10 ft bgs) and had concentrations that were less than direct contact screening levels available from USEPA and KDHE. There were no site contaminants detected in any of the soil samples collected between 0 and 10 ft bgs. As a result, soil exposure is not a concern and is not evaluated in this risk assessment.

5.1.3.1.3 Sediment Data

A total of seven sediment samples were collected and analyzed during the RI field activities. All sediment samples were collected from the sumps and pits on Site. The sediment sample locations are not readily accessible and assumed to have an infrequent exposure potential. Sediment samples were analyzed for cis-1,2-DCE, TCE, and VC, each of which had at least one detected concentration. Table 5-2 displays a general summary of the analytical results for the sediment samples.

5.1.3.1.4 Surface Water

Ten surface water samples were collected from May 14 through May 20, 2015 from ten separate locations. All samples were collected from site sumps and pits. Like the sediment samples, the surface water sample locations are not readily accessible and assumed to have an infrequent exposure potential. Analytical results for surface water are presented in Table 5-3. Surface water was analyzed for cis-1,2-DCE, TCE, and VC, and each were detected in at least one sample.

5.1.3.2 Media of Concern

Based on the previous investigations, the levels of contamination, and the current and reasonably anticipated future uses of the Site, groundwater is of potential concern to human receptors should the groundwater be used in the future and was evaluated in the HHRA. Based on the relatively shallow depth of groundwater at the Site, a VI pathway was also evaluated for contaminants in groundwater that may volatilize into future indoor air in order to determine if additional characterization and/or evaluation of the VI exposure pathway is warranted. As discussed in Section 5.1.2.1.2, soil contamination was not detected within the zone of potential human contact (0 to 10 ft bgs) and was therefore eliminated from further evaluation in this HHRA. Although site conditions and access strongly indicate that contact would be infrequent or even unlikely, sediment and surface water was evaluated in the HHRA for potential human health exposure.

5.1.3.3 Guidelines for Data Reduction

Data reduction involves the evaluation of data qualifiers and their potential use in the HHRA process and describes the treatment of field duplicate samples. The following guidelines for data reduction were used to produce the data summaries for each medium. These approaches are consistent with USEPA RAGS (USEPA, 1989).

- If an analyte was not identified in any sample for a given medium because it was reported as a nondetect (ND, indicated by a "U" qualifier, the limit of detection is less than the decision limit), it was not addressed for that medium.

- "J" qualified analytical data indicates that the reported concentration is estimated. These data were evaluated as detections in the risk assessments, however before inclusion in the HHRA all "J" qualified data were rounded to one significant digit for uncertainty purposes.

If both a primary and field duplicate were detected, the higher of the two detected concentrations was used for subsequent calculations. In the case of a detected sample and a nondetect duplicate, the detected concentration was carried through subsequent calculations.

5.1.3.4 Data Evaluation

The data evaluation summarizes the data by medium for use in the HHRA. Data summary tables were prepared for groundwater, sediment, and surface water and present the following information:

- List of analytes detected.
- Range of detected concentrations.
- Location of maximum detected concentration.
- Frequency of detection.
- Range of quantitation limits.
- Standard deviation.
- Average concentration.

Table 5-1 presents the analytes detected in site groundwater for all wells combined, as well as each individual well. Both cis-1,2-DCE and TCE were detected in at least one well, whereas VC was not detected in any of the wells sampled.

Tables 5-2 and 5-3 present the analytes detected in sediment and surface water, respectively. Both media had at least one detect among the three analytes analyzed (cis-1,2-DCE, TCE and VC).

5.1.3.5 Approach to the Selection of Contaminants of Potential Concern

A COPC selection process was conducted to identify analytes that were detected in the affected media at levels that could pose a potential risk to exposed human receptors (see Tables 5-1, 5-2, and 5-3). Note that based on the site history and previous data collected at the site, the only analytes analyzed across all Site media were cis-1,2-DCE, TCE, and VC and were therefore the only analytes evaluated in the HHRA. The criteria that were used to determine COPCs include:

- Non-detection – If an analyte was not detected in all samples for a given medium, it was not evaluated as a COPC for that medium.

- A comparison of maximum detected concentrations to risk-based criteria – Comparisons were made to the USEPA RSLs (USEPA, 2017a) and the USEPA vapor intrusion screening level (VISLs (USEPA, 2016). Analytes that exceeded their respective screening criteria were retained as COPCs and evaluated in the risk assessment. KDHE RSKs (KDHE, 2015) were included in Tables 5-1 through 5-3, where available, for informational purposes only.

    - To select COPCs in groundwater, each well was evaluated separately in order to determine the well with the highest contaminant concentration for each analyte. The maximum detected concentration for each contaminant at each well was compared to the USEPA tap water RSLs. For screening purposes, the noncancer based RSLs at a target hazard quotient (THQ) of 0.1 was used (USEPA, 2017a). A target risk (TR) for cancer based criteria of one-in-a-million (expressed as 1E-06) was used. In cases where an analyte had both cancer and noncancer screening values, the lower (i.e., more stringent) of the two values was used for screening.

    - It was conservatively assumed that the well with the highest maximum detected concentration for each analyte would be used for the basis of the risk calculations. MW-11 had the highest detected concentration for cis-1,2-DCE (26 µg/L) and MW-02 had the highest detected concentration for TCE (100 µg/L).

    - To select COPCs for the VI pathway, the maximum detected concentration for each contaminant at each well, as well as all wells combined, was compared to the USEPA VISLs based on residential indoor air risks adjusted to correspond to a hazard quotient (HQ) of 0.1 or cancer risks of $1x10^{-6}$.

    - To select COPCs in sediment and surface water, the maximum detected concentrations were compared to the USEPA industrial soil and tapwater RSLs,

respectively. As with groundwater, a THQ of 0.1 and a TR of 1E-06 was used for the RSLs.

The following summarizes the COPCs that were identified per exposure media:

		COPC		
Analyte	Groundwater	VI	Sediment	Surface Water
cis-1,2-DCE	X			X
TCE	X	X		X
Vinyl Chloride			X	X

5.1.4 Exposure Assessment

The exposure assessment characterizes the nature, extent, and magnitude of potential exposure of human receptors to COPCs considering the current and the reasonably anticipated future uses of the Site. The exposure assessment involves several elements, including:

- Developing a CSM for potential human exposures, which includes describing the source(s) of contamination, the transport and release mechanisms, the exposure media, the exposure routes, and the potentially exposed populations;
- Calculating the EPCs for each COPC for each of the exposure scenarios and routes of exposure;
- Identifying the exposure models and parameters that were used to calculate the exposure doses; and
- Calculating the exposure doses for both cancer and noncancer effects.

Doses and risks were calculated based on the reasonable maximum exposure (RME). The RME is a high-end description of risk defined by USEPA guidance (1992) as: "… a plausible estimate of the individual risk for those persons at the upper end of the risk distribution. The intent of this

description is to convey an estimate of risk in the upper range of the distribution, but to avoid estimates which are beyond the true distribution."

5.1.4.1 Exposure Setting

The Forbes S-5 Site is located in a sparsely populated area in Lyon County, Kansas. The closest town is Bushong, Kansas, which has a population of 34, with 12 households and 10 families residing in the city (US Census, 2010). The Site is not currently used for any regular purpose. There is evidence, such as graffiti and trash, that adolescents (i.e., teenagers) periodically use the site for gatherings. Pastureland is the predominant land use surrounding the Site. There is no current use of the site groundwater.

5.1.4.2 Conceptual Site Model for Human Exposures

The CSM for human exposures describes the contaminant source(s), the release and transport mechanisms, the exposure media, the exposure routes, and the potentially exposed human populations. The primary objective of the HHRA CSM is to identify the complete and incomplete exposure pathways. A complete pathway has all the components listed above, whereas an incomplete pathway is missing one or more. Figure 5-1 presents the CSM for human exposure. Each element of the CSM is described in detail in the following sections.

Source of Contamination

There are a number of possible contamination sources associated with the Forbes Atlas Missile S-5 Site. TCE was used to flush missile fuel tanks to remove residual fuel and prevent an accidental explosion. Further, equipment cleaning operations involving the use of metal degreasing compounds is another possible source of TCE contamination. Historical operations such as the use of fuels, hydraulic fluids, oils, and lubricants, and the presence of transformers containing PCBs could also be sources of contamination. The contamination could enter sumps and sump discharge lines, hydraulic systems, USTs, water treatment systems, sewage lagoons, and maintenance activity areas.

Release and Transport Mechanisms

There are four mechanisms that can potentially release and transport COPCs: leaching to groundwater, surface water runoff, wind erosion, and volatilization. Previous investigations indicate that leaching to groundwater is the primary release and transport mechanism associated with the site contamination. Following release to the ground surface, infiltration would transport COPCs downward through the soil column to the groundwater.

Surface water runoff occurs during precipitation events when COPCs in the soil are released and transported to other areas on-site via site drainage. Wind erosion can play a role in releasing COPCs from soil. This holds true in areas with little vegetative cover and where activities such as heavy truck traffic on unpaved roads and other construction-related activity is occurring. It is also possible that VOCs, if present in the soil, can volatilize and be inhaled. As discussed previously, there are no significant contaminant levels in site soils.

Given their tendency to volatilize, VOCs could potentially migrate through the vadose zone and into structures located above the groundwater plume.

Exposure Media and Routes of Exposure

The potentially contaminated media for human exposure include soil, groundwater, sediment, and surface water. COPCs in groundwater may be ingested and absorbed through the skin while bathing/showering. Volatile COPCs in groundwater can be inhaled as a result of indoor use of the groundwater (e.g., showering, running faucets to wash hands) as well as through the VI pathway.

As previously stated, the soil pathway was not evaluated due to lack of detected contaminants. COPCs in sediment and surface water may be incidentally ingested and absorbed through the skin.

5.1.4.3 Potentially Exposed Populations

The Forbes S-5 Site is privately owned. It is not currently used on a regular basis. It is assumed that the Site will be developed for future residential use. Therefore, future residents (child and adult) were evaluated for potential exposure to groundwater.

The potential exists for trespassers to be exposed to sediment and/or surface water while visiting the Site. Given the nature of the Site, it is highly unlikely for individuals to access the locations in which sediment and surface water contamination was observed. However, for conservative purposes, an adult trespasser was assumed to contact these media on a very infrequent basis.

5.1.4.4 Exposure Point Concentrations (EPCs)

An EPC is the concentration of a COPC that a receptor is assumed to contact during exposure to site COPCs. Ideally, EPCs are represented by 95 percent upper-confidence limit (UCL) of the mean values calculated using the USEPA ProUCL software.

For TCE in groundwater, the 95 percent UCL was calculated using USEPA's ProUCL Version 5.1.002 software (USEPA, 2017b). ProUCL calculates 95 percent UCLs on the mean using 15 different computation methods: 5 parametric and 10 non-parametric. Parametric methods rely on the estimation of parameters (such as the mean or the standard deviation) describing the distribution of the variable of interest in the population; non-parametric methods do not. Note that for datasets with censored results (i.e. non-detects), UCLs calculated using estimation procedures (e.g., Kaplan Meier [KM], bootstrapping) were considered instead of employing the simple substitution method (e.g., using one-half the sample quantitation limit for non-detects) for selecting appropriate UCLs as guided by the ProUCL supporting documentation.

A 95 percent UCL could not be calculated for cis-1,2-DCE in groundwater as only four sample results were available from MW-11. A similar situation exists for VC in sediment and cis-1,2-DCE, TCE, and VC in surface water. The maximum detected concentrations were used as the EPCs for these COPCs. This is a conservative assumption that will likely over-estimate the risks calculated in this HHRA.

Support documentation (input for and output from the ProUCL program) for the calculation of the UCL is presented in Appendix P. Tables 5-4 through 5-6 present the EPCs for groundwater, sediment, and surface water, respectively.

5.1.4.5 Identification of Exposure Equations and Parameters

Exposure equations and parameters were used to estimate the chronic daily intakes (exposure doses) of the COPCs through the applicable exposure pathways. Exposure doses are dependent upon the magnitude, frequency, and duration of exposure. They are estimated by combining the COPC concentration (i.e., the EPC) and the exposure parameters. The exposure doses were expressed as intakes in milligrams of COPC per kilogram of body weight per day (mg/kg-day). Two types of doses were calculated in this risk assessment. The first, the lifetime average daily dose (LADD), which was averaged over a 70-year lifetime, was used to estimate cancer risk. The second, the average daily dose (ADD), which is averaged over the actual exposure duration for each receptor, was used to estimate noncancer health effects.

The residential exposure parameters that were used are standard values recommended by USEPA. Table 5-7 presents the exposure parameters and models that were used to estimate residential exposure doses and include the following:

- EF – exposure frequency - a value of 350 days/year was used (USEPA, 2014b).
- ED – exposure duration - a value of 26 years (20 years as an adult and 6 years as a child) was used (USEPA, 2014b).
- ET – exposure time - it was assumed that the residents would be on-site for 24 hours (USEPA, 2014b).
- BW – body weight - the child and adult BWs used were 15 kg and 80 kg, respectively (USEPA, 2014b).
- AT – averaging time - the cancer AT was based on a 70-year lifetime for all age groups, which equals 25,550 days (i.e., 70 years x 365 days/year). The noncancer AT equals the receptor-specific ED multiplied by 365 days/year.
- Water ingestion rate (IRW) – represents the amount of drinking water that is ingested daily, expressed in units of liters per day (L/day). The child and adult IRWs used were 0.78 L/day and 2.5 L/day, respectively (USEPA, 2014b).
- FI – fraction ingested - a value of 1.0 was used for groundwater ingestion.

- ABS – absorption factor - the ABS factors were obtained from USEPA's dermal risk assessment guidance (USEPA, 2004).
- Event frequency (EV) – represents the number of bathing/showering events per day (events/day) that a receptor takes. It was assumed that the hypothetical future residents (child and adult) bathe/shower once a day (USEPA, 2004).
- Dose model for dermal contact while bathing/showering (DAevent) – was estimated following the approach presented in the dermal risk assessment guidance (USEPA, 2004). SA values of 6,365 cm2 and 19,652 cm2 will be used for the child and adult, respectively (USEPA, 2014b). The child bathing time or event duration (tevent) used was 0.54 hour/event (approximately 32 minutes per bath) (USEPA, 2014b). The assumed adult showering time used was 43 minutes (0.71 hour/event) (USEPA, 2014b).
- Andelman Volatilization Factor (K) (L/m3) – an estimate of the rate at which a volatile COPC is emitted from water as a vapor due to indoor use of the water. USEPA's default value of 0.5 L/m3 will be used (USEPA, 2017a).

The adult trespasser exposure parameters and models that were used are presented in Tables 5-8 and 5-9, respectively and include the following;

- EF – a value of 22 days/year was used (professional judgement).
- ED – a value of 20 years (USEPA, 2014b).
- BW – the adult BW used was 80 kg (USEPA, 2014b).
- FI – the adult fraction ingested used was 0.5 (professional judgement).
- SA – the adult SA was 6,032 cm^2 and is represented by hands, head, feet, forearms, and lower legs (USEPA, 2014b).
- Adherence factor (AF) – the adult AF of 0.3 mg/cm^2-event was used (USEPA, 2014b).
- AT – the cancer AT was based on a 70-year lifetime for an AT_c of 25,550 days/year and the noncancer AT equals the ED multiplied by 365 days/year for an AT_{NC} of 7,300.
- FI – a value of 0.5 was used for surface water ingestion (professional judgement).
- Sediment ingestion rate (IR-SD) – the IR-SD was assumed to be 100 mg/day (USEPA, 2014b).
- IRW –The adult IRW used was 0.071 L/hour (USEPA, 2017a).
- EV – It was assumed that the adult trespasser EV was once a day (professional judgement).

- DAevent – The adult SA value of 6,032 cm^2 was used (USEPA, 2014b). The t_{event} was assumed to be 1 hour/event (professional judgement). See Tables 5-10 and 5-11.

5.1.5 Toxicity Assessment

The toxicity assessment identifies the toxicity values for the COPCs used in the estimation of potential cancer risks and noncancer health effects. It also provides a description of the terms that are used to estimate toxic effects (i.e., cancer and noncancer effects) along with the data sources. Summary tables are included (Tables 5-12 through 5-15) that present the toxicity values for each of the COPCs.

5.1.5.1 Cancer Effects

For cancer effects, the toxicity values are expressed as oral cancer slope factors (CSF) in units of milligrams of COPC per kilogram of body weight per day $(mg/kg\text{-}day)^{-1}$, and as inhalation unit risk factors (URF) in units of micrograms of COPC per cubic meter $(\mu g/m^3)^{-1}$. The CSFs are used for the oral and dermal routes of exposure, whereas the URFs are used to evaluate the inhalation route of exposure. USEPA has assigned each contaminant a "weight-of-evidence" category that represents the likelihood of it being a human carcinogen (USEPA, 2005a). Five weight-of-evidence categories exist:

- Carcinogenic to humans;
- Likely to be carcinogenic to humans;
- Suggestive evidence of carcinogenic potential;
- Inadequate information to assess carcinogenic potential; and
- Not likely to be carcinogenic in humans.

COPCs that are classified in the first three categories according to the classification system are generally carried through the risk characterization step if CSFs or URFs have been developed.

For carcinogens that act with a mutagenic mode of action (MOA) for carcinogenesis (e.g., TCE and VC), USEPA recommends application of Age-Dependent Adjustment Factors (ADAFs) to the CSF to address early lifetime exposures and the increased susceptibility of children to carcinogens (USEPA, 2005b). This approach was followed in the HHRA and is presented in Subsection 5.1.5.1.

5.1.5.2 Noncancer Effects

Noncarcinogens refer to contaminants that cause toxic effects other than cancer. Noncancer effects can include, for example, central nervous system damage, reproductive effects, and other systemic effects. For noncancer effects, the toxicity values are expressed as reference doses (RfD) in units of mg/kg-day and reference concentrations (RfC) in units of mg/m^3. The RfDs are used for the oral and dermal routes of exposure whereas the RfCs are used to evaluate the inhalation route of exposure. The premise of noncancer toxicity values is that there is an exposure level below which deleterious noncancer effects are not expected to occur.

5.1.5.3 Sources of Toxicity Values

When available, CSFs and reference doses were obtained from the following sources in the order presented (USEPA, 2003):

- Integrated Risk Information System (IRIS) (USEPA, 2017c).
- California Environmental Protection Agency (CalEPA) Office of Environmental Health Hazard Assessment's Chronic Reference Exposure Level values for noncancer health effects and CSFs/URFs for cancer effects.

5.1.5.4 Dermal Exposure

Toxicity values have not been developed for the dermal contact and absorption pathway. Dermal toxicity values were derived from the oral toxicity values as described in USEPA dermal risk assessment guidance (USEPA, 2004). In general, the oral CSFs and oral RfDs are expressed as administered doses (i.e., the amount of a contaminant administered per unit time and weight). Conversely, exposures resulting from the dermal pathway are expressed as absorbed doses.

Therefore, it is necessary to make an adjustment to the oral toxicity value to account for the contaminant-specific absorption efficiency.

The fraction of a COPC that is absorbed in the gastrointestinal tract, also known as ABS_{GI}, is a critical factor when adjusting from an administered to an absorbed dose. The ABS_{GI} values that were used in this risk assessment were obtained from USEPA (2004). In the case of the COPCs evaluated in this HHRA, there are no COPC-specific ABS_{GI} values available from USEPA. As recommended by USEPA (2004) for those volatile chemicals without an ABS_{GI} value, a value of 100 percent is assumed (see Tables 5-12 and 5-14). Thus, the dermal toxicity value is equal to the oral toxicity value.

5.1.6 Risk Characterization

The risk characterization integrates the information developed in the exposure assessment and the toxicity assessment into an evaluation of the potential risks associated with exposure to COPCs. Carcinogenic risks were calculated for those COPCs with evidence of carcinogenicity and for which cancer toxicity values are available. Noncancer health effects were evaluated for all COPCs (i.e., including carcinogens) for which noncancer toxicity values are available.

5.1.6.1 Cancer Risk

Potential cancer risk from the ingestion and dermal contact pathways were calculated by multiplying the estimated LADD that is calculated for a COPC through an exposure route by the exposure route-specific CSF, as follows (Equation 5-1):

Equation 5-1

$$\text{Cancer Risk} = \text{LADD} * \text{CSF}$$

Where:

LADD = Lifetime average daily dose; intake averaged over a 70-year lifetime as mg COPC/kg-body weight per day.

CSF = COPC- and route-specific cancer slope factor $(mg/kg\text{-}day)^{-1}$.

Potential cancer risks from the inhalation pathway were calculated by multiplying the modeled air concentration by the URF, as follows (Equation 5-2):

Equation 5-2

$$\text{Inhalation Cancer Risk} = CA \times URF$$

Where:

CA = Air concentration ($\mu g/m^3$).

URF = COPC-specific inhalation unit risk factor $(\mu g/m^3)^{-1}$.

Cancer risks were summed across the relevant pathways for a given receptor and exposure scenario to yield a cumulative lifetime risk. USEPA has established that in the CERCLA program, risks within the range of 1E-04 to 1E-06 are generally considered protective. These are written in scientific notation such as 1x10-05, (1E-05) and read as one in one hundred thousand (0.00001).

Trichloroethene

TCE, which exhibits a mutagenic MOA for carcinogenesis, was evaluated following a different approach (USEPA, 2005b). TCE is carcinogenic by a mutagenic MOA for induction of kidney tumors. There is also more limited evidence for non-Hodgkin lymphoma (NHLymphoma) and

liver carcinogenicity. In order to account for the mutagenic MOA for kidney tumors, USEPA recommends applying ADAFs (see table below) when calculating kidney cancer risks from early life exposure to TCE (see https://www.epa.gov/risk/supplemental-guidance-assessing-susceptibility-early-life-exposure-carcinogens).

Age-Dependent Adjustment Factors	
Age (years)	**ADAF (unitless)**
0 – <2	10
2 – <16	3
≥16	1

However, NHLymphoma and liver cancer must also be accounted for in the TCE cancer risk calculations. To accommodate all three carcinogenic effects, TCE cancer risks were derived using the adjusted kidney cancer potency values and unadjusted potency values for liver cancer and NHLymphoma. The equations presented below (Equations 5-3 through 5-5) illustrate how the ADAFs were included in the pathway-specific risk calculations for TCE and how the adjusted kidney and unadjusted liver and NHLymphoma CSFs were integrated:

Equation 5-3

$$\text{Ingestion Risk}_{moa} = (\text{LADD} \times \text{CSF}_{kidney} \times \text{ADAF}) + (\text{LADD} \times \text{CSF}_{liver+nonHodgkinLymphoma})$$

Equation 5-4

$$\text{Dermal Risk}_{moa} =$$

$$(\text{DAevent} \times \text{LADD} \times \text{CSF}_{kidney} \times \text{ADAF}) + (\text{DAevent} \times \text{LADD} \times \text{CSF}_{liver+NHLymphoma})$$

Equation 5-5

$$\text{Inhalation Risk}_{moa} = (\text{CA} \times \text{URF}_{kidney} \times \text{ADAF}) + (\text{CA} \times \text{CSF}_{liver+NHLymphoma})$$

Where:

Risk_{moa}	=	Age-group specific cancer risk from TCE exposure.
LADD	=	Lifetime average daily dose based on intake parameters specific to the age group evaluated; intake averaged over a 70-year lifetime as mg COPC/kg-body weight per day.
DAevent	=	Dose model for dermal contact while bathing/showering (mg/cm^2).
CA	=	Modeled indoor air concentration ($\mu g/m^3$).
CSF	=	TCE end point-specific cancer slope factor $(mg/kg\text{-}day)^{-1}$.
URF	=	TCE end point-specific inhalation unit risk factor $(\mu g/m^3)^{-1}$.
ADAF	=	Age group specific Age-Dependent Adjustment Factor.

Total TCE Risk for resident exposures = $\text{Risk}_{0 \text{ to } <2} + \text{Risk}_{2 \text{ to } <6} + \text{Risk}_{6 \text{ to } <16} + \text{Risk}_{16 \text{ to } <30}$

5.1.6.2 Noncancer Health Effects

Potential noncancer health effects were evaluated by the calculation of HQs and hazard indices (HIs). For the ingestion and dermal contact pathways, the HQ is the ratio of the exposure duration averaged estimated daily intake (ADD) through a given exposure route to the COPC- and route-specific RfD. The HQ-RfD relationship is illustrated in Equation 5-6.

Equation 5-6

$$HQ = ADD/RfD$$

Where:

HQ	=	Hazard quotient.
ADD	=	Average daily dose; estimated daily intake averaged over the exposure duration (mg/kg-day).
RfD	=	Reference dose (mg/kg-day).

For inhalation exposure, the HQ is the ratio of the modeled air concentration and the COPC-specific RfC as presented in Equation 5-7.

Equation 5-7

$$\text{Inhalation } HQ = CA / (RfC \times CF)$$

Where:

HQ	=	Hazard quotient
CA	=	Air concentration ($\mu g/m^3$)
RfC	=	COPC-specific reference concentration (mg/m^3)
CF	=	Conversion factor (1,000 µg/mg)

HQs were summed to calculate HIs for the residential scenario. HIs were calculated for each exposure route, and a total HI was calculated based on exposure to the COPCs. HIs of less than one indicate that adverse health effects associated with the exposure scenario are unlikely to occur.

5.1.6.3 Risk Results

5.1.6.3.1 Groundwater

Table 5-16 presents the TCE cancer risk calculations for the mutagenic MOA. Table 5-17 presents the cancer risks for the age-adjusted residents. Tables 5-18 and 5-19 present the HQs/HIs for the adult and child residents, respectively.

The total groundwater cancer risk is at the high end of the USEPA's generally acceptable cancer risk range of 1E-06 to 1E-04 with a total cancer risk of 1E-04 (rounded) from TCE exposure (Table 5-17). Although cis-1,2-DCE was also a groundwater COPC, it is not a carcinogen. The total noncancer HIs range from 21 (adult, Table 5-18) to 24 (child, Table 5-19) and are primarily driven by the inhalation pathway. In both scenarios, the noncancer point of departure of 1.0 was exceeded and was driven by TCE. Furthermore, TCE exceeded the groundwater VISL of 0.52 µg/L, demonstrating additional evaluation of the VI exposure pathway is warranted.

5.1.6.3.2 Sediment and Surface Water

An IRA for sediment and surface water in the areas sampled has been determined as part of the June 2017 *Final Interim Remedial Action Decision Document* (USACE, 2017). However, in order to fully characterize current and potential future risks based on exposure to these areas, the sediment and surface water pathways were included in the HHRA. Tables 5-20 and 5-21 present the sediment and surface water cancer risks and non-cancer HQs/HIs for the adult trespasser scenario, respectively. The total cancer risks based on sediment and surface water exposure were 8E-08 and 4E-07, respectively. The total noncancer HIs for sediment and surface water were 0.00013 and 0.015, respectively. The cancer risks were well below EPA's generally acceptable risk range of 1E-06 to 1E-04 and the non-cancer point of departure of 1.0 for both sediment and surface water. In addition to the infrequent or unlikely exposure potential, the risk results indicate that sediment and surface water are not a concern for human health exposure at the Site.

5.1.7 Uncertainty Analysis

The goal of a risk assessment uncertainty analysis is to provide decision makers (i.e., risk managers, stakeholders) information about the key assumptions, their inherent uncertainty and

variability, and the impact of this uncertainty and variability on the estimates of risk. The uncertainty analysis shows that risks are relative in nature and do not represent an absolute quantification. This is an important point that is vital to the proper interpretation and understanding of the risks presented in this report. This section describes some of the more important assumptions used in the risk assessment process and provides a discussion of the impact of these assumptions on the estimation of risk from exposure to groundwater, sediment and surface water.

- EPCs – As a conservative approach, a hypothetical well was assumed to contain the highest levels of COPCs. MW-11 had the highest levels of cis-1,2-DCE and MW-02 had the highest levels of TCE. The risk calculations were based on the result from these wells. There were only 4 samples collected from MW-11 and therefore, the maximum concentration was used as the EPC for cis-1,2-DCE.Sixteen samples were collected from MW-02, which allowed for the calculation of a 95 percent UCL for TCE. Both EPCs used were conservative assumptions of hypothetical COPC exposure. Using less conservative EPCs, the HHRA would have resulted in slightly lower risks but would likely not change the overall conclusions of the HHRA. In addition, the lack of temporal variability associated with using a maximum concentration as the EPC for cis-1,2-DCE would over-estimate exposure and risk because it is unrealistic to assume an individual would be exposed to a maximum concentration over the course of the exposure period.

- Selection of exposure assumptions – It is likely that the RME approach taken in developing exposure assumptions would overestimate realistic exposures, and therefore, overestimate the risk. The RME is defined as the - "maximum exposure that is reasonably expected to occur at the Site " (USEPA, 1989). Several significant variables that determined the groundwater exposure doses in particular are based on upper bound estimates (typically 90^{th} to 95^{th} percentile values and sometimes higher). These include intake/contact rates (2.5 L/day), exposure frequency (350 days/year), and exposure duration (26 years). The calculated exposure dose for any given COPC is a product of these upper bound estimates. The integration of all of these variables compounds and

their inherent conservatism results in an overestimate of the exposure doses and resulting risks/HIs.

- Use of conservative toxicity factors – Both cancer risks and noncancer health effects were evaluated using USEPA-approved (or provisional) toxicity criteria. CSFs, URFs, RfDs, and RfCs are derived to be health protective and tend to overestimate the true toxicity of a COPC in humans. Therefore, the estimated risks, which are partially based on the toxicity of a COPC, may be overstated in general. The exact degree of overestimation cannot be determined and each COPC must be evaluated on a case-by-case basis.

- It is likely that the scenarios evaluated overstate realistic exposures, and thus overestimate the actual site risks. For example, the evaluation of a future residential scenario would significantly overestimate potential site risks given the current conditions and anticipated future land uses. Additionally, although the TCE plume is not fully defined, downgradient risks are anticipated to be less than those calculated on Site based on the concentrations detected at the property boundary.

Based on the above referenced uncertainties, it is assumed the concluding cancer risks/noncancer hazards within this risk assessment are likely overestimated.

5.1.8 HHRA Summary

The total cancer risk (1E-04) associated with site groundwater exposure is equal to the upper end of USEPA's generally acceptable cancer risk range of 1E-06 to 1E-04. In addition, the noncancer HIs for both child and adult resident exceed the noncancer benchmark of one. The groundwater risks (cancer and noncancer) are driven by TCE. Site groundwater concentrations of TCE also exceeded the MCL and KDHE RSK of 5 µg/L. As a result, TCE is identified as a contaminant of concern (COC) for the Forbes S-5 Site. Furthermore, TCE exceeded the groundwater VISL of 0.52 µg/L, demonstrating additional evaluation of the VI exposure pathway is warranted.

The total cancer risks associated with sediment and surface water exposures (8E-08 and 4E-07, respectively) fell well below the USEPA's generally acceptable cancer risk range of 1E-06 to 1E-04. In addition, the noncancer HIs for both sediment and surface water did not exceed the noncancer benchmark of 1.0.

Based on the results of the assessment of risk for the Site, a feasibility study (FS) should be performed to evaluate remedial alternatives to mitigate the identified risk to future groundwater users from TCE exposure. There is enough information at the Site to adequately evaluate remedial alternative in the FS. However, as plume delineation to the south and east could not be completed during the RI, access to the property should be pursued as necessary to complete evaluation of potential remedial alternatives and remediation of the Site if required.

5.2 ECOLOGICAL RISK ASSESSMENT

As stated in the HHRA, the only sediment and surface water associated with the Site were located within deep pits and sumps. These locations are not natural habitats, they are small and relatively inaccessible to wildlife. Therefore, sediment and surface water was not evaluated for ecological risk considerations. In addition, groundwater was not a medium of concern for ecological receptors and was not evaluated. The nearest surface water bodies to the Site are shallow-bedded ephemeral streams as well as cattle stock tanks to the east and west of the site that capture overland flow during precipitation events. The downstream portions of these tanks are dry for the most part and are not recharged by bedrock groundwater. The streams are dry most of the year except during precipitation events. Through the site investigation, the static water levels in the shallow monitoring wells were found to be below the elevations of the bottom of the stream beds within bedrock. Further, Bluff creek to the east of the site is more than 7600 ft away; and over 5600 ft to the southeast. On a localized scale specific to the Site, the bedrock groundwater will not recharge the ephemeral streams, the stock tank ponds, or Bluff Creek. Any ecological receptors in nearby surface water bodies are therefore not exposed to any groundwater recharge from the Site.

The only medium of potential concern for ecological receptors was soil. Surface soil (0 to 1 ft bgs) was originally planned to be compared to ecological screening level benchmarks for soil.

However, as stated previously, there were no detects in surface soil or subsurface soil (0 to 10 ft bgs) samples. Due to this lack of detected contaminants, the screening-level ecological risk assessment (SLERA) process was not required.

6. REMEDIAL INVESTIGATION SUMMARY AND CONCLUSIONS/ RECOMMENDATIONS

6.1 SUMMARY

6.1.1 Summary of the Site Characteristics

The Forbes S-5 Site is located within the eastern portion of the Flint Hills Upland Region of the Osage Plains physiographic province. The former Forbes S-5 Site is one of nine Atlas E missile launch facilities constructed near the FAFB between 1959 and 1965 to house ICBM.

Surface drainage generally flows from west to east/southeast following surface topography. The drainage empties into an unnamed tributary that parallels Road D and which eventually discharges to Bluff Creek. The subsurface geology at the Site is composed of alternating sequences of Permian Age shale and limestone.

The primary aquifer formation at the Site is the Wreford Limestone which contains the Schroyer and Threemile Limestone Members. The Havensville Shale Member is situated between the two limestone members and serves as an aquitard. Groundwater yields in these limestone units is highly variable, depending primarily on the amount of secondary permeability such as fractures and solution-enlarged features present.

The two private wells near the Site are both roughly 0.8 miles away. The first is located approximately 0.8 miles northwest of the Site and is a domestic well approximately 45 ft deep with a reported yield of 15 gpm. Based on the ground surface elevation and well depth, this well is probably screened across a portion of the Schroyer Limestone Member. The second well is 0.74 miles to the east/southeast and is classified as a domestic and livestock well. This well is approximately 50 ft deep and is believed to be screened in a limestone unit below the limestone units screened at the Forbes S-5 Site.

6.1.2 Summary of Groundwater Contamination

Eight rounds of low-flow groundwater samples were collected from shallow monitoring wells installed in 2015 and four rounds of samples were collected from shallow monitoring wells installed in 2016. The samples collected during these sampling events indicate that TCE concentrations are present in 9 of 11 shallow monitoring wells with samples from 6 of the 11 wells exceeding the MCL (5 µg/L). TCE was detected at concentrations above the MCL at shallow Monitoring Wells MW-02S, MW-03S, MW-06S, MW-07S, MW-11S, and MW-13S. cis-1,2-DCE was detected in 6 of the 11 shallow monitoring wells sampled at concentrations ranging from 0.44 µg/L to 26 µg/L.

TCE was detected in the deep monitoring wells MW-01D, MW-02D, MW-03D, MW-05D, and MW-06D, at concentrations ranging 0.24 µg/L to 0.92 µg/L, indicating only minor transport to the deeper water bearing zones. cis-1,2-DCE was not detected in groundwater samples for the deep monitoring wells.

6.1.3 Summary of Soil Contamination

cis-1,2-DCE was detected in soil boring samples SB-01-17-18 and SB-07-12-13 with concentrations below both USEPA and KDHE screening criteria. TCE was detected in soil boring samples SB-01-11-12, SB-01-17-18, and SB-07-12-13 with concentrations below both USEPA and KDHE screening criteria. VC was detected in soil boring SB-07-12-13 with concentration below both USEPA and KDHE screening criteria.

6.1.4 Summary of Sediment Contamination

TCE and cis-1,2-DCE were both detected below their respective USEPA and KDHE screening criteria in sediment samples SD-01 and SD-06. VC was detected above both USEPA and KDHE screening criteria in sediment sample SD-01. An IRA is planned to remediate contaminated sediment. The Decision Document for this action was finalized in June 2017.

6.1.5 Summary of Surface Water Contamination

TCE and cis-1,2-DCE were detected in the flame pit above their respective screening levels at concentrations of 50 µg/L and 45 µg/L, respectively. VC was detected above the screening level in the sediment trap (15 µg/L), deep sump (23 µg/L), and flame pit (24 µg/L). An IRA is planned to remediate contaminated surface water. The Decision Document for this action was finalized in June 2017.

6.1.6 Summary of Vapor Intrusion

Although the Site is not regularly used for any purpose, it has been used in the past for both commercial and residential purposes. Structures still exist on the Site but are not continuously used. The VI pathway was evaluated for potential future on-site and/or off-site residential receptors. Based on the above VISL evaluation, TCE exceeded its VISL of 0.52 µg/L in both the combined well scenario and individual well comparison (Table 5-1). Seven out of 11 wells (MW-02, -03, -06, -07, -11, -12, -13) had detections which exceeded the chemical specific VISL for TCE. TCE was retained as a COPC for the VI pathway, demonstrating further characterization and/or evaluation may be warranted for this pathway. The responsibility of the DOD is to evaluate the VI pathway. The pathway is currently incomplete for this Site. The Site and the structures are not currently habitable. The DERP Manual (DOD, 2012) provides guidance on the path forward for sites where there is a potential for future VI.

6.1.7 Summary of the Risk Assessment

Comparisons were made to the USEPA RSLs (USEPA, 2017a). Analytes that exceeded their respective screening criteria were retained as COPCs and evaluated in the risk assessment. No soil samples contained detectable concentrations of potential COCs within the depth range for possible human exposure (0 – 10 ft bgs). As a result, soil exposure was eliminated from the risk assessment.

The total cancer risk (1E-04) associated with site groundwater exposure exceeds USEPA's generally acceptable cancer risk range of 1E-04 to 1E-06. The noncancer HIs (30: adult, 34: child) greatly exceed the noncancer benchmark of 1.0. The groundwater risks (cancer and

noncancer) are driven by TCE. Site concentrations of TCE exceed the MCL of 5 µg/L. As a result, TCE has been identified as a COC for the Site. Furthermore, TCE exceeded the groundwater VISL of 0.52 µg/L, demonstrating additional evaluation of the VI exposure pathway is warranted.

The total cancer risks associated with sediment and surface water exposures (8E-08 and 2E-07, respectively) fell well below the USEPA's generally acceptable cancer risk range of 1E-04 to 1E-06. In addition, the noncancer HIs for both sediment and surface water (0.001 and 0.01, respectively) did not exceed the noncancer benchmark of 1.0. Such low risk values are due to the infrequent and unlikely exposure potential within the sumps and pits at the Site. Even though risks are within acceptable ranges for both cancer and noncancer, the elevated levels of contamination within these media will be addressed through an IRA planned to remediate contaminated surface water and sediment. (USACE, 2017).

The SLERA was not conducted within this RI due to the lack of detected analytes in surface soil samples.

6.2 CONCLUSIONS/RECOMMENDATIONS

6.2.1 Conclusions

Based on the results of this RI and previous investigations, the following conclusions can be made regarding the Site:

- Contaminants, primarily TCE, were released at the Site. At least two source areas are believed to exist, one at or near the main sump area within the missile erection facility, and one in the southern portion of the Site, at the sediment trap. TCE subsequently migrated to the groundwater and created one or more plumes, which have migrated to the northeast and southwest in the direction of groundwater flow.
- Contaminants have not been detected above residential screening levels in soil samples taken on the S-5 Site and there has been no identification of a significant TCE source in soil. VOCs were detected in surface water and sediment samples collected from sumps and pits within the erection facility and the sediment trap. An IRA is planned to clean out the contaminated surface water and sediment. A Decision Document for this interim action was finalized in June 2017.

- Based on the use of the 5 µg/L isoconcentration line, the TCE groundwater plume has not been fully delineated on all sides. Groundwater concentrations of TCE above the MCL are believed to be migrating to areas downgradient and off-site. The extent of TCE contaminated groundwater south of the Site could not be determined but the delineation is sufficient to evaluate risk. USACE will continue to pursue access to fully delineate the Site but the data collected has provided enough information to allow completion of the RI.

- Fate and transport processes, including advection, diffusion, dispersion, adsorption, and volatilization, may be attenuating contaminant mass along the direction of groundwater flow although groundwater VOC levels have not changed appreciably during the eight rounds of monitoring.

- The total groundwater cancer risk is at the high end of the USEPA's generally acceptable cancer risk range of 1E-04 to 1E-06 with a total cancer risk of 1E-04 (rounded) from TCE exposure. The noncancer HIs exceed the noncancer benchmark of one. Furthermore, TCE exceeded the groundwater VISL of 0.52 µg/L, demonstrating additional evaluation of the VI exposure pathway is warranted.

6.2.2 Recommendations

Based on the data collected during the RI and the results of the assessment of risk for the Site, a feasibility study (FS) should be performed to evaluate remedial alternatives to mitigate the identified risk to future groundwater users from TCE exposure. There is enough information at the Site to adequately evaluate remedial alternative in the FS. However, as plume delineation to the south and east could not be completed during the RI, access to the property will be pursued as necessary to complete evaluation of potential remedial alternatives and remediation of the Site if required.

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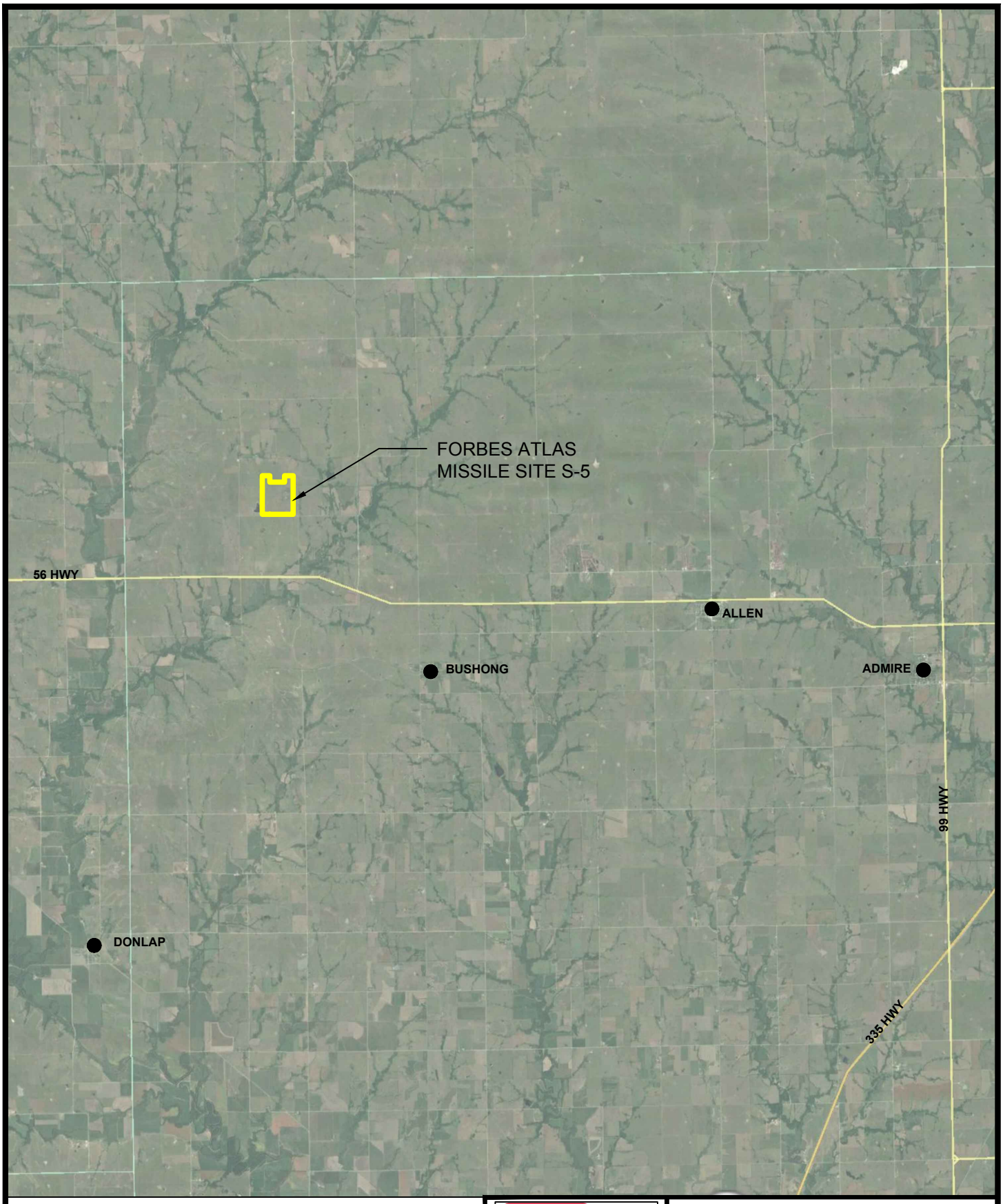
FIGURES



NOTES:

1. IMAGE PROVIDED BY GOOGLE EARTH.

N

0 12000' 24000'

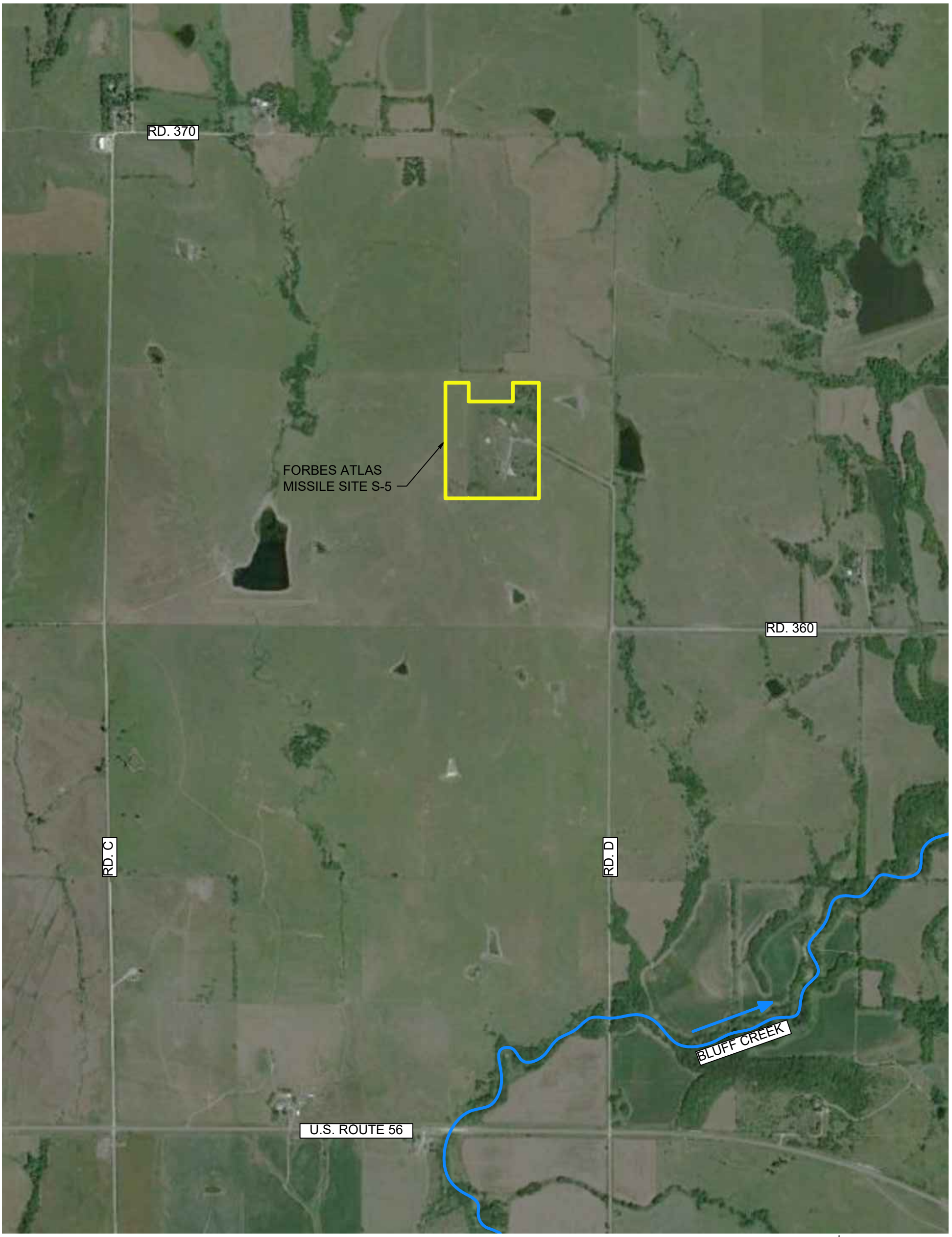
SCALE IN FEET

US Army Corps of Engineers ®
Kansas City District

FIGURE 1-1

REGIONAL LOCATION MAP
FORBES ATLAS S-5
ALLEN, KANSAS

1200C PERM
B07KS020401_03.10_0001_a



LEGEND:

RIVER

FLOW DIRECTION

N

0 1000' 2000'

SCALE IN FEET

NOTE:

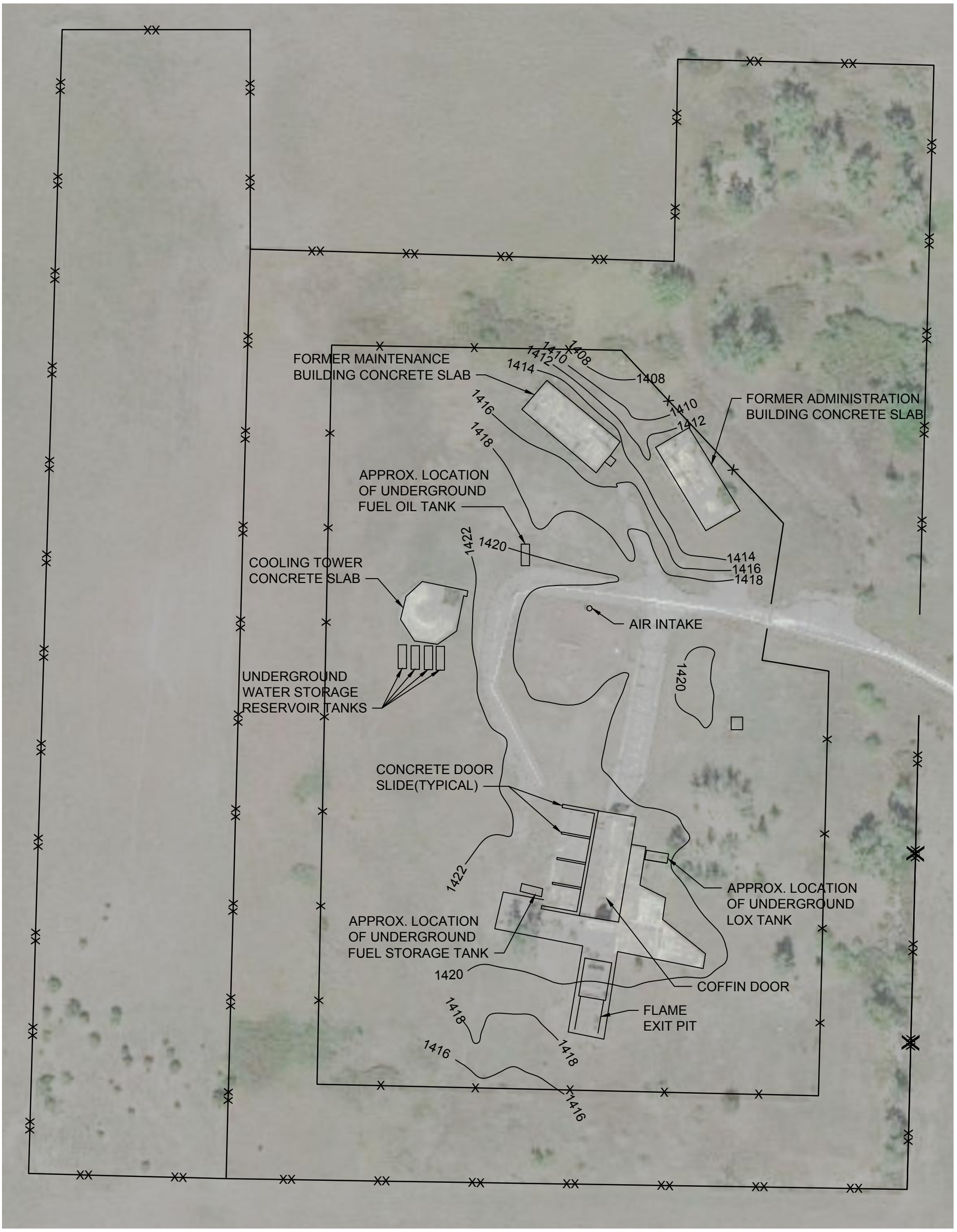
1. AERIAL IMAGE PROVIDED BY GOOGLE EARTH.

US Army Corps of Engineers ®
Kansas City District

Figure 1-2
AERIAL OVERVIEW
FORBES ATLAS S-5
ALLEN, KANSAS

1200C PERM
B07KS020401_03.10_0001_a

PW\ Avatar Environmental LLC\ Project Numbers\ 80447 AVATAR FORBES ATLAS S-5 RI\ Cadd\ Figures\ 80447-FIG 1-2-AERIAL OVERVIEW.dwg DHINEMAN October 16, 2017



LEGEND:

CHAIN LINK FENCE

BARB WIRE FENCE

CONTOUR

N

0 100' 200'

SCALE IN FEET

NOTES:

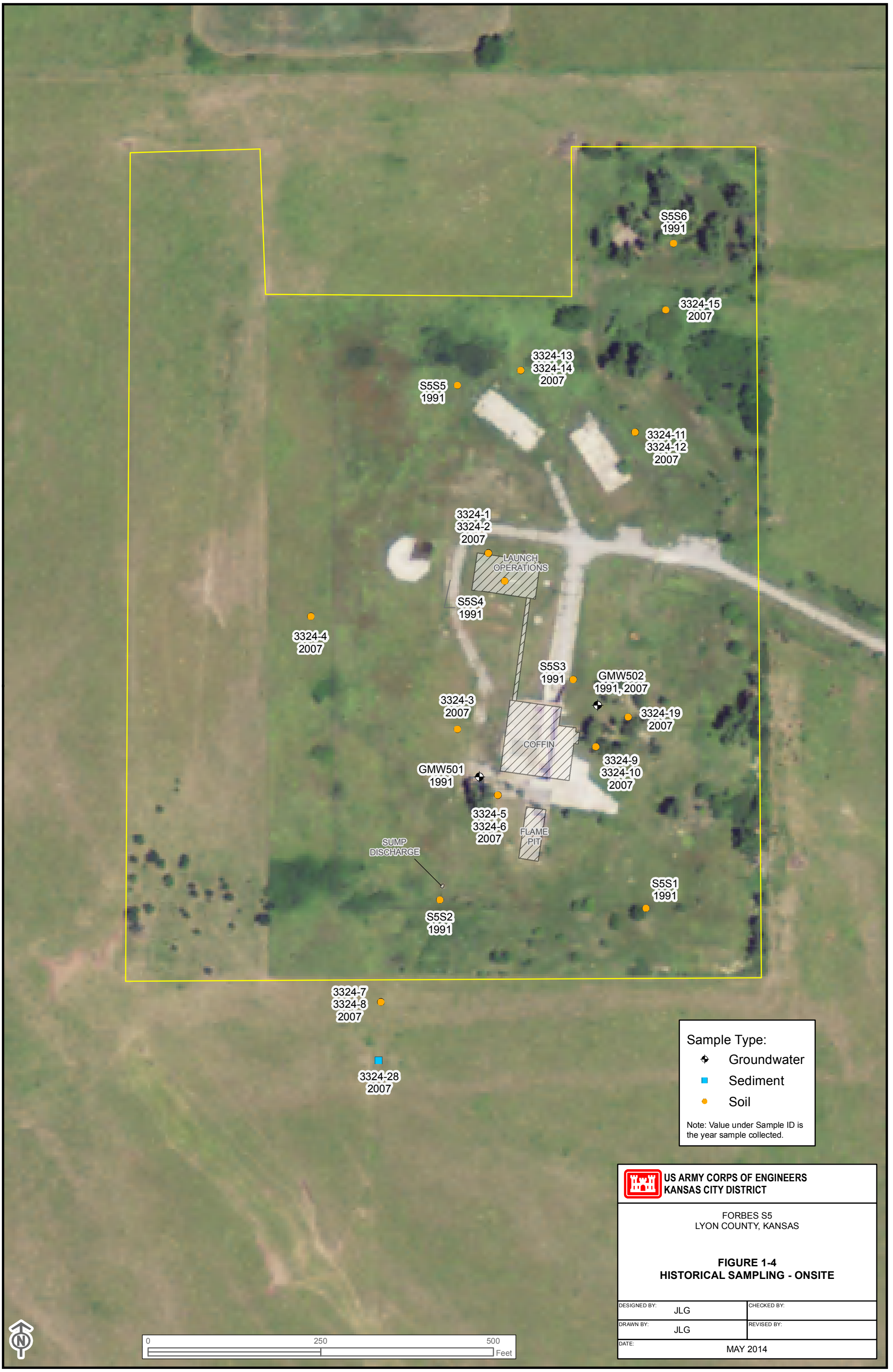
1. SITE PLAN AND ELEVATIONS BASED ON TOPOGRAPHIC SURVEY PERFORMED BY FORGY SURVEYING, ON JULY 13, 1990.
2. AERIAL IMAGE PROVIDED BY GOOGLE EARTH.

US Army Corps of Engineers ®
Kansas City District

Figure 1-3

FORMER SITE LAYOUT
FORBES ATLAS S-5
ALLEN, KANSAS

1200C PERM
B07KS020401_03.10_0001_a



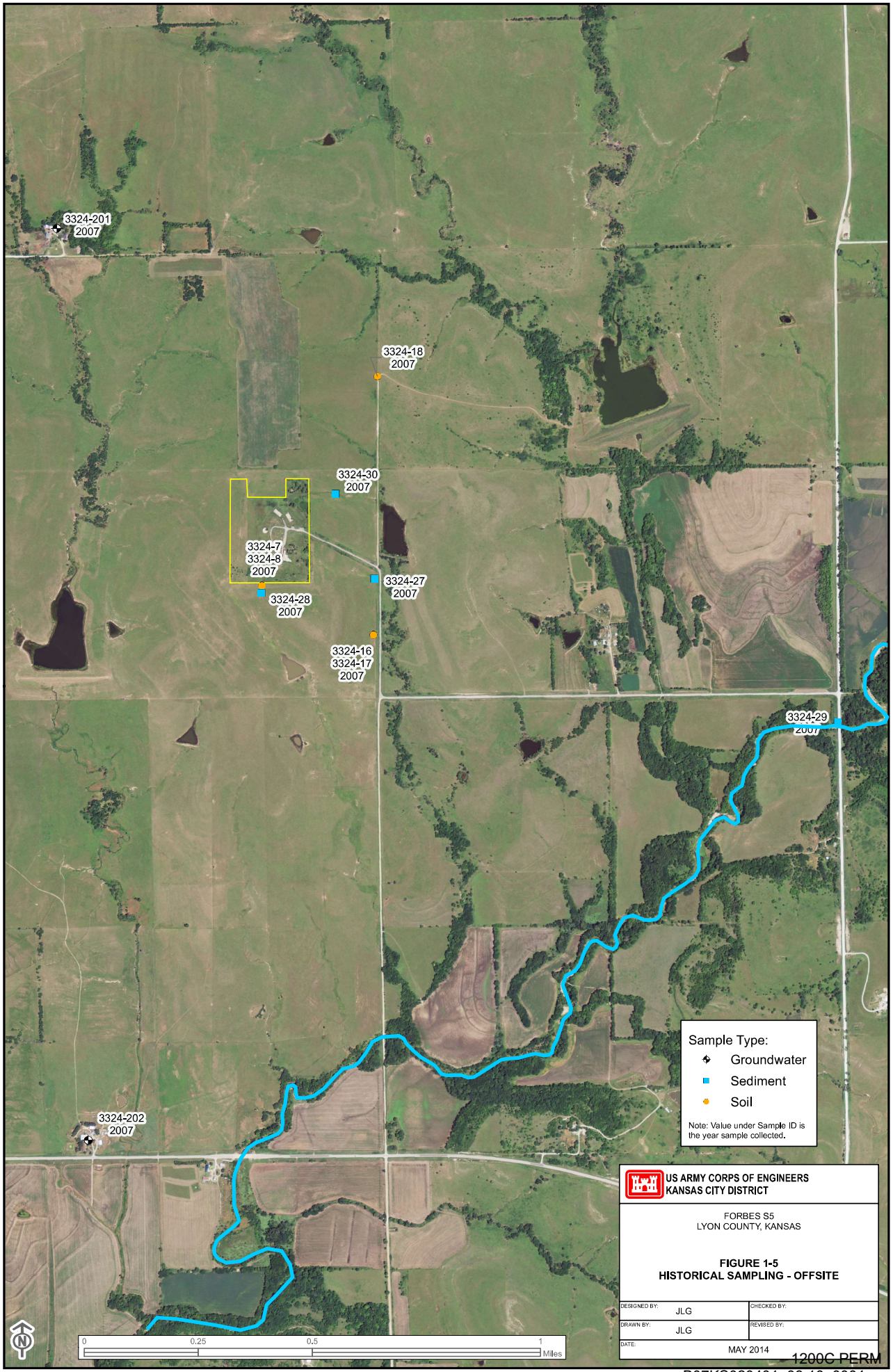
US ARMY CORPS OF ENGINEERS
KANSAS CITY DISTRICT

FORBES S5
LYON COUNTY, KANSAS

FIGURE 1-4
HISTORICAL SAMPLING - ONSITE

DESIGNED BY: JLG	CHECKED BY:
DRAWN BY: JLG	REVISED BY:
DATE: MAY 2014	

1200C PERM
B07KS020401_03.10_0001_a



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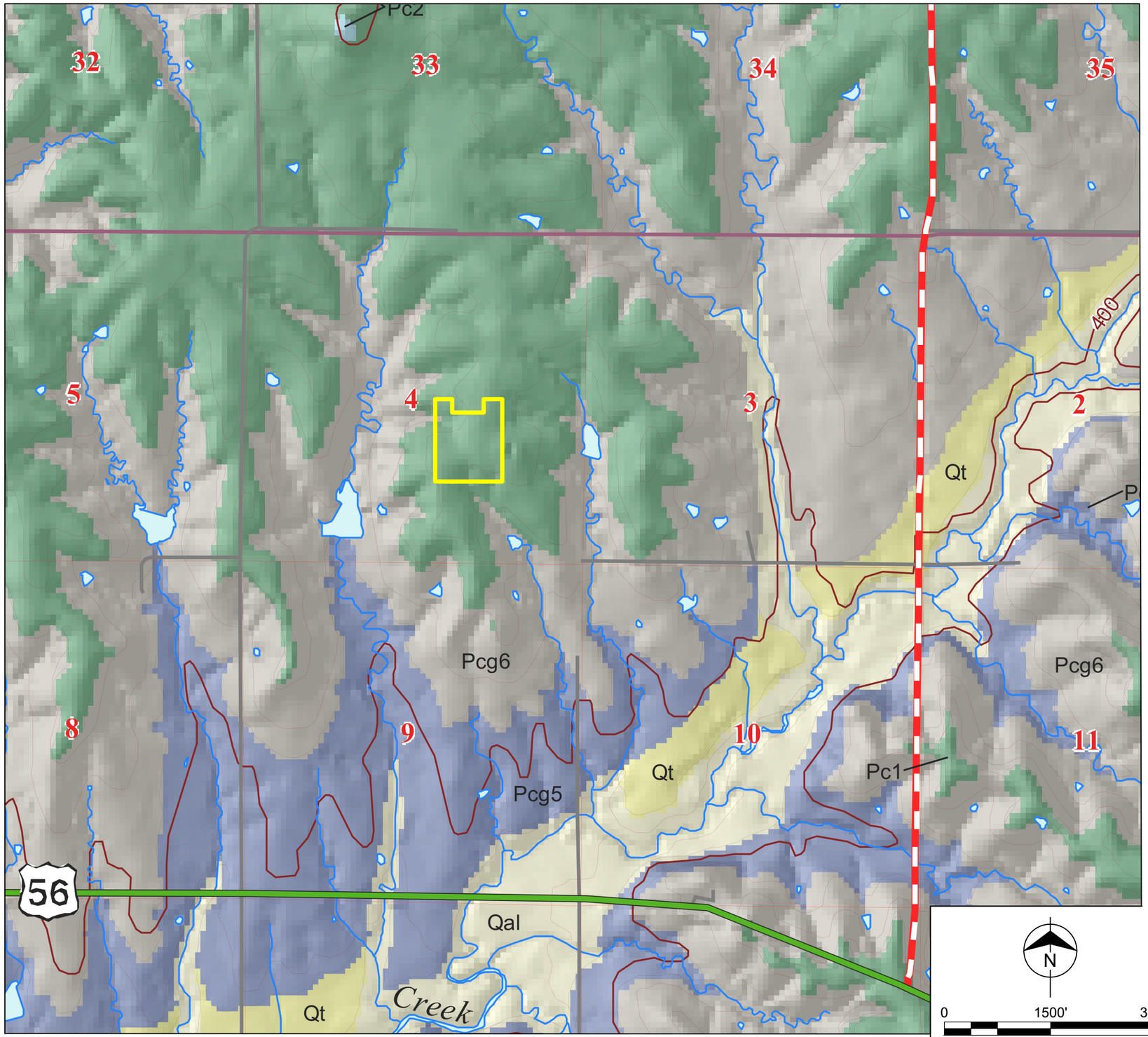
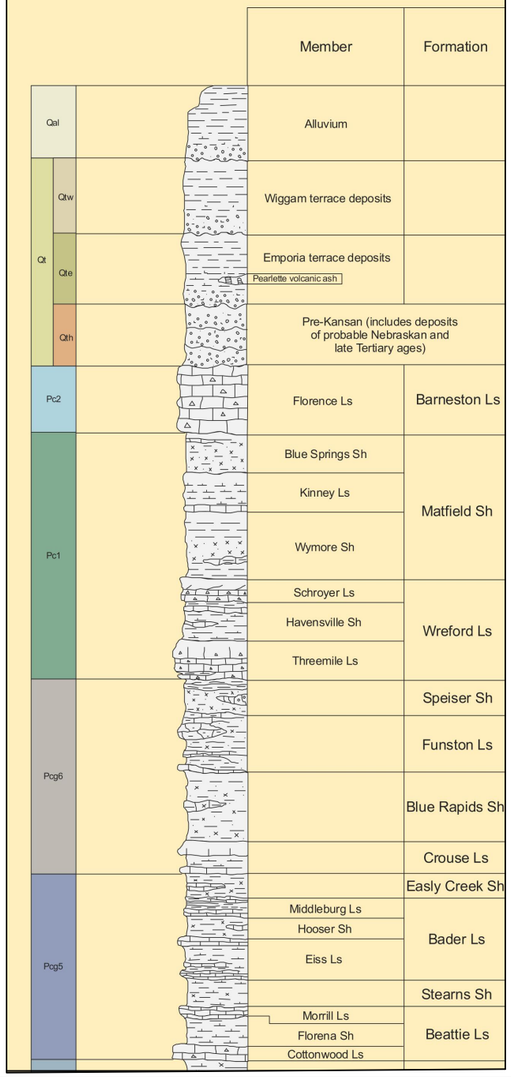


KANSAS GEOLOGICAL SURVEY
THE UNIVERSITY OF KANSAS
MAP M-105

Computer compilation
and cartography by

Jorgina A. Ross
David Means
Jason Hartman
Ian J. Ramirez
Christopher R. Bieker



N

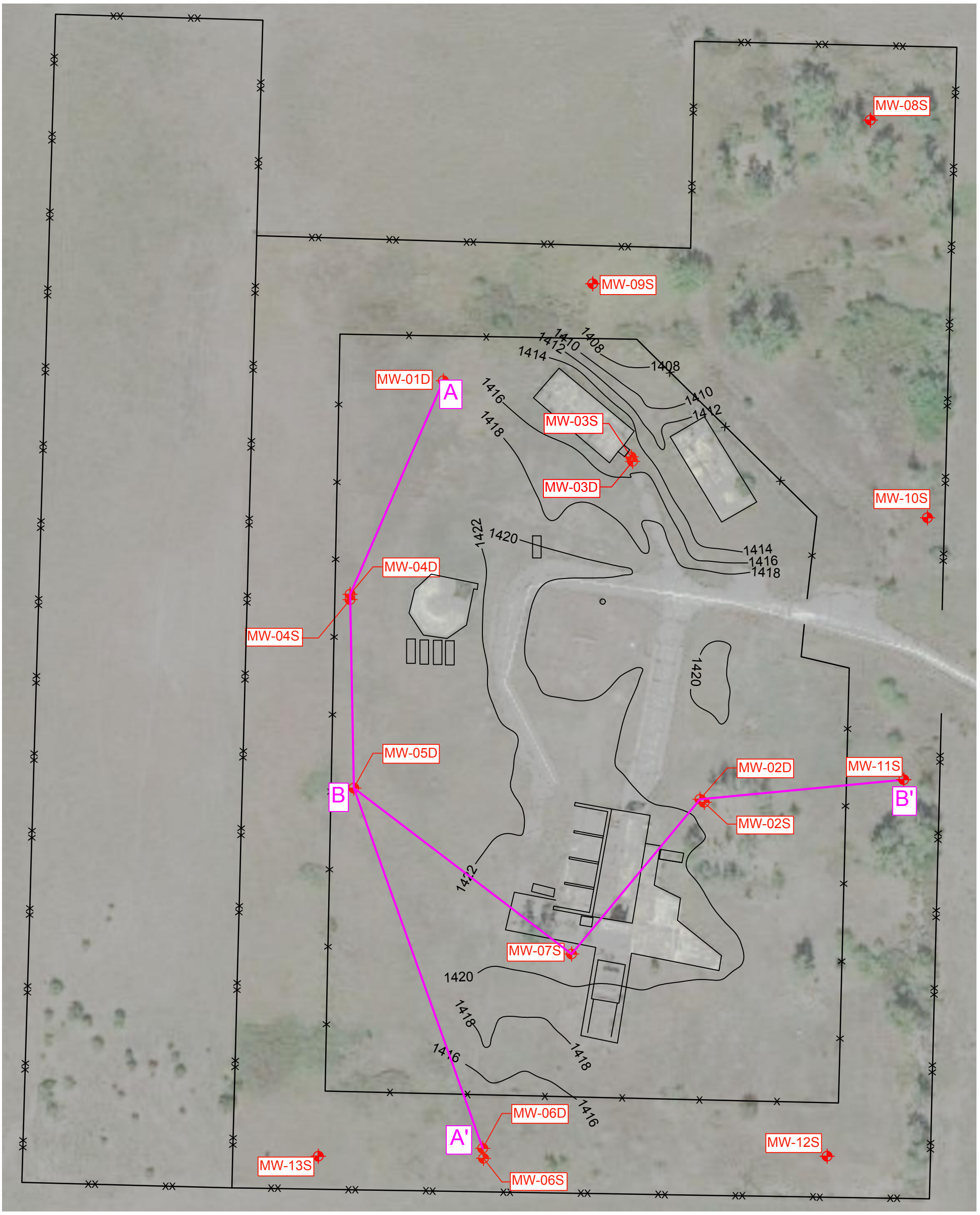
0 1500' 3000'

SCALE IN FEET

US Army Corps of Engineers ®
Kansas City District

FIGURE 2-1
BEDROCK GEOLOGY MAP
FORBES ATLAS S-5
ALLEN, KANSAS

1200C PERM
B07KS020401_03.10_0001_a



LEGEND:

A——A'	CROSS SECTION
MW-01	MONITORING WELL
——x——	CHAIN LINK FENCE
——xx——	BARB WIRE FENCE

N

0 100' 200'

SCALE IN FEET

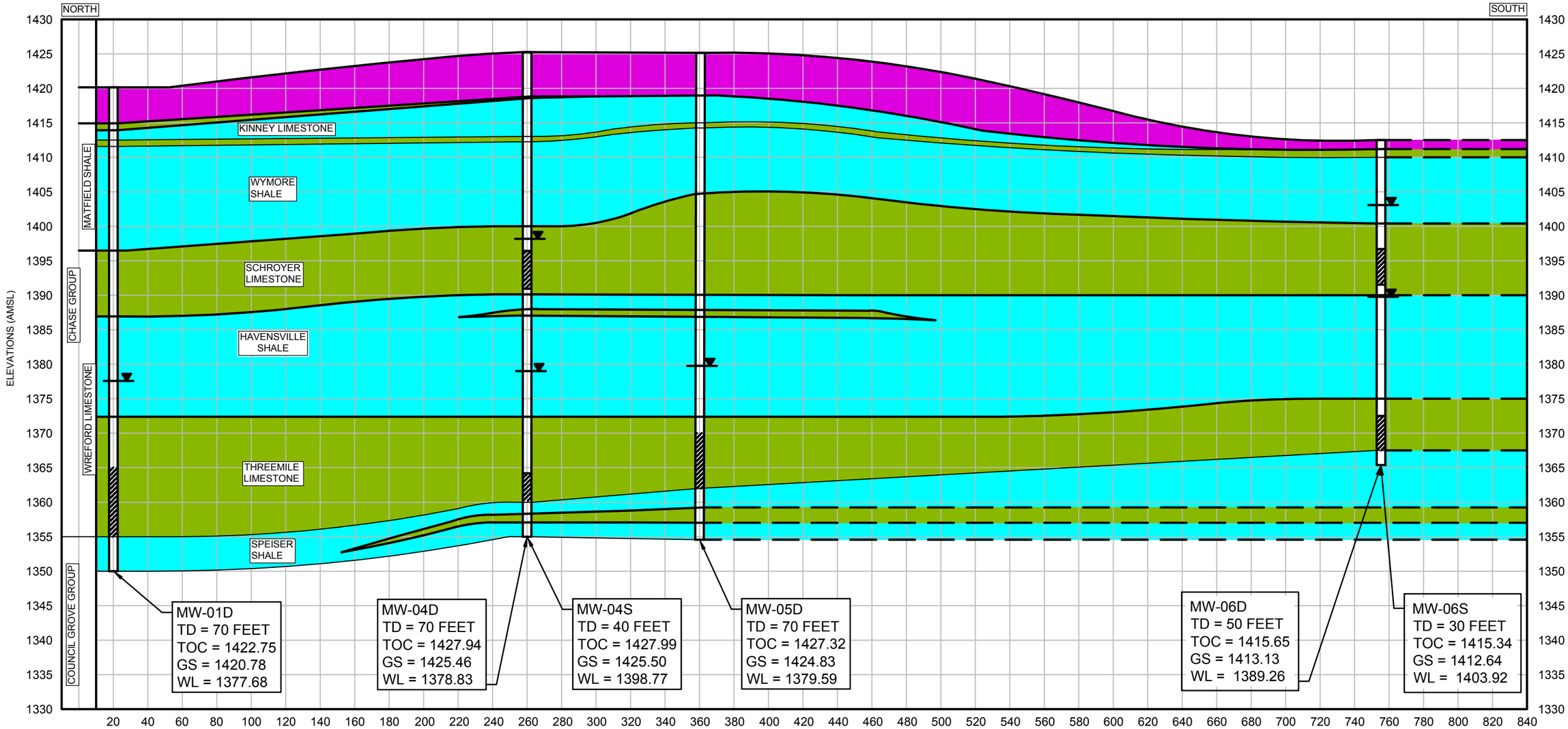
NOTES:

1. AERIAL IMAGE PROVIDED BY GOOGLE EARTH.
2. SITE PLAN AND ELEVATIONS BASED ON TOPOGRAPHIC SURVEY PERFORMED BY FORGY SURVEYING, ON JULY 13, 1990.

US Army Corps of Engineers ®
Kansas City District

Figure 2-2
GEOLOGICAL CROSS SECTION LOCATIONS
FORBES ATLAS S-5
ALLEN, KANSAS

1200C PERM
B07KS020401_03.10_0001_a



LEGEND:

- CLAY
- LIMESTONE
- SHALE
- SCREEN
- ▼ STATIC WATER LEVEL (FT. AMSL). MEASURED MARCH 27, 2017.

VERTICAL

0 15' 30'

SCALE IN FEET

HORIZONTAL

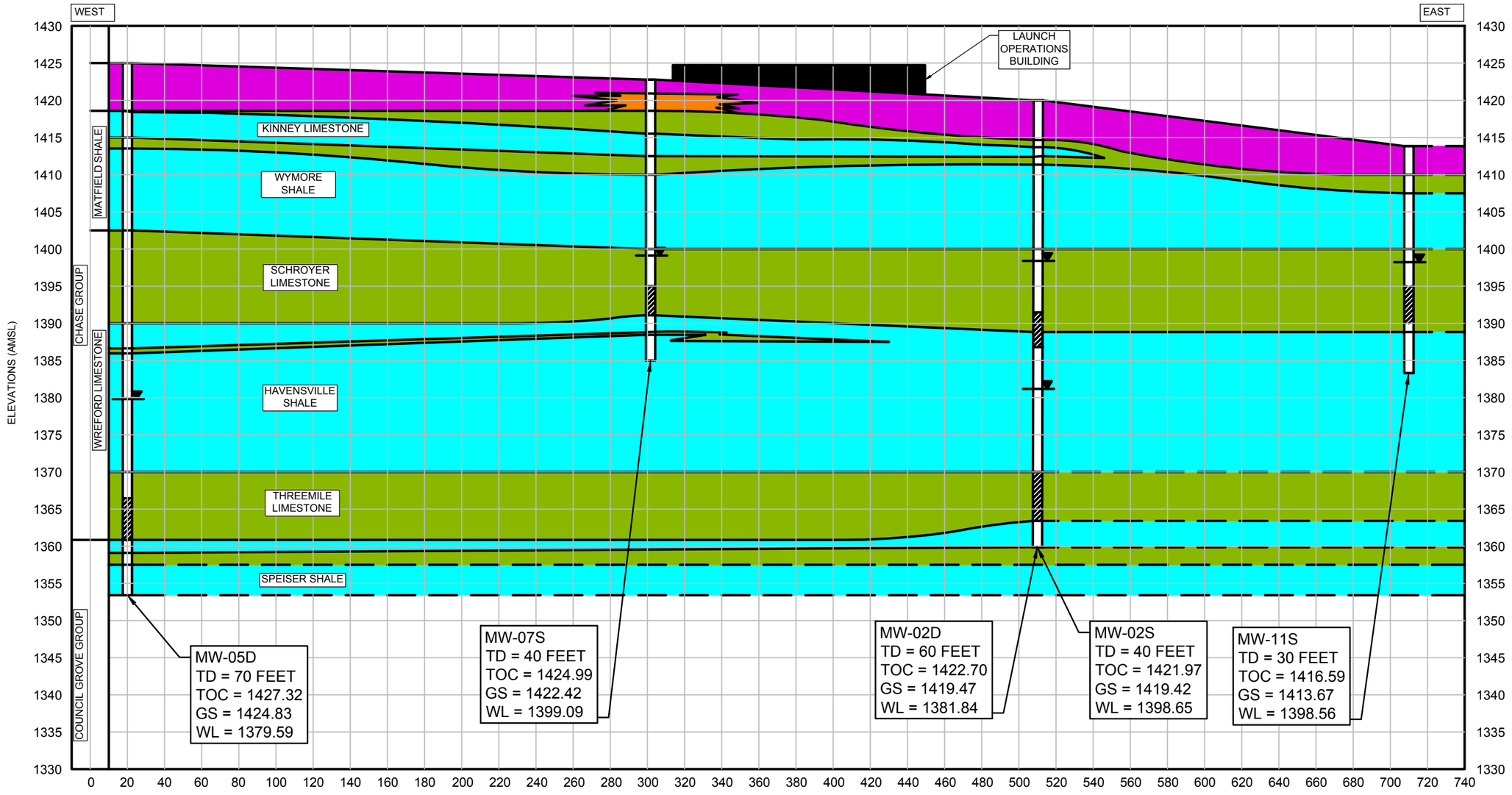
0 60' 120'

SCALE IN FEET

US Army Corps of Engineers ®
Kansas City District

FIGURE 2-3
GEOLOGICAL CROSS SECTION A-A'
FORBES ATLAS S-5
ALLEN, KANSAS

1200C PERM
B07KS020401_03.10_0001_a



LEGEND:

- CLAY
- CLAYEY GRAVEL
- LIMESTONE
- SHALE
- SCREEN
- STATIC WATER LEVEL (FT. AMSL). MEASURED MARCH 27, 2017.

VERTICAL

0 15' 30'

SCALE IN FEET

HORIZONTAL

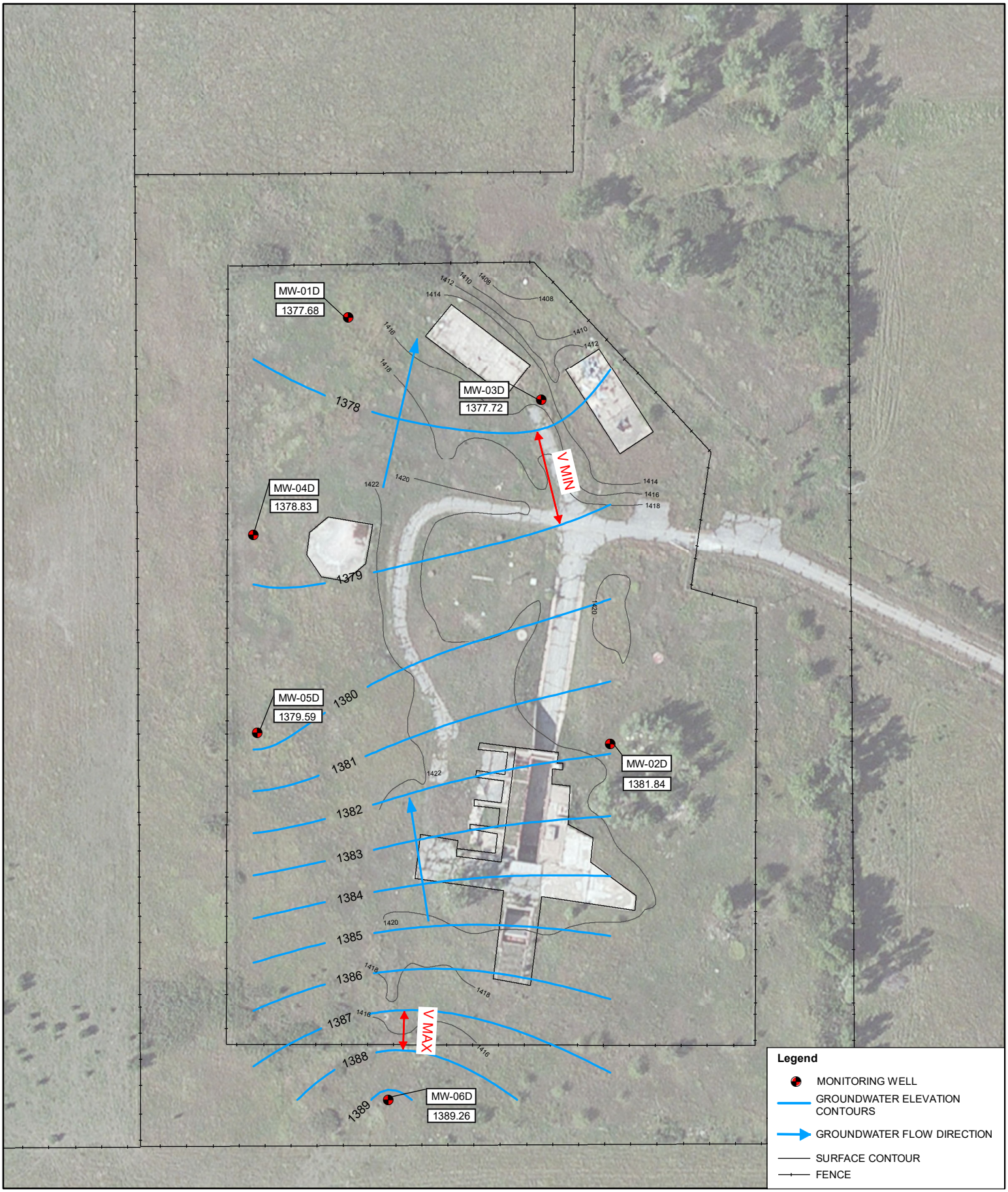
0 60' 120'

SCALE IN FEET

US Army Corps of Engineers ®
Kansas City District

FIGURE 2-4
GEOLOGICAL CROSS SECTION B-B'
FORBES ATLAS S-5
ALLEN, KANSAS

1200C PERM
B07KS020401_03.10_0001_a



NOTES:

1. AERIAL IMAGE PROVIDED BY ESRI.

2. SITE PLAN AND ELEVATION BASED ON TOPOGRAPHIC SURVEY PERFORMED BY FORGY SURVEYING, ON JULY 13,1990

3. V MAX - MAXIMUM AVERAGE GROUNDWATER VELOCITY.

4. V MIN - MINIMUM AVERAGE GROUNDWATER VELOCITY.

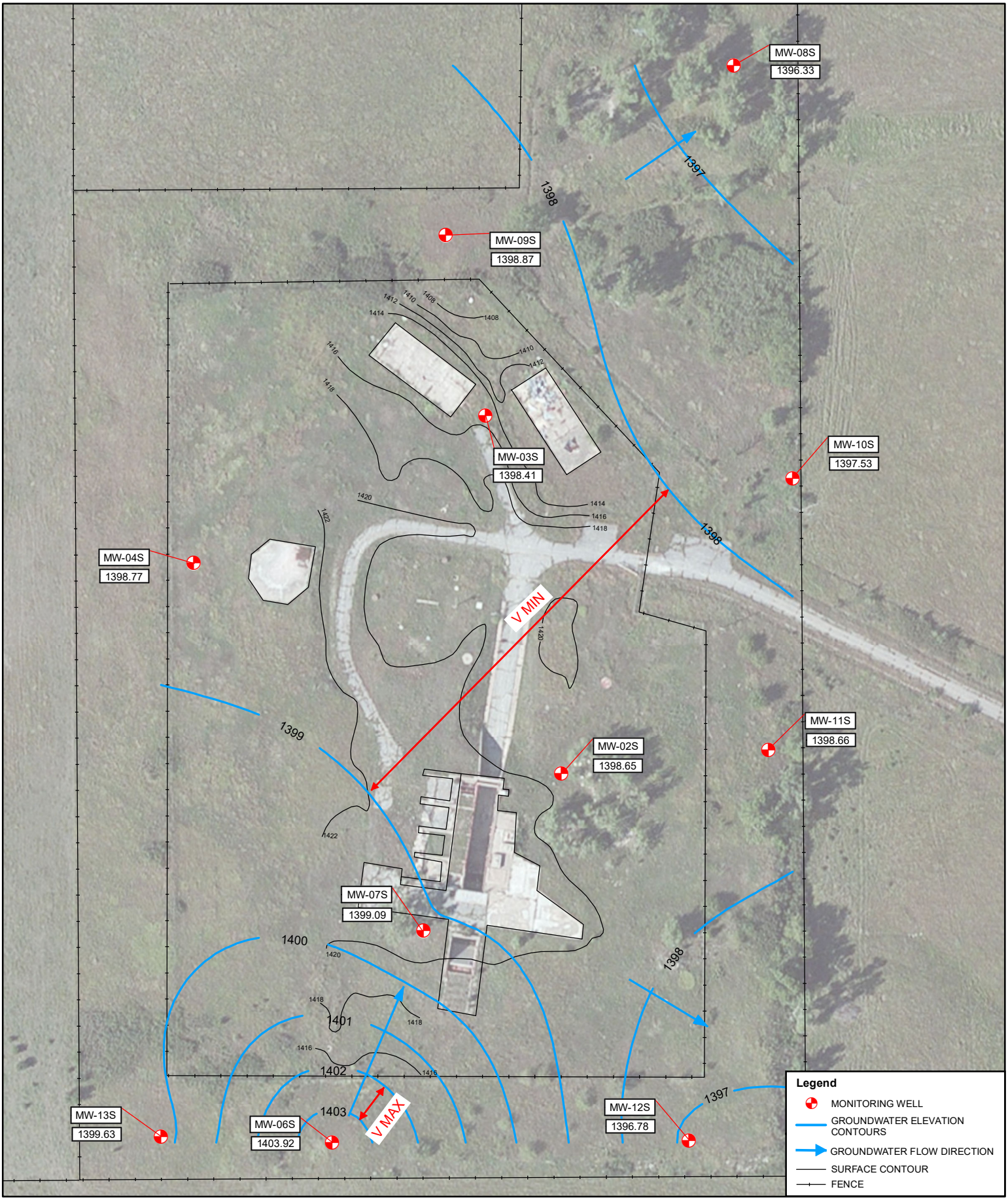
N
W E
S

0 50 100 200 Feet

US Army Corps of Engineers
Kansas City District

FIGURE 2-5
TYPICAL GROUNDWATER ELEVATION MAP
DEEP MONITORING WELL LOCATIONS
FORBES ATLAS S-5
ALLEN, KANSAS
MARCH 23, 2017

1200C PERM
B07KS020401_03.16_0001_a



NOTES:

1. AERIAL IMAGE PROVIDED BY ESRI.

2. SITE PLAN AND ELEVATION BASED ON TOPOGRAPHIC SURVEY PERFORMED BY FORGY SURVEYING, ON JULY 13,1990

3. V MAX - MAXIMUM AVERAGE GROUNDWATER VELOCITY.

4. V MIN - MINIMUM AVERAGE GROUNDWATER VELOCITY.

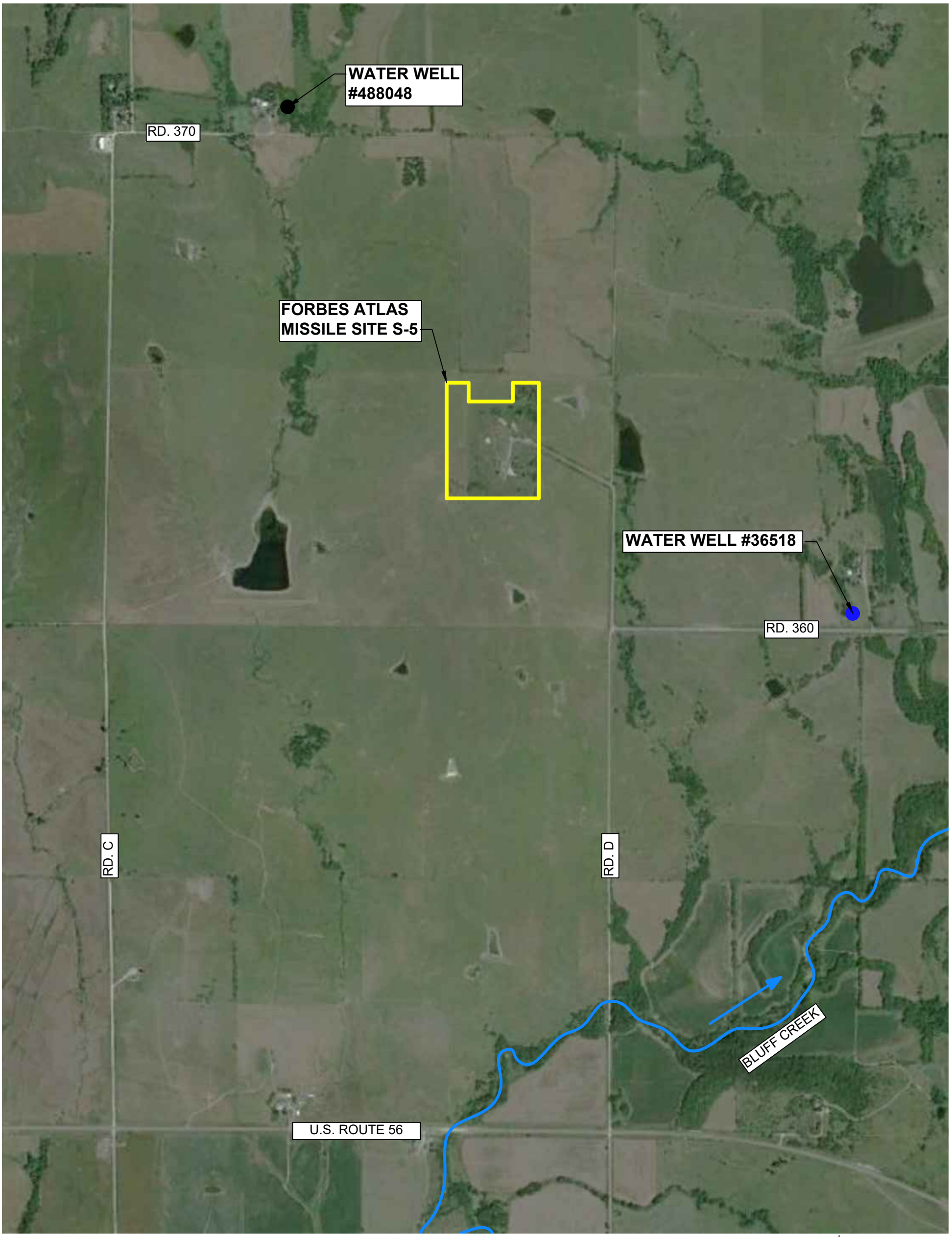
N
W E
S

0 50 100 200 Feet

US Army Corps of Engineers Kansas City District

FIGURE 2-6
TYPICAL GROUNDWATER ELEVATION MAP SHALLOW MONITORING WELL LOCATIONS FORBES ATLAS S-5 ALLEN, KANSAS MARCH 23, 2017

1200C PERM
B07KS020401_03.16_0001_a



LEGEND

- WATER WELLS
- RIVER
- FLOW DIRECTION

N

0 1000' 2000'

SCALE IN FEET

NOTE:

1. AERIAL IMAGE PROVIDED BY GOOGLE EARTH.

US Army Corps of Engineers ®
Kansas City District

Figure 2-7
OFF SITE KANSAS
WATER WELLS
FORBES ATLAS S-5
ALLEN, KANSAS

1200C PERM
B07KS020401_03.10_0001_a

PW\ Avatar Environmental LLC\ Project Numbers\ 80447 AVATAR FORBES ATLAS S-5 RI\ Cadd\ Figures\ 80447-FIG 2-7 kansas Water Wells.dwg KSCHUTTE October 16, 2017

LEGEND:

SB-01	SOIL BORING
——x——	CHAIN LINK FENCE
——xx——	BARB WIRE FENCE

N

0 100' 200'

SCALE IN FEET

NOTES:

1. AERIAL IMAGE PROVIDED BY GOOGLE EARTH.

2. SITE PLAN AND ELEVATIONS BASED ON TOPOGRAPHICAL SURVEY PERFORMED BY FORGY SURVEYING, ON JULY 13, 1990.

3. SURVEY SITE DATA FROM KAW VALLEY ENGINEERING INC. SURVEY DATES JUNE 12, 2015 AND JUNE 29, 2016.

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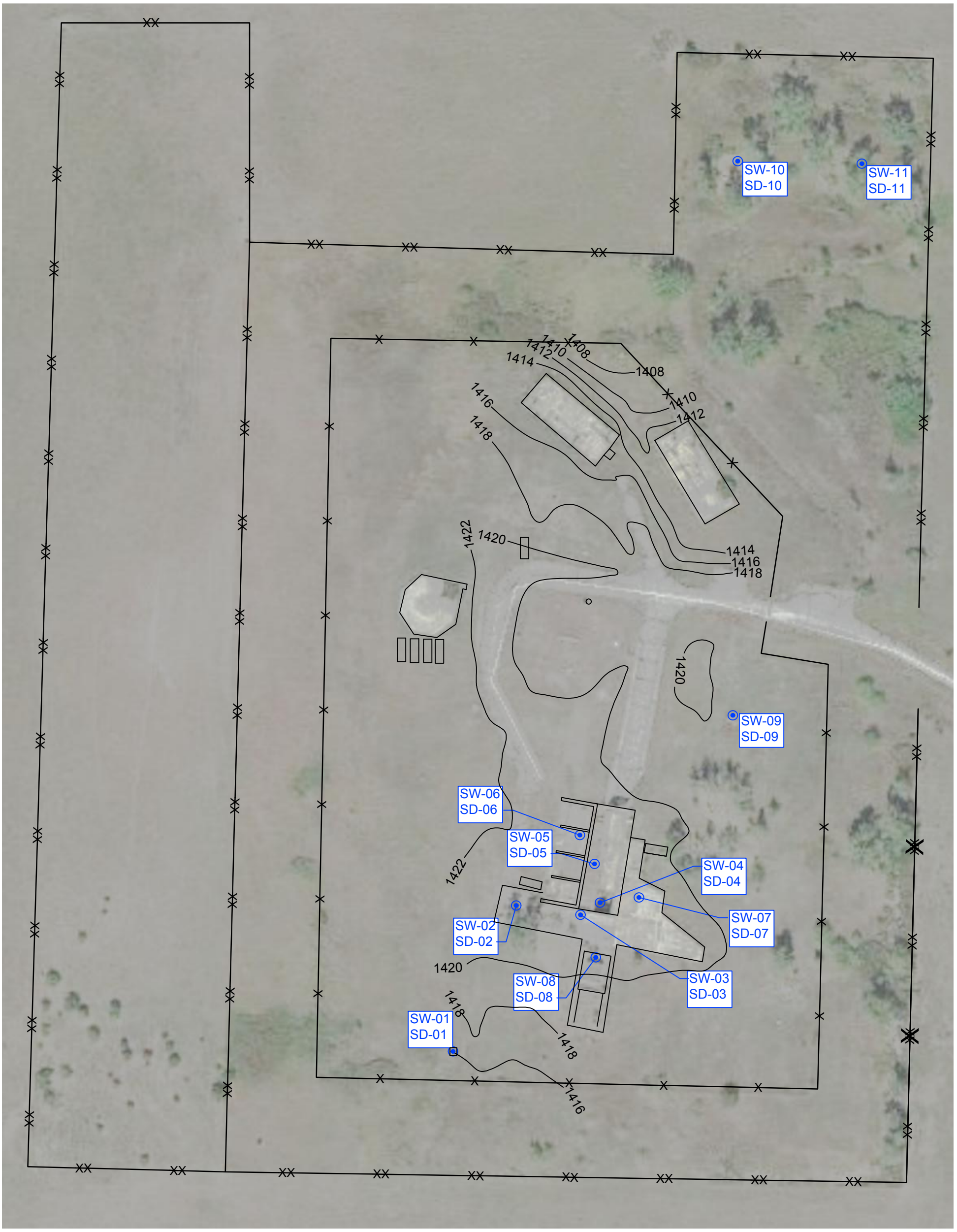
Kansas City District

Figure 3-1
SOIL BORING LOCATIONS
REMEDIAL INVESTIGATION
FORBES ATLAS S-5
ALLEN, KANSAS

1200C PERM
B07KS020401_03.10_0001_a



LEGEND:

SW-01 / SD-01 — SURFACE WATER / SEDIMENT SAMPLE

CHAIN LINK FENCE

BARB WIRE FENCE

N

0 100' 200'

SCALE IN FEET

NOTES:

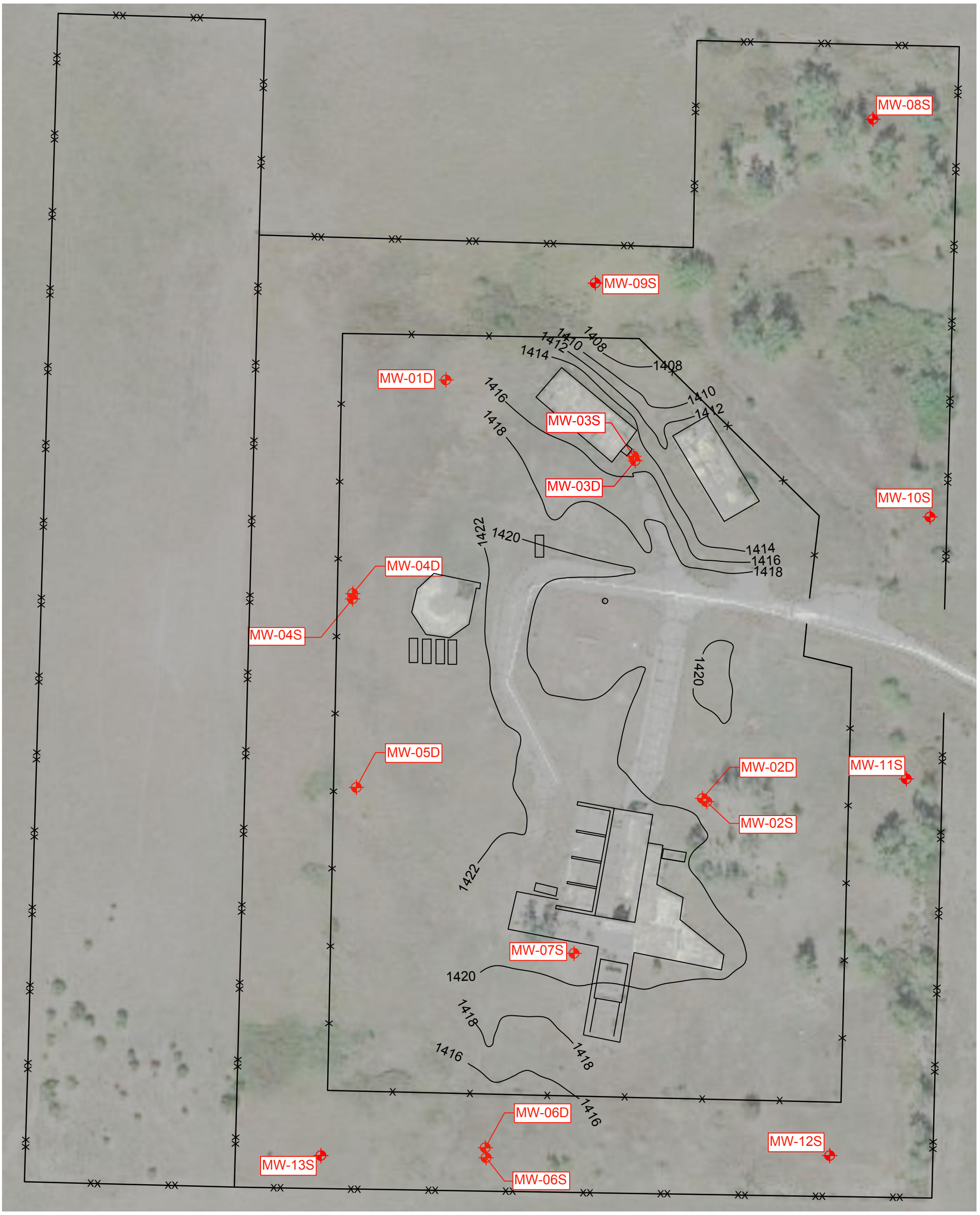
1. AERIAL IMAGE PROVIDED BY GOOGLE EARTH.

2. SITE PLAN AND ELEVATIONS BASED ON TOPOGRAPHICAL SURVEY PERFORMED BY FORGY SURVEYING, ON JULY 13, 1990.

US Army Corps of Engineers ®
Kansas City District

Figure 3-2
SURFACE WATER & SEDIMENT SAMPLE LOCATIONS
REMEDIAL INVESTIGATION
FORBES ATLAS S-5
ALLEN, KANSAS

1200C-PERM
B07KS020401_03.10_0001_a



LEGEND:

MW-01	MONITORING WELL
——x——	CHAIN LINK FENCE
——xx——	BARB WIRE FENCE

N

0 100' 200'

SCALE IN FEET

NOTES:

1. AERIAL IMAGE PROVIDED BY GOOGLE EARTH.

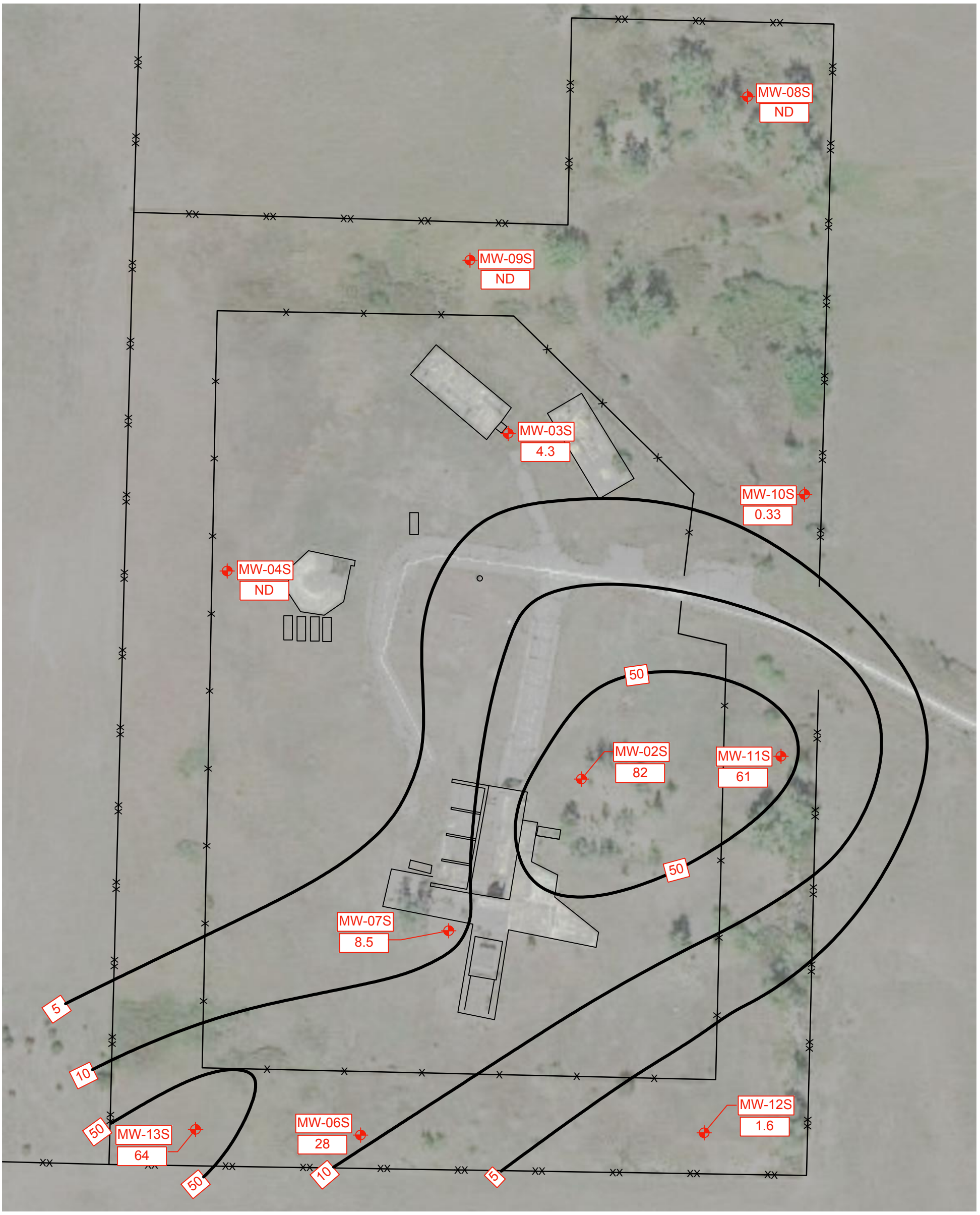
2. SITE PLAN AND ELEVATIONS BASED ON TOPOGRAPHICAL SURVEY PERFORMED BY FORGY SURVEYING, ON JULY 13, 1990.

3. SURVEY SITE DATA FROM KAW VALLEY ENGINEERING INC. SURVEY DATES JUNE 12, 2015 AND JUNE 29, 2016.

US Army Corps of Engineers ®
Kansas City District

Figure 3-3
MONITORING WELL LOCATION MAP
FORBES ATLAS S-5
ALLEN, KANSAS

1200C PERM
B07KS020401_03.10_0001_a



NOTES:

1. AERIAL IMAGE PROVIDED BY GOOGLE EARTH.

2. SITE PLAN AND ELEVATIONS BASED ON TOPOGRAPHICAL SURVEY PERFORMED BY FORGY SURVEYING, ON JULY 13, 1990.

3. SURVEY SITE DATA FROM KAW VALLEY ENGINEERING INC. SURVEY DATES JUNE 12, 2015 AND JUNE 29, 2016.

4. TCE ISOCONCENTRATION CONTOURS GENERATED FROM SHALLOW MONITORING WELLS.

LEGEND:

MW-01	MONITORING WELL
6.6	ANALYTICAL RESULT (µg/L)
ND	NON-DETECT
	CHAIN LINK FENCE
	BARB WIRE FENCE
	SURFACE CONTOUR

N

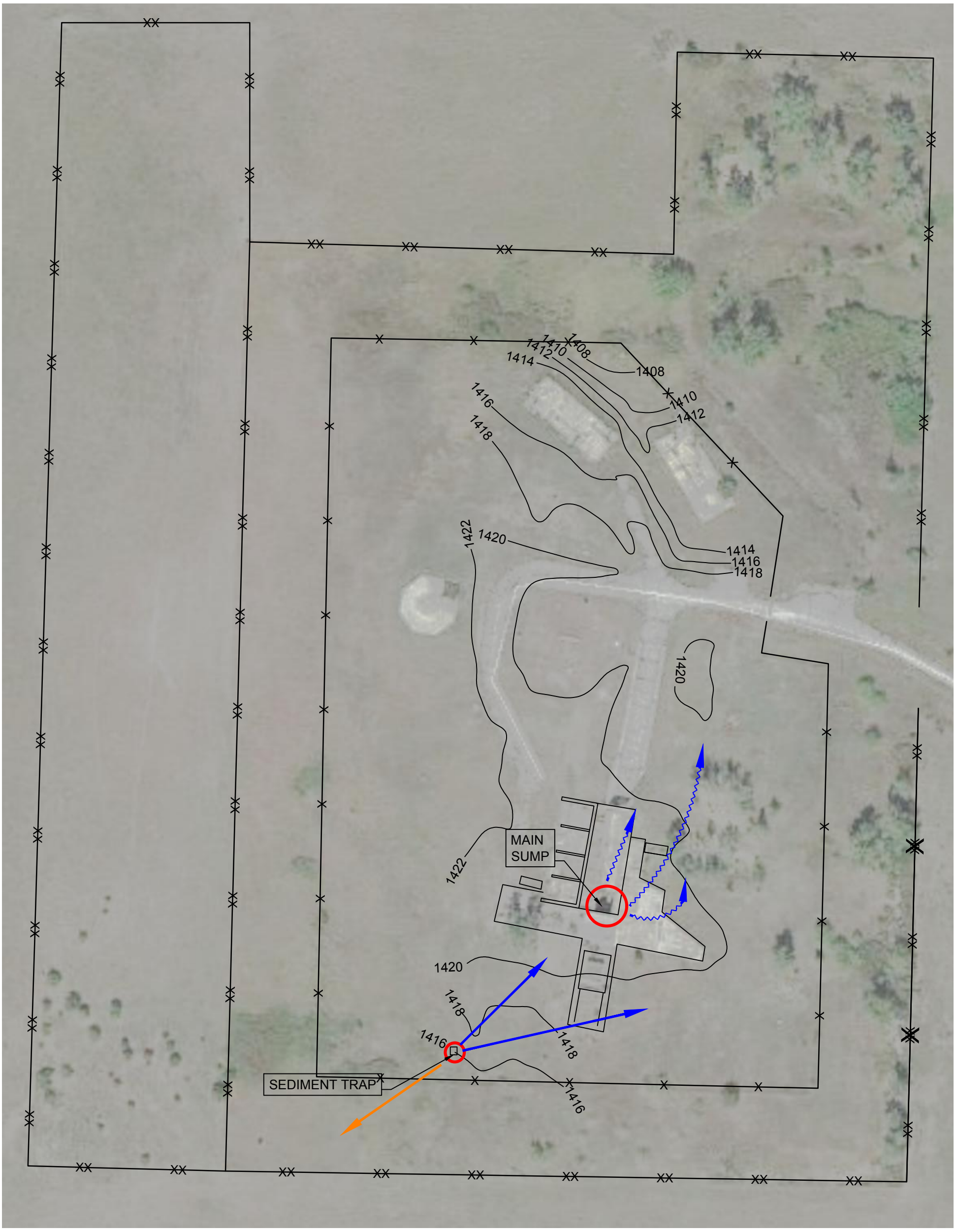
0 100' 200'

SCALE IN FEET

US Army Corps of Engineers ®
Kansas City District

Figure 3-4
TYPICAL TCE ISOCONCENTRATION MAP
SHALLOW MONITORING WELL LOCATIONS
FORBES ATLAS S-5
ALLEN, KANSAS
MARCH, 2017 1200C PERM

B07KS020401_03.10_0001_a



LEGEND:

- CHAIN LINK FENCE
- BARB WIRE FENCE
- CONTOUR
- OVERLAND FLOW
- POTENTIAL ROUTES OF MIGRATION
- SOURCE POINT

N

0 100' 200'

SCALE IN FEET

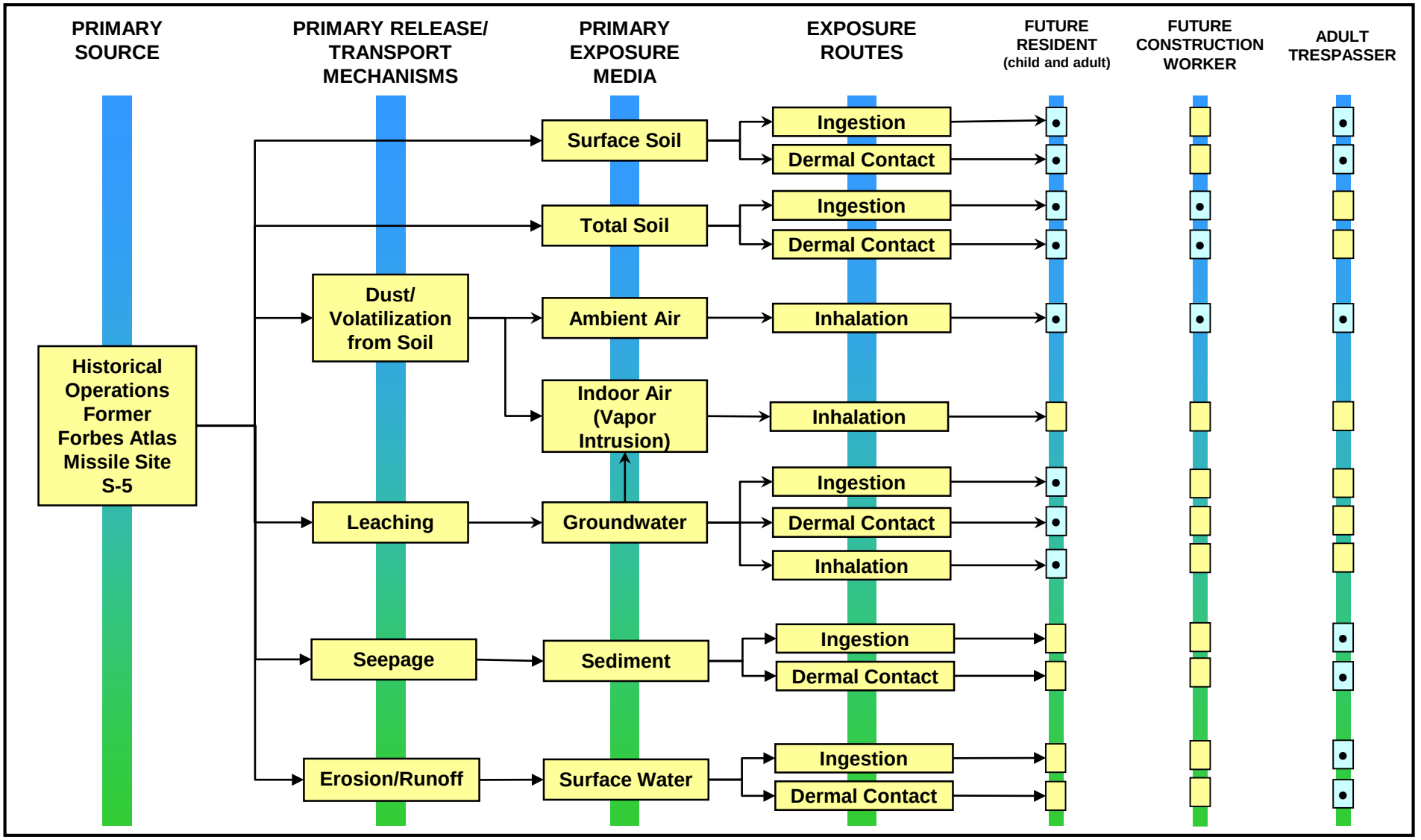
NOTES:

1. SITE PLAN AND ELEVATIONS BASED ON TOPOGRAPHIC SURVEY PERFORMED BY FORGY SURVEYING, ON JULY 13, 1990.
2. AERIAL IMAGE PROVIDED BY GOOGLE EARTH.

US Army Corps of Engineers ®
Kansas City District

Figure 4-1
POTENTIAL ROUTES OF MIGRATION
FORBES ATLAS S-5
ALLEN, KANSAS

1200C PERM
B07KS020401_03.10_0001_a



LEGEND:

= complete exposure pathway for quantification in the risk assessment.

= Potential exposure pathway.

Property Number B07KS0204

FIGURE 5-1
CONCEPTUAL SITE MODEL – HUMAN HEALTH RISK ASSESSMENT

Former Forbes Atlas Missile Site S-5

1200C-PERM
B07KS020401_03.10_0001_a

TABLES

Section 2

Tables

Table 2-1
Monitoring Well Gauging Data
Remedial Investivation
Former Forbes Atlas S5 Missle Site
Lyon County, Kansas

Well ID	Northing	Easting	Top of Casing Elevation (ft)	Date	Depth to Water (ft btoc)	Total Depth (ft btoc)	Groundwater Surface Elevation (ft)[1]
MW-01D	2055491.76	1939416.73	1422.75	7/6/2015	46.72	68.43	1376.03
				9/21/2015	47.24	68.43	1375.51
				12/14/2015	46.88	68.43	1375.87
				3/7/2016	45.70	68.43	1377.05
				6/27/2016	45.85	68.39	1376.90
				9/12/2016	46.09	68.39	1376.66
				12/12/2016	45.95	68.39	1376.80
				3/27/2017	45.07	68.47	1377.68
MW-02D	2055059.6	1939681.85	1422.7	7/6/2015	41.19	58.63	1381.51
				9/21/2015	42.56	58.63	1380.14
				12/14/2015	42.70	58.63	1380.00
				3/7/2016	40.87	58.63	1381.83
				6/27/2016	41.24	58.63	1381.46
				9/12/2016	41.89	58.63	1380.81
				12/12/2016	41.28	58.63	1381.42
				3/27/2017	40.86	58.58	1381.84
MW-2S	2033056.33	1939686.33	1421.97	7/6/2015	21.18	34.43	1400.79
				9/21/2015	24.95	34.43	1397.02
				12/14/2015	24.27	34.43	1397.70
				3/7/2016	23.93	34.43	1398.04
				6/27/2016	21.93	34.42	1400.04
				9/12/2016	22.91	34.42	1399.06
				12/12/2016	24.60	34.42	1397.37
				3/27/2017	23.32	34.39	1398.65
MW-3D	2055408.32	1939612.23	1418.65	7/6/2015	42.57	57.33	1376.08
				9/21/2015	43.27	57.33	1375.38
				12/14/2015	42.84	57.33	1375.81
				3/7/2016	41.08	57.33	1377.57
				6/27/2016	42.03	57.32	1376.62
				9/12/2016	42.08	57.32	1376.57
				12/12/2016	41.71	57.32	1376.94
				3/27/2017	40.93	57.32	1377.72
MW-3S	2055413.02	1939610.72	1418.29	7/6/2015	20.46	30.47	1397.83
				9/21/2015	23.62	30.47	1394.67
				12/14/2015	22.22	30.47	1396.07
				3/7/2016	20.87	30.47	1397.42
				6/27/2016	20.84	30.47	1397.45
				9/12/2016	20.60	30.47	1397.69
				12/12/2016	22.31	30.47	1395.98
				3/27/2017	19.88	30.44	1398.41
MW-04D	2055271.16	1939320.39	1427.94	7/6/2015	50.51	66.77	1377.43
				9/21/2015	51.15	66.77	1376.79
				12/14/2015	51.19	66.77	1376.75
				3/7/2016	49.96	66.77	1377.98
				6/27/2016	49.63	66.57	1378.31
				9/12/2016	49.98	66.77	1377.96
				12/12/2016	49.98	66.77	1377.96
				3/27/2017	49.11	66.58	1378.83
MW-4S	2055265.66	1939320.33	1427.99	7/6/2015	29.11	37.18	1398.88
				9/21/2015	31.76	37.18	1396.23
				12/14/2015	31.39	37.18	1396.60
				3/7/2016	30.46	37.18	1397.53
				6/27/2016	29.49	37.17	1398.50
				9/12/2016	29.34	37.17	1398.65
				12/12/2016	31.29	37.17	1396.70
				3/27/2017	29.22	37.14	1398.77
MW-05D	2055070.99	1939324.21	1427.32	7/6/2015	49.22	64.40	1378.10
				9/21/2015	50.26	64.40	1377.06
				12/14/2015	50.47	64.40	1376.85
				3/7/2016	48.50	64.40	1378.82
				6/27/2016	48.27	64.37	1379.05
				9/12/2016	48.57	64.37	1378.75
				12/12/2016	48.40	64.37	1378.92
				3/27/2017	47.73	64.34	1379.59

Table 2-1
Monitoring Well Gauging Data
Remedial Investivation
Former Forbes Atlas S5 Missle Site
Lyon County, Kansas

Well ID	Northing	Easting	Top of Casing Elevation (ft)	Date	Depth to Water (ft btoc)	Total Depth (ft btoc)	Groundwater Surface Elevation (ft)[1]
MW-06D	2054699.05	1939457.41	1415.65	7/6/2015	27.73	51.50	1387.92
				9/21/2015	29.46	51.50	1386.19
				12/14/2015	30.06	51.50	1385.59
				3/7/2016	26.47	51.50	1389.18
				6/27/2016	26.65	51.51	1389.00
				9/12/2016	26.91	51.51	1388.74
				12/12/2016	27.05	51.51	1388.60
				3/27/2017	26.39	51.47	1389.26
MW-6S	2054688.69	1939458.24	1415.34	7/6/2015	13.04	23.55	1402.30
				9/21/2015	17.22	23.55	1398.12
				12/14/2015	17.28	23.55	1398.06
				3/7/2016	13.45	23.55	1401.89
				6/27/2016	12.67	23.57	1402.67
				9/12/2016	13.32	23.57	1402.02
				12/12/2016	16.45	23.57	1398.89
				3/27/2017	11.42	23.53	1403.92
MW-7S	2054899.67	1939549.18	1424.99	7/6/2015	23.92	35.42	1401.07
				9/21/2015	27.80	35.42	1397.19
				12/14/2015	26.67	35.42	1398.32
				3/7/2015	26.62	35.42	1398.37
				6/27/2016	24.69	35.31	1400.30
				9/12/2016	25.46	35.31	1399.53
				12/12/2016	27.50	35.31	1397.49
				3/27/2017	25.90	35.37	1399.09
MW-8S	2055760.96	1939857.99	1407.62	6/27/2016	16.43	23.07	1391.19
				9/12/2016	13.71	23.07	1393.91
				12/12/2016	13.55	23.07	1394.07
				3/27/2017	11.29	23.05	1396.33
MW-9S	2055592.1	1939571.14	1412.19	6/27/2016	14.98	25.54	1397.21
				9/12/2016	14.69	25.54	1397.50
				12/12/2016	16.13	25.54	1396.06
				3/27/2017	13.32	25.55	1398.87
MW-10S	2055350.28	1939916.88	1412.92	6/27/2016	14.17	24.83	1398.75
				9/12/2016	14.17	24.83	1398.75
				12/12/2016	16.55	24.83	1396.37
				3/27/2017	15.39	24.79	1397.53
MW-11S	2055079.78	1939892.43	1416.59	6/27/2016	16.77	24.87	1399.82
				9/12/2016	18.11	24.87	1398.48
				12/12/2016	19.35	24.87	1397.24
				3/27/2017	19.93	24.92	1396.66
MW-12S	2054690.93	1939813.22	1418.05	6/27/2016	18.53	27.09	1399.52
				9/12/2016	20.54	27.09	1397.51
				12/12/2016	20.75	27.09	1397.30
				3/27/2017	21.27	27.12	1396.78
MW-13S	2054694.52	1939287.59	1412.7	6/27/2016	10.97	19.78	1401.73
				9/12/2016	11.19	19.78	1401.51
				12/12/2016	13.93	19.78	1398.77
				3/27/2017	13.07	19.78	1399.63

Notes:
[1] = Calculated by subtracting depth to water from the top of casing elevation.
ft = feet
ft btoc = feet below top of casing

Table 2-2
Maximum Horizontal Hydraulic Gradient and Estimated Linear Groundwater Velocity
Deep Monitoring Wells - March 2017
Remedial Investigation
Former Forbes Atlas S5 Missle Site
Lyon County, Kansas

Horizontal Hydraulic Gradient:

$$i = \frac{dh}{dL}$$

Where:
- i = hydraulic gradient (feet/foot)
- dh = head difference between data points (feet)
- dL = horizontal distance over which head difference occurs (feet)

$$i_{max} = \frac{1 \text{ ft}}{40 \text{ ft}}$$ (between 1387' and 1388' contours - see Figure 2-5)

i_{max} = 0.025 feet/feet

Estimated Linear Groundwater Velocity:

$$V = \frac{k \times i}{n_e}$$

Where:
- V = estimated linear groundwater velocity (feet/day)
- k = hydraulic conductivity
  - = 2.06 x10-6 cm/sec
  - = 5.839 x10-3 ft/day
- i = estimated hydraulic gradient (ft/ft)
- n_{emax} = effective porosity (percent)
  - = 0.14 The effective porosity for limestone is assumed to be 14% of the total porosity. Source: McWorter and Sunada (1977).

$$V_{max} = \frac{(5.839 \times 10^{-3} \text{ ft/day}) * (0.025 \text{ ft/ft})}{0.14}$$

V_{max} = 0.001 ft/day

V_{max} = 0.381 ft/year

Note: Information contained in this table is related to Figure 2-5.

Table 2-3
Minimum Horizontal Hydraulic Gradient and Estimated Linear Groundwater Velocity
Deep Monitoring Wells - March 2017
Remedial Investigation
Former Forbes Atlas S5 Missle Site
Lyon County, Kansas

Hydraulic Gradient:

$$i_{min} = \frac{dh}{dL}$$

Where:
- i = hydraulic gradient (feet/foot)
- dh = head difference between data points (feet)
- dL = horizontal distance over which head difference occurs (feet)

$$i_{min} = \frac{1 \text{ ft}}{100 \text{ ft}}$$ (between 1399' and 1398' contours - see Figure 2-5)

i_{min} = 0.010 feet/feet

Estimated Linear Groundwater Velocity:

$$V_{min} = \frac{k \times i}{n_e}$$

Where:
- V = estimated linear groundwater velocity (feet/day)
- k = hydraulic conductivity
  - = 9.406×10^{-7} cm/sec
  - = 2.666×10^{-3} ft/day
- i = estimated hydraulic gradient (ft/ft)
- n_e = effective porosity (percent)
  - = 0.14 The effective porosity for limestone is assumed to be 14% of the total porosity. Source: McWorter and Sunada (1977).

$$V_{min} = \frac{(2.666 \times 10^{-3} \text{ ft/day}) * (0.010 \text{ ft/ft})}{0.14}$$

V_{min} = 0.0002 ft/day

Vmin = 0.070 ft/year

Note: The information contained in this table relates to Figure 2-5.

Table 2-4
Maximum Horizontal Hydraulic Gradient and Estimated Linear Groundwater Velocity
Shallow Monitoring Wells - March 2017
Remedial Investigation
Former Forbes Atlas S5 Missle Site
Lyon County, Kansas

Hydraulic Gradient:

$$i = \frac{dh}{dL}$$

Where: i = hydraulic gradient (feet/foot)
dh = head difference between data points (feet)
dL = horizontal distance over which head difference occurs (feet)

$$i_{max} = \frac{1 \text{ ft}}{38 \text{ ft}}$$ (between 1403' and 1402' contours - see Figure 2-6)

i_{max} = 0.026 feet/feet

Estimated Linear Groundwater Velocity:

$$V = \frac{k \times i}{n_e}$$

Where: V = estimated linear groundwater velocity (feet/day)
k = hydraulic conductivity
= 4.71x10-4 cm/sec
= 1.335 ft/day
i = estimated hydraulic gradient (ft/ft)
n_{emax} = effective porosity (percent)
= 0.14 (The effective porosity for till is assumed to be 14% of the total porosity. Source: McWorter and Sunada (1977).

$$V_{max} = \frac{(1.335 \text{ ft/day}) * (0.026 \text{ ft/ft})}{0.14}$$

V_{max} = 0.251 ft/day

V_{max} = 91.59 ft/year

Note: Information contained in this table is related to Figure 2-6.

Table 2-5
Minimum Horizontal Hydraulic Gradient and Estimated Linear Groundwater Velocity
Shallow Monitoring Wells - March 2017
Remedial Investigation
Former Forbes Atlas S5 Missle Site
Lyon County, Kansas

Hydraulic Gradient:

$$i_{min} = \frac{dh}{dL}$$

Where:
- i = hydraulic gradient (feet/foot)
- dh = head difference between data points (feet)
- dL = horizontal distance over which head difference occurs (feet)

$$i_{min} = \frac{1 \text{ ft}}{420 \text{ ft}}$$ (between 1399' and 1398' contours - see Figure 2-6)

i_{min} = 0.002 feet/feet

Estimated Linear Groundwater Velocity:

$$V_{min} = \frac{k \times i}{n_e}$$

Where:
- V = estimated linear groundwater velocity (feet/day)
- k = hydraulic conductivity
  - = 1.65×10^{-5} cm/sec
  - = 4.67×10^{-2} ft/day
- i = estimated hydraulic gradient (ft/ft)
- n_e = effective porosity (percent)
  - = 0.14 (The effective porosity for till is assumed to be 14% of the total porosity. Source: McWorter and Sunada (1977).

$$V_{min} = \frac{(4.67 \times 10^{-2} \text{ ft/day}) * (0.002 \text{ ft/ft})}{0.14}$$

V_{min} = 0.0008 ft/day

Vmin = 0.290 ft/year

Note: The information contained in this table relates to Figure 2-6.

Table 2-6
Vertical Hydraulic Gradient - March 2017
Remedial Investigation
Former Forbes S-5 Atlas Missile Facility,
Lyon County, Kansas

Well Name	TOC Elevation (feet amsl)	Ground Surface Elevation (feet amsl)	Depth to Top of Screen (feet below TOC)	Depth to Mid-Point of Screen (feet below TOC)	Screen Length (feet)	Depth to Water (feet below TOC)	Groundwater Surface Elevation (feet amsl)	Change in Head (feet)	Change in Distance from Mid-Point of Screen (feet)	Vertical Hydraulic Gradient (feet/feet)	Vertical Hydraulic Gradient Direction
MW-02D	1422.70	1419.47	53.40	55.90	5.00	40.86	1381.84	17.54	24.26	0.7230	Downward
MW-02S	1421.97	1419.42	29.14	31.67	5.05	23.32	1398.65				
MW-03D	1418.65	1416.10	52.09	54.59	5.00	40.93	1377.72	21.05	26.86	0.7837	Downward
MW-03S	1418.29	1415.77	25.23	27.73	5.00	19.88	1398.41				
MW-04D	1427.94	1425.46	61.20	63.70	5.00	49.11	1378.83	19.89	29.38	0.6770	Downward
MW-04S	1427.99	1425.50	31.82	34.32	5.00	29.22	1398.77				
MW-06D	1415.65	1413.13	46.23	48.76	5.05	26.39	1389.26	14.97	27.88	0.5369	Downward
MW-06S	1415.34	1412.64	18.35	20.85	5.00	11.42	1403.92				

Notes:
1. Depth to water and groundwater surface elevation measuremnts are from March 27, 2017
amsl = above mean sea level
MW = monitoring well
TOC = top of casing

Table 2-7
Slug Test Performance Criteria
Remedial Investigation
Forbes Atlas S-5 Missile Site
Lyon County, Kansas

Well Name	Test Date	Well Depth (BTOC)	Static Water Level (BTOC)	Initial Test Level (BTOC)	Volume Removed (ft)	90% Static Level	Final Water Level
Shallow Monitoring Wells							
MW-02S	7/28/2015	34.43	21.14	26.81	5.67	23.25	21.19
MW-03S	7/27/2015	30.47	20.30	26.30	6.00	22.33	20.39
MW-04S	7/27/2015	37.18	28.86	34.02	5.16	31.75	29.64
MW-06S	7/28/2015	23.55	11.35	15.61	4.26	12.49	11.63
MW-07S	7/27/2015	35.42	23.55	31.60	8.05	25.91	23.62
MW-08S	7/12/2016	23.07	15.55	21.25	5.7	17.11	16.07
MW-09S	7/12/2016	25.54	14.38	23.65	9.27	15.82	14.65
MW-10S	7/12/2016	24.83	13.07	23.31	10.24	14.38	14.09
MW-11S	7/12/2016	24.89	15.19	23.74	8.55	16.71	15.91
MW-12S	7/12/2016	27.09	17.79	25.85	8.06	19.57	18.58
MW-13S	7/12/2016	19.78	9.94	18.2	8.26	10.93	10.89
Deep Monitoring Wells							
MW-01D	8/25/2015	68.43	47.13	51.12	3.99	51.843	49.90
MW-02D	7/28/2015	58.63	40.93	46.44	5.51	45.02	42.02
MW-03D	7/27/2015	57.33	42.40	45.91	3.51	46.64	43.56
MW-04D	8/25/2015	66.77	50.91	55.80	4.89	56.00	54.85
MW-05D	8/25/2015	64.40	49.85	54.34	4.49	54.84	53.73
MW-06D	7/28/2015	51.50	26.83	33.47	6.64	29.51	31.92

Notes:
BTOC = below top of casing
ft = feet

Table 2-8
Hydraulic Conductivity Testing Results
Remedial Investigation
Forbes Atlas S-5 Missile Site
Lyon County, Kansas

Well Name	Test Date	Aquifer Model	Bouwer-Rice Hydraulic Conductivity (cm/sec)	Springer-Gelhar Hydraulic Conductivity (cm/sec)	Hvorslev Hydraulic Conductivity (cm/sec)
Shallow Monitoring Wells					
MW-02S	7/28/2015	Unconfined	4.71 E^{-4}	4.71 E^{-4}	NA
MW-03S	7/27/2015	Unconfined	2.168 E^{-4}	2.629 E^{-4}	NA
MW-04S	7/27/2015	Unconfined	2.405 E^{-4}	4.983 E^{-5}	NA
MW-06S	7/28/2015	Unconfined	8.241 E^{-5}	1.784 E^{-4}	NA
MW-07S	7/27/2015	Unconfined	2.021 E^{-4}	2.021 E^{-4}	NA
MW-08S	7/12/2016	Unconfined	3.45 E^{-5}	5.593 E^{-4}	NA
MW-09S	7/12/2016	Unconfined	1.909 E^{-4}	1.909 E^{-4}	NA
MW-10S	7/12/2016	Unconfined	4.111 E^{-5}	4.983 E^{-5}	NA
MW-11S	7/12/2016	Unconfined	3.989 E^{-5}	1.127 E^{-4}	NA
MW-12S	7/12/2016	Unconfined	1.791 E^{-5}	8.329 E^{-5}	NA
MW-13S	7/12/2016	Unconfined	1.65 E^{-5}	1.001 E^{-4}	NA
Deep Monitoring Wells					
MW-01D	8/25/2015	Confined	3.761 E^{-6}	NA	2.52 E^{-5}
MW-02D	7/28/2015	NA	NA	NA	NA
MW-03D	7/27/2015	NA	NA	NA	NA
MW-04D	8/25/2015	Confined	2.725 E^{-6}	NA	6.685 E^{-6}
MW-05D	8/25/2015	Confined	2.06 E^{-6}	NA	2.969 E^{-6}
MW-06D	7/28/2015	Confined	9.406 E^{-7}	NA	9.406 E^{-7}

Notes:
1. Analysis of slug test data from shallow monitoring wells was performed using the Bouwer and Rice (1976) and Springer-Gelhar (1991) solution methods for unconfined aquifer conditions.
2. Analysis of slug test data from deep monitoring wells was performed using the Bouwer and Rice (1976) and Hvorslev (1951) solution methods for confined aquifer conditions.
cm/sec = centimeters per second
ft = feet
NA = not analzed

Section 3

Tables

TABLE 3-1
REMEDIATION INVESTIGATION FIELD ACTIVITIES
FORMER FORBES S-5 ATLAS MISSILE FACILITY
LYON COUNTY, KANSAS

Field Activity	Dates	Number	Samples	Analytes Requested
Well Drilling, Installation, and Development	May 12 - June 17, 2015	11 wells	N/A	N/A
Soil Borings/Soil Sampling	May 12 - June 2, 2015	10 locations	51 samples	VOCs, TOC
Sediment Sampling	May 14 - May 20, 2015	7 locations	7 samples	VOCs
Surface Water Sampling	May 14 - May 20, 2015	10 locations	10 samples	VOCs
Groundwater Sampling-Round 1	July 6 - July 9, 2015	11 wells	11 samples	VOC, 9056 Anions, MEE, Alk, Sulfide
IDW Sampling-solid	July 9, 2015	4 drums	4 samples	pH, Flashpoint, TCLP-RCRA 8 Metals, PCBs, % moisture
IDW Sampling-liquid	July 9, 2015	1 drum	1 sample	VOCs
Slug Testing	July 27 - July 29, 2015	8 wells	N/A	N/A
Slug Testing	August 25, 2015	3 wells	N/A	N/A
Frac Tank Cleaning and demobilization	August 25, 2015	1 tank	N/A	N/A
Groundwater Sampling-Round 2	September 21 - September 23, 2015	11 wells	11 samples	VOC, 9056 Anions, MEE, Alk, Sulfide
IDW Sampling-liquid	September 23, 2015	3 drums	3 samples	pH, Flashpoint
Groundwater Sampling-Round 3	December 14 - December 16, 2015	11 wells	11 samples	VOC, 9056 Anions, MEE, Alk, Sulfide
Drum Removal	December 14 - December 15, 2015	28 drums	N/A	N/A
Groundwater Sampling-Round 4	March 7 - March 9, 2016	11 Wells	11 samples	VOC, 9056 Anions, MEE, Alk, Sulfide
Well Drilling, Installation, and Development	May 24 - June 5, 2016	6 wells	6 soil samples from 2 locations	VOCs, TOC
Groundwater Sampling-Round 5	June 27 - July 1, 2016	17 wells	17 samples	VOC, 9056 Anions, MEE, Alk, Sulfide
IDW Sampling - solid	July 1, 2016	6 drums	6 samples	VOCs (4), pH, Flashpoint
Slug Testing	July 12, 2016	6 wells	N/A	N/A
Groundwater Sampling-Round 6	September 12 - September 15, 2016	17 wells	17 samples	VOC, 9056 Anions, MEE, Alk, Sulfide
Groundwater Sampling-Round 7	December 13 - December 15, 2016	17 wells	17 samples	VOC, 9056 Anions, MEE, Alk, Sulfide
Groundwater Sampling-Round 8	March 27 - March 30, 2017	17 wells	17 samples	VOC, 9056 Anions, MEE, Alk, Sulfide

Notes

IDW - Investigation Derived Waste
N/A - Not Applicable
VOCs - Volatile Organic Compounds
TOC - Total Organic Carbon
MEE - Methane, Ethane, Ethene
Alk - Alkalinity
PCBs - polychlorinated biphenyls
TCLP - Toxicity Characteristic Leaching Procedure
RCRA - The Resource Conservation and Recovery Act

Table 3-2
Soil Sampling Analytical Results
Remedial Investigation, Former Forbes Atlas S-5 Missile Site
Lyon County, Kansas

				Sample ID:	SB-01-0-1	DUP-3-SB	SB-01-3-4	SB-01-8-9	SB-01-11-12	SB-01-14-15	SB-01-17-18	SB-01-23-24
				Lab ID:	HS15050844-01	HS15050844-10	HS15050844-02	HS15050844-03	HS15050844-04	HS15050844-05	HS15050844-06	HS15050844-07
				Date Collected:	5/19/2015	5/19/2015	5/19/2015	5/19/2015	5/19/2015	5/19/2015	5/19/2015	5/19/2015
				Sample Description:	Located near former MW-502 and north east of the missile erection structure.							
				Depth (ft):	0-1	0-1	3-4	8-9	11-12	14-15	17-18	23-24
		Screening Levels				Duplicate						
Analyte	Units	KDHE RSK Resid. Soil	USEPA RSL Resid. Soil		Result	Result	Result	Result	Result	Result	Result	Result
cis-1,2-dichloroethene	ug/kg	23000	160000		3.8 U	5.7 U	2.9 U	2.9 U	2.4 U	2.4 U	**17**	3.1 U
Trichloroethene	ug/kg	5850	940		3.8 U	5.7 U	2.9 U	2.9 U	**1.7 J**	2.4 U	**65**	3.1 U
Vinyl Chloride	ug/kg	4470	59		1.8 U	5.7 U	1.4 U	1.4 U	1.2 U	1.2 U	1.1 U	1.5 U
Total Organic Carbon	% dry wt	NA	NA		**2.42**	**1.76**	**0.331**	**0.206**	**0.0955**	**2.32**	**0.849**	**6.19**

				Sample ID:	SB-02-0-1	SB-02-2-3	SB-02-8-9	SB-02-25-26
				Lab ID:	HS15050681-01	HS15050681-02	HS15050681-03	HS15050681-04
				Date Collected:	5/15/2015	5/15/2015	5/15/2015	5/15/2015
				Sample Description:	Located at the approximate location of the underground LOX tank to the east of the missile erection structure.			
				Depth (ft):	0-1	2-3	8-9	25-26
		Screening Levels						
Analyte	Units	KDHE RSK Resid. Soil	USEPA RSL Resid. Soil		Result	Result	Result	Result
cis-1,2-dichloroethene	ug/kg	23000	160000		2.7 U	2.4 U	2.4 U	2.7 U
Trichloroethene	ug/kg	5850	940		2.7 U	2.4 U	2.4 U	2.7 U
Vinyl Chloride	ug/kg	4470	59		1.3 U	1.1 U	1.2 U	1.3 U
Total Organic Carbon	% dry wt	NA	NA		**0.550**	**0.890**	**0.484**	**4.91**

Bold indicates detected results.

J = Estimated value

U = Compound was not detected

ug/kg = micrograms per kilogram

% dry wt= Percent Dry Weight

KDHE RSK at HQ=1 or TR=1E-05 (September, 2015)

USEPA Residential Soil RSL at HQ=1 or Cancer TR=1E-06 (June, 2017)

RSK=Risk-based Standards (Kansas)

RSL=Regional Screening Levels

J-qualified results presented with the number of significant digits provided in the validated SEDD. The level of precision is best represented by only one significant digit.

Table 3-2
Soil Sampling Analytical Results
Remedial Investigation, Former Forbes Atlas S-5 Missile Site
Lyon County, Kansas

			Sample ID:	SB-03-0-1	SB-03-3-4	SB-03-9-10	SB-03-11-12	Dup-2-SB	SB-03-14-15	SB-03-18-19
			Lab ID:	HS15050789-01	HS15050789-02	HS15050789-03	HS15050789-04	HS15050789-13	HS15050789-05	HS15050789-06
			Date Collected:	5/18/2015	5/18/2015	5/18/2015	5/18/2015	5/18/2015	5/18/2015	5/18/2015
			Sample Description:	Located to the east of the Flame Exit Pit						
			Depth (ft):	0-1	3-4	9-10	11-12	11-12	14-15	18-19
		Screening Levels						Duplicate		
Analyte	Units	KDHE RSK Resid. Soil	USEPA RSL Resid. Soil	Result	Result	Result	Result	Result	Result	Result
cis-1,2-dichloroethene	ug/kg	23000	160000	3.5 U	2.9 U	2.5 U	2.8 U	3.0 U	2.5 U	2.8 U
Trichloroethene	ug/kg	5850	940	3.5 UJ	2.9 U	2.5 U	2.8 U	3.0 U	2.5 U	2.8 U
Vinyl Chloride	ug/kg	4470	59	1.7 U	1.4 U	1.2 U	1.4 U	1.4 U	1.2 U	1.3 U
Total Organic Carbon	% dry wt	NA	NA	**3.24 J**	**0.789 J**	0.06 U	**0.274 J**	**0.118 J**	**1.39 J**	**0.176 J**

			Sample ID:	SB-04-0-1	SB-04-7-8	SB-04-13-14	DUP-4-SB	SB-04-16-17	SB-04-19-20	SB-04-20-21
			Lab ID:	HS15051226-01	HS15051226-02	HS15051226-03	HS15051226-07	HS15051226-04	HS15051226-05	HS15051226-06
			Date Collected:	5/28/2015	5/28/2015	5/28/2015	5/28/2015	5/28/2015	5/28/2015	5/28/2015
			Sample Description:	Located to the west of the Flame Exit Pit						
			Depth (ft):	0-1	7-8	13-14	13-14	16-17	19-20	20-21
		Screening Levels					Duplicate			
Analyte	Units	KDHE RSK Resid. Soil	USEPA RSL Resid. Soil	Result	Result	Result	Result	Result	Result	Result
cis-1,2-dichloroethene	ug/kg	23000	160000	3.3 UJ	2.6 U	2.5 U	2.8 U	2.8 U	2.5 U	2.2 U
Trichloroethene	ug/kg	5850	940	3.3 UJ	2.6 U	2.5 U	2.8 U	2.8 U	2.5 U	2.2 U
Vinyl Chloride	ug/kg	4470	59	1.6 U	1.2 U	1.2 U	1.3 U	1.3 U	1.2 U	1.1 U
Total Organic Carbon	% dry wt	NA	NA	**7.22 J**	**0.216 J**	**0.795 J**	**0.126 J**	**1.03 J**	**0.254 J**	**0.671 J**

Bold indicates detected results.

J = Estimated value

U = Compound was not detected

ug/kg = micrograms per kilogram

% dry wt= Percent Dry Weight

KDHE RSK at HQ=1 or TR=1E-05 (September, 2015)

USEPA Residential Soil RSL at HQ=1 or Cancer TR=1E-06 (June, 2017)

RSK=Risk-based Standards (Kansas)

RSL=Regional Screening Levels

J-qualified results presented with the number of significant digits provided in the validated SEDD. The level of precision is best represented by only one significant digit.

Table 3-2
Soil Sampling Analytical Results
Remedial Investigation, Former Forbes Atlas S-5 Missile Site
Lyon County, Kansas

				Sample ID:	SB-05-0-1	SB-05-1.5-2.5	Dup-1-SB	SB-05R-12-13	SB-05R-20-21
				Lab ID:	HS15050673-03	HS15050673-04	HS15050673-08	HS15050681-05	HS15050681-06
				Date Collected:	5/14/2015	5/14/2015	5/14/2015	5/15/2015	5/15/2015
				Sample Description:	Located adjacent to the manhole to the west of the primary sump, and west of the missile erection structure				
				Depth (ft):	0-1	1.5-2.5	1.5-2.5	12-13	20-21
		Screening Levels					Duplicate		
Analyte	Units	KDHE RSK Resid. Soil	USEPA RSL Resid. Soil		Result	Result	Result	Result	Result
cis-1,2-dichloroethene	ug/kg	23000	160000		2.4 U	2.9 U	3.2 U	2.9 U	2.3 U
Trichloroethene	ug/kg	5850	940		2.4 U	2.9 U	3.2 U	2.9 U	2.3 U
Vinyl Chloride	ug/kg	4470	59		1.1 U	1.4 U	1.5 U	1.4 U	1.1 U
Total Organic Carbon	% dry wt	NA	NA		**1.56**	**2.32**	**2.09**	**0.514 J**	**0.828**

				Sample ID:	SB-06-0-1	SB-06-1-2	SB-07-0-1	SB-07-3-4	SB-07-9-10	SB-07-12-13	SB-07-26-27	SB-07-28-29
				Lab ID:	HS15050673-05	HS15050673-06	HS15050789-07	HS15050789-08	HS15050789-09	HS15050789-10	HS15050789-11	HS15050789-12
				Date Collected:	5/14/2015	5/14/2015	5/18/2015	5/18/2015	5/18/2015	5/18/2015	5/18/2015	5/18/2015
				Sample Description:	Located within presumed backfill to the west of the missile erection structure		Located immediately adjacent to the sump discharge along the south perimeter fence					
				Depth (ft):	0-1	1-2	0-1	3-4	9-10	12-13	26-27	28-29
		Screening Levels										
Analyte	Units	KDHE RSK Resid. Soil	USEPA RSL Resid. Soil		Result	Result	Result	Result	Result	Result	Result	Result
cis-1,2-dichloroethene	ug/kg	23000	160000		2.3 U	2.7 U	3.8 U	2.9 U	3.1 U	**69 J**	2.7 UJ	2.6 U
Trichloroethene	ug/kg	5850	940		2.3 U	2.7 U	3.8 U	2.9 U	3.1 U	**220 J**	2.7 UJ	2.6 U
Vinyl Chloride	ug/kg	4470	59		1.1 U	1.3 U	1.8 U	1.4 U	1.5 U	**21 J**	1.3 UJ	1.2 U
Total Organic Carbon	% dry wt	NA	NA		**1.67**	**0.503**	**4.42 J**	**0.354 J**	**0.845 J**	**6.52 J**	**1.09 J**	**0.0756 J**

Bold indicates detected results.

J = Estimated value

U = Compound was not detected

ug/kg = micrograms per kilogram

% dry wt= Percent Dry Weight

KDHE RSK at HQ=1 or TR=1E-05 (September, 2015)

USEPA Residential Soil RSL at HQ=1 or Cancer TR=1E-06 (June, 2017)

RSK=Risk-based Standards (Kansas)

RSL=Regional Screening Levels

J-qualified results presented with the number of significant digits provided in the validated SEDD. The level of precision is best represented by only one significant digit.

Table 3-2
Soil Sampling Analytical Results
Remedial Investigation, Former Forbes Atlas S-5 Missile Site
Lyon County, Kansas

			Sample ID:	**SB-08-0-1**	**SB-08-4-5**	**SB-08-8-9**	**SB-08-24-25**
			Lab ID:	**HS15051234-01**	**HS15051234-02**	**HS15051234-03**	**HS15051234-04**
			Date Collected:	**5/29/2015**	**5/29/2015**	**5/29/2015**	**5/29/2015**
			Sample Description:	**Located downgradient of the sump discharge**			
			Depth (ft):	**0-1**	**4-5**	**8-9**	**24-25**
		Screening Levels					
Analyte	**Units**	**KDHE RSK Resid. Soil**	**USEPA RSL Resid. Soil**	**Result**	**Result**	**Result**	**Result**
cis-1,2-dichloroethene	ug/kg	23000	160000	3.4 U	2.4 U	2.5 U	2.7 U
Trichloroethene	ug/kg	5850	940	3.4 U	2.4 U	2.5 U	2.7 U
Vinyl Chloride	ug/kg	4470	59	1.6 U	1.2 U	1.2 U	1.3 U
Total Organic Carbon	% dry wt	NA	NA	**1.56**	**0.122**	**0.112**	**0.182**

			Sample ID:	**SB-09-0-1**	**SB-09-2-3**	**SB-09-6-7**	**SB-09-12-13**	**SB-09-15-16**	**SB-09-17-18**
			Lab ID:	**HS15060159-01**	**HS15060159-02**	**HS15060159-03**	**HS15060159-04**	**HS15060159-05**	**HS15060159-06**
			Date Collected:	**6/2/2015**	**6/2/2015**	**6/2/2015**	**6/2/2015**	**6/2/2015**	**6/2/2015**
			Sample Description:	**Located west of the Former Administraion Building concrete slab and south of the Former Maintenance Building concrete slab**					
			Depth (ft):	**0-1**	**2-3**	**6-7**	**12-13**	**15-16**	**17-18**
		Screening Levels							
Analyte	**Units**	**KDHE RSK Resid. Soil**	**USEPA RSL Resid. Soil**	**Result**	**Result**	**Result**	**Result**	**Result**	**Result**
cis-1,2-dichloroethene	ug/kg	23000	160000	6.7 U	3.0 U	2.3 U	2.2 U	2.5 U	2.3 U
Trichloroethene	ug/kg	5850	940	6.7 U	3.0 U	2.3 U	2.2 U	2.5 U	2.3 U
Vinyl Chloride	ug/kg	4470	59	3.2 U	1.5 U	1.1 U	1.1 U	1.2 U	1.1 U
Total Organic Carbon	% dry wt	NA	NA	**8.65 J**	**2.19 J**	**0.674 J**	**0.688 J**	**0.0949 J**	**0.275 J**

Bold indicates detected results.

J = Estimated value

U = Compound was not detected

ug/kg = micrograms per kilogram

% dry wt= Percent Dry Weight

KDHE RSK at HQ=1 or TR=1E-05 (September, 2015)

USEPA Residential Soil RSL at HQ=1 or Cancer TR=1E-06 (June, 2017)

RSK=Risk-based Standards (Kansas)

RSL=Regional Screening Levels

J-qualified results presented with the number of significant digits provided in the validated SEDD. The level of precision is best represented by only one significant digit.

Table 3-2
Soil Sampling Analytical Results
Remedial Investigation, Former Forbes Atlas S-5 Missile Site
Lyon County, Kansas

			Sample ID:	SB-10-0-1	DUP-5-SB	SB-10-3-4	SB-10-8-9	DUP-6-SB	SB-10-12-13	SB-10-18-19	SB-10-21-22
			Lab ID:	HS15060149-01	HS15060149-07	HS15060149-02	HS15060149-03	HS15060149-08	HS15060149-04	HS15060149-05	HS15060149-06
			Date Collected:	6/1/2015	6/1/2015	6/1/2015	6/1/2015	6/1/2015	6/1/2015	6/1/2015	6/1/2015
			Sample Description:	Located east of the Cooling Tower concrete slab							
			Depth (ft):	0-1	0-1	3-4	8-9	8-9	12-13	18-19	21-22
		Screening Levels			Duplicate			Duplicate			
Analyte	Units	KDHE RSK Resid. Soil	USEPA RSL Resid. Soil	Result	Result	Result	Result	Result	Result	Result	Result
cis-1,2-dichloroethene	ug/kg	23000	160000	3.1 U	3.0 U	2.5 U	2.9 U	2.8 U	2.4 U	2.3 U	2.4 U
Trichloroethene	ug/kg	5850	940	3.1 U	3.0 U	2.5 U	2.9 U	2.8 U	2.4 U	2.3 U	2.4 U
Vinyl Chloride	ug/kg	4470	59	1.5 U	1.5 U	1.2 U	1.4 U	1.3 U	1.2 U	1.1 U	1.1 U
Total Organic Carbon	% dry wt	NA	NA	**1.60 J**	**1.44 J**	**0.239 J**	**4.59 J**	**4.53 J**	**0.603 J**	**0.225 J**	**0.805 J**

			Sample ID:	SB-11-0-1	SB-11-5-6	DUP-7-SB	SB-11-14-15	SB-12-0-1	SB-12-3-4	SB-12-6-7
			Lab ID:	HS15050844-01	HS15050844-10	HS15050844-02	HS15050844-03	HS15050844-04	HS15050844-05	HS15050844-06
			Date Collected:	5/26/2016	5/26/2016	5/26/2016	5/26/2016	6/1/2016	6/1/2016	6/1/2016
			Sample Description:	SB-11 is located near the southeast corner of the perimeter fence.				SB-12 is located in the southwest corner of the perimeter fence.		
			Depth (ft):	0-1	5-6	5-6	14-15	0-1	3-4	6-7
		Screening Levels				Duplicate				
Analyte	Units	KDHE RSK Resid. Soil	USEPA RSL Resid. Soil	Result	Result	Result	Result	Result	Result	Result
cis-1,2-dichloroethene	ug/kg	23000	160000	4.0 UJ	5.0 U	5.1 U	4.3 U	1.8 U	1.3 U	1.3 U
Trichloroethene	ug/kg	5850	940	4.0 U	5.0 U	5.1 U	4.3 U	1.8 U	1.3 U	1.3 U
Vinyl Chloride	ug/kg	4470	59	1.2 U	1.5 U	1.5 U	1.3 U	1.8 U	1.3 U	1.3 U
Total Organic Carbon	% dry wt	NA	NA	**2.81**	**1.56**	**1.73**	**0.0600**	**2.37**	**0.0678**	**0.0600**

Bold indicates detected results.

J = Estimated value

U = Compound was not detected

ug/kg = micrograms per kilogram

% dry wt= Percent Dry Weight

KDHE RSK at HQ=1 or TR=1E-05 (September, 2015)

USEPA Residential Soil RSL at HQ=1 or Cancer TR=1E-06 (June, 2017)

RSK=Risk-based Standards (Kansas)

RSL=Regional Screening Levels

J-qualified results presented with the number of significant digits provided in the validated SEDD. The level of precision is best represented by only one significant digit.

Table 3-3
PID Field Results
Remedial Investigation
Former Forbes Atlas S-5 Missile Site
Lyon County, Kansas

Monitoring Well Location	Depth (ft. bgs)	Field Screening Results (ppm)
MW-01D	0.5	0.0
	1.0	0.0
	2.0	0.3
	3.0	0.0
	4.0	0.0
	5.0	0
	5.5	1.7
	6.0	1.6
	7.0	0.0
	8.0	0.0
	9.0	0.0
MW-02D	0.5	0.0
	1.0	0.0
	2.0	0.0
	3.0	0.0
	4.0	0.0
	5.0	0.0
	6.0	0.0
	7.0	0.0
	8.0	0.0
	9.0	0.0
	10.0	0.0
	11.0	0.0
	12.0	0.0
	13.0	0.0
	14.0	0.0
	15.0	0.0
	16.0	0.0
	17.0	0.0
	18.0	0.0
	19.0	0.0
	20.0	0.0
	21.0	0.0
	22.0	0.0
	23.0	0.0
	24.0	0.0
	25.0	0.0
	26.0	0.0
	27.0	0.0
	28.0	0.0
	29.0	0.0
	30.0	0.0
	31.0	0.0
	32.0	0.0
	33.0	0.0
	34.0	0.0
	35.0	0.0
	36.0	0.0
	37.0	0.0
	38.0	0.0
	39.0	0.0
	40.0	0.0

Table 3-3
PID Field Results
Remedial Investigation
Former Forbes Atlas S-5 Missile Site
Lyon County, Kansas

Monitoring Well Location	Depth (ft. bgs)	Field Screening Results (ppm)
MW-02S/ SB-01	0.5	0.0
	1.0	0.0
	2.0	0.0
	3.0	0.0
	4.0	0.0
	5.5	0.0
	6.0	0.0
	7.0	0.0
	8.0	0.0
	9.0	0.0
	10.0	0.0
	11.0	0.0
	12.0	0.0
	13.0	0.0
	14.0	0.0
	15.0	0.0
	16.0	0.0
	17.0	0.0
	18.0	0.0
	19.0	0.0
	20.0	0.0
	21.0	0.0
	22.0	0.0
	23.0	0.0
MW-04D	0.5	0.0
	1.0	0.0
	2.0	0.0
	3.0	0.0
	4.0	0.0
	5.0	0.0
	6.0	0.0
	7.0	0.0
	8.0	0.0
	9.0	0.0
	10.0	0.0
	11.0	0.0
	12.0	0.0
	13.0	0.0
	14.0	0.0
	15.0	0.0
	16.0	0.0
	17.0	0.0
	18.0	0.0
	19.0	0.0
	20.0	0.0
	21.0	0.0
	22.0	0.0
	23.0	0.0
	23.5	0.0
	24.0	0.0
	25.0	0.0
	26.0	0.0
	27.0	0.0
	28.0	0.0
	29.0	0.0
	30.0	0.0

Table 3-3
PID Field Results
Remedial Investigation
Former Forbes Atlas S-5 Missile Site
Lyon County, Kansas

Monitoring Well Location	Depth (ft. bgs)	Field Screening Results (ppm)
MW-4S/ SB-10	0.5	0.0
	1.0	0.0
	2.0	0.0
	3.0	0.0
	4.0	0.0
	5.0	0.0
	5.5	0.0
	6.0	0.0
	7.0	0.0
	8.0	0.0
	9.0	0.0
	10.0	0.0
	11.0	0.0
	12.0	0.0
	13.0	0.0
	14.0	0.0
	14.5	0.0
	15.0	0.0
	16.0	0.0
	17.0	0.0
	18.0	0.0
	19.0	0.0
	20.0	0.0
	21.0	0.0
	22.0	0.0
	23.0	0.0
	24.0	0.0
	25.0	0.0
	26.0	0.0
	27.0	0.0
	28.0	0.0
	29.0	0.0
	30.0	0.0
	31.0	0.0
	32.0	0.0
	33.0	0.0
	34.0	0.0
	35.0	0.0
	36.0	0.0
	37.0	0.0
	38.0	0.0
	39.0	0.0
	40.0	0.0

Table 3-3
PID Field Results
Remedial Investigation
Former Forbes Atlas S-5 Missile Site
Lyon County, Kansas

Monitoring Well Location	Depth (ft. bgs)	Field Screening Results (ppm)
MW-05D	0.5	0.0
	1.0	0.0
	2.0	0.0
	3.0	0.0
	4.0	0.0
	5.0	0.0
	6.0	0.0
	7.0	0.0
	8.0	0.0
	9.0	0.0
	10.0	0.0
	11.0	0.0
	12.0	0.0
	13.0	0.0
	14.0	0.0
	23.0	0.0
	24.0	0.0
	25.0	0.0
	26.0	0.0
	27.0	0.0
	28.0	0.0
	29.0	0.0
	30.0	0.0
	31.0	0.0
	32.0	0.0
	33.0	0.0
	34.0	0.0
	35.0	0.0
	36.0	0.0
	37.0	0.0
	38.0	0.0
	39.0	0.0
	40.0	0.0

Table 3-3
PID Field Results
Remedial Investigation
Former Forbes Atlas S-5 Missile Site
Lyon County, Kansas

Monitoring Well Location	Depth (ft. bgs)	Field Screening Results (ppm)
MW-06D	0.5	0.0
	1.0	0.0
	2.0	0.0
	3.0	0.0
	4.0	0.0
	5.0	0.0
	5.5	0.0
	6.0	0.0
	7.0	0.0
	8.0	0.0
	9.0	0.0
	10.0	0.0
	11.0	0.0
	12.0	0.0
	13.0	0.0
	14.0	0.0
	14.5	0.0
	15.0	0.0
	16.0	0.0
	17.0	0.0
	18.0	0.0
	19.0	0.0
	20.0	0.0
	21.0	0.0
	22.0	0.0
	23.0	0.0
	24.0	0.0
	25.0	0.0
	26.0	0.0
	27.0	0.0
	28.0	0.0
	29.0	0.0
	30.0	0.0
	31.0	0.0
	32.0	0.0
	33.0	0.0
	34.0	0.0
	35.0	0.0
	36.0	0.0
	37.0	0.0
	38.0	0.0
	39.0	0.0
	40.0	0.0

Table 3-3
PID Field Results
Remedial Investigation
Former Forbes Atlas S-5 Missile Site
Lyon County, Kansas

Monitoring Well Location	Depth (ft. bgs)	Field Screening Results (ppm)
MW-06S/ SB-08	0.5	0.0
	1.0	0.0
	2.0	0.0
	3.0	0.0
	4.0	0.0
	5.0	0.0
	6.0	0.0
	7.0	0.0
	8.0	0.0
	9.0	0.0
	10.0	0.0
	11.0	0.0
	12.0	0.0
	13.0	0.0
	14.0	0.0
	15.0	0.0
	16.0	0.0
	17.0	0.0
	18.0	0.0
	19.0	0.0
	20.0	0.0

Table 3-3
PID Field Results
Remedial Investigation
Former Forbes Atlas S-5 Missile Site
Lyon County, Kansas

Monitoring Well Location	Depth (ft. bgs)	Field Screening Results (ppm)
MW-07S/ SB-04	0.5	0.0
	1.0	0.0
	2.0	0.0
	3.0	0.0
	4.0	0.0
	5.0	0.0
	5.5	0.0
	6.0	0.0
	7.0	0.0
	8.0	0.0
	9.0	0.0
	10.0	0.0
	11.0	0.0
	12.0	0.0
	13.0	0.0
	14.0	0.0
	14.5	0.0
	15.0	0.0
	16.0	0.0
	17.0	0.0
	18.0	0.0
	19.0	0.0
	20.0	0.0
	21.0	0.0
	22.0	0.0
	23.0	0.0
	23.5	0.0
	24.0	0.0
	25.0	0.0
	26.0	0.0
	27.0	0.0
	28.0	0.0
	29.0	0.0
	30.0	0.0
	31.0	0.0
	32.0	0.0
	32.5	0.0
	33.0	0.0
	34.0	0.0
	35.0	0.0
	36.0	0.0
	37.0	0.0
	38.0	0.0
	39.0	0.0
	40.0	0.0

Table 3-3
PID Field Results
Remedial Investigation
Former Forbes Atlas S-5 Missile Site
Lyon County, Kansas

Monitoring Well Location	Depth (ft. bgs)	Field Screening Results (ppm)
MW-08S	0.5	0.0
	1.0	0.0
	2.0	0.0
	3.0	0.0
	4.0	0.0
	5.0	0.0
	6.0	0.0
	7.0	0.0
	8.0	0.0
	9.0	0.0
	10.0	0.0
	11.0	0.0
	12.0	0.0
	13.0	0.0
	14.0	0.0
	15.0	0.0
	16.0	0.0
	17.0	0.0
	18.0	0.0
	19.0	0.0
	20.0	0.0
	21.0	0.0
	22.0	0.0
	23.0	0.0
MW-09S	0.5	0.0
	1.0	0.0
	2.0	0.0
	3.0	0.0
	4.0	0.0
	5.0	0.0
	6.0	0.0
	7.0	0.0
	8.0	0.0
	9.0	0.0
	10.0	0.0
	11.0	0.0
	12.0	0.0
	13.0	0.0
	14.0	0.0
	15.0	0.0
	16.0	0.0
	17.0	0.0
	18.0	0.0
	19.0	0.0
	20.0	0.0
	21.0	0.0
	22.0	0.0
	23.0	0.0

Table 3-3
PID Field Results
Remedial Investigation
Former Forbes Atlas S-5 Missile Site
Lyon County, Kansas

Monitoring Well Location	Depth (ft. bgs)	Field Screening Results (ppm)
MW-10S	0.5	0.0
	1.0	0.0
	2.0	0.0
	3.0	0.0
	4.0	0.0
	5.0	0.0
	6.0	0.0
	7.0	0.0
	8.0	0.0
	9.0	0.0
	10.0	0.0
	11.0	0.0
	12.0	0.0
	13.0	0.0
	14.0	0.0
	15.0	0.0
	16.0	0.0
	17.0	0.0
	18.0	0.0
	19.0	0.0
	20.0	0.0
	21.0	0.0
	22.0	0.0
	23.0	0.0
	24.0	0.0
MW-11S	0.5	0.0
	1.0	0.0
	2.0	0.0
	3.0	0.0
	4.0	0.0
	5.0	0.0
	6.0	0.0
	7.0	0.0
	8.0	0.0
	9.0	0.0
	10.0	0.0
	11.0	0.0
	12.0	0.0
	13.0	0.0
	14.0	0.0
	15.0	0.0
	16.0	0.0
	17.0	0.0
	18.0	0.0
	19.0	0.0
	20.0	0.0
	21.0	0.0
	22.0	0.0
	23.0	0.0
	24.0	0.0
	25.0	0.0
	26.0	0.0
	27.0	0.0
	28.0	0.0
	29.0	0.0

Table 3-3
PID Field Results
Remedial Investigation
Former Forbes Atlas S-5 Missile Site
Lyon County, Kansas

Monitoring Well Location	Depth (ft. bgs)	Field Screening Results (ppm)
MW-12S	0.5	0.0
	1.0	0.0
	2.0	0.0
	3.0	0.0
	4.0	0.0
	5.0	1.6
	6.0	0.0
	7.0	0.0
	8.0	0.0
	9.0	0.0
	10.0	0.0
	11.0	0.0
	12.0	0.0
	13.0	11.1
	14.0	27.5
	15.0	11.7
	16.0	0.0
	17.0	0.0
	18.0	0.0
	19.0	0.0
	20.0	0.0
	21.0	0.0
	22.0	0.0
	23.0	0.0
	24.0	0.0
	25.0	0.0
MW-13S	0.5	0.0
	1.0	0.0
	2.0	0.0
	3.0	0.0
	4.0	0.0
	5.0	0.0
	6.0	0.0
	7.0	0.0
	8.0	0.0
	9.0	0.0
	10.0	0.0
	11.0	0.0
	12.0	0.0
	13.0	0.0
	14.0	0.0
	15.0	0.0
	16.0	0.0
	17.0	0.0
	18.0	0.0
	19.0	0.0
	20.0	0.0

Table 3-3
PID Field Results
Remedial Investigation
Former Forbes Atlas S-5 Missile Site
Lyon County, Kansas

Monitoring Well Location	Depth (ft. bgs)	Field Screening Results (ppm)
SB-02	0.5	0.0
	1.0	0.5
	2.0	0.7
	3.0	0.9
	4.0	0.6
	5.0	0.5
	6.0	0.0
	7.0	0.9
	8.0	4.3
	9.0	3.3
	10.0	2.4
	11.0	0.0
	12.0	0.0
	13.0	0.0
	14.0	0.0
	15.0	0.0
	16.0	0.0
	17.0	0.0
	18.0	0.0
	19.0	0.0
	20.0	0.0
	21.0	0.0
	22.0	0.0
	23.0	0.0
	24.0	0.0
	25.0	0.0
	26.0	0.0
	27.0	0.0
	29.0	0.0
	29.0	0.0
	30.0	0.0

Table 3-3
PID Field Results
Remedial Investigation
Former Forbes Atlas S-5 Missile Site
Lyon County, Kansas

Monitoring Well Location	Depth (ft. bgs)	Field Screening Results (ppm)
SB-03	0.5	0.0
	1.0	0.0
	2.0	0.0
	3.0	0.0
	4.0	0.0
	5.0	0.0
	6.0	0.0
	7.0	0.0
	8.0	0.0
	9.0	0.0
	10.0	0.0
	11.0	0.0
	12.0	0.0
	13.0	0.0
	14.0	0.0
	15.0	0.0
	16.0	0.0
	17.0	0.0
	18.0	0.0
	19.0	0.0
	20.0	0.0
	21.0	0.0
	22.0	0.0
	23.0	0.0
	24.0	0.0
	25.0	0.0
	26.0	0.0
	27.0	0.0
	28.0	0.0
	29.0	0.0
	30.0	0.0

Table 3-3
PID Field Results
Remedial Investigation
Former Forbes Atlas S-5 Missile Site
Lyon County, Kansas

Monitoring Well Location	Depth (ft. bgs)	Field Screening Results (ppm)
SB-05	0.5	0.0
	1.0	0.0
	2.0	0.0
	3.0	0.0
	4.0	0.0
	5.0	0.0
	6.0	1.2
	7.0	1.3
	8.0	1.2
SB-05R	0.5	0.0
	1.0	0.0
	2.0	0.0
	3.0	0.0
	4.0	0.0
	5.0	0.0
	6.0	0.0
	7.0	0.0
	8.0	0.0
	9.0	0.0
	10.0	0.0
	11.0	0.0
	12.0	0.0
	13.0	0.0
	14.0	0.0
	15.0	0.0
	16.0	0.0
	17.0	0.0
	18.0	0.0
	19.0	0.0
	20.0	0.0
	21.0	0.0
	22.0	0.0
	23.0	0.0
	24.0	0.0
	25.0	0.0
	26.0	0.0
	27.0	0.0
	28.0	0.0
	29.0	0.0
	30.0	0.0

Table 3-3
PID Field Results
Remedial Investigation
Former Forbes Atlas S-5 Missile Site
Lyon County, Kansas

Monitoring Well Location	Depth (ft. bgs)	Field Screening Results (ppm)
SB-06	0.5	0.0
	1.0	0.0
	2.0	0.0
	3.0	0.0
	4.0	0.0
	5.0	0.0
	6.0	0.6
	7.0	0.3
	8.0	0.6
	9.0	1.7
	10.0	0.0
	11.0	0.0
	12.0	0.2
	13.0	0.2
	14.0	0.6
	14.5	0.0
	15.0	0.0
	16.0	0.0
	17.0	0.0
	18.0	0.0
	19.0	0.0
	20.0	0.0
SB-07	0.5	0.0
	1.0	0.0
	1.5	0.0
	2.0	0.0
	3.0	0.0
	4.0	0.0
	5.0	0.0
	6.5	0.0
	7.5	0.0
	8.5	0.0
	9.5	0.0
	10.5	0.0
	11.5	0.0
	12.5	0.0
	13.5	0.0

Notes:
ft. bgs = feet below ground surface
ppm = parts per million

Table 3-4
Sediment Sampling Analytical Results (Detections Only)
Remedial Investigation
Former Forbes Atlas S-5 Missile Site
Lyon County, Kansas

				Sample ID:	SD-01	SD-02	SD-04	SD-06	SD-07	SD-10-0-0.5	SD-11-0-0.5	Dup-1-SD
				Lab ID:	HS15050844-08	1506002-1	HS15050887-14	HS15050887-12	HS15050887-13	HS15050673-02	HS15050673-01	HS15050673-07
				Date Collected:	5/19/2015	5/19/2015	5/20/2015	5/20/2015	5/20/2015	5/14/2015	5/14/2015	5/14/2015
				Sample Description:	Sump discharge pit	Manhole to the west of the primary sump	Flame pit (within missile structure)	Northwest room adjacent to the erection area	Southeast corner adjacent to the erection area	Sewage lagoon	Sewage lagoon	
				Depth (ft):	0-0.5	0-0.5	0-0.5	0-0.5	0-0.5	0-0.5	0-0.5	0-0.5
		Screening Levels										Duplicate
Analyte	Units	KDHE RSK Non-Res. Soil	USEPA RSL Industrial Soil		Result	Result	Result	Result	Result	Result	Result	Result
cis-1,2-dichloroethene	ug/kg	38700	2300000		**28000 J**	5 U	21 U	**3.8**	7.0 U	3.8 UJ	3.7 U	3.7 U
Trichloroethene	ug/kg	9910	19000		**120 J**	5 U	21 U	**4.8**	7.0 U	3.8 UJ	3.7 U	3.7 U
Vinyl Chloride	ug/kg	9210	17000		**10000 J**	5 U	10 U	2.7 U	3.4 U	1.8 U	1.8 U	1.8 U

Bold Indicates detected results.

Shading indicates KDHE screening level exceedence.

J = Estimated value

U = Compound was not detected

ug/kg = micrograms per kilogram

KDHE RSK at HQ=1 or TR=1E-05 (March, 2014)

USEPA Industrial Soil RSL at HQ=1 or Cancer TR=1E-05 (June, 2015)

RSK=Risk-based Standards (Kansas)

RSL=Regional Screening Levels

Table 3-5
Surface Water Sampling Analytical Results (Detections Only)
Remedial Investigation
Former Forbes Atlas S-5 Missile Site
Lyon County, Kansas

				Sample ID:	SW-01	SW-03	SW-04	SW-05	SW-06	DUP-1-SW
				Lab ID:	HS15050887-04	HS15050887-05	HS15050887-11	HS15050887-10	HS15050887-08	HS15050887-16
				Date Collected:	5/19/2015	5/19/2015	5/20/2015	5/20/2015	5/20/2015	5/20/2015
				Sample Description:	Sediment trap	Deep sump located at the missile erection area	Flame pit (within missile structure)	Missile erection area	Northwest room adjacent to the erection area	
		Screening Levels								Duplicate
Analyte	Units	EPA MCL	USEPA RSL Tapwater		Result	Result	Result	Result	Result	Result
cis-1,2-Dichloroethene	ug/L	70	36		**17**	**11**	**45**	0.50 U	0.50 U	0.50 U
Trichloroethene	ug/L	5	2.8		0.50 U	**1.4**	***50***	0.50 U	0.50 U	0.50 U
Vinyl Chloride	ug/L	2	0.19		***15***	***23***	***24***	0.50 U	0.50 U	0.50 U

				Sample ID:	SW-07	SW-08	SW-09	SW-10	SW-11
				Lab ID:	HS15050887-09	HS15050887-06	HS15050887-03	HS15050887-01	HS15050887-02
				Date Collected:	5/20/2015	5/19/2015	5/17/2015	5/14/2015	5/14/2015
				Sample Description:	Southeast corner adjacent to the erection area	Flame pit (outside the missile structure)	Radar antenna pit	Sewage lagoon	Sewage lagoon
		Screening Levels							
Analyte	Units	EPA MCL	USEPA RSL Tapwater		Result	Result	Result	Result	Result
cis-1,2-Dichloroethene	ug/L	70	36		0.50 U	0.50 U	0.50 U	0.50 U	0.50 U
Trichloroethene	ug/L	5	2.8		0.50 U	0.50 U	0.50 U	0.50 U	0.50 U
Vinyl Chloride	ug/L	2	0.19		0.50 U	0.50 U	0.50 U	0.50 U	0.50 U

Bold indicates detected results.
Italics indicates EPA MCL screening level exceedence.
Shaded indicates EPA RSL screening level exceedence.
J = Estimated value
U = Compound was not detected
ug/L = micrograms per liter
USEPA Residential Tapwater RSL at HQ=1 or Cancer TR=1E-05 (June, 2015)
MCL=Maximum contaminant level
RSL=Regional Screening Levels

Table 3-6
Monitoring Well Construction Table
Remedial Investigation
Former Forbes S-5 Atlas Missile Facility,
Lyon County, Kansas

Well Name	Well Ownership	Well Type	Date of Installation	Northing (feet)	Easting (feet)	TOC Elevation (feet amsl)	Top of Pad Elevation (feet amsl)	Ground Surface Elevation (feet amsl)	Depth to Top of Screen (feet below TOC)	Top of Screen Elevation (feet amsl)	Bottom of Screen Elevation (feet amsl)	Screen Length (feet)	Screen Size (inch)	Screened Unit	Total Depth (from TOC in feet)
MW-01D	USACE	Above grade	05/13/2015	2055491.8	1939416.7	1422.75	1420.78	1420.78	58.00	1364.75	1354.71	10.04	0.010	Threemile	68.39
MW-02D	USACE	Above grade	05/17/2015	2055059.6	1939681.9	1422.70	1419.47	1419.47	53.40	1369.30	1364.30	5.00	0.010	Threemile	58.63
MW-02S	USACE	Above grade	05/27/2015	2055056.3	1939686.3	1421.97	1419.42	1419.42	29.14	1392.83	1387.78	5.05	0.010	Schroyer	34.42
MW-03D	USACE	Above grade	06/02/2015	2055408.3	1939612.2	1418.65	1416.10	1416.10	52.09	1366.56	1361.56	5.00	0.010	Threemile	57.32
MW-03S	USACE	Above grade	06/09/2015	2055413.0	1939610.7	1418.29	1415.77	1415.77	25.23	1393.06	1388.06	5.00	0.010	Schroyer	30.47
MW-04D	USACE	Above grade	05/31/2015	2055271.2	1939320.4	1427.94	1425.46	1425.46	61.20	1366.74	1361.74	5.00	0.010	Threemile	66.57
MW-04S	USACE	Above grade	06/01/2015	2055265.7	1939320.3	1427.99	1425.50	1425.50	31.82	1396.17	1391.17	5.00	0.010	Schroyer	37.17
MW-05D	USACE	Above grade	05/30/2015	2055071.0	1939324.2	1427.32	1424.83	1424.83	59.14	1368.18	1363.18	5.00	0.010	Threemile	64.37
MW-06D	USACE	Above grade	05/16/2015	2054699.1	1939457.4	1415.65	1413.13	1413.13	46.23	1369.42	1364.37	5.05	0.010	Threemile	51.51
MW-06S	USACE	Above grade	05/29/2015	2054688.7	1939458.2	1415.34	1412.64	1412.64	18.35	1396.99	1391.99	5.00	0.010	Schroyer	23.57
MW-07S	USACE	Above grade	05/28/2015	2054899.7	1939549.2	1424.99	1422.42	1422.42	30.07	1394.92	1389.92	5.00	0.010	Schroyer	35.31
MW-08S	USACE	Above grade	06/03/2016	2055761.0	1939858.0	1407.62	1405.42	1405.42	17.80	1389.82	1384.77	5.05	0.020	Schroyer	23.07
MW-09S	USACE	Above grade	06/02/2016	2055592.1	1939571.1	1412.19	1410.11	1410.11	20.27	1391.92	1386.88	5.04	0.020	Schroyer	25.54
MW-10S	USACE	Above grade	05/24/2016	2055350.3	1939916.9	1412.92	1410.36	1410.36	19.68	1393.24	1388.24	5.00	0.020	Schroyer	24.83
MW-11S	USACE	Above grade	05/25/2016	2055079.8	1939892.4	1416.59	1413.67	1413.67	19.72	1396.87	1391.87	5.00	0.020	Schroyer	24.87
MW-12S	USACE	Above grade	05/26/2016	2054690.9	1939813.2	1418.05	1416.14	1416.14	16.94	1401.11	1391.11	10.00	0.020	Schroyer	27.09
MW-13S	USACE	Above grade	06/01/2016	2054694.5	1939287.6	1412.70	1410.35	1410.35	9.51	1403.19	1393.14	10.05	0.020	Schroyer	19.78

Easting and Northing are in Kansas State Plane South, Zone 1502, NAD 1983 Coordinate System; elevation in NAVD 1988 US Survey Feet.
MW = Monitoring Well
TOC = Top of Casing
Screens are factory slotted, schedule 40, 2-inch nominal inside diame amsl = above mean sea level
Threemile - Threemile limestone
Schroyer - Schroyer limestone

Table 3-7
IDW Inventory and Analytical Data Reports
Remedial Investigation
Forbes Atlas S-5 Missile Site
Lyon County, Kansas

Phase	IDW Soil	IDW Liquid	Location Generated/Comments	Sample Type Available	Sample Location ID for Applicable Analytical Data	Lab Batch ID For Data
Phase 1						
	Drums					
	2		MW-01D	IDW Soil Sample	IDW-S-MW-01D	HS15070430
	1		MW-02S & SB-04/MW-07S	Soil Boring Samples	SB-01	HS15050844
					SB-04	HS15051226
				IDW Soil Sample	IDW-S-SB-01	HS15070430
	1		MW-05D	IDW Soil Sample	IDW-S-MW-05D	HS15070430
	1		MW-06D	Soil Boring Sample	SB-08	HS15051234
	1		MW-07S, MW-06S, & MW-05D	Soil Boring Sample	SB-04	HS15051226
					SB-08	HS15051234
				IDW Soil Sample	IDW-S-MW-05D	HS15070430
	1		SB-05 & SB-06	Soil Boring Sample	SB-05	HS15050673
					SB-06	HS15050673
	1		SB-05R	Soil Boring Sample	SB-05	HS15050673
					SB-05R	HS15050681
	1		SB-02 & SB-03	Soil Boring Sample	SB-02	HS15050681
					SB-03	HS15050789
		1	MW-03S & MW-03D - Purge water	GW Sample Results	IDW-W-MW-03D/03S	HS15091086
					MW-03D, MW-03S	HS15070305
	1		MW-02D	Soil Boring Sample	SB-01	HS15050844
				IDW Soil Sample	IDW-S-SB-01	HS15070430
		1	MW-02S & MW-02D - Purge water	IDW and GW Sample	IDW-W-MW-02S	HS15070430, HS15091086
					MW-02S	HS15070362
					MW-02D	HS15070362
		7	MW-02S - Purge water	IDW and GW Sample	IDW-W-MW-02S	HS15070430, HS15091086
					MW-02S	HS15070362
	2		MW-03D	Soil Boring Sample	SB-09	HS15060159
	1		MW-03S	Soil Boring Sample	SB-09	HS15060159
	1		MW-04S	Soil Boring Sample	SB-10	HS15060149
	1		MW-04D	Soil Boring Sample	SB-10	HS15060149
	2		MW-04S & MW-04D	Soil Boring Sample	SB-10	HS15060149
	1		SB-07 & MW-02S	Soil Boring Sample	SB-07	HS15050789
					SB-01	HS15050844
				IDW Soil Sample	IDW-S-SB-01, IDW-S-SB-07	HS15070430
	1		MW-07S	Soil Boring Sample	SB-04	HS15051226
	Frac Tank					
		1	Drilling Fluid	IDW Waste Water	IDW-WW-052616	HS15050894
		1	Drilling Fluid	IDW Waste Water	IDW-WW-060916	HS15060428
		1	Drilling Fluid	IDW Waste Water	MW-10S, MW-11S, MW-12S	HS15050894
	1		Drilling Fuild Sediment	IDW Soil Sample	MW-08S through MW-13S	HS15060535
Phase 2						
	Drums					
	1		MW-8S	IDW Soil Sample	IDW-S-MW-8S	HS16070082
	1		MW-9S	IDW Soil Sample	IDW-S-MW-9S	HS16070082
	1		MW-10S	IDW Soil Sample	IDW-S-MW-10S	HS16070082
	1		MW-11S	IDW Soil Sample	IDW-S-MW-11S	HS16070082
	1		MW-12S	IDW Soil Sample	IDW-S-MW-12S/ SB-11	HS16070082, HS16051569
	1		MW-13S	IDW Soil Sample	IDW-S-MW-13S/ SB-12	HS16070082, HS16060142
		1	MW-08S through MW13SA	IDW Water Sample	IDW-W-MW-08S-13SA	HS16070015
		1	MW-08S through MW13SB	IDW Water Sample	IDW-W-MW-08S-13SB	HS16070015
	Poly Tank					
		1		IDW Waste Water	IDW-WW-IDW-052016	HS16051567
		1	Drilling Fluid	IDW Waste Water	IDW-WW-IDW-060316	1606080
	1		Drilling Fuild Sediment	IDW Soil Sample	MW-08S through MW-13S	HS15060535
	Total					
	27	**16**				

Table 3-8
Data Validation - VOC Completeness Summary
Remedial Investigation, Forbes S-5 Atlas Missile Site
Lyon County, Kansas

Event	Sample Type	VOC (8260 analysis) % Analytical Completeness (project goal of 98%)	VOC (8260 analysis) % Quality Completeness (project goal of 80%)
Round 1 May/July 2015	SW	100	100
	SD	86	100
	SB	95	100
	MW	66	94
September 2015	MW	100	100
December 2015	MW	100	100
Round 4 March 2016	MW	89	91
Round 5 May/June 2016	SB	95	100
	MW	76	99
September 2016	MW	96	96
December 2016	MW	96	99
Round 8 March 2017	MW	96	96

Notes:
SW = surface water
SB = soil boring
SD = sediment
MW = monitoring well
VOC = volatile organic compound

Table 3-9
Groundwater Sample Results (Collected July 2015)
Remedial Investigation, Former Forbes Atlas S-5 Missile Site
Lyon County, Kansas

		Sample ID:	Natural Attenuation	Natural Attenuation	MW-01D-01	MW-02S-01	MW-02D-01	MW-02D-11	MW-03S-01	MW-03S-11
		Lab ID:	Screening	Screening	HS15070362-05	HS15070362-01	HS15070362-02	HS15070362-03	HS15070305-01	HS15070305-02
		Date Collected:	(Wiedemier)	(Wiedemier)	7/8/2015	7/8/2015	7/8/2015	7/8/2015	7/7/2015	7/7/2015
		Screening Level	Favorable					Duplicate		Duplicate
Analyte	**Units**	**USEPA MCL**	**Concentration**	**Points****	**Result**	**Result**	**Result**	**Result**	**Result**	**Result**
cis-1,2-Dichloroethene	ug/L	70	Daughter	2	0.5 U	**4.3 J**	0.5 U	0.5 U	**0.44 J**	**0.46 J**
Trichloroethene	ug/L	5	Released	0	**0.25 J**	**65 J**	**0.92 J**	**0.65 J**	**4.6 J**	**4.5 J**
Vinyl Chloride	ug/L	2	Daughter	2	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Natural Attenuation Parameters										
Alkalinity as CaCO3	mg/L	NA	2 times background	1	**201**	**311**	**237**	**236**	**299**	**301**
Alkalinity, Bicarbonate (As CaCO3)	mg/L	NA	-	-	**201**	**311**	**237**	**236**	**299**	**301**
Alkalinity, Carbonate (As CaCO3)	mg/L	NA	-	-	5 U	5 U	5 U	5 U	5 U	5 U
Alkalinity, Hydroxide (As CaCO3)	mg/L	NA	-	-	5 U	5 U	5 U	5 U	5 U	5 U
Bromide	mg/L	NA	-	-	**0.476 J**	**0.383 J**	**0.397 J**	**0.401 J**	0.1 U	0.1 U
Chloride	mg/L	* 250	2 times background	2	**49.8**	**4.74**	**29.8**	**30**	**4.62**	**4.68**
Ethane	ug/L	NA	>10/>100 ug/L	2.0/3.0	**1.28**	**0.758**	**1.86**	**1.59**	**1.12**	**1.1**
Ethene	ug/L	NA	>10/>100 ug/L	2.0/3.0	**3.8**	**0.838**	**3.03**	**2.63**	**1.12**	**0.998**
Fluoride	mg/L	* 4	-	-	**0.802**	0.382 U	**1**	**1**	**0.332**	**0.361**
Methane	ug/L	NA	>100/1,000 ug/L	2.0/3.0	**4.21**	**0.519**	**7.95**	**8.28**	**1.28**	**0.758**
Nitrate As N	mg/L	10	<1 mg/L	2	0.1 U	0.264 U	0.1 U	0.1 U	**0.472**	**0.47**
Nitrate/Nitrite	mg/L	10	-	-	0.1 U	0.315 U	0.1 U	0.1 U	**0.524**	**0.521**
Nitrite As N	mg/L	1	-	-	0.1 U	**0.051**	0.1 U	0.1 U	**0.052**	**0.051**
Phosphorus	mg/L	NA	-	-	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	**0.223**
Sulfate	mg/L	* 250	<20 mg/L	2	**223**	**36.6**	**139**	**139**	**38.2**	**38.6**
Sulfide	mg/L	NA	>1 mg/L	3	0.3 U	**0.4**	**0.8**	**0.6**	0.3 U	0.3 U
pH	SU	* 6.5 to 8.5	5<pH<9	0	**6.68**	**5.91**	**7.13**	**NA**	**7.32**	**NA**
Temperature	°C	NA	>20 C	1	**18.50**	**14.73**	**16.90**	**NA**	**15.76**	**NA**
Oxidation-Reduction Potential	mV	NA	< 50 mv/<-100 mv	1.0/2.0	**-21.0**	**19.3**	**-18.3**	**NA**	**-34.9**	**NA**
Disolved Oxygen	mg/L	NA	<0.5 />1 mg/L	3.0/-3.0	**1.49**	**1.01**	**1.15**	**NA**	**1.22**	**NA**
Ferrous iron	mg/L	0.3 for total iron	>1 mg/L	3	**0.1**	ND	**0.1**	**NA**	ND	**NA**
Natural Biodegradation Scoring					**0**	**2**	**0**		**2**	
Other Parameters										
Conductivity	mmhos/cm	NA			**0.893**	**0.520**	**0.897**	**NA**	**0.570**	**NA**
Turbidity	NTUs	NA			**5.27**	**2.33**	**9.05**	**NA**	**3.02**	**NA**
Depth to water	ft TOC	NA			**48.99**	**20.15**	**44.20**	**NA**	**19.96**	**NA**

D = Deep well
J = Estimated value
mg/L = milligrams per liter
MCL = Maximum contaminant level from May 2016 EPA RSL Table.
* = Secondary MCL
mmhos/com = milli mhos per centimeter
mV = millivolts
NTU = Nephelometric Turbidity Unit
S = Shallow well
U = Compound was not detected
ug/L = micrograms per liter
Bold indicates detected results.
Dark gray shading indicates screening level exceedance for VOCs.
- = No natural attenuation criteria

** - Equals points assignment for determining favorable conditions for biodegradation
0-5 = Inadequate
6-14 = Limited Evidense
15-20 = Adequate Evidense
>20 = Strong Evidense
Light gray shading indicates evidence for biodegradation

Table 3-9
Groundwater Sample Results (Collected July 2015)
Remedial Investigation, Former Forbes Atlas S-5 Missile Site
Lyon County, Kansas

Analyte	Units	Screening Level USEPA MCL	Natural Attenuation Screening (Wiedemier) Favorable Concentration	Natural Attenuation Screening (Wiedemier) Points**	MW-03D-01 HS15070305-03 7/7/2015 Result	MW-04S-01 HS15070428-01 7/9/2015 Result	MW-04D-01 HS15070428-02 7/9/2015 Result	MW-05D-01 HS15070305-05 7/7/2015 Result	MW-06S-01 HS15070362-04 7/8/2015 Result
cis-1,2-Dichloroethene	ug/L	70	Daughter	2	0.5 U	0.5 U	0.5 U	0.5 U	**0.81 J**
Trichloroethene	ug/L	5	Released	0	0.5 U	0.5 U	0.5 U	0.5 U	**24 J**
Vinyl Chloride	ug/L	2	Daughter	2	0.5 U	0.5 UJ	0.5 UJ	0.5 U	0.5 U
Natural Attenuation Parameters									
Alkalinity as CaCO3	mg/L	NA	2 times background	1	**143**	**215**	**183**	**184**	**368**
Alkalinity, Bicarbonate (As CaCO3)	mg/L	NA	-	-	**143**	**215**	**183**	**184**	**368**
Alkalinity, Carbonate (As CaCO3)	mg/L	NA	-	-	5 U	5 U	5 U	5 U	5 U
Alkalinity, Hydroxide (As CaCO3)	mg/L	NA	-	-	5 U	5 U	5 U	5 U	5 U
Bromide	mg/L	NA	-	-	**0.385**	**0.426**	**0.397**	**0.429**	**0.376 J**
Chloride	mg/L	* 250	2 times background	2	**25.8**	**32.8**	**24.2**	**35.4**	**2.98**
Ethane	ug/L	NA	>10/>100 ug/L	2.0/3.0	0.361 U	**1.701**	**0.777**	**0.795**	**0.896**
Ethene	ug/L	NA	>10/>100 ug/L	2.0/3.0	**4.08**	**3.721**	**2.26**	**4.19**	**0.789**
Fluoride	mg/L	* 4	-	-	**0.824**	**0.648**	**1.01**	**0.974**	0.225 U
Methane	ug/L	NA	>100/1,000 ug/L	2.0/3.0	**2.77**	**3.196**	**1.5**	**3.77**	**0.351**
Nitrate As N	mg/L	10	<1 mg/L	2	**0.161**	0.129 U	0.1 U	**0.124**	0.456 U
Nitrate/Nitrite	mg/L	10	-	-	**0.196**	0.129 U	0.1 U	**0.124**	0.456 U
Nitrite As N	mg/L	1	-	-	**0.035**	0.1 U	0.1 U	0.1 U	0.1 U
Phosphorus	mg/L	NA	-	-	0.1 U	0.1 UJ	**0.152 J**	**0.141**	0.1 U
Sulfate	mg/L	* 250	<20 mg/L	2	**99.7**	**77.8**	**178**	**162**	**41.6**
Sulfide	mg/L	NA	>1 mg/L	3	0.3 U	**6**	**1**	0.3 U	**0.8**
pH	SU	* 6.5 to 8.5	5<pH<9	0	**6.77**	**7.49**	**6.5**	**7.64**	**6.94**
Temperature	°C	NA	>20 C	1	**15.59**	**20.05**	**24.11**	**17.09**	**16.28**
Oxidation-Reduction Potential	mV	NA	< 50 mv/<-100 mv	1.0/2.0	**-26.3**	**-7.5**	**-70.8**	**-38.1**	**-15.5**
Disolved Oxygen	mg/L	NA	<0.5 />1 mg/L	3.0/-3.0	**2.42**	**1.99**	**1.57**	**1.53**	**1.84**
Ferrous iron	mg/L	0.3 for total iron	>1 mg/L	3	ND	ND	ND	**0.1**	ND
Natural Biodegradation Scoring					**0**	**4**	**1**	**0**	**2**
Other Parameters									
Conductivity	mmhos/cm	NA			**0.504**	**0.580**	**0.867**	**0.904**	**0.618**
Turbidity	NTUs	NA			**12.9**	**256**	**20.0**	**21.3**	**9.5**
Depth to water	ft TOC	NA			**45.64**	**29.53**	**53.51**	**51.94**	**11.45**

D = Deep well
J = Estimated value
mg/L = milligrams per liter
MCL = Maximum contaminant level from May 2016 EPA RSL Table.
* = Secondary MCL
mmhos/com = milli mhos per centimeter
mV = millivolts
NTU = Nephelometric Turbidity Unit
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U = Compound was not detected
ug/L = micrograms per liter
Bold indicates detected results.
Dark gray shading indicates screening level exceedance for VOCs.
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Light gray shading indicates evidence for biodegradation

Table 3-9
Groundwater Sample Results (Collected July 2015)
Remedial Investigation, Former Forbes Atlas S-5 Missile Site
Lyon County, Kansas

Analyte	Units	Screening Level USEPA MCL	Natural Attenuation Screening (Wiedemier) Favorable Concentration	Natural Attenuation Screening (Wiedemier) Points**	MW-06D-01 HS15070230-01 7/6/2015 Result	MW-07S-01 HS15070305-04 7/7/2015 Result
cis-1,2-Dichloroethene	ug/L	70	Daughter	2	0.5 U	0.5 U
Trichloroethene	ug/L	5	Released	0	0.5 U	**1.9 J**
Vinyl Chloride	ug/L	2	Daughter	2	0.5 U	0.5 U
Natural Attenuation Parameters						
Alkalinity as CaCO3	mg/L	NA	2 times background	1	**245**	**313**
Alkalinity, Bicarbonate (As CaCO3)	mg/L	NA	-	-	**245**	**313**
Alkalinity, Carbonate (As CaCO3)	mg/L	NA	-	-	5 U	5 U
Alkalinity, Hydroxide (As CaCO3)	mg/L	NA	-	-	5 U	5 U
Bromide	mg/L	NA	-	-	**0.383**	0.1 U
Chloride	mg/L	* 250	2 times background	2	**22.6**	**4.13**
Ethane	ug/L	NA	>10/>100 ug/L	2.0/3.0	**2.38**	**0.985**
Ethene	ug/L	NA	>10/>100 ug/L	2.0/3.0	**2.47**	**1.13**
Fluoride	mg/L	* 4	-	-	**1.03**	**0.291**
Methane	ug/L	NA	>100/1,000 ug/L	2.0/3.0	**14.4**	**1.02**
Nitrate As N	mg/L	10	<1 mg/L	2	**0.13**	**0.139**
Nitrate/Nitrite	mg/L	10	-	-	**0.13**	**0.139**
Nitrite As N	mg/L	1	-	-	0.1 U	0.1 U
Phosphorus	mg/L	NA	-	-	0.1 U	0.1 U
Sulfate	mg/L	* 250	<20 mg/L	2	**112**	**29.5**
Sulfide	mg/L	NA	>1 mg/L	3	**1.04**	0.3 U
pH	SU	* 6.5 to 8.5	5<pH<9	0	**7.51**	**7.15**
Temperature	°C	NA	>20 C	1	**26.71**	**15.33**
Oxidation-Reduction Potential	mV	NA	< 50 mv/<-100 mv	1.0/2.0	**-18.2**	**-27.0**
Disolved Oxygen	mg/L	NA	<0.5 />1 mg/L	3.0/-3.0	**1.84**	**0.80**
Ferrous iron	mg/L	0.3 for total iron	>1 mg/L	3	ND	ND
Natural Biodegradation Scoring					**4**	**3**
Other Parameters						
Conductivity	mmhos/cm	NA			**0.744**	**0.503**
Turbidity	NTUs	NA			**9.5**	**15.8**
Depth to water	ft TOC	NA			**33.6**	**23.12**

D = Deep well
J = Estimated value
mg/L = milligrams per liter
MCL = Maximum contaminant level from May 2016 EPA RSL Table.
* = Secondary MCL
mmhos/com = milli mhos per centimeter
mV = millivolts
NTU = Nephelometric Turbidity Unit
S = Shallow well
U = Compound was not detected
ug/L = micrograms per liter
Bold indicates detected results.
Dark gray shading indicates screening level exceedance for VOCs.
- = No natural attenuation criteria

** - Equals points assignment for determining favorable conditions for biodegradation.
0-5 = Inadequate
6-14 = Limited Evidense
15-20 = Adequate Evidense
>20 = Strong Evidense
Light gray shading indicates evidence for biodegradation.

Table 3-10
Groundwater Sample Results (Collected September 2015)
Remedial Investigation, Former Forbes Atlas S-5 Missile Site
Lyon County, Kansas

Analyte	Units	Screening Level USEPA MCL	Natural Attenuation Screening (Wiedemier) Favorable Concentration	Natural Attenuation Screening (Wiedemier) Points**	MW-01D-02 HS15091050-02 9/23/2015 Result	MW-02S-02 HS15091050-05 9/23/2015 Result	MW-02D-02 HS15091050-03 9/23/2015 Result	MW-02D-12 HS15091050-04 9/23/2015 Duplicate Result	MW-03S-02 HS15090927-02 9/21/2015 Result	MW-03S-12 HS15090927-03 9/21/2015 Duplicate Result
cis-1,2-Dichloroethene	ug/L	70	Daughter	2	0.5 U	**5.5**	0.5 U	0.5 U	**1.1**	**0.96 J**
Trichloroethene	ug/L	5	Released	0	0.5 U	**95**	0.5 U	0.5 U	**5.4**	**5.3**
Vinyl Chloride	ug/L	2	Daughter	2	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Natural Attenuation Parameters										
Alkalinity as CaCO3	mg/L	NA	2 times background	1	**244**	**345**	**282**	**282**	**330**	**329**
Alkalinity, Bicarbonate (As CaCO3)	mg/L	NA	-	-	**244**	**345**	**282**	**282**	**330**	**329**
Alkalinity, Carbonate (As CaCO3)	mg/L	NA	-	-	5 U	5 U	5 U	5 U	5 U	5 U
Alkalinity, Hydroxide (As CaCO3)	mg/L	NA	-	-	5 U	5 U	5 U	5 U	5 U	5 U
Bromide	mg/L	NA	-	-	**0.171 J**	**0.113 J**	**0.094 J**	**0.091 J**	0.05 UJ	0.05 UJ
Chloride	mg/L	* 250	2 times background	2	**64.3 J**	9.86 UJ	**30.2 J**	**30.3 J**	**3.81**	**3.71**
Ethane	ug/L	NA	>10/>100 ug/L	2.0/3.0	0.361 U	0.361 UJ	0.361 U	0.361 U	0.361 U	0.361 U
Ethene	ug/L	NA	>10/>100 ug/L	2.0/3.0	**1.87**	0.337 UJ	**1.06**	**0.911 J**	0.337 U	**0.746 J**
Fluoride	mg/L	* 4	-	-	**1.29 J**	0.484 UJ	**1.33 J**	**1.3 J**	**0.413 J**	**0.418 J**
Methane	ug/L	NA	>100/1,000 ug/L	2.0/3.0	**1.65**	0.2 UJ	**3.51**	**4.06**	0.2 U	0.2 U
Nitrate as N	mg/L	10	<1 mg/L	2	0.05 U	0.072 U	**0.056 J**	**0.099 J**	**0.33**	**0.349**
Nitrate/Nitrite	mg/L	10	-	-	**0.046 J**	0.072 U	**0.056 J**	**0.099 J**	**0.33**	**0.349**
Nitrite as N	mg/L	1	-	-	**0.046 J**	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U
Phosphorus	mg/L	NA	-	-	0.058 U	0.058 U	0.058 U	0.058 U	0.058 U	0.058 U
Sulfate	mg/L	* 250	<20 mg/L	2	**300**	**48.6**	**124**	**110**	**40.8**	**42**
Sulfide	mg/L	NA	>1 mg/L	3	**1.8 J**	**16.2 J**	0.3 UJ	0.3 UJ	**1.8**	**2.2**
pH	SU	* 6.5 to 8.5	5<pH<9	0	**5.6**	**5.55**	**6.02**	NA	**5.61**	NA
Temperature	°C	NA	>20 C	1	**21.73**	**18.15**	**23.58**	NA	**22.95**	NA
Oxidation-Reduction Potential	mV	NA	< 50 mv/<-100 mv	1.0/2.0	**11.7**	**63.4**	**17.8**	NA	**36.9**	NA
Disolved Oxygen	mg/L	NA	<0.5 />1 mg/L	3.0/-3.0	**1.8**	**0.9**	**2.5**	NA	**1.62**	NA
Ferrous iron	mg/L	0.3 for total iron	>1 mg/L	3	**0.6**	**0.1**	**0.1**	NA	**0.2**	NA
Natural Biodegradation Scoring					**4**	**7**	**1**		**6**	
Other Parameters										
Conductivity	mmhos/cm	NA			**1.186**	**0.631**	**0.347**	NA	**0.708**	NA
Turbidity	NTUs	NA			**23.2**	**3.19**	**3.2**	NA	**25.1**	NA
Depth to water	ft TOC	NA			**50.7**	**25.45**	**46.6**	NA	**23.76**	NA

D = Deep well
J = Estimated value
mg/L = milligrams per liter
MCL = Maximum contaminant level from May 2016 EPA RSL Table.
* = Secondary MCL
mmhos/com = milli mhos per centimeter
mV = millivolts
NTU = Nephelometric Turbidity Unit
S = Shallow well
U = Compound was not detected
ug/L = micrograms per liter
Bold indicates detected results.
Dark gray shading indicates screening level exceedance for VOCs.
- = No natural attenuation criteria

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>20 = Strong Evidense
Light gray shading indicates evidence for biodegradation

Table 3-10
Groundwater Sample Results (Collected September 2015)
Remedial Investigation, Former Forbes Atlas S-5 Missile Site
Lyon County, Kansas

Analyte	Units	Screening Level USEPA MCL	Natural Attenuation Screening (Wiedemier) Favorable Concentration	Natural Attenuation Screening (Wiedemier) Points**	MW-03D-02 HS15090927-01 9/21/2015 Result	MW-04S-02 HS15090989-04 9/22/2015 Result	MW-04D-02 HS15090989-03 9/22/2015 Result	MW-05D-02 HS15090989-02 9/22/2015 Result	MW-06S-02 HS15090989-05 9/22/2015 Result
cis-1,2-Dichloroethene	ug/L	70	Daughter	2	0.5 U	0.5 U	0.5 U	0.5 U	**0.82 J**
Trichloroethene	ug/L	5	Released	0	0.5 U	0.5 U	0.5 U	0.5 U	**25**
Vinyl Chloride	ug/L	2	Daughter	2	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Natural Attenuation Parameters									
Alkalinity as CaCO3	mg/L	NA	2 times background	1	**174**	**299**	**297**	**219**	**368**
Alkalinity, Bicarbonate (As CaCO3)	mg/L	NA	-	-	**174**	**299**	**297**	**219**	**368**
Alkalinity, Carbonate (As CaCO3)	mg/L	NA	-	-	5 U	5 U	5 U	5 U	5 U
Alkalinity, Hydroxide (As CaCO3)	mg/L	NA	-	-	5 U	5 U	5 U	5 U	5 U
Bromide	mg/L	NA	-	-	**0.119 J**	**0.329 J**	**0.125 J**	**0.151 J**	**0.1 J**
Chloride	mg/L	* 250	2 times background	2	**43**	**64.5 J**	**39.1 J**	**48.9 J**	**3.11 J**
Ethane	ug/L	NA	>10/>100 ug/L	2.0/3.0	0.361 U	**0.754 J**	0.361 U	0.361 U	0.361 U
Ethene	ug/L	NA	>10/>100 ug/L	2.0/3.0	**1.25**	**1.78**	**2.12**	**2.27**	0.337 U
Fluoride	mg/L	* 4	-	-	**1.11 J**	**0.608 J**	**1.02 J**	**1.08 J**	**0.397 J**
Methane	ug/L	NA	>100/1,000 ug/L	2.0/3.0	**0.289 J**	**0.905**	**1.58**	**1.62**	0.2 U
Nitrate as N	mg/L	10	<1 mg/L	2	**0.053 J**	**0.096 J**	0.05 U	**0.141**	**0.332**
Nitrate/Nitrite	mg/L	10	-	-	**0.093 J**	**0.096 J**	0.1 U	**0.141**	**0.332**
Nitrite as N	mg/L	1	-	-	**0.04 J**	0.05 U	0.05 U	0.05 U	0.05 U
Phosphorus	mg/L	NA	-	-	0.058 U	0.058 U	0.058 U	0.058 U	0.058 U
Sulfate	mg/L	* 250	<20 mg/L	2	**170**	**394**	**248**	**291**	**50.4**
Sulfide	mg/L	NA	>1 mg/L	3	**5**	**1.6**	**4.4**	**1.8**	0.4 U
pH	SU	* 6.5 to 8.5	5<pH<9	0	**4.85**	**7.07**	**6.18**	**6.23**	**7.14**
Temperature	°C	NA	>20 C	1	**20.47**	**21.2**	**30.3**	**23.87**	**21.23**
Oxidation-Reduction Potential	mV	NA	< 50 mv/<-100 mv	1.0/2.0	**7.7**	**-91.6**	**-27.9**	**-54.6**	**-9.3**
Disolved Oxygen	mg/L	NA	<0.5 />1 mg/L	3.0/-3.0	**1.6**	**0.9**	**2.62**	**2.58**	**0.95**
Ferrous iron	mg/L	0.3 for total iron	>1 mg/L	3	**0.4**	**0.9**	**1.1**	**0.7**	**0.2**
Natural Biodegradation Scoring					**4**	**7**	**7**	**4**	**6**
Other Parameters									
Conductivity	mmhos/cm	NA			**0.79**	**1.497**	**1.369**	**1.216**	**0.72**
Turbidity	NTUs	NA			**15.7**	**49**	**38**	**18**	**17.6**
Depth to water	ft TOC	NA			**46.65**	**32.64**	**53.79**	**53.86**	**18.16**

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mV = millivolts
NTU = Nephelometric Turbidity Unit
S = Shallow well
U = Compound was not detected
ug/L = micrograms per liter
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Light gray shading indicates evidence for biodegradation

Table 3-10
Groundwater Sample Results (Collected September 2015)
Remedial Investigation, Former Forbes Atlas S-5 Missile Site
Lyon County, Kansas

Analyte	Units	Screening Level USEPA MCL	Natural Attenuation Screening (Wiedemier) Favorable Concentration	Natural Attenuation Screening (Wiedemier) Points**	MW-06D-02 HS15091050-01 9/23/2015 Result	MW-07S-02 HS15090989-01 9/22/2015 Result
cis-1,2-Dichloroethene	ug/L	70	Daughter	2	0.5 U	0.5 U
Trichloroethene	ug/L	5	Released	0	**0.42 J**	**4.5**
Vinyl Chloride	ug/L	2	Daughter	2	0.5 U	0.5 U
Natural Attenuation Parameters						
Alkalinity as CaCO3	mg/L	NA	2 times background	1	**276**	**308**
Alkalinity, Bicarbonate (As CaCO3)	mg/L	NA	-	-	**276**	**308**
Alkalinity, Carbonate (As CaCO3)	mg/L	NA	-	-	5 U	5 U
Alkalinity, Hydroxide (As CaCO3)	mg/L	NA	-	-	5 U	5 U
Bromide	mg/L	NA	-	-	**0.096 J**	0.05 UJ
Chloride	mg/L	* 250	2 times background	2	**20.7 J**	**5.44 J**
Ethane	ug/L	NA	>10/>100 ug/L	2.0/3.0	**0.93 J**	**1.05**
Ethene	ug/L	NA	>10/>100 ug/L	2.0/3.0	**1.58**	**3.34**
Fluoride	mg/L	* 4	-	-	**1.08 J**	**0.368 J**
Methane	ug/L	NA	>100/1,000 ug/L	2.0/3.0	**0.898**	**1.68**
Nitrate as N	mg/L	10	<1 mg/L	2	**0.144**	**0.065 J**
Nitrate/Nitrite	mg/L	10	-	-	**0.176**	**0.065 J**
Nitrite as N	mg/L	1	-	-	**0.032 J**	0.05 U
Phosphorus	mg/L	NA	-	-	0.058 U	0.058 U
Sulfate	mg/L	* 250	<20 mg/L	2	**142**	**36.3**
Sulfide	mg/L	NA	>1 mg/L	3	0.3 UJ	0.3 U
pH	SU	* 6.5 to 8.5	5<pH<9	0	**7.32**	**7.28**
Temperature	°C	NA	>20 C	1	**19.3**	**21.37**
Oxidation-Reduction Potential	mV	NA	< 50 mv/<-100 mv	1.0/2.0	**10.7**	**-23.8**
Disolved Oxygen	mg/L	NA	<0.5 />1 mg/L	3.0/-3.0	**2.4**	**2.22**
Ferrous iron	mg/L	0.3 for total iron	>1 mg/L	3	**0**	**0.3**
Natural Biodegradation Scoring					**0**	**1**
Other Parameters						
Conductivity	mmhos/cm	NA			**0.763**	**0.607**
Turbidity	NTUs	NA			**6**	**27.9**
Depth to water	ft TOC	NA			**32.61**	**27.98**

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mg/L = milligrams per liter
MCL = Maximum contaminant level from May 2016 EPA RSL Table.
* = Secondary MCL
mmhos/com = milli mhos per centimeter
mV = millivolts
NTU = Nephelometric Turbidity Unit
S = Shallow well
U = Compound was not detected
ug/L = micrograms per liter
Bold indicates detected results.
Dark gray shading indicates screening level exceedance for VOCs.
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Table 3-11
Groundwater Sample Results (Collected December 2015)
Remedial Investigation, Former Forbes Atlas S-5 Missile Site
Lyon County, Kansas

		Sample ID:	Natural Attenuation	Natural Attenuation	MW-01D-03	MW-02S-03	MW-02D-03	MW-02D-13	MW-03S-03	MW-03S-13
		Lab ID:	Screening	Screening	HS15120645-04	HS15120645-03/ HS15120645-03DUP	HS15120645-01	HS15120645-02	HS15120573-02	HS15120573-03
		Date Collected:	(Wiedemier)	(Wiedemier)	12/15/2015	12/15/2015	12/15/2015	12/15/2015	12/14/2015	12/14/2015
		Screening Level	Favorable	Points**				Duplicate		Duplicate
Analyte	Units	USEPA MCL	Concentration		Result	Result	Result	Result	Result	Result
cis-1,2-Dichloroethene	ug/L	70	Daughter	2	0.62 U	**6.5**	0.62 U	0.62 U	0.62 U	0.62 U
Trichloroethene	ug/L	5	Released	0	0.62 U	**80**	0.62 U	0.62 U	**5.9**	**5.8**
Vinyl Chloride	ug/L	2	Daughter	2	0.62 U	0.62 U	0.62 U	0.62 U	0.62 U	0.62 U
Natural Attenuation Parameters										
Alkalinity as CaCO3	mg/L	NA	2 times background	1	**381**	**350.8**	**281**	**281**	**311**	**315**
Alkalinity, Bicarbonate (As CaCO3)	mg/L	NA	-	-	**381**	**350.8**	**281**	**281**	**311**	**315**
Alkalinity, Carbonate (As CaCO3)	mg/L	NA	-	-	5 U	5 U	5 U	5 U	5 U	5 U
Alkalinity, Hydroxide (As CaCO3)	mg/L	NA	-	-	5 U	5 U	5 U	5 U	5 U	5 U
Bromide	mg/L	NA	-	-	0.1 UJ	**0.123 J**	**0.09 J**	**0.097 J**	0.1 UJ	0.1 UJ
Chloride	mg/L	* 250	2 times background	2	**66.5**	**5.04**	**24.9**	**25.7**	**2.1**	**2.27**
Ethane	ug/L	NA	>10/>100 ug/L	2.0/3.0	0.361 U	0.361 U	0.361 U	0.361 U	0.361 U	0.361 U
Ethene	ug/L	NA	>10/>100 ug/L	2.0/3.0	0.337 U	0.337 U	0.337 U	0.337 U	0.337 U	0.337 U
Fluoride	mg/L	* 4	-	-	**0.906**	**0.443**	**1.19**	**1.27**	**0.409**	**0.415**
Methane	ug/L	NA	>100/1,000 ug/L	2.0/3.0	0.2 U	**0.426 J**	**1.32**	**3.03**	0.2 U	0.2 U
Nitrate as N	mg/L	10	<1 mg/L	2	0.1 U	**0.123**	0.1 U	0.1 U	**0.683**	**0.645**
Nitrate/Nitrite	mg/L	10	-	-	0.1 U	**0.123**	**0.08 J**	**0.079 J**	**0.683**	**0.645**
Nitrite as N	mg/L	1	-	-	0.1 U	0.1 U	**0.08 J**	**0.079 J**	0.1 U	0.1 U
Phosphorus	mg/L	NA	-	-	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Sulfate	mg/L	* 250	<20 mg/L	2	**340**	**47.8**	**117**	**116**	**31.7**	**32.7**
Sulfide	mg/L	NA	>1 mg/L	3	**3.08**	**0.68**	**2.08**	**0.88**	**0.88**	**1.68**
pH	SU	* 6.5 to 8.5	5<pH<9	0	**6.79**	**6.03**	**7.29**	NA	**6.9**	NA
Temperature	°C	NA	>20 C	1	**13.15**	**12.32**	**10.75**	NA	**12.33**	NA
Oxidation-Reduction Potential	mV	NA	< 50 mv/<-100 mv	1.0/2.0	**-47.6**	**40.9**	**-39.6**	NA	**-9**	NA
Dissolved Oxygen	mg/L	NA	<0.5 />1 mg/L	3.0/-3.0	**0.76**	**0.7**	**1.14**	NA	**0.66**	NA
Ferrous iron	mg/L	0.3 for total iron	>1 mg/L	3	NS	NS	NS	NS	NS	NS
Natural Biodegradation Scoring					**6**	**5**	**3**		**3**	
Other Parameters										
Conductivity	mmhos/cm	NA			**1.71**	**0.792**	**0.852**	NA	**0.747**	NA
Turbidity	NTUs	NA			**18.5**	**1.43**	**8.09**	NA	**8.04**	NA
Depth to water	ft TOC	NA			**50.55**	**24.57**	**47.56**	NA	**22.87**	NA

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mg/L = milligrams per liter
MCL = Maximum contaminant level from May 2016 EPA RSL Table.
* = Secondary MCL
mmhos/com = milli mhos per centimeter
mV = millivolts
NS = Not Sampled
NTU = Nephelometric Turbidity Unit
S = Shallow well
U = Compound was not detected
ug/L = micrograms per liter
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Table 3-11
Groundwater Sample Results (Collected December 2015)
Remedial Investigation, Former Forbes Atlas S-5 Missile Site
Lyon County, Kansas

		Sample ID:	Natural Attenuation	Natural Attenuation	MW-03D-03	MW-04S-03	MW-04D-03	MW-05D-03	MW-06S-03
		Lab ID:	Screening	Screening	HS15120573-01	HS15120645-06	HS15120645-05	HS15120703-01	HS15120703-03
		Date Collected:	(Wiedemier)	(Wiedemier)	12/14/2015	12/15/2015	12/15/2015	12/16/2015	12/16/2015
		Screening Level	Favorable	Points**					
Analyte	**Units**	**USEPA MCL**	**Concentration**		**Result**	**Result**	**Result**	**Result**	**Result**
cis-1,2-Dichloroethene	ug/L	70	Daughter	2	0.62 U	0.62 U	0.62 U	0.62 U	0.62 U
Trichloroethene	ug/L	5	Released	0	0.62 U	0.62 U	0.62 U	0.62 U	**21**
Vinyl Chloride	ug/L	2	Daughter	2	0.62 U	0.62 U	0.62 U	0.62 U	0.62 U
Natural Attenuation Parameters									
Alkalinity as CaCO3	mg/L	NA	2 times background	1	**242**	**305**	**406**	**281**	**375**
Alkalinity, Bicarbonate (As CaCO3)	mg/L	NA	-	-	**242**	**305**	**406**	**281**	**375**
Alkalinity, Carbonate (As CaCO3)	mg/L	NA	-	-	5 U	5 U	5 U	5 U	5 U
Alkalinity, Hydroxide (As CaCO3)	mg/L	NA	-	-	5 U	5 U	5 U	5 U	5 U
Bromide	mg/L	NA	-	-	**0.164 J**	**0.124 J**	**0.114 J**	0.1 U	**0.091 J**
Chloride	mg/L	* 250	2 times background	2	**53.1**	**27.8**	**46.2**	**56.7**	**2.79**
Ethane	ug/L	NA	>10/>100 ug/L	2.0/3.0	0.361 U	0.361 U	**1.34**	0.361 U	0.361 U
Ethene	ug/L	NA	>10/>100 ug/L	2.0/3.0	**5.84**	0.337 U	**5.9**	**6.25**	0.337 U
Fluoride	mg/L	* 4	-	-	**1.03**	**0.573**	**0.938**	**1.02**	**0.342**
Methane	ug/L	NA	>100/1,000 ug/L	2.0/3.0	**4.63**	0.2 U	**8.65**	**4.1**	0.2 U
Nitrate as N	mg/L	10	<1 mg/L	2	0.1 U	0.1 U	0.1 U	0.1 U	**0.585**
Nitrate/Nitrite	mg/L	10	-	-	0.1 U	0.1 U	0.1 U	0.1 U	**0.585**
Nitrite as N	mg/L	1	-	-	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Phosphorus	mg/L	NA	-	-	0.1 U	**0.341**	0.1 U	**0.274**	0.1 U
Sulfate	mg/L	* 250	<20 mg/L	2	**257**	**154**	**255**	**348**	**54.8**
Sulfide	mg/L	NA	>1 mg/L	3	**0.88**	0.3 U	**3.28**	**2.28**	**1.48**
pH	SU	* 6.5 to 8.5	5<pH<9	0	**6.01**	**7.15**	**6.57**	**6.37**	**6.83**
Temperature	°C	NA	>20 C	1	**9.99**	**14.85**	**15.93**	**7.12**	**11.95**
Oxidation-Reduction Potential	mV	NA	< 50 mv/<-100 mv	1.0/2.0	**16.2**	**-90.9**	**-56.2**	**-41.6**	**1.2**
Dissolved Oxygen	mg/L	NA	<0.5 />1 mg/L	3.0/-3.0	**0.83**	**0.75**	**1.02**	**1.29**	**3.65**
Ferrous iron	mg/L	0.3 for total iron	>1 mg/L	3	NS	NS	NS	NS	NS
Natural Biodegradation Scoring					**3**	**3**	**3**	**3**	**3**
Other Parameters									
Conductivity	mmhos/cm	NA			**1.232**	**1.08**	**1.626**	**1.483**	**0.889**
Turbidity	NTUs	NA			**11.3**	**259**	**92.9**	**7.28**	**15.7**
Depth to water	ft TOC	NA			**48.65**	**33.2**	**54.96**	**55.09**	**17.19**

D = Deep well
J = Estimated value
mg/L = milligrams per liter
MCL = Maximum contaminant level from May 2016 EPA RSL Table.
* = Secondary MCL
mmhos/com = milli mhos per centimeter
mV = millivolts
NS = Not Sampled
NTU = Nephelometric Turbidity Unit
S = Shallow well
U = Compound was not detected
ug/L = micrograms per liter
Bold indicates detected results.
Dark gray shading indicates screening level exceedance for VOCs.
- = No natural attenuation criteria

** - Equals points assignment for determining favorable conditions for biodegradation
0-5 = Inadequate
6-14 = Limited Evidense
15-20 = Adequate Evidense
>20 = Strong Evidense
Light gray shading indicates evidence for biodegradation

Table 3-11
Groundwater Sample Results (Collected December 2015)
Remedial Investigation, Former Forbes Atlas S-5 Missile Site
Lyon County, Kansas

		Sample ID:	Natural Attenuation	Natural Attenuation	MW-06D-03	MW-07S-03
		Lab ID:	Screening	Screening	HS15120703-02	HS15120573-04
		Date Collected:	(Wiedemier)	(Wiedemier)	12/16/2015	12/14/2015
Analyte	Units	Screening Level USEPA MCL	Favorable Concentration	Points**	Result	Result
cis-1,2-Dichloroethene	ug/L	70	Daughter	2	0.62 U	0.62 U
Trichloroethene	ug/L	5	Released	0	0.62 U	**4.1**
Vinyl Chloride	ug/L	2	Daughter	2	0.62 U	0.62 U
Natural Attenuation Parameters						
Alkalinity as CaCO3	mg/L	NA	2 times background	1	**286**	**320**
Alkalinity, Bicarbonate (As CaCO3)	mg/L	NA	-	-	**286**	**320**
Alkalinity, Carbonate (As CaCO3)	mg/L	NA	-	-	5 U	5 U
Alkalinity, Hydroxide (As CaCO3)	mg/L	NA	-	-	5 U	5 U
Bromide	mg/L	NA	-	-	0.1 U	0.1 UJ
Chloride	mg/L	* 250	2 times background	2	**19.8**	**2.73**
Ethane	ug/L	NA	>10/>100 ug/L	2.0/3.0	**1.43**	0.361 U
Ethene	ug/L	NA	>10/>100 ug/L	2.0/3.0	**4.3**	**1.39**
Fluoride	mg/L	* 4	-	-	**1.04**	**0.34**
Methane	ug/L	NA	>100/1,000 ug/L	2.0/3.0	**9.09**	**0.637**
Nitrate as N	mg/L	10	<1 mg/L	2	0.1 U	**0.096 J**
Nitrate/Nitrite	mg/L	10	-	-	0.1 U	**0.096 J**
Nitrite as N	mg/L	1	-	-	0.1 U	0.1 U
Phosphorus	mg/L	NA	-	-	0.1 U	0.1 U
Sulfate	mg/L	* 250	<20 mg/L	2	**140**	**28.8**
Sulfide	mg/L	NA	>1 mg/L	3	**1.68**	**1.88**
pH	SU	* 6.5 to 8.5	5<pH<9	0	**7.24**	**7.02**
Temperature	°C	NA	>20 C	1	**7.32**	**11.76**
Oxidation-Reduction Potential	mV	NA	< 50 mv/<-100 mv	1.0/2.0	**-90.4**	**-35.2**
Dissolved Oxygen	mg/L	NA	<0.5 />1 mg/L	3.0/-3.0	**1.3**	**0.56**
Ferrous iron	mg/L	0.3 for total iron	>1 mg/L	3	NS	NS
Natural Biodegradation Scoring					**3**	**6**
Other Parameters						
Conductivity	mmhos/cm	NA			**0.867**	**0.724**
Turbidity	NTUs	NA			**7.84**	**5.89**
Depth to water	ft TOC	NA			**33.61**	**27.59**

D = Deep well
J = Estimated value
mg/L = milligrams per liter
MCL = Maximum contaminant level from May 2016 EPA RSL Table.
* = Secondary MCL
mmhos/com = milli mhos per centimeter
mV = millivolts
NS = Not Sampled
NTU = Nephelometric Turbidity Unit
S = Shallow well
U = Compound was not detected
ug/L = micrograms per liter
Bold indicates detected results.
Dark gray shading indicates screening level exceedance for VOCs.
- = No natural attenuation criteria

** - Equals points assignment for determining favorable conditions for biodegradation.
0-5 = Inadequate
6-14 = Limited Evidense
15-20 = Adequate
>20 = Strong Evidense
Light gray shading indicates evidence for biodegradation.

Table 3-12
Groundwater Sample Results (Collected March 2016)
Remedial Investigation, Former Forbes Atlas S-5 Missile Site
Lyon County, Kansas

		Sample ID:	Natural Attenuation	Natural Attenuation	MW-01D-04		MW-02S-04		MW-02D-04		MW-02D-14		MW-03S-04	
		Lab ID:			HS16030437-03		HS16030437-06		HS16030437-04		HS16030437-05		HS16030331-02	
		Date Collected:	Screening (Wiedemier)	Screening (Wiedemier)	3/9/2016		3/9/2016		3/9/2016		3/9/2016		3/7/2016	
		Screening Level	Favorable	Points**							Duplicate			
Analyte	Units	USEPA MCL	Concentration		Result		Result		Result		Result		Result	
cis-1,2-Dichloroethene	ug/L	70	Daughter	2	0.62	U	**5.8**		0.62	U	0.62	U	**0.81**	J
Trichloroethene	ug/L	5	Released	0	0.62	U	**120**	J	0.62	U	0.62	U	**4.7**	
Vinyl Chloride	ug/L	2	Daughter	2	0.62	U	0.62	U	0.62	U	0.62	U	0.62	U
Natural Attenuation Parameters														
Alkalinity as CaCO3	mg/L	NA	2 times background	1	**385**		**351**		**278**		**276**		**308**	
Alkalinity, Bicarbonate (As CaCO3)	mg/L	NA	-	-	**385**		**351**		**278**		**276**		**308**	
Alkalinity, Carbonate (As CaCO3)	mg/L	NA	-	-	5	U	5	U	5	U	5	U	5	U
Alkalinity, Hydroxide (As CaCO3)	mg/L	NA	-	-	5	U	5	U	5	U	5	U	5	U
Bromide	mg/L	NA	-	-	**0.202**		0.1	U	**0.097**	J	**0.096**	J	0.1	U
Chloride	mg/L	* 250	2 times background	2	**73.2**		**5.02**		**27.5**		**27.4**		**2.46**	
Ethane	ug/L	NA	>10/>100 ug/L	2.0/3.0	**1.79**		0.361	UJ	0.361	U	0.361	U	0.361	U
Ethene	ug/L	NA	>10/>100 ug/L	2.0/3.0	**1.75**		0.337	UJ	**1.11**		**1.16**		**0.665**	J
Fluoride	mg/L	* 4	-	-	**0.967**		**0.369**		**1.27**		**1.27**		**0.338**	
Methane	ug/L	NA	>100/1,000 ug/L	2.0/3.0	**13.6**		**1.59**		**5.1**		**4.9**		0.2	U
Nitrate as N	mg/L	10	<1 mg/L	2	0.1	U	**0.223**		**0.061**	J	**0.06**	J	**0.667**	
Nitrate/Nitrite	mg/L	10	-	-	0.1	U	**0.223**		**0.061**	J	**0.06**	J	**0.667**	
Nitrite as N	mg/L	1	-	-	0.1	U	0.1	U	0.1	U	0.1	U	0.1	U
Phosphorus	mg/L	NA	-	-	**0.105**		0.1	U	0.1	U	0.1	U	0.1	U
Sulfate	mg/L	* 250	<20 mg/L	2	**371**		**43.9**		**121**		**130**		**33.4**	
Sulfide	mg/L	NA	>1 mg/L	3	**2.28**		**4.28**		**2.08**		**1.28**		3.96	U
pH	SU	* 6.5 to 8.5	5<pH<9	0	**6.84**		**5.61**		**6.53**		NA		**6.94**	
Temperature	°C	NA	>20 C	1	**16.06**		**15.57**		**17.88**		NA		**19.5**	
Oxidation-Reduction Potential	mV	NA	< 50 mv/<-100 mv	1.0/2.0	**-30.9**		**108.4**		**24.2**		NA		**-2.1**	
Dissolved Oxygen	mg/L	NA	<0.5 />1 mg/L	3.0/-3.0	**2.04**		**1.66**		**1.46**		NA		**1.4**	
Ferrous iron	mg/L	0.3 for total iron	>1 mg/L	3	**1.2**		**0.0**		**0.1**		NA		**0.0**	
Natural Biodegradation Scoring					**6**		**2**		**3**		**5**		**3**	
Other Parameters														
Conductivity	mmhos/cm	NA			**1.453**		**0.655**		**0.79**		NA		**0.58**	
Turbidity	NTUs	NA			**41.6**		**3.5**		**7.6**		NA		**15.4**	
Depth to water	ft TOC	NA			**48.58**		**24.45**		**44.67**		NA		**22.15**	

D = Deep well
J = Estimated value
mg/L = milligrams per liter
MCL = Maximum contaminant level from May 2016 EPA RSL Table.
* = Secondary MCL
mmhos/com = milli mhos per centimeter
mV = millivolts
NS = Not Sampled
NTU = Nephelometric Turbidity Unit
S = Shallow well
U = Compound was not detected
ug/L = micrograms per liter
Bold indicates detected results.
Dark gray shading indicates screening level exceedance for VOCs.
- = No natural attenuation criteria
OOR - Out of Range

** - Equals points assignment for determining favorable conditions for biodegradation
0-5 = Inadequate
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15-20 = Adequate Evidense
>20 = Strong Evidense
Light gray shading indicates evidence for biodegradation

Table 3-12
Groundwater Sample Results (Collected March 2016)
Remedial Investigation, Former Forbes Atlas S-5 Missile Site
Lyon County, Kansas

		Sample ID:	Natural Attenuation	Natural Attenuation	MW-03S-14		MW-03D-04		MW-04S-04		MW-04D-04		MW-05D-04		MW-06S-04	
		Lab ID:	Screening	Screening	HS16030331-03		HS16030331-01		HS16030390-04		HS16030390-03		HS16030437-02		HS16030390-02	
		Date Collected:	(Wiedemier)	(Wiedemier)	3/7/2016		3/7/2016		3/8/2016		3/8/2016		3/9/2016		3/8/2016	
		Screening Level	Favorable	Points**	Duplicate											
Analyte	Units	USEPA MCL	Concentration		Result		Result		Result		Result		Result		Result	
cis-1,2-Dichloroethene	ug/L	70	Daughter	2	**0.85**	**J**	0.62	U	0.62	U	0.62	U	0.62	U	**0.69**	**J**
Trichloroethene	ug/L	5	Released	0	**4.6**		0.62	U	0.62	U	0.62	U	**0.24**	**J**	**16**	
Vinyl Chloride	ug/L	2	Daughter	2	0.62	U	0.62	U	0.62	U	0.62	U	0.62	U	0.62	U
Natural Attenuation Parameters																
Alkalinity as CaCO3	mg/L	NA	2 times background	1	**306**		**329**		**301**		**370**		**333**		**362**	
Alkalinity, Bicarbonate (As CaCO3)	mg/L	NA	-	-	**306**		**329**		**301**		**370**		**333**		**362**	
Alkalinity, Carbonate (As CaCO3)	mg/L	NA	-	-	5	U	5	U	5	U	5	U	5	U	5	U
Alkalinity, Hydroxide (As CaCO3)	mg/L	NA	-	-	5	U	5	U	5	U	5	U	5	U	5	U
Bromide	mg/L	NA	-	-	0.1	U	**0.184**		**0.108**		**0.154**		**0.219**		**0.101**	
Chloride	mg/L	* 250	2 times background	2	**2.36**		**66.7**		**16.5**		**47.3**		**68.8**		**3.44**	
Ethane	ug/L	NA	>10/>100 ug/L	2.0/3.0	0.361	U	0.361	U	**1.03**		**0.99**	**J**	**1.05**		0.361	U
Ethene	ug/L	NA	>10/>100 ug/L	2.0/3.0	**0.912**	**J**	**4.68**		**4.91**		**5.88**		**5.19**		0.337	U
Fluoride	mg/L	* 4	-	-	**0.334**		**0.875**		**0.42**		**0.899**		**1.18**		**0.273**	
Methane	ug/L	NA	>100/1,000 ug/L	2.0/3.0	0.2	U	**10.1**		**2.05**		**7.98**		**10.4**		0.2	U
Nitrate as N	mg/L	10	<1 mg/L	2	**0.655**		**0.053**	**J**	0.05	U	0.05	U	0.1	U	**0.478**	
Nitrate/Nitrite	mg/L	10	-	-	**0.655**		**0.053**	**J**	0.1	U	0.1	U	0.1	U	**0.478**	
Nitrite as N	mg/L	1	-	-	0.1	U	0.1	U	0.05	U	0.05	U	0.1	U	0.05	U
Phosphorus	mg/L	NA	-	-	0.1	U	**0.159**		0.05	UJ	0.05	UJ	**0.113**		0.05	UJ
Sulfate	mg/L	* 250	<20 mg/L	2	**32.2**		**324**		**80.6**		**248**		**462**		**53.3**	
Sulfide	mg/L	NA	>1 mg/L	3	**1.76**		**1.96**		2.48	U	**2.68**		**2.88**		**2.28**	
pH	SU	* 6.5 to 8.5	5<pH<9	0	NA		**6.84**		**7.01**		**6.12**		**7.06**		**6.77**	
Temperature	°C	NA	>20 C	1	NA		**21.3**		**14.02**		**14.94**		**12.6**		**15.01**	
Oxidation-Reduction Potential	mV	NA	< 50 mv/<-100 mv	1.0/2.0	NA		**-81.1**		**-55.1**		**19.1**		**-74.1**		**49.9**	
Dissolved Oxygen	mg/L	NA	<0.5 />1 mg/L	3.0/-3.0	NA		**1.33**		**3.12**		**3.06**		**2.5**		**3.65**	
Ferrous iron	mg/L	0.3 for total iron	>1 mg/L	3	NA		**0.7**		**0.8**		**0**		**1.1**		**0**	
Natural Biodegradation Scoring					**5**		**4**		**3**		**3**		**6**		**3**	
Other Parameters																
Conductivity	mmhos/cm	NA			NA		**1.388**		**0.671**		**1.143**		**1.447**		**0.682**	
Turbidity	NTUs	NA			NA		**26.6**		**OOR**		**104**		**17**		**20.1**	
Depth to water	ft TOC	NA			NA		**45.5**		**31.59**		**53.4**		**51.54**		**15.17**	

D = Deep well
J = Estimated value
mg/L = milligrams per liter
MCL = Maximum contaminant level from May 2016 EPA RSL Table.
* = Secondary MCL
mmhos/com = milli mhos per centimeter
mV = millivolts
NS = Not Sampled
NTU = Nephelometric Turbidity Unit
S = Shallow well
U = Compound was not detected
ug/L = micrograms per liter
Bold indicates detected results.
Dark gray shading indicates screening level exceedance for VOCs.
- = No natural attenuation criteria
OOR - Out of Range

** - Equals points assignment for determining favorable conditions for biodegradation
0-5 = Inadequate
6-14 = Limited Evidense
15-20 = Adequate Evidense
>20 = Strong Evidense
Light gray shading indicates evidence for biodegradation

Table 3-12
Groundwater Sample Results (Collected March 2016)
Remedial Investigation, Former Forbes Atlas S-5 Missile Site
Lyon County, Kansas

		Sample ID:	Natural Attenuation	Natural Attenuation	MW-06D-04		MW-07S-04	
		Lab ID:	Screening	Screening	HS16030390-01		HS16030437-01	
		Date Collected:	(Wiedemier)	(Wiedemier)	3/8/2016		3/9/2016	
Analyte	Units	Screening Level USEPA MCL	Favorable Concentration	Points**	Result		Result	
cis-1,2-Dichloroethene	ug/L	70	Daughter	2	0.62	U	**0.45**	**J**
Trichloroethene	ug/L	5	Released	0	0.62	U	**5.1**	
Vinyl Chloride	ug/L	2	Daughter	2	0.62	U	0.62	U
Natural Attenuation Parameters								
Alkalinity as CaCO3	mg/L	NA	2 times background	1	**293**		**318**	
Alkalinity, Bicarbonate (As CaCO3)	mg/L	NA	-	-	**293**		**318**	
Alkalinity, Carbonate (As CaCO3)	mg/L	NA	-	-	5	U	5	U
Alkalinity, Hydroxide (As CaCO3)	mg/L	NA	-	-	5	U	5	U
Bromide	mg/L	NA	-	-	**0.098**	**J**	0.1	U
Chloride	mg/L	* 250	2 times background	2	**19.2**		**3.23**	
Ethane	ug/L	NA	>10/>100 ug/L	2.0/3.0	**1.96**		**0.727**	**J**
Ethene	ug/L	NA	>10/>100 ug/L	2.0/3.0	**5.48**		**2.38**	
Fluoride	mg/L	* 4	-	-	**0.931**		**0.308**	
Methane	ug/L	NA	>100/1,000 ug/L	2.0/3.0	**19.3**		**0.489**	**J**
Nitrate as N	mg/L	10	<1 mg/L	2	0.05	U	**0.149**	
Nitrate/Nitrite	mg/L	10	-	-	0.1	U	**0.149**	
Nitrite as N	mg/L	1	-	-	0.05	U	0.1	U
Phosphorus	mg/L	NA	-	-	**0.175**	**J**	0.1	U
Sulfate	mg/L	* 250	<20 mg/L	2	**140**		**31.6**	
Sulfide	mg/L	NA	>1 mg/L	3	**4.48**		1	U
pH	SU	* 6.5 to 8.5	5<pH<9	0	**7.13**		**6.91**	
Temperature	°C	NA	>20 C	1	**16.21**		**10.91**	
Oxidation-Reduction Potential	mV	NA	< 50 mv/<-100 mv	1.0/2.0	**-125.3**		**-29.2**	
Dissolved Oxygen	mg/L	NA	<0.5 />1 mg/L	3.0/-3.0	**1.92**		**2.75**	
Ferrous iron	mg/L	0.3 for total iron	>1 mg/L	3	**0.5**		**0.7**	
Natural Biodegradation Scoring					**4**		**0**	
Other Parameters								
Conductivity	mmhos/cm	NA			**0.807**		**0.506**	
Turbidity	NTUs	NA			**5.71**		**270**	
Depth to water	ft TOC	NA			**29.7**		**27**	

D = Deep well
J = Estimated value
mg/L = milligrams per liter
MCL = Maximum contaminant level from May 2016 EPA RSL Table.
* = Secondary MCL
mmhos/com = milli mhos per centimeter
mV = millivolts
NS = Not Sampled
NTU = Nephelometric Turbidity Unit
S = Shallow well
U = Compound was not detected
ug/L = micrograms per liter
Bold indicates detected results.
Dark gray shading indicates screening level exceedance for VOCs.
- = No natural attenuation criteria
OOR - Out of Range

** - Equals points assignment for determining favorable conditions for
0-5 = Inadequate
6-14 = Limited Evidense
15-20 = Adequate Evidense
>20 = Strong Evidense
Light gray shading indicates evidence for biodegradation.

Table 3-13
Groundwater Sample Results (Collected June 2016)
Remedial Investigation, Former Forbes Atlas S-5 Missile Site
Lyon County, Kansas

		Sample ID:	Natural Attenuation	Natural Attenuation	MW-01D-05		MW-02S-05		MW-02D-05		MW-02D-15		MW-03S-05		MW-03S-15	
		Lab ID:	Screening	Screening	HS16061535-08		HS16061470-03 and HS16061535-03		HS16061470-01 & HS16061535-01		HS16061470-02 & HS16061535-02		HS16061535-04		HS16061535-05	
		Date Collected:	(Wiedemier)	(Wiedemier)	6/28/2016		6/27/2016		6/27/2016		6/27/2016		6/28/2016		6/28/2016	
		Screening Level	Favorable	Points**							Duplicate				Duplicate	
Analyte	**Units**	**USEPA MCL**	**Concentration**		**Result**		**Result**		**Result**		**Result**		**Result**		**Result**	
cis-1,2-Dichloroethene	ug/L	70	Daughter	2	0.5	U	0.5	U	0.5	U	0.5	U	**0.62**	**J**	**0.56**	**J**
Trichloroethene	ug/L	5	Released	0	0.5	U	**77**	**J**	0.5	U	0.5	U	**4.5**	**J**	**4.5**	**J**
Vinyl Chloride	ug/L	2	Daughter	2	0.5	U	0.5	U	0.5	U	0.5	U	0.5	U	0.5	U
Natural Attenuation Parameters																
Alkalinity as CaCO3	mg/L	NA	2 times background	1	**347**		**402**		**282**		**279**		**302**		**303**	
Alkalinity, Bicarbonate (As CaCO3)	mg/L	NA	-	-	**347**		**402**		**282**		**279**		**302**		**303**	
Alkalinity, Carbonate (As CaCO3)	mg/L	NA	-	-	5	U	5	U	5	U	5	U	5	U	5	U
Alkalinity, Hydroxide (As CaCO3)	mg/L	NA	-	-	5	U	5	U	5	U	5	U	5	U	5	U
Bromide	mg/L	NA	-	-	0.05	U	**0.123**		0.05	U	0.05	U	0.05	U	0.05	U
Chloride *	mg/L	250	2 times background	2	**72.2**		**6.03**		**25.9**		**26.2**		**2.29**		**2.31**	
Ethane	ug/L	NA	>10/>100 ug/L	2.0/3.0	**1.75**		0.361	U	0.361	U	0.361	U	0.361	U	0.361	U
Ethene	ug/L	NA	>10/>100 ug/L	2.0/3.0	**2.11**		0.337	U	**0.821**	**J**	**0.946**	**J**	0.337	U	0.337	U
Fluoride *	mg/L	4	-	-	**1.08**		**0.386**		**1.25**		**1.27**		**0.366**		**0.367**	
Methane	ug/L	NA	>100/1,000 ug/L	2.0/3.0	**11.8**		**1.11**		**6.83**		**5.09**		0.2	U	0.2	U
Nitrate as N	mg/L	10	<1 mg/L	2	**0.79**	**J**	0.05	U	**0.057**	**J**	0.05	U	**0.717**		**0.706**	
Nitrate/Nitrite	mg/L	10	-	-	**0.79**	**J**	0.1	U	**0.057**	**J**	0.1	U	**0.717**		**0.706**	
Nitrite as N	mg/L	1	-	-	1	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U
Phosphorus	mg/L	NA	-	-	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U
Sulfate *	mg/L	250	<20 mg/L	2	**392**		**66.7**		**120**		**123**		**29.1**		**28.9**	
Sulfide	mg/L	NA	>1 mg/L	3	1	U	1	U	1	U	1	U	1	U	1	U
pH *	SU	6.5 to 8.5	5<pH<9	0	**6.4**		**6.1**		**6.92**		NA		**6.8**		NA	
Temperature	°C	NA	>20 C	1	**24.15**		**23.39**		**28.12**		NA		**17.44**		NA	
Oxidation-Reduction Potential	mV	NA	< 50 mv/<-100 mv	1.0/2.0	**-67.0**		**119.3**		**-14.5**		NA		**141.6**		NA	
Dissolved Oxygen	mg/L	NA	<0.5 />1 mg/L	3.0/-3.0	**1.27**		**1.25**		**1.7**		NA		**4.0**		NA	
Ferrous iron	mg/L	0.3 for total iron	>1 mg/L	3	**1.2**		**0.1**		**0.1**		NA		**0.1**		NA	
Natural Biodegradation Scoring					**4**		**0**		**1**		**2**		**1**		**4**	
Other Parameters																
Conductivity	mmhos/cm	NA			**1.200**		**0.684**		**0.714**				**0.416**			
Turbidity	NTUs	NA			**22.0**		**2.9**		**16.5**				**9.6**			
Depth to water	ft TOC	NA			**51.36**		**22.33**		**47.05**				**21.3**			

D = Deep well
J = Estimated value
mg/L = milligrams per liter
MCL = Maximum contaminant level from May 2016 EPA RSL Table.
* = Secondary MCL
mmhos/com = milli mhos per centimeter
Bold indicates detected results.
Dark gray shading indicates screening level exceedance for VOCs.
- = No natural attenuation criteria

mV = millivolts
NS = Not Sampled
NTU = Nephelometric Turbidity Unit
OOR - Out of Range
S = Shallow well
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ug/L = micrograms per liter

** - Equals points assignment for determining favorable conditions for biodegradation
0-5 = Inadequate
6-14 = Limited Evidense
15-20 = Adequate Evidense
>20 = Strong Evidense
Light gray shading indicates evidence for biodegradation

Table 3-13
Groundwater Sample Results (Collected June 2016)
Remedial Investigation, Former Forbes Atlas S-5 Missile Site
Lyon County, Kansas

		Sample ID:	Natural Attenuation	Natural Attenuation	MW-03D-05		MW-04S-05		MW-04D-05		MW-05D-05		MW-06S-05		MW-06D-05	
		Lab ID:	Screening	Screening	HS16061535-07		HS16061535-10		HS16061535-09		HS16070012-01		HS16070012-05		HS16070012-03	
		Date Collected:	(Wiedemier)	(Wiedemier)	6/28/2016		6/28/2016		6/28/2016		6/30/2016		6/30/2016		6/30/2016	
		Screening Level	Favorable	Points**												
Analyte	**Units**	**USEPA MCL**	**Concentration**		**Result**		**Result**		**Result**		**Result**		**Result**		**Result**	
cis-1,2-Dichloroethene	ug/L	70	Daughter	2	0.5	U	0.5	U	0.5	U	0.5	U	**1.5**	**J**	0.5	U
Trichloroethene	ug/L	5	Released	0	**0.3**	**J**	0.5	U	0.5	U	0.5	U	**23**	**J**	**0.34**	**J**
Vinyl Chloride	ug/L	2	Daughter	2	0.5	U	0.5	U	0.5	U	0.5	U	0.5	U	0.5	U
Natural Attenuation Parameters																
Alkalinity as CaCO3	mg/L	NA	2 times background	1	**335**		**312**		**365**		**352**		**351**		**300**	
Alkalinity, Bicarbonate (As CaCO3)	mg/L	NA	-	-	**335**		**312**		**365**		**352**		**351**		**300**	
Alkalinity, Carbonate (As CaCO3)	mg/L	NA	-	-	5	U	5	U	5	U	5	U	5	U	5	U
Alkalinity, Hydroxide (As CaCO3)	mg/L	NA	-	-	5	U	5	U	5	U	5	U	5	U	5	U
Bromide	mg/L	NA	-	-	0.05	U	0.05	U	0.05	U	1	U	0.05	U	0.05	U
Chloride *	mg/L	250	2 times background	2	**71.5**		**11.7**		**55.2**		**68.6**		**2.61**		**20.1**	
Ethane	ug/L	NA	>10/>100 ug/L	2.0/3.0	0.361	U	**0.632**	**J**	**1.08**		**0.925**	**J**	0.361	U	0.361	U
Ethene	ug/L	NA	>10/>100 ug/L	2.0/3.0	**3.57**		**1.79**		**6.46**		**4.15**		0.337	U	0.337	U
Fluoride *	mg/L	4	-	-	**0.972**		**0.434**		**1.09**		**1.2**		**0.305**		**1.08**	
Methane	ug/L	NA	>100/1,000 ug/L	2.0/3.0	**7.87**		0.2	U	**12.2**		**8.58**		0.2	U	0.2	U
Nitrate as N	mg/L	10	<1 mg/L	2	0.05	U	**0.048**	**J**	0.05	U	**0.152**		**0.459**		**0.106**	
Nitrate/Nitrite	mg/L	10	-	-	0.1	U	**0.048**	**J**	0.1	U	**0.152**		**0.459**		**0.106**	
Nitrite as N	mg/L	1	-	-	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U
Phosphorus	mg/L	NA	-	-	0.05	U	0.05	U	0.05	U	0.07	J	0.05	U	0.05	U
Sulfate *	mg/L	250	<20 mg/L	2	**376**		**67.7**		**292**		**439**		**43.2**		**154**	
Sulfide	mg/L	NA	>1 mg/L	3	1	U	1	U	1	U	**2.4**		**1.6**		1	U
pH *	SU	6.5 to 8.5	5<pH<9	0	**6.9**		**7.1**		**6.6**		**7.0**		**6.9**		**7.1**	
Temperature	°C	NA	>20 C	1	**20.29**		**24.98**		**22.61**		**26.28**		**25.28**		**27.82**	
Oxidation-Reduction Potential	mV	NA	< 50 mv/<-100 mv	1.0/2.0	**-112.1**		**-25.7**		**-37.0**		**-70.2**		**101.0**		**-82.7**	
Dissolved Oxygen	mg/L	NA	<0.5 />1 mg/L	3.0/-3.0	**0.92**		**3.89**		**1.63**		**1.89**		**3.45**		**1.64**	
Ferrous iron	mg/L	0.3 for total iron	>1 mg/L	3	**1.0**		**0.5**		**0.5**		**1.5**		**0.1**		**0.60**	
Natural Biodegradation Scoring					**5**		**1**		**1**		**7**		**5**		**1**	
Other Parameters																
Conductivity	mmhos/cm	NA			**1.088**		**0.574**		**1.033**		**1.456**		**0.59**		**0.761**	
Turbidity	NTUs	NA			**23.0**		**99**		**75.0**		**19.5**		**22.0**		**20.2**	
Depth to water	ft TOC	NA			**46.91**		**31.62**		**55.32**		**52.2**		**14.13**		**31.52**	

D = Deep well
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mg/L = milligrams per liter
MCL = Maximum contaminant level from May 2016 EPA RSL Table.
* = Secondary MCL
mmhos/com = milli mhos per centimeter
Bold indicates detected results.
Dark gray shading indicates screening level exceedance for VOCs.
- = No natural attenuation criteria

mV = millivolts
NS = Not Sampled
NTU = Nephelometric Turbidity Unit
OOR - Out of Range
S = Shallow well
U = Compound was not detected
ug/L = micrograms per liter

** - Equals points assignment for determining favorable conditions for biodegradation
0-5 = Inadequate
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>20 = Strong Evidense
Light gray shading indicates evidence for biodegradation

Table 3-13
Groundwater Sample Results (Collected June 2016)
Remedial Investigation, Former Forbes Atlas S-5 Missile Site
Lyon County, Kansas

		Sample ID:	Natural Attenuation	Natural Attenuation	MW-07S-05		MW-08S-01		MW-09S-01		MW-10S-01		MW-11S-01		MW-12S-01		MW-13S-01	
		Lab ID:	Screening	Screening	HS16070012-02		HS16061651-02		HS16061651-01		HS16061651-03		HS16061651-04		HS16061651-05		HS16070012-04	
		Date Collected:	(Wiedemier)	(Wiedemier)	6/30/2016		6/29/2016		6/29/2016		6/29/2016		6/29/2016		6/29/2016		6/30/2016	
Analyte	Units	Screening Level USEPA MCL	Favorable Concentration	Points**	Result		Result		Result		Result		Result		Result		Result	
cis-1,2-Dichloroethene	ug/L	70	Daughter	2	**0.73**	**J**	0.5	U	0.5	U	0.5	U	**12**	**J**	0.5	U	**5.5**	**J**
Trichloroethene	ug/L	5	Released	0	**6.6**	**J**	**0.44**	**J**	0.5	U	0.5	U	**61**	**J**	**2**	**J**	**51**	**J**
Vinyl Chloride	ug/L	2	Daughter	2	0.5	U	0.5	U	0.5	U	0.5	U	0.5	U	0.5	U	0.5	U
Natural Attenuation Parameters																		
Alkalinity as CaCO3	mg/L	NA	2 times background	1	**322**		**318**		**337**		**351**		**444**		**547**		**364**	
Alkalinity, Bicarbonate (As CaCO3)	mg/L	NA	-	-	**322**		**318**		**337**		**351**		**444**		**547**		**364**	
Alkalinity, Carbonate (As CaCO3)	mg/L	NA	-	-	5	U	5	U	5	U	5	U	5	U	5	U	5	U
Alkalinity, Hydroxide (As CaCO3)	mg/L	NA	-	-	5	U	5	U	5	U	5	U	5	U	5	U	5	U
Bromide	mg/L	NA	-	-	0.05	U	0.05	U	**0.084**	**J**	**0.058**	**J**	**0.173**		**0.884**		**0.051**	**J**
Chloride *	mg/L	250	2 times background	2	**3.23**		**6.07**		**7.85**		**2.84**		**7.86**		**36.7**		**4.18**	
Ethane	ug/L	NA	>10/>100 ug/L	2.0/3.0	0.361	U	0.361	U	**1.39**		0.361	U	0.361	U	**0.753**	**J**	0.361	U
Ethene	ug/L	NA	>10/>100 ug/L	2.0/3.0	0.337	U	0.337	U	**1.83**		**1.05**		**1.62**		**1.45**		0.337	U
Fluoride *	mg/L	4	-	-	**0.33**		**0.476**		**0.509**		**0.48**		**0.291**		**0.491**		**0.469**	
Methane	ug/L	NA	>100/1,000 ug/L	2.0/3.0	**1.45**		**0.334**	**J**	**1.91**		0.2	U	0.2	U	**0.45**	**J**	0.2	U
Nitrate as N	mg/L	10	<1 mg/L	2	0.05	U	**0.044**	**J**	**0.111**		**0.112**		**0.4**		**0.426**		**0.429**	
Nitrate/Nitrite	mg/L	10	-	-	0.1	U	**0.044**	**J**	**0.111**		**0.112**		**0.556**		**0.426**		**0.429**	
Nitrite as N	mg/L	1	-	-	0.05	U	0.05	U	0.05	U	0.05	U	**0.156**	**J**	0.05	U	0.05	U
Phosphorus	mg/L	NA	-	-	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U
Sulfate *	mg/L	250	<20 mg/L	2	**31**		**42**		**59.9**		**31.1**		**69.9**		**87.2**		**32.9**	
Sulfide	mg/L	NA	>1 mg/L	3	**1**		1	U	1	U	1	U	1	U	1	U	2.6	U
pH *	SU	6.5 to 8.5	5<pH<9	0	**7.1**		**7.1**		**7.2**		**7.0**		**6.8**		**6.9**		**7.2**	
Temperature	°C	NA	>20 C	1	**23.52**		**21.6**		**19.66**		**23.91**		**27.53**		**25.24**		**25.22**	
Oxidation-Reduction Potential	mV	NA	< 50 mv/<-100 mv	1.0/2.0	**76.6**		**104.6**		**129.6**		**108.0**		**99.6**		**110.1**		**114.6**	
Dissolved Oxygen	mg/L	NA	<0.5 />1 mg/L	3.0/-3.0	**2.43**		**1.64**		**2.81**		**6.0**		**2.04**		**2.98**		**6.01**	
Ferrous iron	mg/L	0.3 for total iron	>1 mg/L	3	**0.3**		**0.1**		**0.0**		**0.1**		**0.55**		**0.1**		**0.0**	
Natural Biodegradation Scoring					**2**		**0**		**-1**		**0**		**2**		**0**		**5**	
Other Parameters																		
Conductivity	mmhos/cm	NA			**0.49**		**0.537**		**0.533**		**0.614**		**0.788**		**1.009**		**0.593**	
Turbidity	NTUs	NA			**131**		**13.0**		**7.62**		**14.3**		**33.8**		**80.0**		**11.0**	
Depth to water	ft TOC	NA			**25.47**		**17.4**		**15.7**		**16.17**		**18.3**		**19.44**		**11.46**	

D = Deep well
J = Estimated value
mg/L = milligrams per liter
MCL = Maximum contaminant level from May 2016 EPA RSL Table.
* = Secondary MCL
mmhos/com = milli mhos per centimeter
Bold indicates detected results.
Dark gray shading indicates screening level exceedance for VOCs.
- = No natural attenuation criteria

mV = millivolts
NS = Not Sampled
NTU = Nephelometric Turbidity Unit
OOR - Out of Range
S = Shallow well
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** - Equals points assignment for determining favorable conditions for biodegradation
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>20 = Strong Evidense
Light gray shading indicates evidence for biodegradation

Table 3-14
Groundwater Sample Results (Collected September 2016)
Remedial Investigation, Former Forbes Atlas S-5 Missile Site
Lyon County, Kansas

		Sample ID:	Natural Attenuation	Natural Attenuation	MW-01D-06	MW-02S-06	MW-02D-06	MW-02D-16	MW-03S-06	MW-03S-16
		Lab ID:	Screening	Screening	HS16090578-01	HS16090724-05	HS16090578-06	HS16090578-05	HS16090663-02	HS16090663-04
		Date Collected:	(Wiedemier)	(Wiedemier)	9/13/2016	9/15/2016	9/13/2016	9/13/2016	9/14/2016	9/14/2016
		Screening Level	Favorable	Points**				Duplicate		Duplicate
Analyte	**Units**	**USEPA MCL**	**Concentration**		**Result**	**Result**	**Result**	**Result**	**Result**	**Result**
cis-1,2-Dichloroethene	ug/L	70	Daughter	2	0.62 U	**6.9**	0.62 U	0.62 U	**0.45 J**	**0.43 J**
Trichloroethene	ug/L	5	Released	0	0.62 U	**96**	0.62 U	0.62 U	**4.4**	**4.3**
Vinyl Chloride	ug/L	2	Daughter	2	0.62 U	0.5 U	0.62 U	0.62 U	0.5 U	0.5 U
Natural Attenuation Parameters										
Alkalinity as CaCO3	mg/L	NA	2 times background	1	**357**	**382**	**283**	**283**	**320**	**320**
Alkalinity, Bicarbonate (As CaCO3)	mg/L	NA	-	-	**357**	**382**	**283**	**283**	**320**	**320**
Alkalinity, Carbonate (As CaCO3)	mg/L	NA	-	-	5 U	5 U	5 U	5 U	5 U	5 U
Alkalinity, Hydroxide (As CaCO3)	mg/L	NA	-	-	5 U	5 U	5 U	5 U	5 U	5 U
Bromide	mg/L	NA	-	-	**0.241**	**0.435 J**	**0.122**	**0.123**	0.05 UJ	0.05 UJ
Chloride *	mg/L	250	2 times background	2	**77.4**	**5.08**	**26.9**	**26.7**	**2.45**	**2.53**
Ethane	ug/L	NA	>10/>100 ug/L	2.0/3.0	**2.04**	0.772 U	0.772 U	0.772 U	0.772 U	0.772 U
Ethene	ug/L	NA	>10/>100 ug/L	2.0/3.0	**1.8**	0.674 U	0.674 U	0.674 U	0.674 U	0.674 U
Fluoride *	mg/L	4	-	-	**1.15**	**0.382**	**1.25**	**1.24**	**0.313**	**0.323**
Methane	ug/L	NA	>100/1,000 ug/L	2.0/3.0	**13.4**	**0.623**	**1.41**	**1.35**	**0.955**	0.384 U
Nitrate as N	mg/L	10	<1 mg/L	2	0.07 U	**0.209**	0.162 U	0.155 U	**0.597**	**0.701**
Nitrate/Nitrite	mg/L	10	-	-	0.07 U	**0.209**	0.162 U	0.155 U	**0.597**	**0.701**
Nitrite as N	mg/L	1	-	-	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U
Phosphorus	mg/L	NA	-	-	**0.229**	**0.252**	0.05 U	0.05 U	0.05 UJ	0.05 UJ
Sulfate *	mg/L	250	<20 mg/L	2	**390**	**49.3**	**124**	**122**	**29.5**	**33.6**
Sulfide	mg/L	NA	>1 mg/L	3	**5.2**	**2.28**	**5.8**	**1.4**	**2.68**	**1.48**
pH *	SU	6.5 to 8.5	5<pH<9	0	**6.46**	**5.93**	**7.38**	NA	**6.31**	NA
Temperature	°C	NA	>20 C	1	**17.87**	**17.79**	**24.1**	NA	**18**	NA
Oxidation-Reduction Potential	mV	NA	< 50 mv/<-100 mv	1.0/2.0	**-84.7**	**56.9**	**-28.6**	NA	**41.6**	NA
Dissolved Oxygen	mg/L	NA	<0.5 />1 mg/L	3.0/-3.0	**1.11**	**0.54**	**1.87**	NA	**1.94**	NA
Ferrous iron	mg/L	0.3 for total iron	>1 mg/L	3	**1.4**	**0.1**	**0.0**	NA	**0.0**	NA
Natural Biodegradation Scoring					**6**	**5**	**4**	**5**	**3**	**5**
Other Parameters										
Conductivity	mmhos/cm	NA			**1.229**	**0.691**	**0.78**	NA	**0.411**	NA
Turbidity	NTUs	NA			**87.4**	**1.55**	**2.65**	NA	**8.07**	NA
Depth to water	ft TOC	NA			**52.33**	**22.05**	**48.51**	NA	**19.76**	NA

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MCL = Maximum contaminant level from May 2016 EPA RSL Table.
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Bold indicates detected results.
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Table 3-14
Groundwater Sample Results (Collected September 2016)
Remedial Investigation, Former Forbes Atlas S-5 Missile Site
Lyon County, Kansas

		Sample ID:	Natural Attenuation	Natural Attenuation	MW-03D-06	MW-04S-06	MW-04D-06	MW-05D-06	MW-06S-06	MW-06D-06
		Lab ID:	Screening	Screening	HS16090663-01	HS16090529-02	HS16090529-01	HS16090529-03	HS16090724-01	HS16090663-06
		Date Collected:	(Wiedemier)	(Wiedemier)	9/14/2016	9/12/2016	9/12/2016	9/12/2016	9/15/2016	9/14/2016
		Screening Level	Favorable	Points**						
Analyte	**Units**	**USEPA MCL**	**Concentration**		**Result**	**Result**	**Result**	**Result**	**Result**	**Result**
cis-1,2-Dichloroethene	ug/L	70	Daughter	2	0.5 U	0.62 U	0.62 U	0.62 U	**2.3**	0.5 U
Trichloroethene	ug/L	5	Released	0	0.5 U	0.62 U	0.62 U	0.62 U	**24**	0.5 U
Vinyl Chloride	ug/L	2	Daughter	2	0.5 U	0.62 U	0.62 U	0.62 U	0.5 U	0.5 U
Natural Attenuation Parameters										
Alkalinity as CaCO3	mg/L	NA	2 times background	1	**331**	**297**	**325**	**402**	**368**	**315**
Alkalinity, Bicarbonate (As CaCO3)	mg/L	NA	-	-	**331**	**297**	**325**	**402**	**368**	**315**
Alkalinity, Carbonate (As CaCO3)	mg/L	NA	-	-	5 U	5 U	5 U	5 U	5 U	5 U
Alkalinity, Hydroxide (As CaCO3)	mg/L	NA	-	-	5 U	5 U	5 U	5 U	5 U	5 U
Bromide	mg/L	NA	-	-	**0.239 J**	**0.123**	**0.2**	**0.265**	**0.392 J**	**0.119 J**
Chloride *	mg/L	250	2 times background	2	**73**	**14.6**	**62.3**	**77.1**	**2.73**	**20.2**
Ethane	ug/L	NA	>10/>100 ug/L	2.0/3.0	0.772 U	**1.62**	**1.13**	**0.921 J**	0.772 U	**1.82**
Ethene	ug/L	NA	>10/>100 ug/L	2.0/3.0	**3.7**	**2.53**	**3.96**	**4.1**	0.674 U	**2.06**
Fluoride *	mg/L	4	-	-	**0.943**	**0.483**	**1.18**	**1.21**	**0.344**	**1.04**
Methane	ug/L	NA	>100/1,000 ug/L	2.0/3.0	**4.52**	**5.04**	**15.2**	**11.1**	0.384 U	**19.3**
Nitrate as N	mg/L	10	<1 mg/L	2	0.07 U	**0.072 J**	0.05 U	0.05 U	**0.503**	0.07 U
Nitrate/Nitrite	mg/L	10	-	-	0.07 U	**0.072 J**	0.1 U	0.1 U	**0.503**	0.07 U
Nitrite as N	mg/L	1	-	-	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U
Phosphorus	mg/L	NA	-	-	**0.238 J**	0.05 U	**0.067 J**	**0.174**	0.05 U	**0.213 J**
Sulfate *	mg/L	250	<20 mg/L	2	**453**	**69.7**	**324**	**492**	**45.2**	**166**
Sulfide	mg/L	NA	>1 mg/L	3	**4.08**	**2.2**	**4.4**	**5.4**	1 U	**6.08**
pH *	SU	6.5 to 8.5	5<pH<9	0	**5.99**	**7.2**	**6.9**	**7.1**	**6.8**	**7.16**
Temperature	°C	NA	>20 C	1	**16.88**	**28.34**	**23.8**	**26.64**	**19.56**	**23.29**
Oxidation-Reduction Potential	mV	NA	< 50 mv/<-100 mv	1.0/2.0	**-3.7**	**-89.7**	**-78.9**	**-112.2**	**29.0**	**-88.4**
Dissolved Oxygen	mg/L	NA	<0.5 />1 mg/L	3.0/-3.0	**1.73**	**0.64**	**1.42**	**1.07**	**2.44**	**1.2**
Ferrous iron	mg/L	0.3 for total iron	>1 mg/L	3	**0.6**	**0.0**	**0.8**	**0.7**	**0.1**	**0.5**
Natural Biodegradation Scoring					**3**	**7**	**4**	**5**	**0**	**4**
Other Parameters										
Conductivity	mmhos/cm	NA			**0.722**	**0.824**	**1.433**	**2.099**	**0.697**	**0.951**
Turbidity	NTUs	NA			**10.4**	**OOR**	**36.8**	**23.4**	**10.7**	**7.86**
Depth to water	ft TOC	NA			**46.71**	**31.57**	**53.85**	**53.77**	**10.98**	**31.09**

D = Deep well
J = Estimated value
mg/L = milligrams per liter
MCL = Maximum contaminant level from May 2016 EPA RSL Table.
* = Secondary MCL
mmhos/com = milli mhos per centimeter
Bold indicates detected results.
Dark gray shading indicates screening level exceedance for VOCs.
- = No natural attenuation criteria

mV = millivolts
NS = Not Sampled
NTU = Nephelometric Turbidity Unit
OOR - Out of Range
S = Shallow well
U = Compound was not detected
ug/L = micrograms per liter

** - Equals points assignment for determining favorable conditions for biodegradation
0-5 = Inadequate
6-14 = Limited Evidense
15-20 = Adequate Evidense
>20 = Strong Evidense
Light gray shading indicates evidence for biodegradation

Table 3-14
Groundwater Sample Results (Collected September 2016)
Remedial Investigation, Former Forbes Atlas S-5 Missile Site
Lyon County, Kansas

			Sample ID:	Natural Attenuation	Natural Attenuation	MW-07S-06	MW-08S-02	MW-09S-02	MW-10S-02	MW-11S-02	MW-12S-02	MW-13S-02
			Lab ID:	Screening	Screening	HS16090663-05	HS16090578-07	HS16090578-02	HS16090578-03	HS16090724-04	HS16090663-03	HS16090724-02
			Date Collected:	(Wiedemier)	(Wiedemier)	9/14/2016	9/13/2016	9/13/2016	9/13/2016	9/15/2016	9/14/2016	9/15/2016
		Screening Level		Favorable	Points**							
Analyte	**Units**	**USEPA MCL**		**Concentration**		**Result**	**Result**	**Result**	**Result**	**Result**	**Result**	**Result**
cis-1,2-Dichloroethene	ug/L	70		Daughter	2	**0.55 J**	0.62 U	0.62 U	0.62 U	**17**	0.5 U	0.5 U
Trichloroethene	ug/L	5		Released	0	**7.4**	0.62 U	0.62 U	0.62 U	**65**	**1.6**	**4**
Vinyl Chloride	ug/L	2		Daughter	2	0.5 U	0.62 U	0.62 U	0.62 U	0.5 U	0.5 U	0.5 U
Natural Attenuation Parameters												
Alkalinity as CaCO3	mg/L	NA		2 times background	1	**324**	**216**	**353**	**409**	**486**	**600**	**184**
Alkalinity, Bicarbonate (As CaCO3)	mg/L	NA		-	-	**324**	**216**	**353**	**409**	**486**	**600**	**184**
Alkalinity, Carbonate (As CaCO3)	mg/L	NA		-	-	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Alkalinity, Hydroxide (As CaCO3)	mg/L	NA		-	-	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Bromide	mg/L	NA		-	-	0.05 UJ	0.05 U	**0.137**	**0.132**	**0.482 J**	**1.01 J**	**0.364 J**
Chloride *	mg/L	250		2 times background	2	**2.97**	**3.85**	**6.62**	**1.16**	**6.3**	**37.4**	**2.97**
Ethane	ug/L	NA		>10/>100 ug/L	2.0/3.0	0.772 U	0.772 U	0.772 U	0.772 U	0.772 U	**0.732 J**	0.772 U
Ethene	ug/L	NA		>10/>100 ug/L	2.0/3.0	**0.707 J**	0.674 U	**0.937 J**	0.674 U	0.674 U	**1.02**	0.674 U
Fluoride *	mg/L	4		-	-	**0.263**	**0.373**	**0.406**	**0.471**	**0.234**	**0.397**	**0.241**
Methane	ug/L	NA		>100/1,000 ug/L	2.0/3.0	**1.21**	**6.1**	0.384 U	0.384 U	0.384 U	**0.743**	0.384 U
Nitrate as N	mg/L	10		<1 mg/L	2	0.0852 U	0.076 U	0.167 U	0.103 U	**0.295**	**0.366**	0.351 U
Nitrate/Nitrite	mg/L	10		-	-	0.0852 U	0.076 U	0.167 U	0.103 U	**0.295**	**0.366**	0.351 U
Nitrite as N	mg/L	1		-	-	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U
Phosphorus	mg/L	NA		-	-	**0.119 J**	0.05 U	**0.049 J**	0.05 U	**0.229**	0.05 UJ	0.05 U
Sulfate *	mg/L	250		<20 mg/L	2	**28**	**8.93**	**48.1**	**20.9**	**68**	**75.4**	**9.03**
Sulfide	mg/L	NA		>1 mg/L	3	**4.08**	**3.6**	**2.6**	3.2 U	**3.28**	**3.08**	1 U
pH *	SU	6.5 to 8.5		5<pH<9	0	**7.06**	**7.07**	**7.05**	**7.0**	**6.9**	**6.99**	**7.41**
Temperature	°C	NA		>20 C	1	**23.01**	**19.29**	**18.43**	**19.99**	**24.3**	**21.63**	**22.28**
Oxidation-Reduction Potential	mV	NA		< 50 mv/<-100 mv	1.0/2.0	**3.3**	**6.9**	**0.4**	**11.7**	**26.6**	**39.1**	**25.9**
Dissolved Oxygen	mg/L	NA		<0.5 />1 mg/L	3.0/-3.0	**1.17**	**1**	**1.74**	**1.87**	**1.39**	**1.69**	**1.95**
Ferrous iron	mg/L	0.3 for total iron		>1 mg/L	3	**0.2**	**0.0**	**0.0**	**0.1**	**0.1**	**0.1**	**0.0**
Natural Biodegradation Scoring						**4**	**8**	**3**	**0**	**4**	**4**	**3**
Other Parameters												
Conductivity	mmhos/cm	NA				**0.509**	**0.349**	**0.658**	**0.687**	**1.049**	**1.223**	**0.375**
Turbidity	NTUs	NA				**26.5**	**38.2**	**14**	**14.5**	**24.5**	**147.0**	**35.3**
Depth to water	ft TOC	NA				**24.68**	**12.86**	**14.01**	**15.63**	**17.23**	**21.75**	**11.18**

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mg/L = milligrams per liter
MCL = Maximum contaminant level from May 2016 EPA RSL Table.
* = Secondary MCL
mmhos/com = milli mhos per centimeter
Bold indicates detected results.
Dark gray shading indicates screening level exceedance for VOCs.
- = No natural attenuation criteria

mV = millivolts
NS = Not Sampled
NTU = Nephelometric Turbidity Unit
OOR - Out of Range
S = Shallow well
U = Compound was not detected
ug/L = micrograms per liter

** - Equals points assignment for determining favorable conditions for biodegradation
0-5 = Inadequate
6-14 = Limited Evidense
15-20 = Adequate Evidense
>20 = Strong Evidense
Light gray shading indicates evidence for biodegradation

Table 3-15
Groundwater Sample Results (Collected December 2016)
Remedial Investigation, Former Forbes Atlas S-5 Missile Site
Lyon County, Kansas

		Sample ID:	Natural Attenuation	Natural Attenuation	MW-01D-07	MW-02S-07	MW-02S-17	MW-02D-07	MW-02D-17	MW-03S-07
		Lab ID:	Screening	Screening	HS16120711-01	HS16120899-06	HS16120899-07	HS16120711-04	HS16120711-05	HS16120767-03
		Date Collected:	(Wiedemier)	(Wiedemier)	12/13/2016	12/15/2016	12/15/2016	12/13/2016	12/13/2016	12/14/2016
		Screening Level	Favorable	Points**			Duplicate		Duplicate	
Analyte	Units	USEPA MCL	Concentration		Result	Result	Result	Result	Result	Result
cis-1,2-Dichloroethene	ug/L	70	Daughter	2	0.62 U	**6.1**	**5.9**	0.62 U	0.62 U	0.62 U
Trichloroethene	ug/L	5	Released	0	0.5 U	**100**	**100**	0.5 U	0.5 U	**3.4**
Vinyl Chloride	ug/L	2	Daughter	2	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Natural Attenuation Parameters										
Alkalinity as CaCO3	mg/L	NA	2 times background	1	**459**	**444**	**444**	**304**	**303**	**341**
Alkalinity, Bicarbonate (As CaCO3)	mg/L	NA	-	-	**459**	**444**	**444**	**304**	**303**	**341**
Alkalinity, Carbonate (As CaCO3)	mg/L	NA	-	-	5 U	5 U	5 U	5 U	5 U	5 U
Alkalinity, Hydroxide (As CaCO3)	mg/L	NA	-	-	5 U	5 U	5 U	5 U	5 U	5 U
Bromide	mg/L	NA	-	-	**0.683**	**0.07 J**	**0.21**	0.05 U	0.05 U	0.05 U
Chloride *	mg/L	250	2 times background	2	**81.8**	**4.31**	**4.36**	**26.6**	**27.7**	**2.7**
Ethane	ug/L	NA	>10/>100 ug/L	2.0/3.0	**2.17**	0.772 U	0.772 U	0.772 U	0.772 U	0.772 U
Ethene	ug/L	NA	>10/>100 ug/L	2.0/3.0	**1.55**	0.674 U	0.674 U	**0.617 J**	**0.795 J**	0.674 U
Fluoride *	mg/L	4	-	-	**1.21**	**0.334**	**0.34**	**1.24**	**1.32**	**0.337**
Methane	ug/L	NA	>100/1,000 ug/L	2.0/3.0	**16.2**	**1.53**	**1.67**	**5.39**	**5.54**	0.384 U
Nitrate as N	mg/L	10	<1 mg/L	2	**0.266**	**0.036 J**	0.05 U	0.05 U	**0.125**	**0.638**
Nitrate/Nitrite	mg/L	10	-	-	**0.266**	**0.036 J**	0.1 U	0.1 U	**0.125**	**0.638**
Nitrite as N	mg/L	1	-	-	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U
Phosphorus	mg/L	NA	-	-	**0.198**	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U
Sulfate *	mg/L	250	<20 mg/L	2	**409**	**47.1**	**48**	**125**	**129**	**34.4**
Sulfide	mg/L	NA	>1 mg/L	3	**4.52**	1 U	1 U	1 U	1 U	**1.32**
pH *	SU	6.5 to 8.5	5<pH<9	0	**8.25**	**6.89**	NA	**7.06**	NA	**7.7**
Temperature	°C	NA	>20 C	1	**10.65**	**13.67**	NA	**5.9**	NA	**10.46**
Oxidation-Reduction Potential	mV	NA	< 50 mv/<-100 mv	1.0/2.0	**-61.2**	**65.4**	NA	**46.2**	NA	**26.6**
Dissolved Oxygen	mg/L	NA	<0.5 />1 mg/L	3.0/-3.0	**1.28**	**0.58**	NA	**1.26**	NA	**1.54**
Ferrous iron	mg/L	0.3 for total iron	>1 mg/L	3	**0.3**	0	NA	0	NA	0
Natural Biodegradation Scoring					**3**	**2**	**2**	**0**	**2**	**3**
Other Parameters										
Conductivity	mmhos/cm	NA			**1.817**	**0.953**	NA	**0.757**	NA	**0.664**
Turbidity	NTUs	NA			**31.2**	**3.12**	NA	**4.46**	NA	**14.1**
Depth to water	ft TOC	NA			**50.9**	**25.28**	NA	**48.26**	NA	**22.81**

D = Deep well
J = Estimated value
mg/L = milligrams per liter
MCL = Maximum contaminant level from May 2016 EPA RSL Table.
* = Secondary MCL
mmhos/com = milli mhos per centimeter
Bold indicates detected results.
Dark gray shading indicates screening level exceedance for VOCs.
- = No natural attenuation criteria

mV = millivolts
NS = Not Sampled
NTU = Nephelometric Turbidity Unit
S = Shallow well
U = Compound was not detected
ug/L = micrograms per liter
NA = Not available

** - Equals points assignment for determining favorable conditions for biodegradation
0-5 = Inadequate
6-14 = Limited Evidence
15-20 = Adequate Evidence
>20 = Strong Evidence
Light gray shading indicates evidence for biodegradation

Table 3-15
Groundwater Sample Results (Collected December 2016)
Remedial Investigation, Former Forbes Atlas S-5 Missile Site
Lyon County, Kansas

		Sample ID:	Natural Attenuation	Natural Attenuation	MW-03D-07	MW-04S-07	MW-04D-07	MW-05D-07	MW-06S-07	MW-06D-07
		Lab ID:	Screening	Screening	HS16120767-02	HS16120645-02	HS16120645-01	HS16120645-03	HS16120899-02	HS16120899-01
		Date Collected:	(Wiedemier)	(Wiedemier)	12/14/2016	12/12/2016	12/12/2016	12/12/2016	12/15/2016	12/15/2016
		Screening Level	Favorable	Points**						
Analyte	**Units**	**USEPA MCL**	**Concentration**		**Result**	**Result**	**Result**	**Result**	**Result**	**Result**
cis-1,2-Dichloroethene	ug/L	70	Daughter	2	0.62 U	0.62 U	0.62 U	0.62 U	**0.88 J**	0.62 U
Trichloroethene	ug/L	5	Released	0	0.5 U	0.5 U	0.5 U	0.5 U	**15**	0.5 U
Vinyl Chloride	ug/L	2	Daughter	2	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Natural Attenuation Parameters										
Alkalinity as CaCO3	mg/L	NA	2 times background	1	**377**	**300**	**301**	**419**	**405**	**344**
Alkalinity, Bicarbonate (As CaCO3)	mg/L	NA	-	-	**377**	**300**	**301**	**419**	**405**	**344**
Alkalinity, Carbonate (As CaCO3)	mg/L	NA	-	-	5 U	5 U	5 U	5 U	5 U	5 U
Alkalinity, Hydroxide (As CaCO3)	mg/L	NA	-	-	5 U	5 U	5 U	5 U	5 U	5 U
Bromide	mg/L	NA	-	-	0.05 U	**0.109**	**0.203**	**0.272**	0.05 U	0.05 U
Chloride *	mg/L	250	2 times background	2	**91.5**	**11.4**	**69.3**	**82**	**2.74**	**19.9**
Ethane	ug/L	NA	>10/>100 ug/L	2.0/3.0	0.772 U	**0.964 J**	**1.08**	**0.671 J**	0.772 U	**1.56**
Ethene	ug/L	NA	>10/>100 ug/L	2.0/3.0	**1.31**	**1.71**	**4.91**	**4.59**	0.674 U	**2.72**
Fluoride *	mg/L	4	-	-	**1.15**	**0.486**	**1.34**	**1.32**	**0.326**	**1.05**
Methane	ug/L	NA	>100/1,000 ug/L	2.0/3.0	**5.38**	**1.35**	**12.9**	**10.5**	0.384 U	**15.2**
Nitrate as N	mg/L	10	<1 mg/L	2	0.05 U	0.05 U	0.05 U	0.05 U	**0.36 J**	0.05 UJ
Nitrate/Nitrite	mg/L	10	-	-	0.1 U	0.1 U	0.1 U	0.1 U	**0.36 J**	0.1 UJ
Nitrite as N	mg/L	1	-	-	0.05 U	0.05 U	0.05 U	0.05 U	0.05 UJ	0.05 UJ
Phosphorus	mg/L	NA	-	-	0.05 U	0.05 U	**0.066 J**	**0.071 J**	0.05 U	**0.162**
Sulfate *	mg/L	250	<20 mg/L	2	**473**	**43.2**	**351**	**519**	**49.3**	**159**
Sulfide	mg/L	NA	>1 mg/L	3	**2.72**	**5.12**	**2.92**	**4.52**	1 U	1 U
pH *	SU	6.5 to 8.5	5<pH<9	0	**7.14**	**8.54**	**8.6**	**8.68**	**7.62**	**7.54**
Temperature	°C	NA	>20 C	1	**9.7**	**5.95**	**6.29**	**6.86**	**9.74**	**10.85**
Oxidation-Reduction Potential	mV	NA	< 50 mv/<-100 mv	1.0/2.0	**-4.6**	**-61.4**	**-105.9**	**-54.2**	**15**	**-45.3**
Dissolved Oxygen	mg/L	NA	<0.5 />1 mg/L	3.0/-3.0	**1.56**	**1.84**	**1.09**	**1.11**	**2.11**	**1**
Ferrous iron	mg/L	0.3 for total iron	>1 mg/L	3	0	**0.3**	**0.5**	**0.3**	**0.1**	**0.3**
Natural Biodegradation Scoring					**3**	**4**	**5**	**4**	**1**	**3**
Other Parameters										
Conductivity	mmhos/cm	NA			**1.683**	**0.614**	**1.343**	**2.107**	**0.784**	**1.008**
Turbidity	NTUs	NA			**14.1**	**354**	**35.1**	**19**	**11.3**	**6.4**
Depth to water	ft TOC	NA			**46.63**	**32.94**	**57.94**	**55.86**	**17.58**	**33.62**

D = Deep well
J = Estimated value
mg/L = milligrams per liter
MCL = Maximum contaminant level from May 2016 EPA RSL Table.
* = Secondary MCL
mmhos/com = milli mhos per centimeter
Bold indicates detected results.
Dark gray shading indicates screening level exceedance for VOCs.
- = No natural attenuation criteria

mV = millivolts
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0-5 = Inadequate
6-14 = Limited Evidence
15-20 = Adequate Evidence
>20 = Strong Evidence
Light gray shading indicates evidence for biodegradation

Table 3-15
Groundwater Sample Results (Collected December 2016)
Remedial Investigation, Former Forbes Atlas S-5 Missile Site
Lyon County, Kansas

			Sample ID:	Natural Attenuation	Natural Attenuation	MW-07S-07	MW-08S-03	MW-09S-03	MW-10S-03	MW-11S-03	MW-12S-03	MW-13S-03
			Lab ID:	Screening	Screening	HS16120767-05	HS16120767-01	HS16120711-02	HS16120711-03	HS16120899-05	HS16120767-04	HS16120899-03
			Date Collected:	(Wiedemier)	(Wiedemier)	12/14/2016	12/14/2016	12/13/2016	12/13/2016	12/15/2016	12/14/2016	12/15/2016
		Screening Level		Favorable	Points**							
Analyte	Units	USEPA MCL		Concentration		Result	Result	Result	Result	Result	Result	Result
cis-1,2-Dichloroethene	ug/L	70		Daughter	2	0.62 U	0.62 UJ	0.62 U	0.62 U	**18**	0.62 U	**8.6**
Trichloroethene	ug/L	5		Released	0	**6.7**	0.5 UJ	0.5 U	0.5 U	**69**	**1.3**	**97**
Vinyl Chloride	ug/L	2		Daughter	2	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	2 U
Natural Attenuation Parameters												
Alkalinity as CaCO3	mg/L	NA		2 times background	1	**354**	**396**	**373**	**442**	**495**	**658**	**336**
Alkalinity, Bicarbonate (As CaCO3)	mg/L	NA		-	-	**354**	**396**	**373**	**442**	**495**	**658**	**336**
Alkalinity, Carbonate (As CaCO3)	mg/L	NA		-	-	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Alkalinity, Hydroxide (As CaCO3)	mg/L	NA		-	-	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Bromide	mg/L	NA		-	-	0.05 U	**0.034 J**	0.05 U	0.05 U	**0.14**	**1.02**	0.05 U
Chloride *	mg/L	250		2 times background	2	**2.35**	**8.57**	**6.5**	**0.971**	**7.2**	**42.1**	**2.76**
Ethane	ug/L	NA		>10/>100 ug/L	2.0/3.0	0.772 U	0.772 U	0.772 U	0.772 U	0.772 U	**0.674 J**	0.772 U
Ethene	ug/L	NA		>10/>100 ug/L	2.0/3.0	0.674 U	**1.1**	**2.05**	**1.75**	**2.09**	0.674 U	0.674 U
Fluoride *	mg/L	4		-	-	**0.258**	**0.278**	**0.397**	**0.459**	**0.256**	**0.39**	**0.293**
Methane	ug/L	NA		>100/1,000 ug/L	2.0/3.0	**0.19 J**	**34.7**	0.384 U	0.384 U	0.384 U	0.384 U	0.384 U
Nitrate as N	mg/L	10		<1 mg/L	2	0.05 U	0.05 U	**0.064 J**	0.05 U	**0.043 J**	**0.581**	**0.414**
Nitrate/Nitrite	mg/L	10		-	-	0.1 U	0.1 U	**0.064 J**	0.1 U	**0.043 J**	**0.581**	**0.414**
Nitrite as N	mg/L	1		-	-	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U
Phosphorus	mg/L	NA		-	-	0.05 U	0.05 U	0.05 U	0.05 U	**0.081 J**	0.05 U	0.05 U
Sulfate *	mg/L	250		<20 mg/L	2	**29**	**43**	**45.5**	**19.7**	**68.9**	**68.6**	**19.6**
Sulfide	mg/L	NA		>1 mg/L	3	1 U	1 U	**1.52**	**2.12**	1 U	1 U	1 U
pH *	SU	6.5 to 8.5		5<pH<9	0	**7.8**	**6.61**	**8.06**	**7.82**	**7.09**	**7.13**	**7.91**
Temperature	°C	NA		>20 C	1	**11.16**	**11.31**	**10.02**	**9.24**	**10.72**	**10.87**	**9.88**
Oxidation-Reduction Potential	mV	NA		< 50 mv/<-100 mv	1.0/2.0	**7.3**	**54**	**-3.5**	**13.1**	**56.6**	**62**	**21.7**
Dissolved Oxygen	mg/L	NA		<0.5 />1 mg/L	3.0/-3.0	**1.33**	**1.8**	**1.4**	**1.34**	**2.12**	**2.4**	**3.32**
Ferrous iron	mg/L	0.3 for total iron		>1 mg/L	3	**0.2**	**0.3**	**0.1**	0	**0.2**	**0.1**	0
Natural Biodegradation Scoring						**1**	**1**	**3**	**5**	**0**	**0**	**3**
Other Parameters												
Conductivity	mmhos/cm	NA				**0.66**	**0.815**	**0.758**	**0.752**	**0.973**	**1.364**	**0.625**
Turbidity	NTUs	NA				**57.9**	**44.8**	**13.2**	**20.6**	**29.1**	**168**	**44.7**
Depth to water	ft TOC	NA				**27.85**	**15.19**	**16.6**	**18.8**	**20.64**	**22.12**	**14.71**

D = Deep well
J = Estimated value
mg/L = milligrams per liter
MCL = Maximum contaminant level from May 2016 EPA RSL Table.
* = Secondary MCL
mmhos/com = milli mhos per centimeter
Bold indicates detected results.
Dark gray shading indicates screening level exceedance for VOCs.
- = No natural attenuation criteria

mV = millivolts
NS = Not Sampled
NTU = Nephelometric Turbidity Unit
S = Shallow well
U = Compound was not detected
ug/L = micrograms per liter
NA = Not available

** - Equals points assignment for determining favorable conditions for biodegradation
0-5 = Inadequate
6-14 = Limited Evidence
15-20 = Adequate Evidence
>20 = Strong Evidence
Light gray shading indicates evidence for biodegradation

Table 3-16
Groundwater Sample Results (Collected March 2017)
Remedial Investigation, Former Forbes Atlas S-5 Missile Site
Lyon County, Kansas

			Sample ID:	Natural Attenuation	Natural Attenuation	MW-01D-08	MW-02S-08	MW-02S-18	MW-02D-08	MW-03S-08	MW-03D-08
			Lab ID:	Screening	Screening	HS17031470-04	HS17031646-05	HS17031646-06	HS17031611-03	HS17031646-01	HS17031611-05
			Date Collected:	(Wiedemier)	(Wiedemier)	3/28/2017	3/30/2017	3/30/2017	3/29/2017	3/30/2017	3/29/2017
		Screening Level		Favorable	Points**			Duplicate			
Analyte	Units	Federal MCL		Concentration		Result	Result	Result	Result	Result	Result
Cis-1,2-Dichloroethene	ug/L	70		Daughter	2	0.5 U	**7.5**	**7**	0.5 U	0.5 U	0.5 U
Trichloroethene	ug/L	5		Released	0	0.5 U	**82**	**77**	0.5 U	**4.3**	0.5 U
Vinyl Chloride	ug/L	2		Daughter	2	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Natural Attenuation Parameters											
Alkalinity as CaCO3	mg/L	NA		2 times background	1	**459**	**439**	**444**	**299**	**430**	**399**
Alkalinity, Bicarbonate (As CaCO3)	mg/L	NA		-	-	**459**	**439**	**444**	**299**	**430**	**399**
Alkalinity, Carbonate (As CaCO3)	mg/L	NA		-	-	5 U	5 U	5 U	5 U	5 U	5 U
Alkalinity, Hydroxide (As CaCO3)	mg/L	NA		-	-	5 U	5 U	5 U	5 U	5 U	5 U
Bromide	mg/L	NA		-	-	**0.518 J**	**0.45**	**0.448**	0.05 U	0.05 U	**0.52**
Chloride *	mg/L	250		2 times background	2	**83.1**	**4.11**	**3.97**	**25.7**	**3.18**	**84.2**
Ethane	ug/L	NA		>10/>100 ug/L	2.0/3.0	**0.575 J**	0.361 U	0.361 U	0.361 U	0.361 U	**0.267 J**
Ethene	ug/L	NA		>10/>100 ug/L	2.0/3.0	**0.693 J**	0.337 U	0.337 U	0.337 U	0.337 U	1.2 U
Fluoride *	mg/L	4		-	-	**1.24 J**	**0.409**	**0.414**	**1.35**	**0.394**	**1.05**
Methane	ug/L	NA		>100/1,000 ug/L	2.0/3.0	**3.67**	**2.09**	**1.96**	**3.33**	**0.635**	**5.29**
Nitrate as N	mg/L	10		<1 mg/L	2	0.05 U	**0.24**	**0.224**	0.05 U	**1.24**	0.05 U
Nitrate/Nitrite	mg/L	10		-	-	0.05 U	**0.24**	**0.224**	0.05 U	**1.24**	0.05 U
Nitrite as N	mg/L	1		-	-	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U
Phosphorus	mg/L	NA		-	-	**4.29**	0.1 U	0.1 U	0.1 U	0.1 U	**1.54**
Sulfate *	mg/L	250		<20 mg/L	2	**399**	**40.9**	**40.4**	**115**	**29**	**451**
Sulfide	mg/L	NA		>1 mg/L	3	**4.84**	**2.16**	**1.16**	1 U	**1.96**	1 U
pH *	SU	6.5 to 8.5		5<pH<9	0	**7.11**	**6.93**	NA	**7.41**	**6.97**	**6.66**
Temperature	°C	NA		>20 C	1	**13.29**	**12.7**	NA	**13.63**	**11.51**	**15.95**
Oxidation-Reduction Potential	mV	NA		< 50 mv/<-100 mv	1.0/2.0	**-89.6**	**89.8**	NA	**0.2**	**118**	**-50**
Dissolved Oxygen	mg/L	NA		<0.5 />1 mg/L	3.0/-3.0	**5.97**	**2.96**	NA	**2.92**	**1.4**	**1.97**
Ferrous iron	mg/L	0.3 for total iron		>1 mg/L	3	**0.7**	0	NA	**0.1**	**0.1**	**0.8**
Natural Biodegradation Scoring						**3**	**4**	NA	**0**	**0**	**0**
Other Parameters											
Conductivity	mmhos/cm	NA				**1.260**	**0.574**	NA	**0.595**	**0.539**	**1.343**
Turbidity	NTUs	NA				**35.4**	**6.95**	NA	**8.98**	**12.8**	**38.4**
Depth to water	ft TOC	NA				**49.45**	**17.91**	NA	**45.6**	**18.02**	**44.45**

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mg/L = milligrams per liter
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Bold indicates detected results.
Dark gray shading indicates screening level exceedance for VOCs.
- = No natural attenuation criteria

mV = millivolts
NS = Not Sampled
NTU = Nephelometric Turbidity Unit
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0-5 = Inadequate
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Light gray shading indicates evidence for biodegradation

Table 3-16
Groundwater Sample Results (Collected March 2017)
Remedial Investigation, Former Forbes Atlas S-5 Missile Site
Lyon County, Kansas

		Sample ID:	Natural Attenuation	Natural Attenuation	MW-04S-08	MW-04D-08	MW-05D-08	MW-06S-08	MW-06S-18	MW-06D-08
		Lab ID:	Screening	Screening	HS17031470-02	HS17031414-01, HS17031470-01	HS17031470-03	HS17031470-08	HS17031470-09	HS17031470-07
		Date Collected:	(Wiedemier)	(Wiedemier)	3/28/2017	3/27/2017	3/28/2017	3/28/2017	3/28/2017	3/28/2017
		Screening Level	Favorable	Points**					Duplicate	
Analyte	Units	Federal MCL	Concentration		Result	Result	Result	Result	Result	Result
Cis-1,2-Dichloroethene	ug/L	70	Daughter	2	0.5 U	0.5 U	0.5 U	**2.9**	**2.5**	0.5 U
Trichloroethene	ug/L	5	Released	0	0.5 U	0.5 U	0.5 U	**28**	**29**	**0.83 J**
Vinyl Chloride	ug/L	2	Daughter	2	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Natural Attenuation Parameters										
Alkalinity as CaCO3	mg/L	NA	2 times background	1	**335**	**310**	**483**	**399**	**395**	**362**
Alkalinity, Bicarbonate (As CaCO3)	mg/L	NA	-	-	**335**	**310**	**483**	**399**	**395**	**362**
Alkalinity, Carbonate (As CaCO3)	mg/L	NA	-	-	5 U	5 U	5 U	5 U	5 U	5 U
Alkalinity, Hydroxide (As CaCO3)	mg/L	NA	-	-	5 U	5 U	5 U	5 U	5 U	5 U
Bromide	mg/L	NA	-	-	0.05 UJ	**0.475 J**	**0.54 J**	0.05 UJ	0.05 UJ	0.05 UJ
Chloride *	mg/L	250	2 times background	2	**7.47**	**62.5**	**83.3**	**2.92**	**2.46**	**20.8**
Ethane	ug/L	NA	>10/>100 ug/L	2.0/3.0	0.361 U	0.361 U	0.361 U	0.361 U	0.361 U	**1.11**
Ethene	ug/L	NA	>10/>100 ug/L	2.0/3.0	0.337 U	**3.55**	0.337 U	0.337 U	0.337 U	**2.209**
Fluoride *	mg/L	4	-	-	**0.458 J**	**1.38**	**1.31 J**	**0.375 J**	**0.361 J**	**1.17 J**
Methane	ug/L	NA	>100/1,000 ug/L	2.0/3.0	**0.894**	**9.22**	**2.09**	0.193 U	**0.277 J**	**11.1**
Nitrate as N	mg/L	10	<1 mg/L	2	0.05 U	0.05 U	0.05 U	**0.504**	**0.661**	0.05 U
Nitrate/Nitrite	mg/L	10	-	-	0.05 U	0.1 U	0.05 U	**0.504**	**0.661**	0.05 U
Nitrite as N	mg/L	1	-	-	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U
Phosphorus	mg/L	NA	-	-	**0.538**	**0.815 J**	**4.3**	0.1 U	0.1 U	**0.816**
Sulfate *	mg/L	250	<20 mg/L	2	**28.9**	**334**	**557**	**40.4**	**42.1**	**170**
Sulfide	mg/L	NA	>1 mg/L	3	1 U	**1.04**	**1.64**	1 U	1 U	**3.24**
pH *	SU	6.5 to 8.5	5<pH<9	0	**7.13**	**6.97**	**7.2**	**6.96**	NA	**6.92**
Temperature	°C	NA	>20 C	1	**13.14**	**13.61**	**13.31**	**14.06**	NA	**14.68**
Oxidation-Reduction Potential	mV	NA	< 50 mv/<-100 mv	1.0/2.0	**-51.6**	**-81.7**	**-99.8**	**8.8**	NA	**-107.6**
Dissolved Oxygen	mg/L	NA	<0.5 />1 mg/L	3.0/-3.0	**3.32**	**0.92**	**6.02**	**3.35**	NA	**1.84**
Ferrous iron	mg/L	0.3 for total iron	>1 mg/L	3	**0.4**	**1.1**	**0.5**	**0.1**	NA	**0.8**
Natural Biodegradation Scoring					**0**	**9**	**4**	**2**	NA	**4**
Other Parameters										
Conductivity	mmhos/cm	NA			**0.45**	**0.988**	**1.582**	**0.544**	NA	**0.744**
Turbidity	NTUs	NA			**302**	**43.8**	**55.8**	**32.2**	NA	**20.4**
Depth to water	ft TOC	NA			**31.41**	**54.5**	**52.9**	**9.63**	NA	**29.78**

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- = No natural attenuation criteria

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Light gray shading indicates evidence for biodegradation

Table 3-16
Groundwater Sample Results (Collected March 2017)
Remedial Investigation, Former Forbes Atlas S-5 Missile Site
Lyon County, Kansas

		Sample ID:	Natural Attenuation	Natural Attenuation	MW-07S-08	MW-08S-04	MW-09S-04	MW-10S-04	MW-11S-04	MW-12S-04	MW-13S-04
		Lab ID:	Screening	Screening	HS17031646-03	HS17031611-04	HS17031611-01	HS17031611-02	HS17031646-04	HS17031646-02	HS17031470-05
		Date Collected:	(Wiedemier)	(Wiedemier)	3/30/2017	3/29/2017	3/29/2017	3/29/2017	3/30/2017	3/30/2017	3/28/2017
		Screening Level	Favorable	Points**							
Analyte	**Units**	**Federal MCL**	**Concentration**		**Result**	**Result**	**Result**	**Result**	**Result**	**Result**	**Result**
Cis-1,2-Dichloroethene	ug/L	70	Daughter	2	**0.71 J**	0.5 U	0.5 U	0.5 U	**26**	0.5 U	**6.7**
Trichloroethene	ug/L	5	Released	0	**8.5**	0.5 U	0.5 U	**0.33 J**	**61**	**1.6**	**64**
Vinyl Chloride	ug/L	2	Daughter	2	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Natural Attenuation Parameters											
Alkalinity as CaCO3	mg/L	NA	2 times background	1	**357**	**196.5**	**363**	**453**	**525**	**656**	**367**
Alkalinity, Bicarbonate (As CaCO3)	mg/L	NA	-	-	**357**	**196.5**	**363**	**453**	**525**	**656**	**367**
Alkalinity, Carbonate (As CaCO3)	mg/L	NA	-	-	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Alkalinity, Hydroxide (As CaCO3)	mg/L	NA	-	-	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Bromide	mg/L	NA	-	-	0.05 U	0.05 U	**0.414**	**0.414**	**0.514**	**1.17**	0.05 UJ
Chloride *	mg/L	250	2 times background	2	**2.68**	**4.34**	**6.43**	**1.31**	**5.83**	**33.1**	**2.88**
Ethane	ug/L	NA	>10/>100 ug/L	2.0/3.0	0.361 U	0.361 U	0.361 U	**0.352 J**	0.361 U	0.361 U	0.361 U
Ethene	ug/L	NA	>10/>100 ug/L	2.0/3.0	0.337 U	0.337 U	0.337 U	0.337 U	0.337 U	0.337 U	0.337 U
Fluoride *	mg/L	4	-	-	**0.36**	**0.392**	**0.444**	**0.492**	**0.222**	**0.431**	**0.328** J
Methane	ug/L	NA	>100/1,000 ug/L	2.0/3.0	**5.12**	**7.49**	**0.521**	**0.383 J**	**0.925**	**0.607**	0.5 U
Nitrate as N	mg/L	10	<1 mg/L	2	**0.224**	0.05 U	**0.263 J**	0.05 U	0.05 U	**0.779**	**0.546**
Nitrate/Nitrite	mg/L	10	-	-	**0.224**	0.05 U	**0.263 J**	0.05 U	0.05 U	**0.779**	**0.546**
Nitrite as N	mg/L	1	-	-	0.05 U	0.05 U	0.05 UJ	0.05 U	0.05 U	0.05 U	0.05 U
Phosphorus	mg/L	NA	-	-	0.1 U	0.1 U	0.1 UJ	0.1 U	0.1 U	0.1 U	0.1 U
Sulfate *	mg/L	250	<20 mg/L	2	0.5 U	**10.3**	**38.3**	**16.5**	**55.1**	**62.8**	**17.3**
Sulfide	mg/L	NA	>1 mg/L	3	1 U	1 U	1 U	1 U	**1.96**	**1.36**	**1.44**
pH *	SU	6.5 to 8.5	5<pH<9	0	**6.98**	**7.31**	**7.34**	**7.03**	**6.87**	**7.02**	**7.15**
Temperature	°C	NA	>20 C	1	**12.95**	**13.74**	**11.21**	**11.69**	**13.91**	**13.64**	**13.36**
Oxidation-Reduction Potential	mV	NA	< 50 mv/<-100 mv	1.0/2.0	**-7.4**	**22.9**	**121.8**	**130.3**	**109.1**	**130.2**	**64**
Dissolved Oxygen	mg/L	NA	<0.5 />1 mg/L	3.0/-3.0	**0.93**	**1.27**	**6.73**	**2.68**	**3.02**	**3.63**	**3.84**
Ferrous iron	mg/L	0.3 for total iron	>1 mg/L	3	**0.1**	**0.1**	0	**0.1**	**0.1**	**0.1**	**0.1**
Natural Biodegradation Scoring					**7**	**2**	**-1**	**1**	**4**	**2**	**6**
Other Parameters											
Conductivity	mmhos/cm	NA			**0.466**	**0.268**	**0.473**	**0.525**	**0.709**	**0.933**	**0.473**
Turbidity	NTUs	NA			**139**	**30.8**	**17**	**31.4**	**65.4**	**153**	**36.8**
Depth to water	ft TOC	NA			**20.39**	**12.1**	**12.45**	**14.5**	**13.17**	**20.79**	**12.86**

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Section 5

Tables

Table 5-1
Summary of Analytes Detected in Groundwater
Remedial Investigation, Former Forbes Atlas Missile Site S-5
Lyon County, Kansas

Analyte	Minimum Concentration	Maximum Concentration	Units	Location of Maximum Concentration	Detection Frequency	Detection Limits[b]	Arithmetic Mean	Standard Deviation	KDHE Risk-based Standards for Kansas (RSK)	EPA Regional Screening Level[a] (Tap Water)	EPA Vapor Intrusion Screening Level (VISL)[b]	Ratio of Maximum Concentration to EPA RSL	Ratio of Maximum Concentration to EPA VISLs	Groundwater COPC	Vapor Intrusion COPC
All Wells															
cis-1,2-Dichloroethene	0.40	26	µg/L	MW-11S-04	30/112	0.50 - 0.62	1.8	3.69	70	3.6 n	NA	7.2	--	Yes	--
Trichloroethene	0.20	100	µg/L	MW-02S-17, MW-02S-07, MW-02S-04	53/112	0.50 - 0.62	13.0	26.7	5.0	0.28 n	0.52 n	357	192	Yes	Yes
MW-01															
Trichloroethene	0.20	0.20	µg/L	MW-01D-01	1/8	0.50 - 0.62	0.51	0.14	5.0	0.28 n	0.52 n	0.71	0.38	No	No
MW-02															
cis-1,2-Dichloroethene	4.0	7.5	µg/L	MW-02S-08	7/16	0.50 - 0.62	3.0	2.9	70	3.6 n	NA	2.1	--	Yes	--
Trichloroethene	0.60	100	µg/L	MW-02S-04, MW-02S-07, MW-02S-17	9/16	0.50 - 0.62	43.6	45.4	5.0	0.28 n	0.52 n	357	192	Yes	Yes
MW-03															
cis-1,2-Dichloroethene	0.40	1.1	µg/L	MW-03S-02	5/16	0.50 - 0.62	0.59	0.16	70	3.6 n	NA	0.31	--	No	--
Trichloroethene	0.30	5.9	µg/L	MW-03S-03	9/16	0.50 - 0.62	2.6	2.20	5.0	0.28 n	0.52 n	21.1	11	Yes	Yes
MW-05															
Trichloroethene	0.20	0.20	µg/L	MW-05D-04	1/8	0.50 - 0.62	0.49	0.13	5.0	0.28 n	0.52 n	0.71	0.38	No	No
MW-06															
cis-1,2-Dichloroethene	0.70	2.9	µg/L	MW-06S-08	7/16	0.50 - 0.62	0.96	0.74	70	3.6 n	NA	0.81	--	No	--
Trichloroethene	0.30	29	µg/L	MW-06S-18	11/16	0.50 - 0.62	10.9	11.2	5.0	0.28 n	0.52 n	104	56	Yes	Yes
MW-07															
cis-1,2-Dichloroethene	0.40	0.70	µg/L	MW-07S-08, MW-07S-05	4/8	0.50 - 0.62	0.58	0.11	70	3.6 n	NA	0.19	--	No	--
Trichloroethene	2.0	8.5	µg/L	MW-07S-08	8/8	NA	5.7	2.1	5.0	0.28 n	0.52 n	30.36	16	Yes	Yes
MW-8															
Trichloroethene	0.40	0.40	µg/L	MW-08S-01	1/4	0.50 - 0.62	0.51	0.09	5.0	0.28 n	0.52 n	1.4	0.77	Yes	No
MW-10															
Trichloroethene	0.30	0.30	µg/L	MW-10S-04	1/4	0.50 - 0.62	0.48	0.13	5.0	0.28 n	0.52 n	1.1	0.58	Yes	No
MW-11															
cis-1,2-Dichloroethene	10	26	µg/L	MW-11S-04	4/4	NA	18	6.6	70	3.6 n	NA	7.2	--	Yes	--
Trichloroethene	60	69	µg/L	MW-11S-03	4/4	NA	64	4.1	5.0	0.28 n	0.52 n	246	133	Yes	Yes
MW-12															
Trichloroethene	1.3	2.0	µg/L	MW-12S-01	4/4	NA	1.6	--	5.0	0.28 n	0.52 n	7.1	3.8	Yes	Yes
MW-13															
cis-1,2-Dichloroethene	6.0	8.6	µg/L	MW-13S-03	3/4	0.50 - 0.50	5.5	3.5	70	3.6 n	NA	2.4	--	Yes	--
Trichloroethene	4.0	97	µg/L	MW-13S-03	4/4	NA	53.8	38.6	5.0	0.28 n	0.52 n	346	187	Yes	Yes

[a]USEPA, 2017a.
[b]VISL Calculator (USEPA, 2016)
c = Cancer based, target risk equals 1E-06.
n = Noncancer based, target hazard quotient equals 0.1.
µg/L = micrograms per Liter
COPC = Contaminant of Potential Concern
RSL = Regional Screening Level
RSK = Risk-based Standards of Kansas (KDHE, 2015)
VISL = Vapor Intrustion Screening Level; Assumed residential scenario, THQ = 0.1, TCR = 1.0E-6, and average GW temperature = 25°c

Table 5-2
Summary of Analytes Detected in Sediment
Remedial Investigation, Former Forbes Atlas Missile Site S-5
Lyon County, Kansas

Analyte	Minimum Concentration	Maximum Concentration	Units	Location of Maximum Concentration	Detection Frequency	Detection Limits	Arithmetic Mean	Standard Deviation	KDHE Risk-based Standards for Kansas (RSK)	EPA Regional Screening Level[a] (Industrial Soil)	Ratio of Maximum Concentration to EPA RSL	COPC
cis-1,2-Dichloroethene	0.0040	30	mg/kg	SD-01	2/7	0.0037 - 0.021	4.29	11.3	NBA	230 n	0.13	No
Trichloroethene	0.01	0.10	mg/kg	SD-01	2/7	0.0037 - 0.021	0.02	0.035	NBA	1.9 n	0.053	No
Vinyl Chloride	10	10	mg/kg	SD-01	1/7	0.0018 - 0.010	1.43	3.8	NBA	1.7 c	5.9	Yes

[a]USEPA, 2017a.
mg/kg = milligrams per kilogram.
c = Cancer based, target risk equals 1E-06.
n = Noncancer based, target hazard quotient equals 0.1.
COPC = Contaminant of Potential Concern
NBA = No benchmark available
RSL = Regional Screening Level
RSK = Risk-based Standards of Kansas (KDHE, 2015)

Table 5-3
Summary of Analytes Detected in Surface Water
Remedial Investigation, Former Forbes Atlas Missile Site S-5
Lyon County, Kansas

Analyte	Minimum Concentration	Maximum Concentration	Units	Location of Maximum Concentration	Detection Frequency	Detection Limits[b]	Arithmetic Mean	Standard Deviation	KDHE Risk-based Standards for Kansas (RSK)	EPA Regional Screening Level[a] (Tap Water)	Ratio of Maximum Concentration to EPA SL	COPC
cis-1,2-Dichloroethene	11	45	µg/L	SW-04	3/10	0.50 - 0.50	7.65	14.3	70	3.6 n	13	Yes
Trichloroethene	1.4	50	µg/L	SW-04	2/10	0.50 - 0.50	5.54	15.6	2.7	0.28 n	179	Yes
Vinyl Chloride	15	24	µg/L	SW-04	3/10	0.50 - 0.50	6.55	10.0	2	0.019 c	1263	Yes

[a]USEPA, 2017a.
c = Cancer based, target risk equals 1E-06.
n = Noncancer based, target hazard quotient equals 0.1.
µg/L = micrograms per Liter
COPC = Contaminant of Potential Concern
RSK = Risk-based Standards of Kansas (KDHE, 2015)
SL = Screening Level.
SW = surface water.

Table 5-4
Summary of Exposure Point Concentrations for COPCs - Groundwater*
Remedial Investigation, Former Forbes Atlas Missile Site S-5
Lyon County, Kansas

COPC	Arithmetic Mean (µg/L)	95% UCL (µg/L)	Maximum Detected Concentration (µg/L)	Exposure Point Concentration		
				Value (µg/L)	Statistic	Rationale
cis-1,2-Dichloroethene	17.8	NC	26	26	Maximum	Less than 8 samples
Trichloroethene	43.6	94.4	100	94.4	95% KM Chebyshev UCL	ProUCL Recommendation

*See Table 5-1
NC = Not calculated.
µg/L = micrograms per Liter.
UCL = Upper confidence limit
cis-1,2-Dichloroethene value based on MW-11, Trichloroethene value based on MW-02.

Table 5-5
Summary of Exposure Point Concentrations for COPCs - Sediment
Remedial Investigation, Former Forbes Atlas Missile Site S-5
Lyon County, Kansas

COPC	Arithmetic Mean (mg/kg)	95% UCL (mg/kg)	Maximum Detected Concentration (mg/kg)	Exposure Point Concentration		
				Value (mg/kg)	Statistic	Rationale
Vinyl Chloride	1.4	NC	10	10	Maximum	Less than 8 samples

*See Table 5-2
NC = Not calculated.
mg/kg = milligram per kilogram.
UCL = Upper confidence limit.

Table 5-6
Summary of Exposure Point Concentrations for COPCs - Surface Water
Remedial Investigation, Former Forbes Atlas Missile Site S-5
Lyon County, Kansas

COPC	Arithmetic Mean (µg/L)	95% UCL (µg/L)	Maximum Detected Concentration (µg/L)	Exposure Point Concentration		
				Value (µg/L)	Statistic	Rationale
cis-1,2-Dichloroethene	7.7	NC	45	45	Maximum	Less than 8 samples
Trichloroethene	5.5	NC	50	50	Maximum	Less than 8 samples
Vinyl Chloride	6.6	NC	24	24	Maximum	Less than 8 samples

*See Table 5-3
NC = Not calculated.
µg/L = micrograms per Liter.
UCL = Upper confidence limit

Table 5-7
Values Used for Daily Intake Equations - Future Resident - Groundwater
Remedial Investigation, Former Forbes Atlas Missile Site S-5
Lyon County, Kansas

Scenario Timeframe: Future
Medium: Groundwater
Exposure Medium: Groundwater
Receptor Population: Future Residents
Receptor Age: Child/Adult

Exposure Route	Exposure Point	Parameter Code	Parameter Definition	Value	Units	Rationale/ Reference	Intake Equation/ Model Name
Ingestion	Tap Water	EPC	Exposure Point Concentration	COPC-specific	µg/L	See Table 5-4	Chronic daily intake (CDI) (mg/kg-day) =
		IFW_{adj}	Age-adjusted water ingestion factor	0.9	L-year/kg-day	Calculated	$EPC \times IFW_{adj} \times CF1 \times FI \times EF \times 1/AT_C$
		FI	Fraction Ingested	1	unitless	USEPA, 1989a	Where
		EF	Exposure Frequency	350	days/year	USEPA, 2014b	$IFW_{adj} = (IRW_c \times ED_c \times 1/BW_c) + (IRW_a \times ED_a \times 1/BW_a)$
		ED_c	Exposure Duration - child	6	years	USEPA, 2014b	
		ED_a	Exposure Duration - adult	20	years	USEPA, 2014b	
		IRW_c	Ingestion Rate of Water - child	0.78	L/day	USEPA, 2014b	
		IRW_a	Ingestion Rate of Water - adult	2.5	L/day	USEPA, 2014b	
		BW_c	Body Weight - child	15	kg	USEPA, 2014b	
		BW_a	Body Weight - adult	80	kg	USEPA, 2014b	
		CF1	Conversion Factor 1	1.00E-03	mg/µg	-----	
		AT_C	Averaging Time (Cancer)	25,550	days	USEPA, 2014b	
	Tap Water (Child Exposure)	EPC	Exposure Point Concentration	COPC-specific	µg/L	See Table 5-4	Chronic daily intake (CDI) (mg/kg-day) =
		IRW	Ingestion Rate of Water	0.78	L/day	USEPA, 2014b	$EPC \times IRW \times CF1 \times FI \times EF \times ED \times 1/BW \times 1/AT_{NC}$
		FI	Fraction Ingested	1	unitless	USEPA, 1989a	
		EF	Exposure Frequency	350	days/year	USEPA, 2014b	
		ED	Exposure Duration	6	years	USEPA, 2014b	
		CF1	Conversion Factor 1	1.00E-03	mg/µg	-----	
		BW	Body Weight	15	kg	USEPA, 2014b	
		AT_{NC}	Averaging Time (Non-Cancer)	2,190	days	Calculated	
	Tap Water (Adult Exposure)	EPC	Exposure Point Concentration	COPC-specific	µg/L	See Table 5-4	Chronic daily intake (CDI) (mg/kg-day) =
		IRW	Ingestion Rate of Water	2.5	L/day	USEPA, 2014b	$EPC \times IRW \times CF1 \times FI \times EF \times ED \times 1/BW \times 1/AT_{NC}$
		FI	Fraction Ingested	1	unitless	USEPA, 1989a	
		EF	Exposure Frequency	350	days/year	USEPA, 2014b	
		ED	Exposure Duration	20	years	USEPA, 2014b	
		CF1	Conversion Factor 1	1.00E-03	mg/µg	-----	
		BW	Body Weight	80	kg	USEPA, 2014b	
		AT_{NC}	Averaging Time (Non-Cancer)	7,300	days	Calculated	

Table 5-7
Values Used for Daily Intake Equations - Future Resident - Groundwater
Remedial Investigation, Former Forbes Atlas Missile Site S-5
Lyon County, Kansas

Scenario Timeframe: Future
Medium: Groundwater
Exposure Medium: Groundwater
Receptor Population: Future Residents
Receptor Age: Child/Adult

Exposure Route	Exposure Point	Parameter Code	Parameter Definition	Value	Units	Rationale/ Reference	Intake Equation/ Model Name
Dermal Contact	Tap Water While Bathing/Showering	SFS_{adj}	Age-adjusted skin contact factor	7.46E+03	event-year-cm^2/kg-day	Calculated	Dermally Absorbed Dose (DAD) (mg/kg-day) =
		SA_c	Skin Surface Area Available for Contact - child	6,365	cm^2	USEPA, 2014b	$DA_{EVENT-adj} \times SFS_{adj} \times EF \times 1/AT_C$
		SA_a	Skin Surface Area Available for Contact - adult	19,652	cm^2	USEPA, 2014b	
		$DA_{EVENT-adj}$	Absorbed Dose Per Event	COPC-specific	mg/cm^2-event	See Table 5-10	$SFS_{adj} = (SA_c \times EV_c \times ED_c \times 1/BW_c) + (SA_a \times EV_a \times ED_a \times 1/BW_a)$
		EV_c	Event Frequency - child	1	event/day	USEPA, 2004	$DA_{EVENT-adj}$ Calculations
		EV_a	Event Frequency - adult	1	event/day	USEPA, 2004	$t_{event-adj} = (ED_c \times t_{event-c}) + (ED_a \times t_{event-a})/(ED_c + ED_a)$
		EF	Exposure Frequency	350	days/year	USEPA, 2014b	
		ED_c	Exposure Duration - child	6	years	USEPA, 2014b	if $t_{event-adj} \leq t^*$, then $DA_{EVENT-adj}$ (Organic) =
		ED_a	Exposure Duration - adult	20	years	USEPA, 2014b	2 FA x K_p x C_w x CF2 x CF3 x Ö ($6t_{event} \times t_{event-adj}/p$)
		BW_c	Body Weight - child	15	kg	USEPA, 2014b	
		BW_a	Body Weight - adult	80	kg	USEPA, 2014b	otherwise if $t_{event-adj} > t^*$, then $DA_{EVENT-adj}$ (Organic) =
		AT_C	Averaging Time (Cancer)	25,550	days	USEPA, 2014b	FA x K_p x C_w x CF2 x CF3 x
		$t_{event-adj}$	Age-adjusted event duration	0.67	hr/event	Calculated	$[((t_{event-adj})/(1+B)) + 2t_{event} ((1 + 3B + 3B^2)/(1+B)^2)$
		$t_{event-c}$	Event Duration - child	0.54	hr/event	USEPA, 2014b	
		$t_{event-a}$	Event Duration - adult	0.71	hr/event	USEPA, 2014b	$DA_{EVENT-adj}$ (Inorganic) =
		FA	Fraction Absorbed Water	COPC-specific	unitless	USEPA, 2004	$K_p \times C_w \times CF2 \times CF3 \times t_{event-adj}$
		K_p	Dermal Permeability Coefficient	COPC-specific	cm/hour	USEPA, 2004	
		C_w	Chemical Concentration in Water	COPC-specific	µg/L	See Table 5-4	
		CF2	Conversion Factor 2	1.0E-03	mg/µg	-----	
		CF3	Conversion Factor 3	1.0E-03	L/cm^3	-----	
		B	Ratio of Permeability Coefficient	COPC-specific	unitless	USEPA, 2004	
		t*	Time to Reach Steady State	COPC-specific	hour	USEPA, 2004	
		t_{event}	Lag Time Per Event	COPC-specific	hr/event	USEPA, 2004	

Table 5-7
Values Used for Daily Intake Equations - Future Resident - Groundwater
Remedial Investigation, Former Forbes Atlas Missile Site S-5
Lyon County, Kansas

Scenario Timeframe: Future
Medium: Groundwater
Exposure Medium: Groundwater
Receptor Population: Future Residents
Receptor Age: Child/Adult

Exposure Route	Exposure Point	Parameter Code	Parameter Definition	Value	Units	Rationale/ Reference	Intake Equation/ Model Name
Dermal Contact (continued)	Tap Water While Bathing (Child Exposure)	SA	Skin Surface Area Available for Contact - child	6,365	cm^2	USEPA, 2014	Dermally Absorbed Dose (DAD) (mg/kg-day) =
		DA_{EVENT}	Absorbed Dose Per Event	COPC-specific	mg/cm^2-event	See Table 5-6	$DA_{EVENT} \times EV \times SA \times EF \times ED \times 1/BW \times 1/AT_{NC}$
		EV	Event Frequency	1	event/day	USEPA, 2004	
		EF	Exposure Frequency - child	350	days/year	USEPA, 2014b	DA_{EVENT} Calculations
		ED	Exposure Duration - child	6	years	USEPA, 2014b	if $t_{event} \le t^*$, then DA_{EVENT} (Organic) =
		BW	Body Weight - child	15	kg	USEPA, 2014b	$2\ FA \times K_p \times C_w \times CF2 \times CF3 \times Ö\ (6t_{event} \times t_{event}/p)$
		AT_{NC}	Averaging Time (Non-Cancer)	2,190	days	Calculated	
		FA	Fraction Absorbed Water	COPC-specific	unitless	USEPA, 2004	otherwise if $t_{event} > t^*$, then DA_{EVENT} (Organic) =
		K_p	Dermal Permeability Coefficient	COPC-specific	cm/hour	USEPA, 2004	$FA \times K_p \times C_w \times CF2 \times CF3 \times$
		C_w	Chemical Concentration in Water	COPC-specific	µg/L	See Table 5-4	$[((t_{event})/(1+B)) + 2t_{event}\ ((1 + 3B + 3B^2)/(1+B)^2)$
		CF2	Conversion Factor 2	1.0E-03	mg/µg	-----	
		CF3	Conversion Factor 3	1.0E-03	L/cm^3	-----	DA_{EVENT} (Inorganic) =
		B	Ratio of Permeability Coefficient	COPC-specific	unitless	USEPA, 2004	$K_p \times C_w \times CF2 \times CF3 \times t_{event}$
		t*	Time to Reach Steady State	COPC-specific	hour	USEPA, 2004	
		t_{event}	Lag Time Per Event	COPC-specific	hr/event	USEPA, 2004	
		t_{event}	Event Duration - child	0.54	hr/event	USEPA, 2014b	
	Tap Water While Showering (Adult Exposure)	SA	Skin Surface Area Available for Contact - adult	19,652	cm^2	USEPA, 2014	Dermally Absorbed Dose (DAD) (mg/kg-day) =
		DA_{EVENT}	Absorbed Dose Per Event	COPC-specific	mg/cm^2-event	See Table 5-10	$DA_{EVENT} \times EV \times SA \times EF \times ED \times 1/BW \times 1/AT_{NC}$
		EV	Event Frequency	1	event/day	USEPA, 2004	
		EF	Exposure Frequency - adult	350	days/year	USEPA, 2014b	DA_{EVENT} Calculations
		ED	Exposure Duration - adult	20	years	USEPA, 2014b	if $t_{event} \le t^*$, then DA_{EVENT} (Organic) =
		BW	Body Weight- adult	80	kg	USEPA, 2014b	$2\ FA \times K_p \times C_w \times CF2 \times CF3 \times Ö\ (6t_{event} \times t_{event}/p)$
		AT_{NC}	Averaging Time (Non-Cancer)	7,300	days	Calculated	
		FA	Fraction Absorbed Water	COPC-specific	unitless	USEPA, 2004	otherwise if $t_{event} > t^*$, then DA_{EVENT} (Organic) =
		K_p	Dermal Permeability Coefficient	COPC-specific	cm/hour	USEPA, 2004	$FA \times K_p \times C_w \times CF2 \times CF3 \times$
		C_w	Chemical Concentration in Water	COPC-specific	µg/L	See Table 5-4	$[((t_{event})/(1+B)) + 2t_{event}\ ((1 + 3B + 3B^2)/(1+B)^2)$
		CF2	Conversion Factor 2	1.0E-03	mg/µg	-----	
		CF3	Conversion Factor 3	1.0E-03	L/cm^3	-----	DA_{EVENT} (Inorganic) =
		B	Ratio of Permeability Coefficient	COPC-specific	unitless	USEPA, 2004	$K_p \times C_w \times CF2 \times CF3 \times t_{event}$
		t*	Time to Reach Steady State	COPC-specific	hour	USEPA, 2004	
		t_{event}	Lag Time Per Event	COPC-specific	hr/event	USEPA, 2004	
		t_{event}	Event Duration - adult	0.71	hr/event	USEPA, 2014b	

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Table 5-7
Values Used for Daily Intake Equations - Future Resident - Groundwater
Remedial Investigation, Former Forbes Atlas Missile Site S-5
Lyon County, Kansas

Scenario Timeframe: Future
Medium: Groundwater
Exposure Medium: Groundwater
Receptor Population: Future Residents
Receptor Age: Child/Adult

Exposure Route	Exposure Point	Parameter Code	Parameter Definition	Value	Units	Rationale/ Reference	Intake Equation/ Model Name
Inhalation	Vapors During Indoor Use of Groundwater	EPC	Exposure Point Concentration	COPC-specific	µg/L	Table 5-4	Exposure Concentration (EC) (µg/m^3) =
		K	Volatilization Factor	0.5	L/m3	USEPA 2014a	EPC x K x ET x EF x ED x CF2 x 1/AT
		ET	Exposure Time	24	hours/day	Professional Judgment	
		EF	Exposure Frequency	350	days/year	USEPA 2014b	
		ED	Exposure Duration	26	years	USEPA 2014b	
		ED_A	Adult Exposure Duration	20	years	USEPA 2014b	
		ED_C	Child Exposure Duration	6	years	USEPA 2014b	
		CF2	Conversion Factor 2	0.042	days/hour	-----	
		ATC	Averaging Time (Cancer)	25,550	days	USEPA 1989a	
		ATNC-A	Adult Averaging Time (Non-Cancer)	7,300	days	Calculated	
		ATNC-C	Child Averaging Time (Non-Cancer)	2,190	days	Calculated	

Table 5-8
Values Used for Daily Intake Equations - Adult Trespasser - Sediment
Remedial Investigation, Former Forbes Atlas Missile Site S-5
Lyon County, Kansas

Scenario Timeframe: Future
Medium: Sediment
Exposure Medium: Sediment
Receptor Population: Adult Trespasser
Receptor Age: Adult

Exposure Route	Parameter Code	Parameter Definition	Units	Value	Rationale/ Reference	Intake Equation/ Model Name
Ingestion	C_{Sed}	Concentration in Sediment	mg/kg	COPC-Specific	Table 5-5	Intake (mg/kg-day) =
	IR-SD	Sediment Ingestion Rate	mg/day	100	USEPA, 2014b	C_{Sed} x IR-SD x FI x EF x ED x CF/(BW x AT)
	FI	Fraction Ingested From Contaminated Source	--	0.5	Professional judgment	
	EF	Exposure Frequency	days/year	22	USEPA, 2014b	
	ED	Exposure Duration	years	20	Professional judgment	
	CF1	Conversion Factor	kg/mg	1E-06	--	
	BW	Body Weight	kg	80	USEPA, 2014b	
	AT-C	Averaging Time (Cancer)	days	25,550	USEPA, 1989	
	AT-N	Averaging Time (Non-Cancer)	days	7,300	ED x 365 days/year	
Dermal	C_{Sed}	Concentration in Sediment	mg/kg	COPC-Specific	Table 5-5	Dermal Absorbed Dose (mg/kg-day) =
	SA	Surface Area	cm^2	6,032	USEPA, 2014b	C_{Sed} x SA x SSAF x DABS x EV x EF x ED x CF/(BW x AT)
	SSAF	Sediment-to-Skin Adherence Factor	mg/cm^2-event	0.3	USEPA, 2014b	
	DABS	Dermal Absorption Factor (Solid)	--	COPC-Specific	Table 5-20	
	EV	Event Frequency	events/day	1	Professional judgment	
	EF	Exposure Frequency	days/year	22	Professional judgment	
	ED	Exposure Duration	years	20	Professional judgment	
	BW	Body Weight	kg	80	USEPA, 2014b	
	CF1	Conversion Factor	kg/mg	1E-06	--	
	AT-C	Averaging Time (Cancer)	days	25,550	USEPA, 1989	
	AT-N	Averaging Time (Non-Cancer)	days	7,300	ED x 365 days/year	

Table 5-9
Values Used for Daily Intake Equations - Adult Trespasser - Surface water
Remedial Investigation, Former Forbes Atlas Missile Site S-5
Lyon County, Kansas

Scenario Timeframe: Future
Medium: Surface Water
Exposure Medium: Surface Water
Receptor Population: Adult
Receptor Age: Adult

Exposure Route	Parameter Code	Parameter Definition	Units	RME Value	RME Rationale/ **Reference**	Intake Equation/ Model Name
Ingestion	EPC	Exposure Point Concentration	COPC-specific	µg/L	See Table 5-4	Chronic daily intake (CDI) (mg/kg-day) =
	IRWrec-a	Recreator Surface Water Ingestion Rate	0.071	L/day	USEPA 2016b	EPC x IRWrec x CF1 x FI x ET x EV x EF x ED x 1/AT x 1/BW
	FI	Fraction Ingested	0.5	unitless	USEPA, 1989a	
	ET_v	Exposure Time of Event	1	hr/event	Professional judgment	
	EV	Event Frequency	1	event/day	USEPA 2016b	
	EF	Exposure Frequency	22	days/year	USEPA, 2014b	
	ED	Exposure Duration	20	years	USEPA, 2014b	
	BW	Body Weight	80	kg	USEPA, 2014b	
	CF1	Conversion Factor 1	1.00E-03	mg/µg	-----	
	AT_C	Averaging Time (Cancer)	25,550	days	USEPA, 2014b	
	AT_C	Averaging Time (Cancer)	7,300	days	USEPA, 2014b	
Dermal	DA_{event}	Absorbed Dose per Event	mg/cm^2-event	calculated	Table 5-11	Dermal Absorbed Dose (mg/kg-day) =
	SA	Surface Area	cm^2	6,032	USEPA, 2014b	DA_{event} x SA x EV x EF x ED /(BW x AT)
	EV	Event Frequency	events/day	1	Professional judgment	
	EF	Exposure Frequency	days/year	22	Professional judgment	for inorganics:
	ED	Exposure Duration	years	20	Professional judgment	DA_{event} = CW x Kp x t_{event} x CF
	BW	Body Weight	kg	80	USEPA, 2014b	Equations for DA_{event} for organics:
	AT-C	Averaging Time (Cancer)	days	25,550	USEPA, 1989	If t_{event} < t*
	AT-N	Averaging Time (Non-Cancer)	days	7,300	ED x 365 days/year	
	CW	Concentration in Surface Water	µg/L	COPC-Specific	Table 5-6	$DA_{event} = 2FA \times Kp \times CW \times CF \sqrt{\frac{6 \times \tau_{event} \times t_{event}}{\pi}}$
	Kp	Dermal Permeability Coefficients	cm/hr	COPC-Specific	Table 5-11	
	t_{event}	Event Duration	hr/event	1	Professional judgment	
	CF	Conversion Factor	mg-L/µg-cm^3	1.00E-06	--	If t_{event} > t*
	FA	Fraction Absorbed Water	unitless	COPC-Specific	Table 5-11	
	t*	Time to Reach Steady State	hr/event	COPC-Specific	Table 5-11	$DA_{event} = FA \times Kp \times CW \times CF \times \left[\frac{t_{event}}{1+B} + 2\tau_{event}\left(\frac{1+3B+3B^2}{(1+B)^2}\right)\right]$
	t_{event}	Lag Time Per Event	hr/event	COPC-Specific	Table 5-11	
	B	Ratio of Permeability Coefficient	unitless	COPC-Specific	Table 5-11	

Table 5-10
Dermally Absorbed Dose Per Event (DA_{event}) Calculations[a] - Groundwater
Remedial Investigation, Former Forbes Atlas Missile Site S-5
Lyon County, Kansas

COPC	EPC[b]		FA	K_p	τ_{event}	B	t^*	$DA_{event-adj}$[c]	DA_{event} (mg/cm^2-event)[d]	
	(µg/L)	(mg/cm^3)	(unitless)	(cm/hr)	(hr/event)	(unitless)	(hr)	mg/cm^2-event	Child	Adult
cis-1,2-Dichloroethene	26	0.000026	1.0	0.011	0.367	0.0417	0.88	3.9E-07	3.9E-07	4.0E-07
Trichloroethene	94.4	0.000094	1.0	0.0116	0.57	0.051	1.4	1.9E-06	1.7E-06	1.9E-06

[a] EPA, 2004

[b] see Table 5-4.

[c] t_{event} was age-adjusted assuming tevent of .54 for 6 years and tevent 0.71 for 20 years. Adjusted value equals 0.67.

[d] Calculated based on Equation 3.2 or 3.3 for organics in EPA, 2004 where t_{event} equals 0.54 for children and 0.71 for adults.

COPC = contaminant of potential concern
EPC = exposure point concentration
B = Ratio of the permeability coefficient of a COPC through the stratum corneum relative to its permeability coefficient across the viable epidermis.
FA = Fraction absorbed.
K_p = Dermal permeability coefficient.
NA = Not applicable.
τ_{event} = Lag time per event.
t^* = Time to reach steady-state.
mg/cm^3 = milligram per cubic centimeter.
µg/L = micrograms per Liter.
cm/hr = centimeter per hour.

Table 5-11

Dermally Absorbed Dose Per Event (DA_{event}) Calculations[a] - Surface Water

Remedial Investigation, Former Forbes Atlas Missile Site S-5

Lyon County, Kansas

COPC	EPC[b] (µg/L)	EPC[b] (mg/cm^3)	FA (unitless)	K_p (cm/hr)	τ_{event} (hr/event)	B (unitless)	t^* (hr)	DA_{event} (mg/cm^2-event)[c] Adult
cis-1,2-Dichloroethene	45	0.000045	1.0	0.011	0.367	0.0417	0.88	7.0E-07
Trichloroethene	50	0.000050	1.0	0.0116	0.57	0.051	1.4	1.0E-06
Vinyl Chloride	24	0.000024	1.0	0.00838	0.24	0.025	0.57	2.5E-07

[a] EPA, 2004

[b] see Table 5-6.

[c] Calculated based on Equation 3.2 or 3.3 for organics in EPA, 2004 where t_{event} equals 0.71 for adults.

COPC = contaminant of potential concern

EPC = exposure point concentration

B = Ratio of the permeability coefficient of a COPC through the stratum corneum relative to its permeability coefficient across the viable epidermis.

FA = Fraction absorbed.

K_p = Dermal permeability coefficient.

NA = Not applicable.

τ_{event} = Lag time per event.

t^* = Time to reach steady-state.

mg/cm^3 = milligram per cubic centimeter.

µg/L = micrograms per Liter.

cm/hr = centimeter per hour.

Table 5-12
Noncancer Toxicity Data - Oral/Dermal
Remedial Investigation, Former Forbes Atlas Missile Site S-5
Lyon County, Kansas

Contaminant of Potential Concern	Chronic/ Subchronic	Oral RfD		Oral Absorption Efficiency for Dermal (2)	Absorbed RfD for Dermal (1)		Primary Target Organ(s)	Combined Uncertainty/Modifying Factors	RfD: Target Organ(s)	
		Value (2)	Units		Value	Units			Source(s)	Dates (3)
cis-1,2-Dichloroethene	Chronic	0.002	(mg/kg-day)	1.0	0.002	(mg/kg-day)	Urinary, Whole Body	3,000	IRIS	8/7/2017
Trichloroethene	Chronic	0.0005	(mg/kg-day)	1.0	0.0005	(mg/kg-day)	Immune system, Developmental, Cardiovascular	Multiple	IRIS	8/7/2017
Vinyl Chloride	Chronic	0.003	(mg/kg-day)	1.0	0.003	(mg/kg-day)	Liver	30	IRIS	8/7/2017

(1) Source: RAGS Part E Guidance.
(2) Values obtained from RSL Table (USEPA, 2017a).
(3) Represents date source was searched.

Definitions:
IRIS = Integrated Risk Information System.
mg/kg = milligram per kilogram.
RfD = Reference Dose.

Table 5-13
Noncancer Toxicity Data - Inhalation
Remedial Investigation, Former Forbes Atlas Missile Site S-5
Lyon County, Kansas

Contaminant of Potential Concern	Chronic/ Subchronic	Inhalation RfC		Primary Target Organ(s)	Combined Uncertainty/Modifying Factors	RfC: Target Organ(s)	
		Value (2)	Units			Source(s)	Dates (1)
cis-1,2-Dichloroethene	---	NA	---	---	---	---	---
Trichloroethene	Chronic	0.002	mg/m^3	Immune system, Developmental, Cardiovascular	Mutliple	IRIS	8/7/2017
Vinyl Chloride	Chronic	0.1	mg/m^3	Liver	30	IRIS	8/7/2017

(1) Represents date source was searched.
(2) Values obtained from RSL Table (USEPA, 2017a).

Definitions:
IRIS = Integrated Risk Information System.
mg/m^3 = milligram per cubic meter.

Table 5-14
Cancer Toxicity Data - Oral/Dermal
Remedial Investigation, Former Forbes Atlas Missile Site S-5
Lyon County, Kansas

Contaminant of Potential Concern	Oral Cancer Slope Factor		Oral Absorption Efficiency for Dermal (2)	Absorbed Cancer Slope Factor for Dermal (1)		Weight of Evidence/ Cancer Guideline Description	Oral CSF	
	Value (2)	Units		Value	Units		Source(s)	Dates (3)
cis-1,2-Dichloroethene	NA	---	---	NA	---	Inadequate data	---	---
Trichloroethene	0.046	(mg/kg-day)-1	1.0	0.046	$(mg/kg\text{-}day)^{-1}$	Carcinogenic to humans	IRIS	8/7/2017
Vinyl Chloride	0.72	$(mg/kg\text{-}day)^{-1}$	1.0	0.72	$(mg/kg\text{-}day)^{-1}$	Carcinogenic to humans	IRIS	8/7/2017

(1) Source: RAGS Part E Guidance.
(2) Values obtained from RSL Table (USEPA, 2017a).
(3) Represents date source was searched.

Definitions:
IRIS = Integrated Risk Information System.
mg/kg-day = milligram per kilogram per day.

Table 5-15
Cancer Toxicity Data - Inhalation
Remedial Investigation, Former Forbes Atlas Missile Site S-5
Lyon County, Kansas

Contaminant of Potential Concern	Unit Risk		Weight of Evidence/ Cancer Guideline Description	Unit Risk: Inhalation CSF	
	Value (2)	Units		Source(s)	Dates (1)
cis-1,2-Dichloroethene	NA	---	Inadequate data	---	---
Trichloroethene	0.0000041	(mg/kg-day)-1	Carcinogenic to humans	IRIS	8/7/2017
Vinyl Chloride	0.0000044	(mg/kg-day)-1	Carcinogenic to humans	IRIS	8/7/2017

(1) Represents date source was searched.
(2) Values obtained from RSL Table (USEPA, 2017a).

Definitions:
IRIS = Integrated Risk Information System.
mg/kg-day = milligram per kilogram per day.

Table 5-16
Calculation of Cancer Risk from Trichloroethene - Mutagenic Mode of Action - Resident - Groundwater
Remedial Investigation, Former Forbes Atlas Missile Site S-5
Lyon County, Kansas

Tapwater Ingestion Risk

Where:

$$Risk = EPC \times \sum_i \left(\left(\frac{IRW \times FI \times EF \times ED \times CF}{BW \times AT} \right) \times CSF_{kidney} \times ADAF \right) + \left(\left(\frac{IRW \times FI \times EF \times ED \times CF}{BW \times AT} \right) \times CSF_{Liver+NHL} \right)$$

Exposure Parameters (by age interval, i)					
Parameter	**Units**	**0-<2**	**2-<6**	**6-<16**	**16-<26**
EPC	µg/L	See Below			
IRW	L/day	0.78	0.78	2.5	2.5
FI	unitless	1	1	1	1
CF	mg/µg	1E-03	1E-03	1E-03	1E-03
EF	days/year	350	350	350	350
ED	years	2	4	10	10
BW	kg	15	15	80	80
AT	days	25550	25550	25550	25550
CSF_{kidney}	$(mg/kg\text{-}day)^{-1}$	9.3E-03			
ADAF	unitless	10	3	3	1
$CSF_{liver+NHL}$	$(mg/kg\text{-}day)^{-1}$	3.7E-02			

	EPC	Tapwater Ingestion Risks			
COPC	**(µg/L)**	**0-<2**	**2-<6**	**6-<16**	**16-<26**
Trichloroethene	9.44E+01	1.7E-05	1.7E-05	2.6E-05	1.9E-05

Dermal Contact Risk

Where:

$$Risk = \sum_i \left(\left(\frac{DAevent \times EV \times SA \times EF \times ED}{BW \times AT} \right) \times CSF_{kidney} \times ADAF \right) + \left(\left(\frac{DAevent \times EV \times SA \times EF \times ED}{BW \times AT} \right) \times CSF_{Liver+NHL} \right)$$

Exposure Parameters (by age interval, i)					
Parameter	**Units**	**0-<2**	**2-<6**	**6-<16**	**16-<26**
DAevent	mg/cm^2-event	See Below			
EV	event/day	1	1	1	1
SA	cm^2	6365	6365	19652	19652
EF	days/year	350	350	350	350
ED	years	2	4	10	10
BW	kg	15	15	80	80
AT	days	25550	25550	25550	25550
CSF_{kidney}	$(mg/kg\text{-}day)^{-1}$	9.3E-03			
ADAF	unitless	10	3	3	1
$CSF_{liver+NHL}$	$(mg/kg\text{-}day)^{-1}$	3.7E-02			

	DAevent	Dermal Contact Risks			
COPC	**(mg/cm^2-event)**	**0-<2**	**2-<6**	**6-<16**	**16-<26**
Trichloroethene	1.9E-06	2.8E-06	2.8E-06	4.1E-06	2.9E-06

Inhalation Risk

Where:

$$Risk = EPC \times \sum_i \left(\left(\frac{K \times ET \times EF \times ED \times CF}{AT} \right) \times IUR_{kidney} \times ADAF \right) + \left(\left(\frac{K \times ET \times EF \times ED \times CF}{AT} \right) \times IUR_{Liver+NHL} \right)$$

Exposure Parameters (by age interval, i)					
Parameter	**Units**	**0-<2**	**2-<6**	**6-<16**	**16-<26**
EPC	µg/L	See Below			
K	L/m^3	0.50	0.50	0.50	0.50
ET	hrs/day	24	24	24	24
CF	day/hour	0.042	0.042	0.042	0.042
EF	days/year	350	350	350	350
ED	years	2	4	10	10
AT	days	25550	25550	25550	25550
IUR_{kidney}	$(\mu g/m^3)^{-1}$	1.1E-06			
ADAF	unitless	10	3	3	1
$IUR_{liver+NHL}$	$(\mu g/m^3)^{-1}$	3.1E-06			

	EPC	Inhalation Risks			
COPC	**(µg/L)**	**0-<2**	**2-<6**	**6-<16**	**16-<26**
Trichloroethene	9.44E+01	1.4E-05	8.7E-06	2.2E-05	7.4E-06

	Total Cancer Risks			
COPC	**Tapwater Ingestion**	**Dermal Contact**	**Inhalation**	**Total**
Trichloroethene	8E-05	1E-05	5E-05	**1E-04**

Table 5-17
Calculation of COPC Cancer Risks - Age-adjusted Residents - Groundwater
Remedial Investigation, Former Forbes Atlas Missile Site S-5
Lyon County, Kansas

Scenario Timeframe: Current/Future
Receptor Population: Resident
Receptor Age: Age-adjusted

Medium	Exposure Medium	Exposure Point	Exposure Route	Contaminant of Potential Concern	EPC*		Cancer Risk Calculations				
					Value	Units	Intake/Exposure Concentration		CSF/Unit Risk		Cancer Risk
							Value	Units	Value	Units	
Groundwater	Groundwater	Site	Ingestion	cis-1,2-Dichloroethene	26.0	µg/L	3.3E-04	mg/kg-day	NA	---	NA
				Trichloroethene	94.4	µg/L	Mutagenic Mode of Action; see Table 5-16				8E-05
			Ingestion Total								8E-05
			Dermal	cis-1,2-Dichloroethene	26.0	µg/L	4.0E-05	mg/kg-day	NA	---	NA
				Trichloroethene	94.4	µg/L	Mutagenic Mode of Action; see Table 5-16				1E-05
			Dermal Total								1E-05
	Indoor Air	Site	Inhalation	cis-1,2-Dichloroethene	26.0	µg/L	4.7E+00	$\mu g/m^3$	NA	---	NA
				Trichloroethene	94.4	µg/L	Mutagenic Mode of Action; see Table 5-16				5E-05
			Inhalation Total								5E-05
Total											1E-04

* See Table 5-4
µg/L = micrograms per Liter.
mg/kg-day = micrograms per kilogram per day.
$\mu g/m^3$ = micrograms per cubic meter.
NA = not available.
EPC = exposure point concentration

Table 5-18
Calculation of COPC Noncancer Hazards - Adult Resident - Groundwater
Remedial Investigation, Former Forbes Atlas Missile Site S-5
Lyon County, Kansas

Scenario Timeframe: Current/Future
Receptor Population: Resident
Receptor Age: Adult

Medium	Exposure Medium	Exposure Point	Exposure Route	Contaminant of Potential Concern	EPC*		Non-Cancer Hazard Calculations				
					Value	Units	Intake/Exposure Concentration		RfD/RfC		
							Value	Units	Value	Units	Hazard Quotient
Groundwater	Groundwater	Site	Ingestion	cis-1,2-Dichloroethene	26.0	µg/L	7.8E-04	mg/kg-day	2.0E-03	(mg/kg-day)	0.4
				Trichloroethene	94.4	µg/L	2.8E-03	mg/kg-day	5.0E-04	(mg/kg-day)	5.7
			Ingestion Total								6.0
			Dermal	cis-1,2-Dichloroethene	26.0	µg/L	9.5E-05	mg/kg-day	2.0E-03	(mg/kg-day)	0.05
				Trichloroethene	94.4	µg/L	4.5E-04	mg/kg-day	5.0E-04	(mg/kg-day)	0.9
			Dermal Total								1.0
	Indoor Air	Site	Inhalation	cis-1,2-Dichloroethene	26.0	µg/L	1.3E+01	$\mu g/m^3$	NA	---	NA
				Trichloroethene	94.4	µg/L	4.6E+01	$\mu g/m^3$	2.0E-03	mg/m^3	23
			Inhalation Total								23
Total											30

* See Table 5-4
µg/L = micrograms per Liter.
mg/kg-day = micrograms per kilogram per day.
$\mu g/m^3$ = micrograms per cubic meters.
mg/m^3 = miligrams per cubic meter.
NA = not available.
EPC = exposure point concentration

Table 5-19
Calculation of COPC Noncancer Hazards - Child Resident - Groundwater
Remedial Investigation, Former Forbes Atlas Missile Site S-5
Lyon County, Kansas

Scenario Timeframe: Current/Future
Receptor Population: Resident
Receptor Age: Child

Medium	Exposure Medium	Exposure Point	Exposure Route	Contaminant of Potential Concern	EPC*		Non-Cancer Hazard Calculations				
					Value	Units	Intake/Exposure Concentration		RfD/RfC		
							Value	Units	Value	Units	Hazard Quotient
Groundwater	Groundwater	Site	Ingestion	cis-1,2-Dichloroethene	26.0	µg/L	1.3E-03	mg/kg-day	2.0E-03	(mg/kg-day)	0.6
				Trichloroethene	94.4	µg/L	4.7E-03	mg/kg-day	5.0E-04	(mg/kg-day)	9.4
			Ingestion Total								10
			Dermal	cis-1,2-Dichloroethene	26.0	µg/L	1.6E-04	mg/kg-day	2.0E-03	(mg/kg-day)	0.08
				Trichloroethene	94.4	µg/L	6.9E-04	mg/kg-day	5.0E-04	(mg/kg-day)	1.4
			Dermal Total								1.4
	Indoor Air	Site	Inhalation	cis-1,2-Dichloroethene	26.0	µg/L	1.3E+01	$\mu g/m^3$	NA	---	NA
				Trichloroethene	94.4	µg/L	4.6E+01	$\mu g/m^3$	2.0E-03	mg/m^3	23
			Dermal Total								23
Total											34

* See Table 5-4
µg/L = micrograms per Liter.
mg/kg-day = micrograms per kilogram per day.
$\mu g/m^3$ = micrograms per cubic meters.
mg/m^3 = miligrams per cubic meter.
NA = not available.
EPC = exposure point concentration

Table 5-20
Calculation of COPC Cancer Risks/Noncancer Hazards - Adult Trespasser - Sediment
Remedial Investigation, Former Forbes Atlas Missile Site S-5
Lyon County, Kansas

Scenario Timeframe: Current/Future
Receptor Population: Adult Trespasser
Receptor Age: Adult

Medium	Exposure Medium	Exposure Point	Exposure Route	Chemical of Potential Concern	EPC*		Cancer Risk Calculations					Non-Cancer Hazard Calculations				
					Value	Units	Intake/Exposure Concentration		CSF/Unit Risk		Cancer Risk	Intake/Exposure Concentration		RfD/RfC		Hazard Quotient
							Value	Units	Value	Units		Value	Units	Value	Units	
Sediment	Sediment	Site	Ingestion	Vinyl Chloride	10.0	mg/kg	1.1E-07	mg/kg-day	7.2E-01	(mg/kg-day)^-1	7.7E-08	3.8E-07	mg/kg-day	3.0E-03	mg/kg-day	0.0001
			Ingestion Total								8E-08					0.0001
			Dermal	Vinyl Chloride	10.0	mg/kg	NA	---	7.2E-01	(mg/kg-day)^-1	NA	NA	---	3.0E-03	mg/kg-day	NA
			Dermal Total								NA					NA
Sediment Total											8E-08					0.0001

* See Table 5-5
mg/kg-day = milligrams per kilogram per day.
NA = not available.
EPC = exposure point concentration

Table 5-21
Calculation of COPC Cancer Risks/Noncancer Hazards - Adult Trespasser - Surface Water
Remedial Investigation, Former Forbes Atlas Missile Site S-5
Lyon County, Kansas

Scenario Timeframe: Current/Future
Receptor Population: Adult Trespasser
Receptor Age: Adult

Medium	Exposure Medium	Exposure Point	Exposure Route	Chemical of Potential Concern	EPC*		Cancer Risk Calculations					Non-Cancer Hazard Calculations				
					Value	Units	Intake/Exposure Concentration		CSF/Unit Risk		Cancer Risk	Intake/Exposure Concentration		RfD/RfC		Hazard Quotient
							Value	Units	Value	Units		Value	Units	Value	Units	
Surface Water	Surface Water	Site	Ingestion	cis-1,2-Dichloroethene	45.0	µg/L	3.4E-07	mg/kg-day	NA	NA	NA	1.2E-06	mg/kg-day	2.0E-03	mg/kg-day	0.0006
				Trichloroethene	50.0	µg/L	3.8E-07	mg/kg-day	4.6E-02	(mg/kg-day)^-1	1.8E-08	1.3E-06	mg/kg-day	5.0E-04	mg/kg-day	0.003
				Vinyl chloride	24.0	µg/L	1.8E-07	mg/kg-day	7.2E-01	(mg/kg-day)^-1	1.3E-07	6.4E-07	mg/kg-day	3.0E-03	mg/kg-day	0.0002
			Ingestion Total								1E-07					0.003
			Dermal	cis-1,2-Dichloroethene	45.0	µg/L	4.8E-08	mg/kg-day	NA	---	NA	8.8E-07	mg/kg-day	2.0E-03	mg/kg-day	0.0004
				Trichloroethene	50.0	µg/L	7.0E-08	mg/kg-day	4.6E-02	(mg/kg-day)^-1	3.2E-09	1.3E-06	mg/kg-day	5.0E-04	mg/kg-day	0.003
				Vinyl chloride	24.0	µg/L	1.7E-08	mg/kg-day	7.2E-01	(mg/kg-day)^-1	1.2E-08	3.1E-07	mg/kg-day	3.0E-03	mg/kg-day	0.0001
			Dermal Total								2E-08					0.003
Surface Water Total											2E-07					0.01

* See Table 5-6
mg/kg-day = milligrams per kilogram per day.
NA = not available.
EPC = exposure point concentration
µg/L = micrograms per Liter.

APPENDICES

(On CD only) 

Appendix A **– Precipitation Graph**
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