FINAL

PHASE II REMEDIAL INVESTIGATION REPORT
FOR
FOX ROAD BURNING GROUND

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
JOHN H. GLENN RESEARCH CENTER AT
NEIL A. ARMSTRONG TEST FACILITY
SANDUSKY, OHIO

Prepared for:

NASA Glenn Research Center
21000 Brookpark Road
Cleveland, Ohio 44135

Prepared by:

Leidos
8866 Commons Boulevard, Suite 201
Twinsburg, Ohio 44087

October 2022

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LIST OF ACRONYMS

µg/dL	Micrograms per Deciliter
µg/kg	Micrograms per Kilogram
µg/L	Micrograms per Liter
ACM	Asbestos-Containing Material
AMSL	Above Mean Sea Level
AOC	Area of Concern
AOPC	Area of Potential Concern
ATF	Armstrong Test Facility
bgs	Below Ground Surface
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CMCOC	Contaminant Migration Chemical of Concern
CMCOPC	Contaminant Migration Chemical of Potential Concern
COC	Chemical of Concern
COPC	Chemical of Potential Concern
COPEC	Chemical of Potential Ecological Concern
CSEM	Conceptual Site Exposure Model
CSF	Cancer Slope Factor
CSM	Conceptual Site Model
D&D	Decontamination and Decommissioning
DAD	Dermal Absorbed Dose
DERR	Division of Environmental Response and Revitalization
DNAP	Division of Natural Areas and Preserves
DNT	Dinitrotoluene
DO	Dissolved Oxygen
DoD	U.S. Department of Defense
DQO	Data Quality Objective
EPC	Exposure Point Concentration
ERA	Ecological Risk Assessment
ESV	Ecological Screening Value
EU	Exposure Unit
FRBG	Fox Road Burning Ground
FS	Feasibility Study
FY	Fiscal Year
GAC	Granular Activated Carbon
GIABS	Gastrointestinal Absorption Fraction
gpm	Gallons per Minute
GRC	Glenn Research Center
HFPO-DA	Hexafluoropropylene Oxide Dimer Acid (aka GenX)
HHRA	Human Health Risk Assessment
HI	Hazard Index
HQ	Hazard Quotient
HRS	Hazard Ranking System
HUC	Hydrologic Unit Code
IDW	Investigation-Derived Waste
IEUBK	Integrated Exposure Uptake Biokinetic
ILCR	Incremental Lifetime Cancer Risk
IRIS	Integrated Risk Information System

LIST OF ACRONYMS (Continued)

K_d	Soil/Water Partitioning Coefficient
Kh	Henry's Law Constant
K_{oc}	Water/Organic Carbon Partition Coefficient
LOAEL	Lowest-Observable-Adverse-Effect Level
MCL	Maximum Contaminant Level
MDC	Maximum Detected Concentration
mg/kg	Milligrams per Kilogram
mg/kg-day	Milligrams per Kilogram of Body Weight per Day
mg/m^3	Milligrams per Cubic Meter
mL/min	Milliliters per Minute
MW	Molecular Weight
NAD 83	North American Datum of 1983
NASA	National Aeronautics and Space Administration
NCEA	National Center for Environmental Assessment
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NERR	National Estuarine Research Reserve
NFA	No Further Action
ng/L	Nanograms per Liter
NOAEL	No-Observable-Adverse-Effect Level
NPL	National Priorities List
NTU	Nephelometric Turbidity Unit
ODNR	Ohio Department of Natural Resources
Ohio EPA	Ohio Environmental Protection Agency
ORP	Oxidation Reduction Potential
OU	Operable Unit
PA	Preliminary Assessment
PAH	Polycyclic Aromatic Hydrocarbons
PBOW	Plum Brook Ordnance Works
PBS	Plum Brook Station
PCB	Polychlorinated Biphenyl
PETN	Pentaerythritol Tetranitrate
PFAS	Per- and Polyfluoroalkyl Substances
PMU	Project Management Unit
PREscore	Preliminary Ranking Evaluation Score
PVC	Polyvinyl Chloride
QC	Quality Control
RCRA	Resource Conservation and Recovery Act
RDX	Hexahydro-1,3,5-Trinitro-1,3,5-Triazine
RfD	Reference Dose
RI	Remedial Investigation
RME	Reasonable Maximum Exposure
RSL	Regional Screening Level
SAP	Sampling and Analysis Plan
SARA	Superfund Amendments and Reauthorization Act
SI	Site Investigation
SNP	State Nature Preserve
SRBG	Snake Road Burning Ground
SRC	Site-Related Chemical

LIST OF ACRONYMS (Continued)

SVOC	Semivolatile Organic Compound
TAL	Target Analyte List
TCE	Trichloroethene
TNT	Trinitrotoluene
TR	Target Risk
TRBG	Taylor Road Burning Ground
UCL	Upper Confidence Limit
USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
VISL	Vapor Intrusion Screening Level
VOC	Volatile Organic Compound
XRF	X-ray Fluorescence

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EXECUTIVE SUMMARY

Leidos has prepared this Phase II Remedial Investigation (RI) Report on behalf of the National Aeronautics and Space Administration (NASA) as part of an RI conducted within the John H. Glenn Research Center at Neil A. Armstrong Test Facility (GRC-ATF) in Sandusky, Ohio (Figure 1-1). This report summarizes Phase II RI activities conducted at Fox Road Burning Ground (FRBG) and provides conclusions and recommendations regarding the evaluation of groundwater data collected from the investigation activities.

Groundwater was not previously evaluated at FRBG during the 2015 Site Inspection or 2017 Phase I RI. The objective of the Phase II RI is to fully characterize the nature and extent of contamination and evaluate exposure risk to hazardous substances in groundwater, and if necessary, soil vapor, due to historical activities at the three burning grounds. All field activities were performed in accordance with the *Burning Grounds Phase II Remedial Investigation Sampling and Analysis Plan* (Leidos 2020).

Investigative activities completed in support of the Phase II RI included:

- Installation and development of four permanent groundwater monitoring wells (FRBG-MW01, FRBG-MW02, FRBG-MW03, and FRBG-MW04); and
- Two seasonal groundwater sampling events, each consisting of the four new wells sampled for metals, explosives, volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), and polychlorinated biphenyls (PCBs).

Due to the nature of the site (former burning ground), Ohio Environmental Protection Agency (Ohio EPA) correspondence stated that if VOCs were not detected as potential chemicals of concern (COCs) for the site, assessing the soil vapor pathway would not be triggered (Ohio EPA 2019). Vapor-forming chemicals were not detected in subsurface soils at FRBG as part of the Phase I RI or groundwater in Phase II. Evidence determined that vapor points were not warranted at FRBG.

ES.1 SUMMARY OF NATURE AND EXTENT

During the Phase I RI for FRBG, the site was divided into four exposure units (EUs) to allow for refined evaluation of potential chemical contamination and potential exposure. These EUs were the General Area, Subsurface Debris Area, Drainage Ditch, and Concrete Pits. The sampling rationale for each groundwater sampling location was to assess potential impacts to overburden groundwater within or downgradient from the General Areas and Subsurface Debris Area. Conservative transport modeling in the Phase I RI indicated 11 chemicals may leach from soil and migrate to the groundwater table beneath their respective sources at concentrations exceeding maximum contaminant levels (MCLs)/regional screening levels (RSLs). The 11 chemicals included organic (mercury), explosives (2,4,6-trinitrotoluene [TNT]; 2,4-dinitrotoluene [DNT]; 2,6-DNT; 2-amino-4,6-DNT; 4-amino-2,6-DNT; and pentaerythritol tetranitrate [PETN]), SVOCs (benzaldehyde and naphthalene), and pesticides (beta-hexachlorocyclohexane and dalapon). A qualitative assessment of the sample results was performed, and the limitations and assumptions of the models were considered to identify if any soil contaminant migration chemicals of concern (CMCOCs) were present in soil at FRBG that may potentially impact groundwater. This qualitative assessment concluded that without available groundwater data, seven initial CMCOCs (2,4,6-TNT; 2,4-DNT; 2,6-DNT; 2 amino-4,6-DNT; 4-amino-2,6-DNT; naphthalene; and beta-hexachlorocyclohexane) should be assessed during future groundwater studies at the site (Leidos 2018a). Of the 11 chemicals from the transport modeling, only naphthalene was detected in groundwater above the tap water RSL. Pesticides were not included in the analytical suite at FRBG because pesticide analyte surface and subsurface soil samples results did not exceed their respective background concentrations or resident regional screening levels.

Only nine total inorganics (aluminum, antimony, arsenic, cadmium, iron, lead, manganese, thallium, and vanadium) exceeded their respective background concentrations and/or the tap water RSL in groundwater at FRBG. Aluminum and antimony exceedances were limited to FRBG-MW03 and FRBG-MW04 located in and to the north of the Subsurface Debris Area. Aluminum and antimony were only detected above screening criteria during the November 2021 sampling event at these wells. Total arsenic exceeded screening criteria at FRBG-MW03 in November 2021 and at FRBG-MW-04 during both events. However, only the November 2021 concentration at FRBG-MW03 exceeded the MCL. The single cadmium (total) exceedance was limited to the November 2021 sample collected at FRBG-MW03 located in the Subsurface Debris Area, but the concentration was below the MCL. Total iron exceeded the screening criteria at three of the four sampling locations: FRBG-MW02 (May 2021), FRBG-MW03 (November 2021), and FRBG-MW04 (November 2021). None of the filtered iron results exceeded the tap water RSL. Total and dissolved lead only exceeded screening criteria at one location (FRBG-MW03 location in the Subsurface Debris Area) in November 2021. Total manganese exceeded the tap water RSL in all sampling locations, but concentrations were only above the corresponding background concentration at FRBG-MW01 in May 2021. Total thallium exceeded screening criteria during the November 2021 event at FRBG-MW03 and FRBG-MW-04. Dissolved thallium only exceeded screening criteria in May 2021 at FRBG-MW01. Vanadium exceedances were limited to two locations (FRBG-MW03 and FRBG-MW-04) during the November 2021 event; only total vanadium exceeded screening criteria. Most metal exceedances were at FRBG-MW03, which is located in the Subsurface Debris Area and cross/upgradient of FRBG-MW01 and FRBG-MW02.

Naphthalene was the only organic constituent detected above screening criteria at FRBG. Naphthalene was only detected at FRBG-MW-03 during the November 2021 sampling event at a concentration of 0.24 µg/L, exceeding the tap water RSL of 0.12 µg/L. Naphthalene was not detected in any of the other samples; however, the detection limits ranged from 0.19 to 0.22 µg/L, which are above the RSL.

The groundwater in the overburden is in discontinuous pockets during dry time periods, as evidenced by FRBG-MW01 and FRBG-MW-02 being dry in November 2021 and the slow recharge of FRBG-MW-04 also in November 2021. During wet periods, the general flow direction in the overburden water-bearing zone is radially to the west/northwest from FRBG, largely mirroring surface topography (Shaw 2005). Since most metals and the naphthalene concentration exceedances were at FRBG-MW03, which is located to the east of the other wells sampled in the General Area EU, it appears the extent of the contaminants in the FRBG groundwater has been adequately characterized. Naphthalene is the only CMCOC identified during the Phase I RI that was detected in the groundwater above screening criteria.

ES.2 SUMMARY OF FATE AND TRANSPORT

The Phase I RI fate and transport evaluation identified 2,4,6-TNT; 2,4-DNT; 2,6-DNT; 2 amino-4,6-DNT; 4-amino-2,6-DNT; naphthalene; and beta-hexachlorocyclohexane for future groundwater evaluation to assess the modeling results. Explosives were not detected in groundwater above screening criteria, and samples were not analyzed for beta-hexachlorocyclohexane at FRBG during the Phase II RI because pesticide analyte surface and subsurface soil samples results did not exceed their respective background concentrations or resident regional screening levels. The only site-related chemicals (SRCs) present in groundwater at FRBG include metals and naphthalene. Contaminant leaching from soil to the water table (vertical migration) and mixing with groundwater beneath the source is the contaminant release mechanism identified at FRBG.

One of the principal migration pathways at the site is percolation through the unsaturated soil to the water table (i.e., vertical leaching of contaminants from soil into groundwater). The rate of percolation is controlled by soil cover, ground slope, saturated conductivity of the soil, and meteorological conditions. Once the contaminant leachate percolates through the soil and reaches the water table, it mixes with groundwater beneath the source. The potential receptor location would be a hypothetical domestic water well beneath the site. However, because of the heterogeneous nature of the unconsolidated glacial material, groundwater flow patterns within unconsolidated soil are difficult to predict. The presence of inorganics above screening levels in groundwater either leached from soil prior to previous investigations or are naturally occurring. The presence of naphthalene above screening levels, although only at one location and at low concentrations, leached from soil.

ES.3 SUMMARY OF HUMAN HEALTH RISK ASSESSMENT

The human health risk assessment (HHRA) documents the potential health risks to humans resulting from exposure to groundwater contamination within FRBG. The HHRA was performed consistent with previous GRC-ATF HHRAs and is based on U.S. Environmental Protection Agency (USEPA) and Ohio EPA guidance.

GRC-ATF is expected to remain under the control of NASA for the foreseeable future. Although it is unlikely that FRBG will be developed for residential purposes, a hypothetical onsite residential scenario was included to represent unrestricted use and evaluate the upper bound for long-term exposure. Generally, sites that “pass” a residential risk assessment can be released for use without restriction. FRBG is best classified as an inactive area, and plausible receptors include groundskeepers and hunters. No groundwater at GRC-ATF is used for drinking water under current or planned future use. At the time of this report, NASA is working to develop an implementation plan to ensure the property is managed in accordance with the land use control prohibiting groundwater use at GRC-ATF.

The groundwater exposure routes evaluated in the HHRA include ingestion, dermal contact, and inhalation (associated with the household use of water). Groundwater data for VOCs also were screened for potential impacts associated with the vapor intrusion pathway. Risks were calculated for both cancer and non-cancer effects. Lead exposures were evaluated for the resident child using USEPA’s Integrated Exposure Uptake Biokinetic (IEUBK) model, which is used to predict the relative increase in blood lead concentration that might result from environmental exposure.

For hypothetical residential land use, the total resident child hazard index (HI) for groundwater (8) exceeds the target of 1. Because the total HI exceeds 1, the chemicals were segregated according to target organ or system, and an HI was calculated for each target organ. The following target organ HIs exceed the target of 1 for the resident child: the HI of 2 for neurological effects (due to manganese and to a lesser extent aluminum) and for the HI of 5 for dermal effects (due to thallium [4], arsenic [1], and vanadium [0.2]). The total incremental lifetime cancer risk (ILCR) of 1E-04 for groundwater exposure is at the upper bound of the target cancer risk range and is associated almost entirely with arsenic. The lead model results for the resident child show that the probability the blood-lead concentration would exceed the level of concern is less than the USEPA target.

Upon further evaluation of the groundwater data by comparing detected concentrations with background levels and the concentrations detected in filtered samples, none of the chemicals of potential concern (COPCs) were identified as a COC for groundwater.

Vapor-forming chemicals were not detected in subsurface soils at FRBG as part of the Phase I RI; however, VOCs were detected at low concentrations in two groundwater samples collected at two monitoring wells as part of the Phase II RI. The Vapor Intrusion Screening Levels (VISL) screening results and evaluation of other factors concluded that no chemicals of potential concern (COPCs) were identified for the vapor intrusion pathway.

ES.4 SUMMARY OF ECOLOGICAL RISK ASSESSMENT

An ecological risk assessment (ERA) was completed and detailed in the Phase I RI Report. FRBG is approximately 17.2 acres and is vegetated with deciduous shrubland and forest, with portions of three wetlands present on the eastern boundary of the site. Wetlands are considered important ecological resources, and there is documentation of contamination at FRBG, so further analysis was conducted in a Level II ERA. It was determined that there were no final chemicals of potential ecological concern (COPECs) at FRBG. Consequently, no further action (NFA) was recommended to be protective of important ecological resources (Leidos 2018a).

Ecological receptors are not typically exposed to groundwater except for caves and when groundwater daylights to surface water. No known caves are at GRC-ATF, and this site does not contain surface water bodies. As a result, ecological exposures to chemicals in the groundwater is not a concern.

ES.5 RECOMMENDATIONS OF THE PHASE II REMEDIAL INVESTIGATION

This Phase II RI only evaluated groundwater at FRBG, since soil was evaluated in the Phase I RI. Based on the Phase II RI results, FRBG groundwater has been adequately characterized, and further investigation is not warranted to complete the RI for groundwater. The nature and extent of potentially impacted media have been sufficiently characterized. Emerging contaminants will continue to be evaluated separately.

The HHRA did not identify any COCs with residential use of groundwater at FRBG. Ecological exposures to chemicals in the groundwater is not a concern.

NFA was recommended to address chemical contamination within soil at FRBG. Since no COCs were identified with residential use of groundwater at FRBG, NFA is also recommended for groundwater. However, it is recommended that the soil RSLs used in the Phase I RI be compared to current RSLs to determine if any additional COCs are present in surface and subsurface soils.

During the 2015 Site Investigation (SI) and the 2017 Phase I RI, soil sample results indicated that two samples collected contained chrysolite asbestos at less than 1 percent. The Phase I RI Report recommended NFA for asbestos-containing material (ACM); however, it is NASA's policy to assess and remove all detectable asbestos at GRC-ATF. Therefore, it is recommended that a Feasibility Study (FS) be completed to address the asbestos contamination at FRBG.

1. INTRODUCTION

Leidos has prepared this Phase II Remedial Investigation (RI) Report on behalf of the National Aeronautics and Space Administration (NASA) as part of an RI conducted within the John H. Glenn Research Center at Neil A. Armstrong Test Facility (GRC-ATF) in Sandusky, Ohio (Figure 1-1). This report summarizes Phase II RI activities conducted at Fox Road Burning Ground (FRBG) and provides conclusions and recommendations regarding the evaluation of groundwater data collected from the investigation activities.

This Phase II RI is being conducted in accordance with U.S. Environmental Protection Agency (USEPA), Ohio Environmental Protection Agency (Ohio EPA), and NASA guidance. Investigative activities were conducted in compliance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended, and the National Oil and Hazardous Substances Pollution Contingency Plan (NCP).

1.1 PURPOSE OF REPORT

The primary scope and objectives of this Phase II RI Report for FRBG are to:

- Discuss historical activities, identify potential sources of contamination, and update the conceptual site model (CSM);
- Summarize previous assessments and investigations conducted at the site;
- Characterize the nature and extent of contamination in groundwater;
- Evaluate the impact of groundwater contamination on human health and the environment;
- Present the results of the soil gas evaluation of the potential impact of vapor-forming volatile organic compounds (VOCs) on human health and the environment; and
- Identify any unacceptable risk to be further addressed in a Feasibility Study (FS).

In August 2015, a Site Investigation (SI) of soil, sediment, and surface water was performed at FRBG. This SI was supplemented by the Phase I RI sampling performed in January 2017. Information from all historical documents and data gathered during the 2015 SI and 2017 RI will be used in this report to define the nature and extent of contamination and evaluate potential impacts to human health and the environment at FRBG.

In March 2018, the Phase I RI Report (Leidos 2018a) evaluated soil, sediment, and surface water at FRBG. The Phase I RI Report recommended a Phase II RI be conducted to collect and assess groundwater data at FRBG. This Phase II RI report evaluates groundwater and soil gas at FRBG. Two rounds of groundwater sampling were performed in May and November 2021 to address seasonal variations in groundwater. Since no vapor-forming chemicals were detected above vapor intrusion screening levels (VISLs) in the first or second round of groundwater sampling or as part of the Phase II RI, a soil gas investigation was not warranted based on the desktop soil vapor evaluation.

1.2 BACKGROUND

1.2.1 Armstrong Test Facility

1.2.1.1 Site Description

GRC-ATF (formerly known as Plum Brook Station [PBS]) is in southern Erie County, Ohio, approximately 3 miles south of Sandusky, Ohio, and approximately 50 miles west of the NASA John H. Glenn Research Center (GRC) in Cleveland, Ohio (Figure 1-1). The GRC-ATF site is currently 6,740 acres. Local farmers lease approximately 895 acres outside the security fence (Leidos 2018b). Most of GRC-ATF is in Perkins and Oxford Townships, with some lands in Huron and Milan Townships. The site boundaries are Bogart Road to the north, Mason Road to the south, U.S. Highway 250 to the east, and County Road 43 to the west. The northernmost boundary of GRC-ATF occurs at latitude 41°2'3""N and extends as far south as latitude 41°2'0""N. The westernmost longitude occurs at 82°4'1""W and extends as far east as 82°3'3""W.

GRC-ATF is situated in an area known for its agricultural productivity and is bordered by farmland, some of which NASA leases to local farmers. The area surrounding GRC-ATF is largely rural and agricultural, with some recent residential and commercial development. Some food processing facilities are in the area, including dairy and meat processing operations. Tourism and recreation are important economic influences in the Sandusky area. The Erie County Perkins School District currently uses certain former NASA facilities near the former GRC-ATF main gate and outside the fenced area for transportation and storage purposes. Intensive commercial development, consisting of highway-oriented uses (e.g., motels, restaurants, and service stations) and shopping malls, predominate immediately to the east along U.S. Highway 250 and its intersections with Bogart Road and State Highway 2 in Sandusky. A U.S. Army Reserve Center is situated adjacent to the southeastern corner, just off Mason Road (SAIC 2013a).

An 8-foot security fence surrounds approximately 5,845 acres of GRC-ATF. Most of the land at GRC-ATF consists of forestland and old fields. An estimated 75 percent of NASA's property at ATF is considered unused. The remaining land is used for offices, test facilities, roads, and infrastructure. Public access is restricted at GRC-ATF, and access to the site is gained through the security office on East Scheid Road. The main gate and security office are staffed by armed guards 24 hours per day. During each 8-hour shift, a security guard patrols the inside perimeter road (Patrol Road) of the facility. Persons gain access to the station by showing the guard a badge that authorizes entry.

1.2.1.2 History

GRC-ATF is operated as a satellite facility (or component installation) of NASA GRC. Use of GRC-ATF by the Federal Government began in 1941 when the Army established the Plum Brook Ordnance Works (PBOW) for manufacturing of trinitrotoluene (TNT), dinitrotoluene (DNT), and pentolite (MK 1994). The PBOW facility consisted of 9,009 acres inland, 1.35 acres for 2 pumping stations on Lake Erie, and approximately 700 buildings. Munitions production was conducted from 1941 to 1945, after which buildings and production lines were decontaminated and decommissioned. Between 1941 and 1945, more than one billion pounds of ordnance were estimated to have been manufactured.

In 1956, NASA obtained 500 acres in the northern portion of the site for construction of a nuclear test reactor (MK 1994). This reactor was the first of 15 test facilities that NASA eventually constructed and operated from 1958 to 1973. Between 1958 and 1960, NASA demolished hundreds of buildings, renovated approximately 41 buildings, and used 99 magazines (Gray and Pape 2008). In 1963, NASA acquired an additional 6,000 acres and took control over what is now referred to as GRC-ATF. From 1967 through 1971, NASA purchased approximately 2,000 acres outside the fence line from local farmers as "buffer."

On April 18, 1978, NASA declared approximately 2,152 acres of GRC-ATF as excess. This excess included approximately 1,500 acres outside the fence and was sold as farmland (NASA 2013). The 46 acres outside the fence in the northeastern corner of the PBOW facility near the guard house were conveyed to the Perkins Township Board of Education for use as a bus transportation area. In addition, three parcels have since transferred, including Parcel 4 (3.0951 acres) in March 2016, Parcel 63 (Former Taylor Road Wastewater Treatment Plant [11.5 acres]) in June 2016, and Rye Beach Pump Station (1.35 acres) in December 2014 (Leidos 2018b). According to the April 2018 update of the Environmental Resources Document, NASA currently controls approximately 6,740 acres; this includes approximately 5,845 acres within the fence line and 895 acres outside the fence, which are leased for agriculture (Leidos 2018b).

Most of the aerospace testing facilities built in the 1960s at GRC-ATF have been demolished or are currently on standby or inactive status. Additional tenants at ATF include the U.S. Department of Agriculture (USDA), U.S. Department of the Interior, the Federal Bureau of Investigation, and the Ohio Air National Guard. Additional details regarding the site history are presented in the *Preliminary Assessment/Visual Site Inspection Report for NASA Plum Brook Station* (TechLaw 1998).

1.2.2 Fox Road Burning Ground

1.2.2.1 Site Description

FRBG is located in the east-central portion of GRC-ATF on the northern side of the intersection of Fox Road and Snake Road. (Figure 1-2). FRBG is approximately 17.2 acres, although the exact locations of historical activities and extents are not certain. FRBG currently comprises forest and shrubland on the eastern portion of the site. The western half of the General Area was a mixture of flat, grassy area with some mature trees, areas of heavy shrub/scrub vegetation, and few soil piles. The three wetlands are independent of each other and are only partially inside the eastern boundaries of the General Area and Drainage Ditch.

In addition to being used as burning grounds, FRBG was documented to have also been used as a landfill (SAIC 1991). Referred to as Disposal Area 1B, it is located to the north of the burning ground area, is accessible by a gravel road, and is approximately 5 acres (SAIC 1991). Disposal Area 1B was created by NASA in the 1960s and was not used by the Army. For the purpose of this investigation, FRBG includes Disposal Area 1B.

Various types of waste have been observed in this area, including wood, several empty rusted drums, drum bands, transformer insulators, broken glass, nuts, bolts, and gaskets. No buildings are onsite; however, the remains of a suspected maintenance area (i.e., large concrete slab, two shallow pits with steps) are located in the forested area in the western portion of the site. Surface debris, including fragments of asphalt and concrete, was observed within and around a soil pile within the General Area.

1.2.2.2 Historical Usage

The Army and NASA have used burning grounds for destroying hazardous and nonhazardous material. These burning grounds are considered potential sources of environmental contamination because they were disposal sites for contaminated wastes. The contaminants included explosives, acids, asbestos, waste oil, and solvents.

Per the PBS Preliminary Assessment (PA) (SAIC 1991), the Army used burning grounds during the decontamination and decommissioning (D&D) of PBOW. These grounds were used for destroying explosives-contaminated wastewater flumes, intermediate settling tanks, and catch basins from the TNT areas. Contaminated putty, packing, and asbestos insulation removed from buildings at the TNT areas also were burned. All contaminated building material from the pentolite production area was also destroyed at the burning grounds.

The PBS PA contains conflicting information as to whether the Army used FRBG. Section 4.2.2.5 of the PBS PA states the following:

> *"…the U.S. Army established the Snake Road burning grounds, which are still used by NASA. In addition to the Snake Road burning grounds, the Army used burning grounds in three other locations: located off Taylor Road; on Fox Road; and west of the raw water pond."*

However, Figure 5-8 of the PBS PA indicates that only NASA used FRBG. To be conservative, this Phase II RI Report assumes that both the Army and NASA used FRBG.

Excavated contaminated soil from the TNT areas and from removal of the underground flume was treated at the burning grounds. Taylor Road Burning Ground (TRBG) was used for destroying combustible wastes that were not contaminated with acids or explosives. FRBG was used in approximately 1962 for destroying combustible and non-combustible waste contaminated or potentially contaminated with acids and explosives. Snake Road Burning Ground (SRBG) was used for disposing of combustible, non-contaminated solid waste and for waste oil and flammable solvents.

The Records Review Report for the PBOW (DM 1995; herein referred to as the 1995 Records Review Report) indicates that FRBG was used for "decontamination of Flume Lines on July 10, 1963." This is shown in several photographs of the site from that date. The report also indicates that large numbers and lengths of pipe and other materials were burned during decontamination efforts during the 1960s and that the site, along with others, was used for decontaminating TNT-contaminated pipes.

The Final Multi-site Investigation Report (Leidos 2016b; herein referred to as the 2016 SI Report) indicated that decontamination efforts were conducted from approximately 1954 to 1958. The text detailing those activities is as follows:

> *"Between approximately 1954 and 1958, portions of PBOW were deconstructed and decontaminated. CB&I (2015) reported that the decontamination included removal and disposal of contaminated surface and subsurface soil around the buildings and wooden and ceramic waste disposal lines containing TNT. The material is reported to include thousands of pounds of TNT recovered from catch basins. The materials were reportedly burned at burning grounds located at several areas, including the FRBG."*

The 2016 SI Report (Leidos 2016b) confirms that decontamination efforts continued from 1963 to 1964. The report describes the activities completed as follows:

> *"…activities included destruction of all buildings by fire and decontamination of sump basins, followed by removal of debris and concrete foundations. Materials from the areas, including soil, were thermally treated and the area was then rough graded. The process also included removal and burning of wastewater lines contaminated with nitroaromatic compounds."*

In addition to use as a burning ground, the GRC-ATF PA (SAIC 1991) identified FRBG as a landfill. Waste was reportedly deposited randomly within this area, although NASA personnel questioned about this disposal area were unfamiliar with its use and sources contributing to its use.

1.3 CONCEPTUAL SITE MODEL

This section provides additional information to support and present the CSM for use in the assessment of FRBG. This CSM presents the contamination sources, exposure pathways, human receptors, and ecological resources. Section 1.2.2 presents the site descriptions (history and current conditions), Section 2 presents environmental assessments and how data gaps were filled to complete the RI, and Section 3 presents the GRC-ATF and site-specific physical characteristics.

1.3.1 Potential Sources

FRBG is considered a potential source of environmental contamination at GRC-ATF due to historical usage as a disposal site and burning ground. The primary source of contamination includes contaminated wastes, including explosives, waste oil, solvents, asbestos, and acids. Except for some scattered debris, the site has no more primary source material.

No buildings are onsite; however, the remains of a suspected maintenance area (i.e., large concrete slab, two shallow pits with steps) are located in the forested area in the western portion of the site. The source medium or secondary source is surface and subsurface soil that was potentially contaminated from burning of the primary source material.

1.3.2 Potential Receptors

The following sections discuss potential human and ecological resources at FRBG. Figure 1-3 presents the pathway network receptor diagram to support the FRBG human health risk assessment (HHRA) and ecological risk assessment (ERA).

1.3.2.1 Human Receptors

FRBG is best classified as an inactive area, and plausible receptors include occasional groundskeepers and hunters. Even though hunting is not currently permitted in this area, hunting is permitted in other areas within GRC-ATF; therefore, a future hunting scenario was evaluated. GRC-ATF is expected to remain under the control of NASA for the foreseeable future. Although it is unlikely that FRBG will be developed for residential purposes, a hypothetical onsite residential scenario was evaluated to assess the upper bound for long-term exposure. Generally, sites that “pass” a residential risk assessment can be released for use without restriction. Similarly, while it is unlikely that FRBG will be developed for industrial or commercial purposes, a hypothetical industrial scenario is evaluated for long-term non-residential exposure.

Residential (onsite resident), occupational (industrial/commercial/construction worker), and recreational (hunter) exposure scenarios are used to evaluate potential risks from contaminated soil, soil vapor, and groundwater at FRBG.

1.3.2.2 Ecological Resources

FRBG is dominated by terrestrial resources and primarily consists of dry, mid-successional, cold-deciduous shrubland, with oak (Quercus palustris-Quercus bicolor) seasonally flooded forest dominating the eastern portion of the site.

FRBG has few aquatic resources. No streams or ponds are at the site, and no surface water or sediment exists. The ditch on the site was dry during the 2015 SI and 2017 RI, and thus the medium in the ditch was classified as soil instead of sediment. The wetlands at the site are ephemeral in nature and occur along the dry ditch and straddle the eastern boundary of the site.

1.4 REPORT ORGANIZATION

This report is organized in accordance with Ohio EPA and USEPA CERCLA RI/FS guidance. The components of the report and a list of appendices are provided below:

- Section 2 summarizes previous assessments, evaluations, and investigations at the site.
- Section 3 describes the environmental setting, including the topography, meteorology, hydrology, geology, soil, hydrogeology, demography, water resources, and ecology.
- Section 4 describes the methods used to perform the Phase II data collection activities.
- Section 5 presents the data use, quality, and evaluation methods to support this Phase II RI.

- Section 6 discusses the occurrence and distribution of groundwater contamination at the site.
- Section 7 presents an evaluation of contaminant fate and transport.
- Section 8 includes the methods and results of the HHRA.
- Section 9 includes a discussion of the ERA.
- Section 10 provides the conclusions and recommendations of this Phase II RI.
- Section 11 lists the references used to develop this report.
- Appendices:
  - Appendix A Field Documentation;
  - Appendix B Survey Report;
  - Appendix C Waste Manifests;
  - Appendix D Complete Groundwater Results;
  - Appendix E Analytical Laboratory Reports;
  - Appendix F Data Quality Assessments; and
  - Appendix G Human Health Risk Assessment Supporting Information.

Figure 1-1. NASA GRC-ATF Location in Ohio

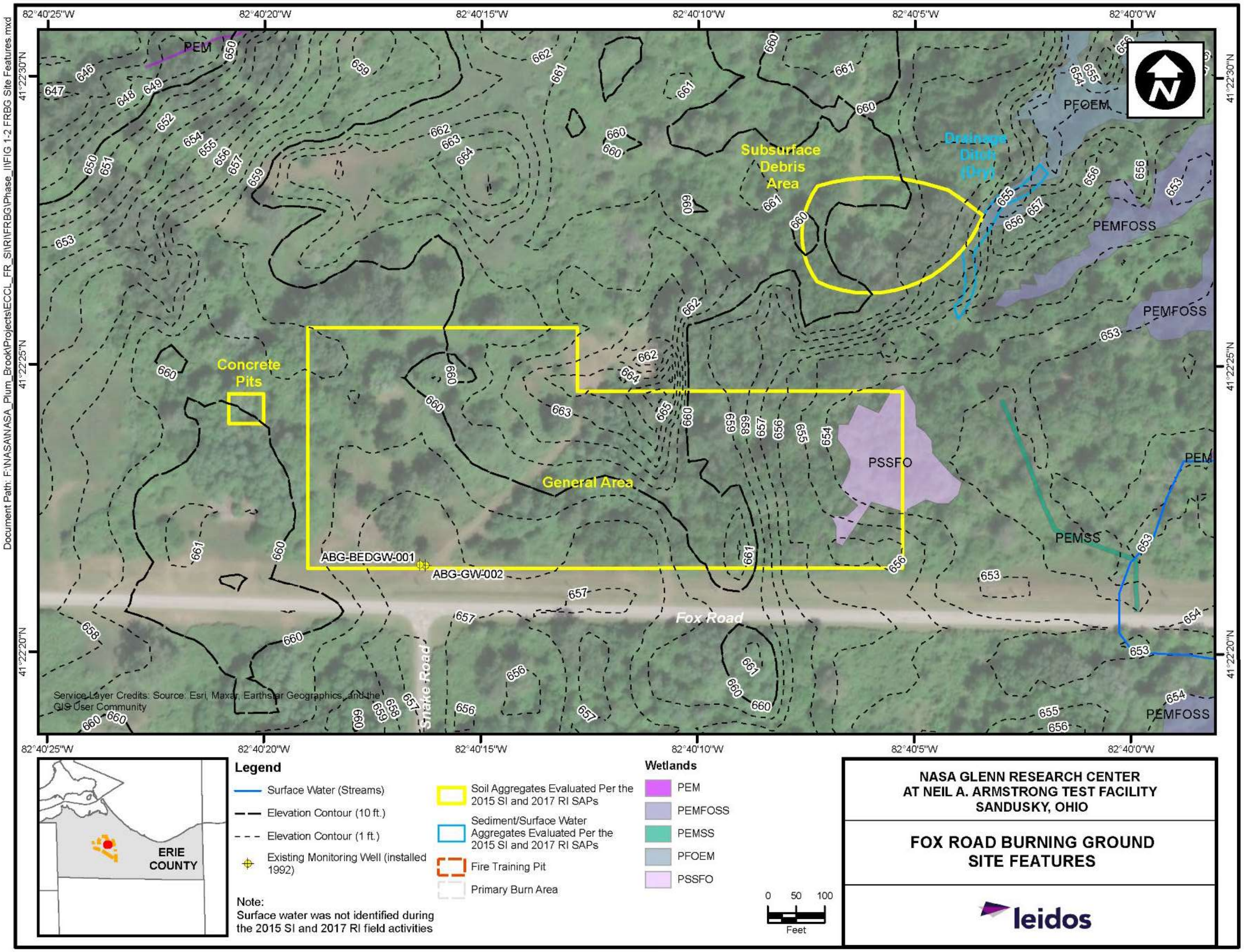

Figure 1-2. Fox Road Burning Ground Site Features

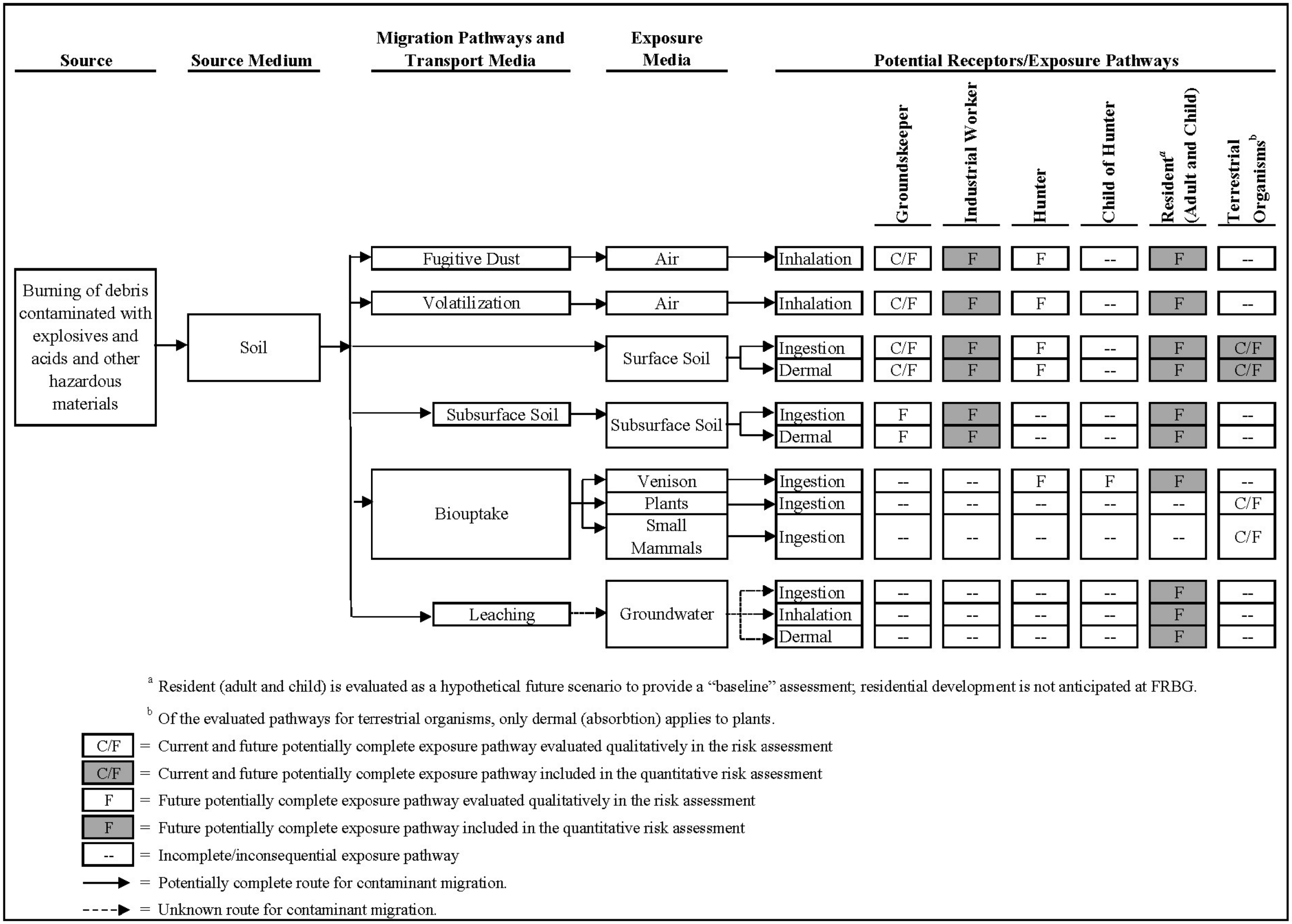

Figure 1-3. Fox Road Burning Ground Pathway Network Receptor Diagram

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2. STUDY AREA INVESTIGATION

2.1 PREVIOUS ASSESSMENT AND EVALUATIONS

This section summarizes previous assessments and evaluations conducted at FRBG. These activities were generally performed as an initial evaluation and/or prioritization assessment of the site. The data collected as part of these prioritization assessments and evaluations are not used in the nature and extent, fate and transport, HHRA, or ERA due to their age, specific data quality objectives (DQOs), or lack of data quality documentation.

2.1.1 1991 Plum Brook Station Preliminary Assessment

The PBS PA was performed to determine if any hazardous substances had been released from the facility that posed a potential threat to human health and the environment. To perform the assessment, documentation from NASA and various local, state, and Federal Government agencies was compiled and reviewed to obtain all available information pertaining to hazardous substance management at the facility, local and regional environmental conditions, demographics, and indications of hazardous substance contamination in and around the facility. Long-time facility employees were also interviewed regarding their personal recollections of hazardous substance management practices and historical releases (SAIC 1991).

The PBS PA indicated that NASA established three distinct disposal areas in the 1960s for solid waste generated at GRC-ATF: Disposal Area 1, Disposal Area 2, and Disposal Area 3. Although these areas were primarily used to dispose of or store solid waste or unwanted materials, evidence exists that they may have been used for the disposal of hazardous waste.

Figure 2-1 shows the locations of these disposal areas, as presented in the PBS PA. Disposal Areas 1B and 3 were associated with FRBG and SRBG, respectively. Disposal Area 2 was located on the western side of GRC-ATF and was not included in the scope of the PA evaluation. Although TRBG was included in Operable Unit (OU) 4, as described in the following subsection, it was not identified as a disposal area in the PBS PA.

2.1.1.1 Operable Unit 4: Burning Grounds

The PBS PA identified potential sources of environmental contamination and placed them in preliminary OUs. These sources and units were identified through document reviews, site surveillance, and interviews with GRC-ATF employees. To determine potential sources of environmental contamination, all current management and handling practices for hazardous substances (waste and product) were evaluated, including receipt, storage, use, and disposal of all CERCLA-listed substances. Practices were evaluated to determine whether they resulted in planned or unplanned releases of hazardous constituents to the environment.

The historical management of products and wastes at GRC-ATF was also evaluated in the PBS PA. Through these evaluations, 14 OUs were identified. Several of these OUs consist of multiple potential sources of environmental contamination, which have been grouped to streamline further CERCLA investigations and remedial actions.

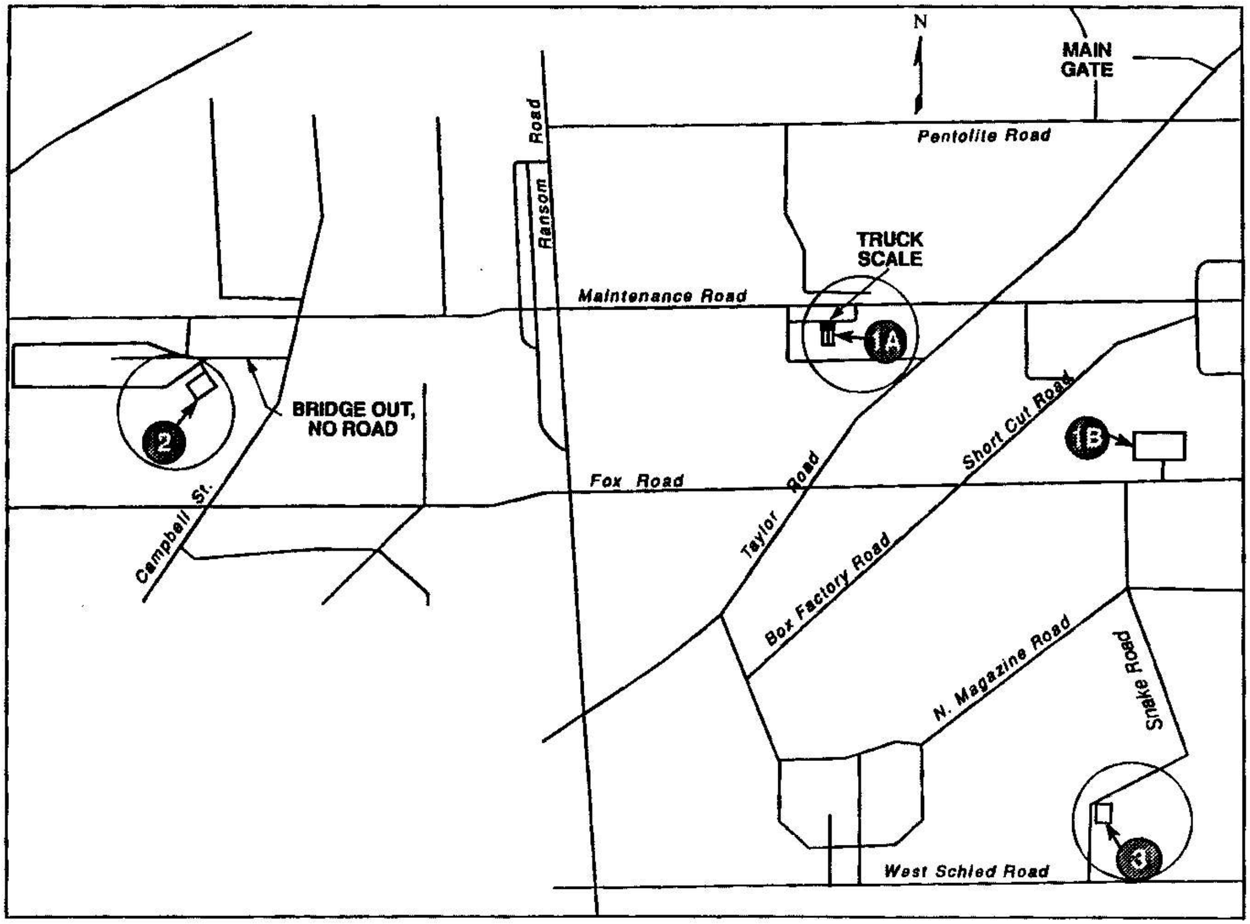


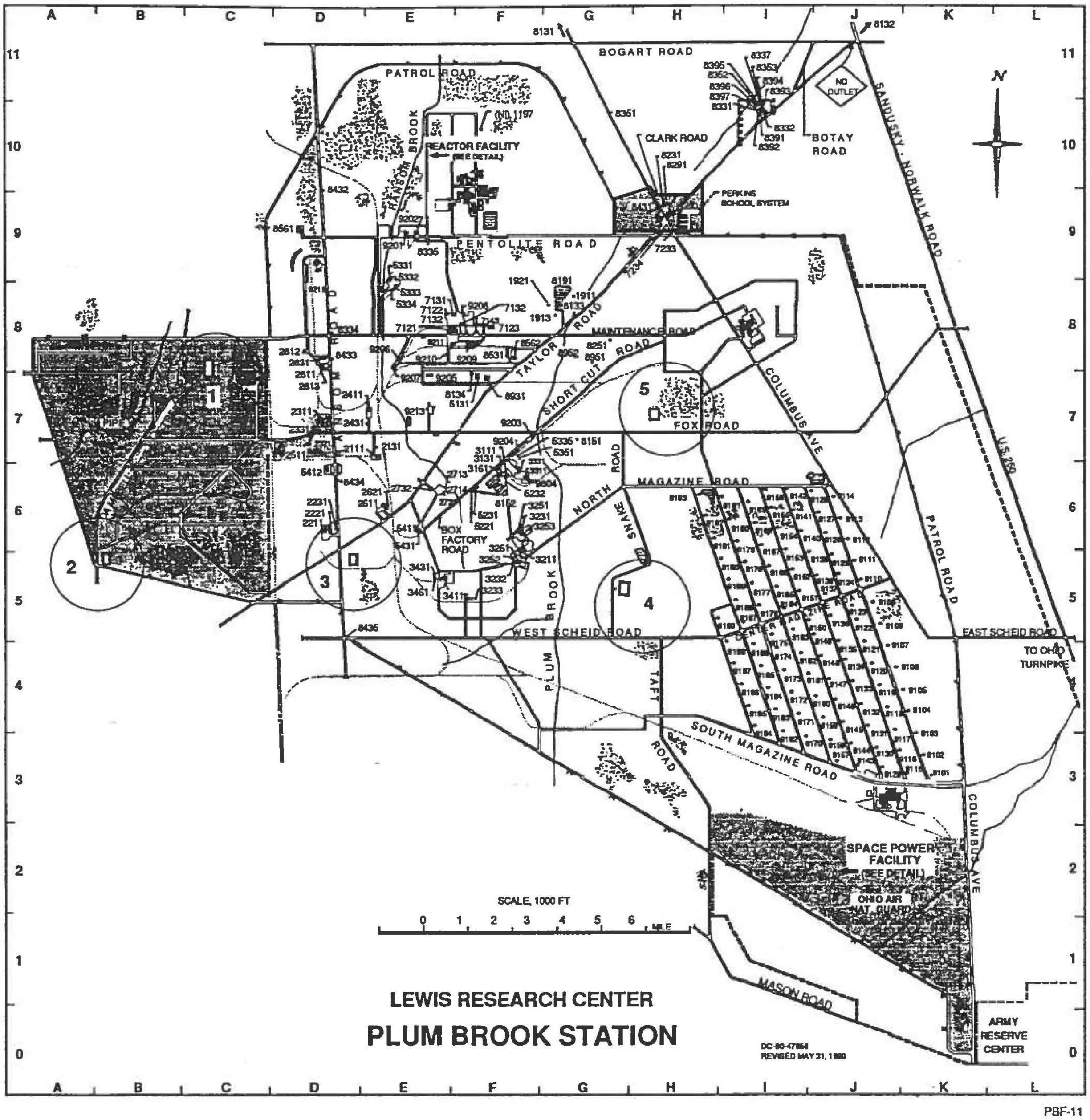
Figure 2-1. Distinct Disposal Areas for Solid Waste (SAIC 1991, Figure 4-1)

OU4 was for the burning grounds, and contaminants included explosives, acids, asbestos, waste oil, and solvents. OU4 included the following burning grounds, as summarized in Figure 2-2:

- West of Reservoir #2, dimensions unknown;
- East of G-8, dimensions unknown;
- Taylor Road, approximately 100 by 140 feet;
- Snake Road, approximately 100 by 200 feet; and
- Fox Road, no dimensions provided.

The Army used burning grounds during the D&D of PBOW. Five burning grounds that the Army formerly used were identified, although the PBS PA suspected that additional burning grounds may have been used. These grounds were used for destroying explosives-contaminated wastewater flumes, intermediate settling tanks, and catch basins from the TNT areas. Contaminated putty, packing, and asbestos insulation removed from buildings at the TNT areas also were burned. All contaminated building material from the pentolite production area was also destroyed at the burning grounds. Excavated contaminated soil from the TNT areas and from removal of underground flumes was treated at the burning grounds.

NASA also used burning grounds TRBG, FRBG, and SRBG. TRBG was used for destroying combustible wastes that were not contaminated with acids or explosives. FRBG was used in approximately 1962 for combustible and non-combustible waste contaminated or potentially contaminated with acids and explosives. SRBG was used for combustible, non-contaminated solid waste and for waste oil and flammable solvents.



Burning Ground	Name	Use	Comment
1	West of Reservoir #2	DOD	Location approximated, dimensions unknown
2	East of G-8	DOD	Location approximated, dimensions unknown
3	Taylor Road	DOD/NASA	Approximately 100 x 140 feet
4	Snake Road	DOD/NASA	Approximately 100 x 200 feet
5	Fox Road	NASA	

Figure 2-2. Locations of GRC-ATF Burning Grounds (SAIC 1991, Figure 4-2)

2.1.1.1.1 Hazardous Substance Management

Hazardous substances that the Army destroyed at the burning grounds included materials contaminated with DNT, TNT, pentolite, acids, solvents, waste oil, and asbestos (USACE 1999). The quantity of Army waste destroyed at the burning grounds is unknown. Hazardous materials that NASA disposed of at the burning grounds may have included waste oils, solvents, and other chemicals.

In areas where explosives were encountered, controlled burning was conducted. After destruction by fire, the ground was plowed to a depth of 6 inches and tested again for explosive material. If explosives were detected, the process was repeated.

Soil samples were collected in October 1989 from TRBG and SRBG to approximate depths of 4 feet. These sampling activities were conducted to support the IT Corporation 1991 Contamination Evaluation (IT 1991). These samples were used in the PBS PA to evaluate potential environmental impacts associated with the entire OU4. Two samples (SB-01 and SB-02) were collected from TRBG, and four samples (SB-03 to SB06) were collected from SRBG. Samples were not collected or assessed from the other three locations included in OU4, including FRBG.

2.1.1.1.2 Conclusions and Recommendations

OU4 Burning Grounds was one of the four OUs documented where hazardous substances were released to the environment. The environmentally impacted medium at OU4 was soil with solvents and unknown chemicals being the suspected contaminants. The extent and depth of potential contamination at the burning grounds are unknown. The limited soil sampling conducted at TRBG and SRBG indicates that minimal soil contamination had occurred; therefore, groundwater contamination is unlikely. However, groundwater monitoring data were not available at the time the PBS PA was prepared. Consequently, the impacted media may include groundwater. Samples were not collected or assessed from the other three locations included in OU4, including FRBG.

To quantify the potential hazard resulting from identified sources at GRC-ATF, each OU was assigned a score using USEPA's Hazard Ranking System (HRS). A draft HRS version provided by USEPA Region 5 was applied to all PBS PA OUs identified. This version was an abbreviated form of the HRS that USEPA developed as a simplified initial screening tool.

The HRS score is the primary criterion USEPA uses to determine whether a site should be placed on the National Priorities List (NPL). The NPL identifies sites that warrant further investigation to determine if they pose risks to public health or the environment. Sites on the NPL are eligible for long-term "remedial action" financed under CERCLA, as amended by the Superfund Amendments and Reauthorization Act (SARA).

The HRS score was based on the evaluation of the following migration pathways: groundwater, surface water, and air. The two other pathways (direct contact and fire/explosion) were evaluated to determine the need for immediate removal (emergency) action. HRS scores ranged from 0 to 100. Sites that scored 28.5 and above on the original HRS were eligible for the NPL.

Application of the abbreviated HRS model produced the following scores for the OU4 Burning Grounds (cumulative of all five sites of OU4):

- Groundwater pathway – 4.36;
- Surface water pathway – 2.16;
- Soil pathway – 3.8;
- Air pathway – 5.45; and
- Site score – 4.12.

The low HRS scores suggest that environmental impacts from the burning grounds are not significant. Accordingly, the PBS PA recommended giving a low priority for further investigation.

2.1.1.2 Operable Unit 11: Disposal Area 1B

The PBS PA created a separate OU for FRBG. This separate OU was called OU11: Disposal Area 1B. Disposal Area 1B was considered a landfill. Reportedly, waste was deposited randomly within this area, although NASA personnel questioned about this disposal area were unfamiliar with its use and sources contributing to its use. The evaluation of this OU had to do with the suspected source of environmental contamination by solvents and paint-related compounds.

The area identified in the PBS PA was approximately 5 acres, surrounded on the western and northern sides by an embankment. The largest section is flat and appears to have been scraped of vegetation at one time. The estimated extent of the landfilled waste was believed to be beyond the flat area and into the trees and brush.

2.1.1.2.1 Hazardous Substance Management

NASA designated this area in the 1960s as an area to dispose of non-contaminated, salvageable scrap metal. However, the types of waste observed in this area during site visits included wood, several empty rusted drums, drum bands, transformer insulators, broken glass, nuts, bolts, and gaskets. Several metal container labels, which read "vapor, degreaser," and oil can lids were also observed lying on the ground. It appeared that this area might have also been used as a burning ground, as evidence existed that at least one building had been burned at this site. Other items observed include a broken toilet and what appeared to be the dried-up paint from paint cans and containers used to clean paint brushes. Disposal Area 1B has been closed by administrative action.

2.1.1.2.2 Conclusions and Recommendations

Hazardous substance releases from Disposal Area 1B to the environment were not confirmed during the PBS PA. The following low scores were obtained when the abbreviated HRS model was applied:

- Groundwater pathway – 4.8;
- Surface water pathway – 2.16;
- Soil pathway – 3.8;
- Air pathway – 5.45; and
- Site score – 4.24.

A significant adverse environmental impact is not indicated by observed site conditions and the HRS scores. Accordingly, the PBS PA recommended giving a low priority for further investigation.

2.1.2 1994 Site Investigation

Under the direction of NASA and in accordance with CERCLA, Morrison Knudsen Corporation performed an SI at GRC-ATF. The purpose of the SI was to collect information concerning conditions at the facility sufficient to assess the threat posed to human health and the environment and to determine the need for any additional investigation. This investigation included reviewing previous information, sampling waste and environmental media to test PBS PA hypotheses, evaluating and documenting HRS factors, and collecting additional non-sampling information.

The 1994 SI Report used the OUs from the 1991 PBS PA and their corresponding locations and plotted them on a large-scale map to determine possible project management units (PMUs). Identification of the PMUs allows characterization and remediation, if necessary, of the potential sources of environmental contamination to proceed in an organized manner. The development of the PMUs and assignment of sources was based upon four criteria:

1. Geographic layout of the GRC-ATF site and proximity of sources;
2. Similarities in suspected types of contamination and affected environmental media;
3. Existing level of knowledge regarding the nature of contamination and anticipated priority for further response action; and
4. Similarity in age, type, and usage of OUs.

The 1994 SI Report established five PMUs based upon surface drainage patterns. The PBS PA (SAIC 1991) had identified the surface water pathway as being the principal means of contaminant transport from the sources on GRC-ATF to the receptors downstream. The boundaries between these PMUs were established by an inspection of the overland flow and the creek or ditch that would receive that flow. The five PMUs identified are as follows:

- PMU 1 – Pipe Creek;
- PMU 2 – Ransom Ditch/Brook;
- PMU 3 – Plum Brook;
- PMU 4 – Lindsley Ditch; and
- PMU 5 – Kuebelar, Scheid, and Schlessman Ditches.

FRBG (identified as "Fox Road Burning Ground" in the 1994 SI Report) was in PMU 4 – Lindsley Brook. As shown in Figure 2-3, PMU 4 is located on the eastern border of GRC-ATF. Pentolite Road borders PMU 4 on the north and Patrol Road on the east. North Magazine Road sets the southern limit of the PMU with the western boundary being an arbitrary line running north-south along the general lines of Snake Road.

PMU 4 covers approximately 600 acres of tall grass lands with some small, wooded lots in the southwestern and northeastern corners. The Lindsley ditch, a stream following a north/northeastern direction, is the major stream/surface water body. The ditch empties into Plum Brook at Bogart Road.

The 1994 SI Report identified two possible sources of contamination at PMU 4: TNT Area "A" where the Engineering Building resides, and FRBG. FRBG was described as a burning ground approximately 2 acres in size surrounded by a 2-foot-high earthen dike with debris littered around the burning grounds. Three surface samples and one field duplicate were collected in FRBG: one collected in the western edge of the diked area and the remaining two and the field duplicate collected in the northern edge of the site. Surface soil results within FRBG indicated low concentrations of toluene. Nitroexplosives, pesticides, and polychlorinated biphenyls (PCBs) were not detected in the surface soil. Detected inorganic compound concentrations were below MCLs or secondary MCLs for human consumption. The 1994 SI Report used the Preliminary Ranking Evaluation Score (PREscore) Version 2.0 computer program to assist in HRS site scoring of GRC-ATF. The following is the HRS results for PMU 4.

- Groundwater migration = 0.00;
- Surface water migration = 0.00;
- Soil exposure = 0.00;
- Air migration = 0.00; and
- Site score = 0.00.

Based upon the evaluation of the facility and historical records, the 1994 SI Report recommends that no further action (NFA) under CERCLA is necessary. Areas that indicated levels of contamination above background should be scheduled and remediated under different Federal and state authorities.

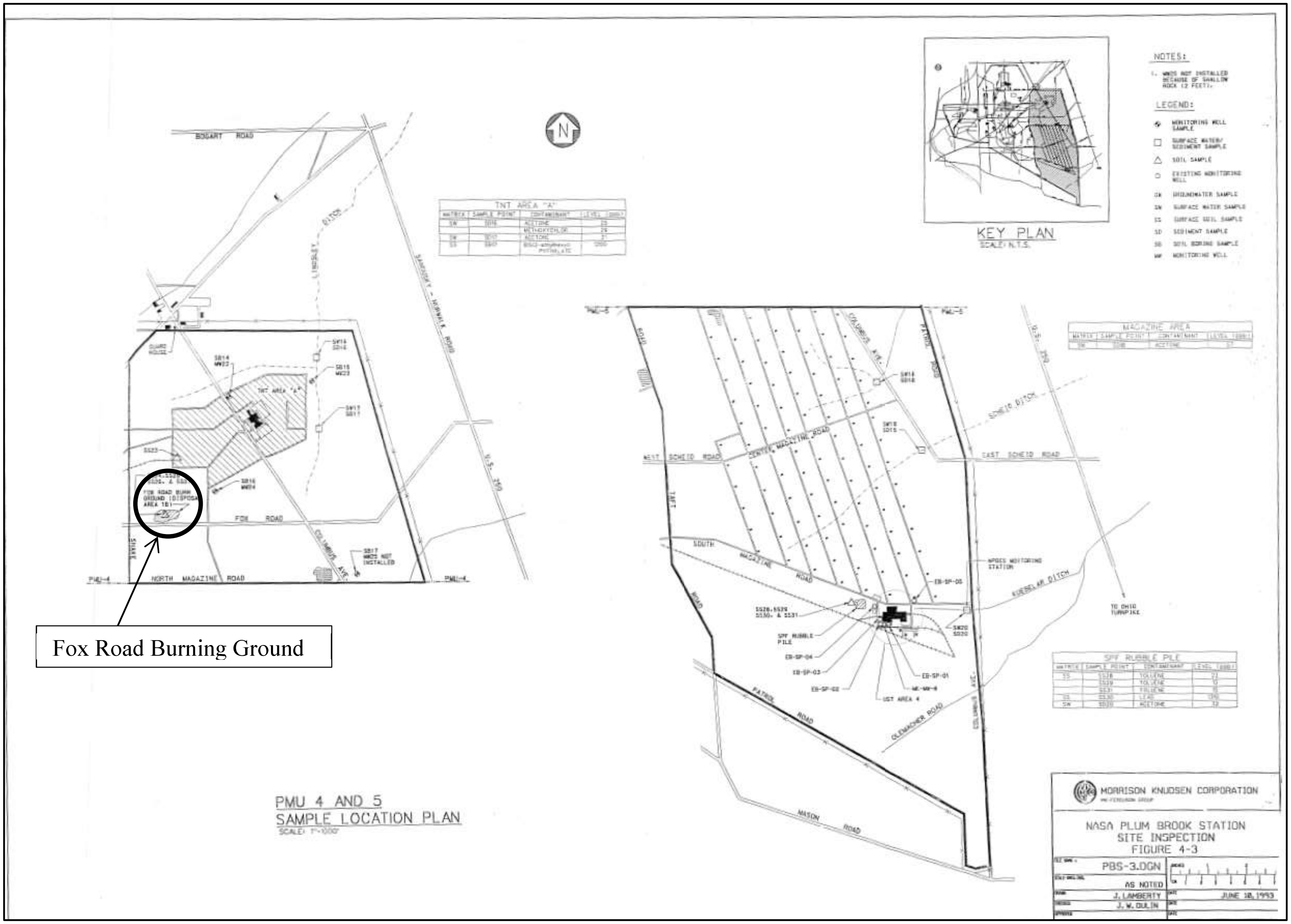


Figure 2-3. PMUs 4 and 5 (MK 1994, Figure 4-3)

2.1.3 1995 Records Review Report

The 1995 Records Review Report summarized information regarding seven OUs identified in the PBS PA. These OUs are called areas of concern (AOCs) in the 1995 Records Review Report (DM 1995).

AOC 4: Burning Grounds was included as one of the seven AOCs summarized in the 1995 Records Review Report. This report included historical site documents and photographs, historical aerial photographs, environmental investigation reports, and TNT manufacturing process information. The TNT manufacturing process information is not pertinent to AOC 4: Burning Grounds.

The 1995 Records Review Report also summarizes the site history, potential sources, and environmental investigations discussed in previous sections of this RI Report.

2.2 PHASE I REMEDIAL INVESTIGATION

During the 2015 SI and 2017 RI described in the following subsections, data of sufficient provenance and quality were collected to be used to support the evaluations in the Phase I RI Report (Leidos 2018a), including soil nature and extent, fate and transport, HHRA, and ERA. The field activities for these events are described below.

The Phase I RI Report (Leidos 2018a) provides site photographs (Phase I RI Report, Appendix D), boring logs and field forms (Phase I RI Report, Appendix E), and analytical data (Phase I RI Report, Appendix F) for both investigations to supplement the findings and conclusions.

2.2.1 2015 Site Investigation

The GRC-ATF Multi-site SI, which included FRBG, was conducted in August 2015, as summarized in the 2016 SI Report (Leidos 2016b). SI field activities were conducted between August 3 and August 21, 2015, in accordance with the *Multi-site Site Characterization Sampling and Analysis Plan* (SAIC 2011). The primary objectives of the SI were to determine the presence or absence of contamination in surface soil, subsurface soil, sediment, and surface water at each site and to either:

- Obtain an NFA decision with regulatory concurrence for qualifying sites;
- Identify the DQOs for conducting follow-on RIs at sites that do not meet the criteria for NFA; or
- Identify qualifying sites for interim removal actions and engineering evaluation/cost analysis.

Groundwater was not included as part of this SI.

2.2.1.1 Field Activities

Soil borings were advanced at 18 different locations. Twenty-seven surface soil samples and 29 subsurface soil samples were collected. All soil samples were analyzed for VOCs, semivolatile organic compounds (SVOCs), herbicides, pesticides, PCBs, explosives, and target analyte list (TAL) metals. Surface soil was also analyzed for asbestos. At sample location FRBG-SL-020, a white substance was identified in the soil boring. A sample was collected of this unknown white substance and was determined to not contain explosives or asbestos-containing material (ACM) and only contained low concentrations of polycyclic aromatic hydrocarbons (PAHs). Borings FRBG-SL-016 and FRBG-SL-018 were located on top of a soil pile, adjacent to rusty steel drums, a vertical pipe, and black tar material. Surface debris, including fragments of asphalt and concrete, was observed within and around a soil pile where boring FRBG-SL-015 was located. Boring FRBG-SL-013 was drilled through a concrete slab between the concrete pits. Table 2-2 lists the soil samples collected and the analyses conducted for each sample during the 2015 SI.

Table 2–1. Soil Samples Collected During the 2015 Site Investigation

Sample Location	Sample ID	Depth (ft)	Analyses Suite
FRBG-SL-001	FRBGSL0001	0-2	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs, Asbestos
FRBG-SL-002	FRBGSL0004	0-2	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs, Asbestos
	FRBGSL0005	2-6	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs
	FRBGSL0006	6-9	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs
FRBG-SL-003	FRBGSL0007	0-2	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs, Asbestos
	FRBGSL0008	2-5.5	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs
FRBG-SL-004	FRBGSL0010	0-2	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs, Asbestos
	FRBGSL0011	2-6	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs
FRBG-SL-005	FRBGSL0013	0-2	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs, Asbestos
	FRBGSL0014	2-6	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs
	FRBGSL0015	6-7.5	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs
FRBG-SL-006	FRBGSL0016	0-2	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs, Asbestos
	FRBGSL0017	2-6	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs
	FRBGSL0018	6-7	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs
FRBG-SL-007	FRBGSL0019	0-2	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs, Asbestos
	FRBGSL0020	2-6	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs
	FRBGSL0021	6-8	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs
FRBG-SL-008	FRBGSL0022	0-2	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs, Asbestos
	FRBGSL0023	2-5.5	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs
FRBG-SL-009	FRBGSL0025	0-2	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs, Asbestos
	FRBGSL0026	2-6	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs
FRBG-SL-010	FRBGSL0028	0-2	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs, Asbestos
	FRBGSL0029	2-6	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs
FRBG-SL-011	FRBGSL0031	0-2	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs, Asbestos
	FRBGSL0032	2-6	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs
FRBG-SL-012	FRBGSL0034	0-2	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs, Asbestos
	FRBGSL0035	2-5.5	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs

Table 2–1. Soil Samples Collected During the 2015 Site Investigation (Continued)

Sample Location	Sample ID	Depth (ft)	Analyses Suite
FRBG-SL-013	FRBGSL0037	0-2	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs
	FRBGSL0038	2-6	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs
	FRBGSL0039	6-7	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs
FRBG-SL-014	FRBGSL0040	0-2	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs
FRBG-SL-015	FRBGSL0041	0-2	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs
FRBG-SL-016	FRBGSL0042	0-2	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs
FRBG-SL-017	FRBGSL0043	0-2	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs, Asbestos
FRBG-SL-018	FRBGSL0044	0-2	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs
FRBG-SL-019	FRBGSL0045	0-2	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs, Asbestos
FRBG-SL-020	FRBGSL0046	0-2	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs, Asbestos
FRBG-SL-021	FRBGSL0047	0-2	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs, Asbestos
FRBG-SL-022	FRBGSL0048	0-2	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs, Asbestos
	FRBGSL0049	2-6	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs
	FRBGSL0050	6-10	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs
FRBG-SL-023	FRBGSL0051	0-2	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs, Asbestos
	FRBGSL0052	2-6	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs
	FRBGSL0053	6-10	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs
FRBG-SL-024	FRBGSL0054	0-2	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs, Asbestos
	FRBGSL0055	2-6	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs
	FRBGSL0056	6-10	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs
FRBG-SL-025	FRBGSL0057	0-2	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs, Asbestos
	FRBGSL0058	2-6	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs
	FRBGSL0059	6-10	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs
FRBG-SL-026	FRBGSL0060	0-2	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs, Asbestos
	FRBGSL0061	2-6	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs
	FRBGSL0062	6-10	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs

Table 2–1. Soil Samples Collected During the 2015 Site Investigation (Continued)

Sample Location	Sample ID	Depth (ft)	Analyses Suite
FRBG-SL-027	FRBGSL0063	0-2	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs, Asbestos
	FRBGSL0064	2-6	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs
	FRBGSL0065	6-10	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs
FRBG-SDSW-001	FRBGSD0001	0-2	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs, Asbestos
FRBG-SDSW-002	FRBGSD0002	0-2	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs, Asbestos
FRBG-SDSW-003	FRBGSD0003	0-2	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs, Asbestos

ft = feet
ID = Identification
PCB = Polychlorinated Biphenyl
SVOC = Semivolatile Organic Compound
TAL = Target Analyte List
VOC = Volatile Organic Compound

No surface water was identified in the Drainage Area; therefore, no surface water samples were collected at the site. Three sediment samples (FRBG-SDSW-001 to FRBG-SDSW-003) were collected and analyzed for the same sample suite as the surface soil samples. Because no surface water was present at the site, these sediment samples are included in the soil medium evaluations discussed later in this report.

Multiple compounds were detected in each medium sampled. In addition, each medium contained one or more compounds at concentrations greater than relevant screening criteria. Sample results indicate FRBG has been impacted by historical site use. A site walk was conducted to detect paint debris. Painted surfaces were screened using a portable X-ray fluorescence (XRF), and no lead was detected in the painted surface.

Also, a site assessment was performed by an Asbestos Hazard Evaluation Specialist. The assessment included collecting 25 soil samples, 1 piece of black tar-like substance, and 1 white cementitious material for analysis of asbestos content. One of the 25 soil samples collected contained asbestos, which had a concentration of 0.5 percent chrysotile. The black tar-like substance and white cementitious material did not contain asbestos.

2.2.1.2 Environmental Hazard Assessment

An ecological risk screening and HHRA were conducted to determine the presence of chemicals of potential ecological concern (COPECs) or chemicals of potential concern (COPCs).

The results of the surface soil and sediment sample screening were used to conduct ecological risk screening. The ecological risk screening identified 25 COPECs in surface soil, including 1 or more metal, SVOC, PCB, and pesticide. No COPECs were identified in sediment.

Potential COPCs were identified in the HHRA by comparing measured medium-specific concentrations to risk-based screening levels available at the time of the SI. The HHRA identified SVOCs and PCBs as SVOCs, PCBs, and one explosive (2,6-dinitrotoluene [DNT]) were identified as COPCs in subsurface soil.

2.2.1.3 Recommendations

Results of the SI activities indicated that surface soil should be evaluated in an RI. NFA was recommended for sediments, and no surface water was detected at FRBG.

Further evaluation in an RI was recommended for surface soil to fully evaluate the potential risk of the identified COPECs to ecological receptors. Further evaluation in an RI was recommended to evaluate the potential risk to human health related to the COPCs identified in surface soil.

The SI indicated that additional ACM assessment was not warranted, and NFA is recommended for ACM. However, an interim removal action was recommended for the debris observed.

2.2.2 2017 Phase I Remedial Investigation

To supplement the 2015 SI, a Phase I RI was performed in accordance with the *Multi-site Remedial Investigation Sampling and Analysis Plan* (Leidos 2016a). The primary objectives of the Phase I RI were to:

- Discuss historical activities, identify potential sources of contamination, and develop a CSM;
- Summarize previous assessments and investigations conducted at the site;
- Characterize the nature and extent of contamination in soil, sediment, and surface water;

- Evaluate the impact of soil, sediment, and surface water contamination on human health and the environment; and
- Identify any unacceptable risk to be further addressed in an FS.

2.2.2.1 Field Activities

A total of 16 surface soil samples were collected by hand auger from 16 locations (FR-1 to FR-16), as presented in Figure 2-4. For samples at locations at FR-1, FR-2, FR-3, FR-7, FR-8, and FR-10 to FR-14, the bucket hand auger method was used for collecting surface soil samples. The soil samples at the other locations were collected with Geoprobe® direct-push sampling equipment using a dual-tube sampler with a diameter of 2.25 inches. Table 2-2 lists the soil samples collected and the analyses conducted for each sample.

No additional sediment or surface water samples were planned. Consistent with the observations during the 2015 SI, surface water was not present in the drainage ditch.

To assist future evaluation of groundwater at this site, two temporary wells (FR-MW-1 and FR-MW-2) were installed to 10 feet below ground surface (bgs) during field activities. Groundwater was collected from these wells and analyzed for SVOCs, TAL metals, pesticides, and PCBs. Table 2-3 lists the groundwater samples collected and the analyses conducted for each sample.

Also, a site assessment was performed by an Asbestos Hazard Evaluation Specialist. Thirteen surface soil samples were analyzed for asbestos content. All sample locations had non-detectable concentrations of asbestos. In addition, black tar was identified within this EU. The field reconnaissance determined this material to be non-friable, and the laboratory analytical results showed that this material contained non-detectable asbestos fibers.

Table 2–2. Soil Samples Collected During the 2017 Remedial Investigation

Sample Location	Sample ID	Depth (ft)	Analysis Suite
FR-1	FRBGSL0066	0–2	SVOCs
FR-2	FRBGSL0067	0–2	SVOCs, pesticides, PCBs
FR-3	FRBGSL0068	0–2	SVOCs, pesticides, PCBs
FR-4	FRBGSL0069	0–2	SVOCs, pesticides
FR-5	FRBGSL0070	0–2	TAL metals, pesticides, SVOCs
FR-6	FRBGSL0071	0–2	TAL metals, pesticides, SVOCs
FR-7	FRBGSL0072	0–2	PCBs, pesticides, SVOCs
FR-8	FRBGSL0073	0–2	TAL metals, SVOCs
FR-9	FRBGSL0074	0–2	TAL metals, SVOCs
FR-10	FRBGSL0075	0–2	PCBs, pesticides, SVOCs
FR-11	FRBGSL0076	0–2	PCBs, pesticides, SVOCs
FR-12	FRBGSL0077	0–2	SVOCs
FR-13	FRBGSL0078	0–2	SVOCs
FR-14	FRBGSL0079	0–2	SVOCs
FR-15	FRBGSL0080	0–2	SVOCs
FR-16	FRBGSL0081	0–2	SVOCs

ft = Feet
ID = Identification
PCB = Polychlorinated Biphenyl
SVOC = Semivolatile Organic Compound
TAL = Target Analyte List

Table 2–3. Temporary Wells Installed During the 2017 Remedial Investigation

Sample Location	Sample ID	Analysis Suite
FR-MW1	FRBGGW0001	SVOCs, TAL metals, pesticides, PCBs
FR-MW2	FRBGGW0002	SVOCs, TAL metals, pesticides, PCBs

ID = Identification
PCB = Polychlorinated Biphenyl
SVOC = Semivolatile Organic Compound
TAL = Target Analyte List

2.2.2.2 Environmental Hazard Assessment

An ERA and HHRA were conducted to determine the presence of COPECs or COPCs (Leidos 2018a). FRBG is divided into four EUs for evaluation: the General Area, Subsurface Debris Area, Drainage Area, and Concrete Pits.

Soil data were collected, but no sediment or surface water was found at the site. Surface soil data were screened against ecological screening values (ESVs) recommended in Ohio EPA guidance, and preliminary COPECs were identified for each EU. Preliminary COPECs were further analyzed to determine if ecological risk was probable with the information available. Frequency of detection, average concentration, sample location, migration to wetlands, and impact of recommended human health remediation were considered applicable for each EU. Consequently, the ERA for FRBG concluded with a Level II Screening ERA, and NFA was recommended to be protective of important ecological resources.

The HHRA documented the potential health risks to humans resulting from exposure to contamination within FRBG. The HHRA was performed consistent with previous GRC-ATF HHRAs and was based on USEPA and Ohio EPA guidance. A residential scenario and industrial scenario were evaluated to identify any chemicals of concern (COCs) that require remediation for residential or industrial land use.

Under the residential scenario, ingestion of venison by a hunter did not contribute significantly to risks at the site. Predicted blood-lead concentrations for a child resident exposed to lead are below target levels for all EUs. Other risk results are summarized in the following subsections.

Under the residential scenario in the Subsurface Debris Area, the total hazard index (HI) for surface soil is 2 and the total incremental lifetime cancer risk (ILCR) is 6E-06. The HI of 2 is associated primarily with thallium (hazard quotient [HQ] = 1.3). The exposure point concentration (EPC) for thallium, 1 milligram per kilogram (mg/kg), is less than the naturally occurring background concentration of 1.3 mg/kg; therefore, this HI is associated with naturally occurring thallium in soil and thallium is not identified as a COC. The total HI for subsurface soil is 0.02, and the total ILCR is 2E-06; therefore, no COCs are identified for subsurface soil at the Subsurface Debris Area.

The total HIs were less than 1 and the total ILCRs are less than 1E-05; therefore, no COCs are identified at the General Area. No COPCs, and thus no COCs, were identified at the Concrete Pits. No COCs were identified in surface soil at the Drainage Ditch under both the residential and industrial scenarios.

Although groundwater samples were collected and analyzed, the Phase I RI Report did not fully address and characterize groundwater at FRBG. The Phase I RI Report only contains an evaluation of transport of contaminants in soil to groundwater.

2.2.2.3 Recommendations

The Phase I RI recommended NFA is required to address chemical contamination within soil at FRBG. Asbestos sampling at the FRBG indicated 1 of 27 samples contained chrysolite asbestos at less than 1 percent. No other asbestos was detected. Based on sampling results, additional ACM assessment is not warranted, and NFA was recommended for ACM. However, it is NASA's policy to assess and remove all detectable asbestos at GRC-ATF.

The Phase I RI Report recommended a Phase II RI be conducted to collect and assess groundwater data at FRBG. In addition, various types of waste and debris was observed at FRBG, including a rusty steel drum and vertical pipe, mainly in the areas of sample locations FRBG-SL-016 and FRBG-SL-017. Although this area was not identified as having chemical contamination posing a risk to human health or the environment, it was recommended that the removal and disposal of this debris be included in site remedial activities.

2.3 2021 PHASE II REMEDIAL INVESTIGATION

To supplement the 2017 Phase I RI, which recommended a Phase II RI be performed to assess groundwater, a Phase II RI was performed at FRBG in accordance with the *Final Burning Grounds Phase II Remedial Investigation Sampling and Analysis Plan* (Leidos 2020). The Phase II RI activities were performed from April 26 through December 2, 2021, to complete a data set that fully characterizes the nature and extent of contamination, assesses potential impacts soil may have on groundwater, and provides data to update and complete the HHRA and ERA. The field activities, findings, and results of the Phase II RI activities are summarized throughout this Phase II RI Report.

2.3.1 Soil Sampling

No additional soil sampling was warranted for the Phase II RI, as the Phase I RI concluded that soils have been adequately characterized.

2.3.2 Sediment and Surface Water Sampling

No additional sediment or surface water samples were planned. Consistent with historical observations, surface water was not present in the Drainage Ditch during the 2021 Phase II RI.

2.3.3 Groundwater Sampling

The 2018 Phase I RI Report (Leidos 2018a) conservative transport modeling indicated that seven chemicals had the potential to leach from soil and migrate to the groundwater table beneath their respective sources at concentrations exceeding MCLs/regional screening levels (RSLs). Therefore, it was recommended that groundwater samples be collected and assessed at FRBG. Table 2-4 provides the sampling locations, sample identifiers, sample date, and analysis suites for the groundwater samples collected during the Phase II RI activities. The Phase II RI activities included the following:

- Installing four new monitoring wells at FRBG: three wells immediately downgradient from FRBG and one within the General Area;
- Sampling the newly installed monitoring wells during two seasonal events; and
- Analyzing groundwater samples for Resource Conservation and recovery Act (RCRA) metals, explosives, VOCs, SVOCs, and PCBs.

Table 2–4. Groundwater Samples Collected During the 2021 Phase II Remedial Investigation

Sample Location	Sample IDs	Sample Dates	Analysis Suite
FRBG-MW01	FRBGGW1001/FRBGGW9101	05/26/2021	RCRA Metals (filtered and unfiltered), Explosives, PCBs, SVOCs, VOCs
FRBG-MW02	FRBGGW1002	05/26/2021	RCRA Metals (filtered and unfiltered), Explosives, PCBs, SVOCs, VOCs
FRBG-MW03	FRBGGW1003 FRBGGW1007	05/25/2021 11/30/2021	RCRA Metals (filtered and unfiltered), Explosives, PCBs, SVOCs, VOCs
FRBG-MW04	FRBGGW1004 FRBGGW10108A, 8B, 8C	05/25/2021 12/02/2021	RCRA Metals (filtered and unfiltered), Explosives, PCBs, SVOCs, VOCs

ID = Identification
PCB = Polychlorinated Biphenyl
RCRA = Resource Conservation and Recovery Act
SVOC = Semivolatile Organic Compound
TAL = Target Analyte List
VOC = Volatile Organic Compound

2.4 2022 PFAS SITE INSPECTION

Based on recommendations from the *Final PFAS (Per- and Polyfluoroalkyl Substances) Preliminary Assessment for the National Aeronautics and Space Administration (NASA) Glenn Research Center at Plum Brook Station* (Leidos 2019), soil, groundwater, sediment, and/or surface water samples were collected from eight areas of potential concern (AOPCs) at GRC-ATF during the 2021 per- and polyfluoroalkyl substances (PFAS) SI field activities. FRBG was one of the eight AOPCs where samples were collected during the SI. Sample locations and complete analytical results are provided in the PFAS SI Report (Leidos 2022). NASA is assessing potential PFAS contamination at FRBG under a separate investigation; therefore, PFAS are not included in this RI.

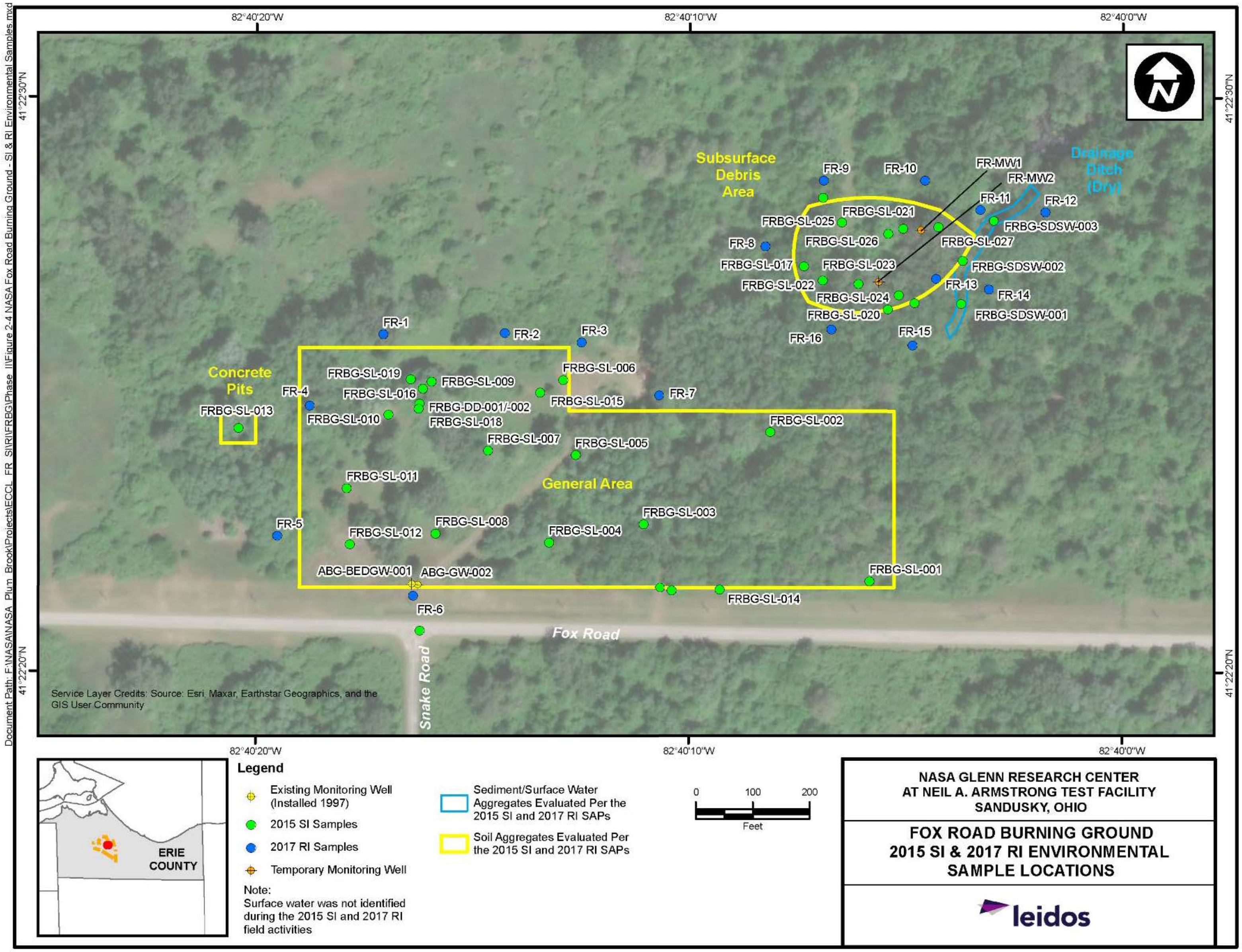


Figure 2-4. Fox Road Burning Ground 2015 SI and 2017 RI Environmental Sample Locations

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3. PHYSICAL CHARACTERISTICS

This section describes the physical features, topography, geology, hydrogeology, and environmental characteristics of FRBG that are factors in identifying the potential contaminant transport pathways, receptor populations, and exposure scenarios to evaluate human health and ecological risks.

3.1 SURFACE FEATURES AND TOPOGRAPHY

3.1.1 Armstrong Test Facility

Erie County is part of the Central Lowland Province and is an area of lake plain and till plain physiography with relatively uniform, level topography. GRC-ATF is situated on land that was once a lake bottom formed from glacial melt waters. GRC-ATF is relatively flat and slopes gently northward. The average slope of the land is less than 6 percent. Topographic relief across GRC-ATF is approximately 50 feet, with higher elevations (±675 feet above mean sea level [AMSL]) present along the south-southwestern facility boundary and lower elevations (±625 feet AMSL) present along the northern facility boundary. The lowest ground surface elevations at GRC-ATF are associated with the two primary surface water drainage features: Plum Brook (north-central portion of facility) and Pipe Creek (northwestern portion of facility).

The general topography of GRC-ATF and the surrounding area is shown in Figure 3-1. This figure shows two adjacent U.S. Geological Survey (USGS) 7.5-minute series topographic maps: Sandusky Quadrangle (northern portion of facility) and Kimball Quadrangle (southern portion of facility).

3.1.2 Fox Road Burning Ground

FRBG is in the eastern central portion of NASA GRC-ATF at the intersection of Fox Road and Snake Road (Figure 1-2). Topographic elevations at FRBG range from ±655 to ±666 feet AMSL. The lowest elevation at FRBG is the drainage ditch that exists to the northeast of the site, east of the Subsurface Debris Area. The highest elevation at FRBG is located at the north-central portion of the General Area.

3.2 METEOROLOGY

At GRC-ATF, the climate is continental in character and influenced by proximity to Lake Erie, which is approximately 6 km (4 miles) to the north. Summers are moderately warm and humid with temperatures occasionally exceeding 32ºC (90ºF). Winters are cold and cloudy with temperatures falling below -18ºC (0ºF) an average of 5 days per year. Annual temperature extremes typically occur after late June for summer climates and in January for winter. First frost typically occurs in October (SAIC 2013a). The predominant wind direction is south-southwest throughout the year. Wind direction was measured via an onsite wind monitoring tower in 2008 (Green Energy Ohio 2009).

Wind data from 2013 to 2020 at the Erie-Ottawa International Airport at Carl R Keller Field in Port Clinton, Ohio (IEM 2020) are presented in Figure 3-1 of the *Final Burning Grounds Phase II Remedial Investigation Sampling and Analysis Plan* (Leidos 2020). The wind direction is predominantly southwest. The Erie-Ottawa International Airport at Carl R Keller Field is approximately 20 miles north of GRC-ATF.

Based on long-term statewide weather records, Ohio receives an average of 38 inches of precipitation per year. Of these, about 10 inches (26 percent) become runoff, which moves immediately to surface water bodies such as streams and lakes. Of the 38 total inches of precipitation annually, 26 inches will enter the soil surface through infiltration. Twenty of these 26 inches go into soil storage and later are returned to the atmosphere by the combination of evaporation and transpiration (Ohio State University 2013). Accordingly, the Ohio

Department of Natural Resources (ODNR) estimates average annual water loss for the area, which includes GRC-ATF, to be between 22 and 23 inches (Harstine 1991). The 2-year, 24-hour rain event was estimated at 2.5 inches for the part of the United States containing Erie County (USDC 1963). Daily high and low temperatures and precipitation data are published in a Cooperative Data Report for this location. More detailed climatological data for GRC-ATF can be obtained from the National Weather Service station at Cleveland Hopkins International Airport (less than 50 miles east of ATF), at http://www.weather.gov/cle/CLENormals.

3.3 SURFACE WATER HYDROLOGY

3.3.1 Armstrong Test Facility

GRC-ATF is in the Lake Erie watershed. Watersheds are categorized according to the Hydrologic Unit Code (HUC) numbering system. The HUC number can range from 2 to 16 digits—the greater the number of digits, the smaller the area of the watershed. Smaller watersheds are nested within larger watersheds. Therefore, GRC-ATF is also located in the Sandusky River Watershed (HUC 04100011). More locally, much of GRC-ATF is drained by the Pipe Creek-Frontal Sandusky Bay Watershed (HUC 041000110102), which includes Plum Brook stream. The waterways in the southeastern portion of GRC-ATF flow toward, and are included in, the Sawmill Creek Watershed (HUC 041000110101). In general, streams at GRC-ATF travel northward toward Lake Erie.

In 2011 to 2012, a wetlands and other waters delineation was conducted at GRC-ATF. A total of 1,050 wetlands, 373 waterways totaling more than 308,726 linear feet, and 15 ponds totaling 15 acres, were delineated as part of the 2012 EnviroScience wetland delineation effort (EnviroScience 2012).

The largest of the major streams crossing GRC-ATF include Pipe Creek, Kuebelar Ditch, Ransom Brook, and Plum Brook. The waterways at GRC-ATF were categorized into three types in the 2011 to 2012 delineation: ephemeral, with 103,400 linear feet; intermittent, with 163,000 linear feet; and perennial, with 42,300 linear feet (EnviroScience 2012). In general, the streams at GRC-ATF travel northward and converge into Pipe Creek, Ransom Brook, Plum Brook, and Sawmill Creek and eventually flow into Lake Erie. The major ditches and streams at GRC-ATF are shown in Figure 3-2 and presented in Table 3-1. The streams could receive some of their volume from groundwater. There are no catch basins specifically intended to collect runoff.

Table 3–1. Major Ditches and Streams at GRC-ATF

Stream	Drainage Areas in Acres	
	Entering	Leaving
Pipe Creek	11,800	12,600
Ransom Brook	*	824
Storrs-Hemminger Ditch	*	130
Plum Brook	260	1,960
E.C. Smith Ditch	*	44
Lindsley Ditch	*	722
Schlessman Ditch	*	238
Scheid Ditch	*	505
Kuebelar Ditch	148	658
Scheid-Olemacher Ditch	40	273
Scherer Ditch	754	778

*Stream originates within facility boundaries
ATF = Armstrong Test Facility
GRC = John H. Glenn Research Center

Ohio EPA classifies all surface waters at GRC-ATF as warmwater habitat. Other use designations applicable to GRC-ATF streams include primary contact recreation (swimming) and agricultural and industrial water supply. Hemming Ditch and Plum Brook ultimately discharge to Lake Erie within the Sheldon Marsh State Nature Preserve (SNP) and are afforded special protection by ODNR.

The largest surface water body near GRC-ATF is Sandusky Bay on Lake Erie, approximately 4 miles to the north. Lake Erie has a surface area of approximately 9,910 square miles and an estimated volume of 116 cubic miles (ODNR 2009). Other surface water features include Bellevue Reservoir Number 5, which is 14 miles to the south-southwest. Numerous other ponds and streams are within a 15-mile radius. The Erie County Health Department does not permit surface water to be used for private drinking water supply.

3.3.2 Fox Road Burning Ground

FRBG is in the headwater areas for Lindsley Ditch (Figure 3-2). Surface drainage at the site flows over preferential pathways and largely into the drainage ditch located on the northeastern portion of the site. The drainage ditch at FRBG is routinely dry and appears to only be active during events of significant precipitation resulting in runoff.

3.4 GEOLOGY

3.4.1 Armstrong Test Facility

The bedrock in northern Ohio consists of Devonian and Silurian age carbonates (limestone and dolomite) and clastics (shale, siltstone, and sandstone) (USDA 2006). These units unconformably overlie older sedimentary sequences of Ordovician and Cambrian Age rocks, which in turn unconformably overlie pre-Cambrian basement rocks. GRC-ATF is situated along the eastern flank of the Findlay Arch, where bedrock dips gently to the east. The bedrock formations become progressively younger from west to east. Depth to the bedrock at GRC-ATF varies from 2 to 25 feet with scattered bedrock outcrops.

Four Devonian Age formations comprise the upper bedrock surface across GRC-ATF, from youngest to oldest:

- Ohio Shale (black, thin bedded with bituminous and carbonaceous material);
- Plum Brook Shale/Prout Limestone (light gray, calcareous);
- Delaware Limestone (buff, earthy, fossiliferous, interbedded with brown crystalline dolomite); and
- Columbus Limestone (brown to gray, fine crystalline, fossiliferous, with tan to buff gray sandy dolomite at base).

The Delaware Limestone Formation is the upper bedrock surface in the northern boundary and northwestern corner of GRC-ATF. The Plum Brook Shale/Prout Limestone are toward the center of GRC-ATF spanning from central west to the northeast portion of GRC-ATF. The Ohio Shale Formation is the upper bedrock surface in the eastern and southern portions (MK 1994). Figure 3-3 shows the general bedrock geology across the facility, and Figure 3-4 illustrates the bedrock topography for GRC-ATF. Detailed cross-sections, Figures 3-5, 3-6, and 3-7, show a detailed lithology of GRC-ATF. FRBG is located to the east of the southern portion of the north-south cross-section and to the south of the eastern portion of the east-west cross-section.

3.4.2 Fox Road Burning Ground

The upper bedrock surface at FRBG is the Devonian Age Ohio Shale. Based on soil boring logs completed at the site, depth to gray to black shale bedrock is approximately 5 to 10 feet bgs.

3.5 SOIL

3.5.1 Armstrong Test Facility

Erie County, which is in the eastern part of the Central Lowland Province, consists primarily of lake plain physiography, but till plain physiography occurs in the southeastern part of the county (ODNR 1998). GRC-ATF is in a transition zone between the Erie Lake Section and the Bellevue-Castalia Karst Plain of the Central Lowland Province. The Erie Lake Section, which occurs throughout the central to southeastern portion of GRC-ATF, is characterized by Pleistocene sand, silt, clay, and clay till over Devonian-aged shales. The Bellevue-Castalia Section, which occurs throughout the northern to northwestern portion of GRC-ATF, is characterized by Columbus and Delaware Limestone overlain by thin silty and sandy lacustrine deposits and clay till (ODNR 1998).

The soil is light-textured and often loamy with moderate to slightly acid pH. Primary soil types encountered at GRC-ATF are Elnora loamy fine sand (15 percent), Hornell Silty Clay Loam (14 percent), Fries silty clay loam (11 percent), Colwood loam (11 percent), Kibbie fine sandy loam (9 percent), and Pewamo silty clay loam (5 percent). In addition, approximately 12 percent of GRC-ATF is considered Udorthents, which is urban land consisting of reworked material and fill. Several other minor soil types are also present at GRC-ATF. Figure 3-8 presents a map illustrating the general distribution of soil types at GRC-ATF.

Based on descriptions provided in the *Soil Survey of Erie County, Ohio* (USDA 2006), soil types at GRC-ATF are generally very deep to deep, level to gently sloping, very poorly to somewhat poorly drained soil derived from glacial or lacustrine deposits and limestone or shale bedrock. The thickness and composition of glacial till vary widely within Erie County. Soil formation in the till is generally only a few feet thick. Where these till layers were very thin or eroded away, soil formed in older, harder till. The clay content of the till is highest near Lake Erie and lowest near bedrock areas where glacial ice sheets eroded and transported some of the coarser local material (USDA 2006).

3.5.2 Fox Road Burning Ground

Soil at FRBG consists largely of Udorthents-disturbed land in the central area of the site consisting of the former burn area and debris piles. Soil immediately surrounding the former burning ground consists of Elnora loamy fine sand (0 to 4 percent slope) and Dunbridge loamy sand (2 to 6 percent slope). Distributions of soil at the site are illustrated in Figure 3-8.

The Dunbridge loamy sand is composed of a till over residuum weathered from limestone. It is a well-drained, non-hydric soil. The Elnora loamy fine sand is derived from glaciolacustrine deposits, is moderately well drained, and does not exhibit flooding or ponding from surface water (USDA 2018).

3.6 HYDROGEOLOGY

3.6.1 Armstrong Test Facility

The USACE has produced numerous reports pertaining to their environmental efforts for groundwater at GRC-ATF. Many of the reports describe monitoring of groundwater chemicals, groundwater elevations, and groundwater flows. In general, GRC-ATF has two upper water-bearing zones, one in the overburden/shale and one in the Delaware Limestone bedrock.

The overburden layer consists of discontinuous groundwater seams across the facility that exhibit seasonal variations. The general flow of groundwater in overburden is to the north-northeast toward Lake Erie, largely mirroring surface topography (Figure 3-9). The flow also corresponds somewhat to the topography of the top of the bedrock. In contrast, the Delaware Limestone water-bearing zone is saturated year-round, but also flows to the north-northeast toward Lake Erie (Figure 3-10). The rate of groundwater flow in the bedrock is controlled by the frequency, orientation, density, and connectivity of the fractures.

Data from USACE groundwater investigations found that groundwater in the overburden occurs in discontinuous pockets during dry time periods. Connectivity between groundwater in the shallow water-bearing zone and surface water is evident in the spring/wet season at GRC-ATF. The overburden layer's connection to surface water has been demonstrated to be more strongly seasonal and less continuous (Shaw 2005). In general, historical data indicate that groundwater elevations in the overburden/shale fluctuate seasonally, irrespective of the area of GRC-ATF. Data collected from the facility do not show a clear correlation between precipitation rates and water level elevations in site wells (Shaw 2005).

Most residents of Erie County receive water from public utilities whose primary sources are from municipal water derived from Lake Erie. Residences to the north and east of GRC-ATF are connected to city, county, or rural services. Erie County's primary groundwater source is from the limestone and dolomite aquifer in the western end of the county (Shaw 2008). At GRC-ATF, the groundwater has been divided into three zones based on location and yield (Figure 3-11). Zone 1 occurs in the northern and northwestern portions of the station in the limestone formations, which typically occurs in joints and along bedding planes. It has been characterized as yielding from 100 to 500 gallons per minute (gpm) from karstic limestone approximately 100 feet below grade. Zone 2 is in the northern portion of GRC-ATF and has yields of 15 gpm or less from limestone approximately 300 feet below grade. Zone 3 is in the eastern and southern portions of the site in predominantly shale bedrock. In addition to being found in the shale, groundwater is in thin sand and gravel horizons interbedded with silt and clay deposits. Most Zone 3 wells are poor yielding, many of them providing less than 3 gallons per minute (Shaw 2008).

Groundwater at GRC-ATF is not used for drinking water, and no injection wells are onsite. The Erie County Health Department does not allow the use of surface water (e.g., river, stream, creek, drainage ditch) for a private drinking water system, in accordance with Ohio Administrative Code 3701-28; however, a pond, spring, or cistern tank could be used as a source for a private water system. Six known private wells are within 1 mile downgradient from GRC-ATF. The nearest known downgradient private well is approximately 840 feet northeast of the facility boundary.

Leidos completed a review of ODNR's water well records via the Water Wells Viewer (https://gis.ohiodnr.gov/MapViewer/?config=waterwells) on November 11, 2021. The search used a 5,000-foot buffer and 4-mile buffer around the NASA GRC-ATF fence line to identify potable wells registered with ODNR that are located upgradient of and downgradient from GRC-ATF. Twenty-one potential potable wells were identified downgradient from and within 5,000 feet of GRC-ATF. Forty-four potential potable wells were identified upgradient of and within 5,000 feet of GRC-ATF. In addition to the potable wells, the ODNR well search also identified well #9922001, a production well located in the southern portion of the GRC-ATF property. The well is not currently in use, and it is unknown if this well has been abandoned. Using a 4-mile radius around the GRC-ATF perimeter, the well search identified approximately 912 ODNR registered wells, which is inclusive of wells used for potable and non-potable purposes.

USACE conducted groundwater investigations in connection with site remediation activities such as the red water ponds. NASA and USACE installed approximately 187 monitoring wells. Between 2014 and 2015, USACE abandoned 122 monitoring wells (CB&I 2014 and 2015). Based on an investigation completed in 1997, naturally occurring petroleum was identified in the groundwater, providing further evidence that groundwater at GRC-ATF is unsuitable for potable use (IT 1997). At the time of this report, NASA is working to establish the requirements for a land use control prohibiting groundwater use at GRC-ATF.

3.6.2 Fox Road Burning Ground

Discontinuous saturated zones in overburden soil were observed at depths ranging from 2.5 to 5.0 feet bgs during field investigation. Four permanent monitoring wells (FRBG-MW01, FRBG-MW02, FRBG-MW03, and FRBG-MW04) were installed to total depths ranging from 7 to 12 feet bgs due to bedrock refusal. During the 2021 Phase II RI, two seasonal rounds of groundwater sampling were performed in May and November/December. Groundwater was collected from these wells and analyzed for VOCs, SVOCs, explosives, TAL metals, and PCBs. Monitoring wells FRBG-MW01 and FRBG-MW02 were found to be dry in November 2021. The monitoring wells could sustain low flow sampling (50 to 175 millimeters per minute) during the May 2021 sampling but had significantly less water present in December 2021, and FRBG-MW03 and FRBG-MW04 were purged dry using a bailer prior to sampling.

3.7 DEMOGRAPHY AND LAND USE

U.S. Census Bureau data collected in 2020 for Erie County, Ohio, estimate the 2020 population of Erie County to be 75,622, with 37,897 total housing units (U.S. Census Bureau 2020). The population in 2020 was estimated as being 83.0 percent White but not Hispanic, 8.9 percent African American, 4.5 percent Hispanic or Latino, and 3.3 percent two or more races, with the remaining percentage consisting of Native American, Asian, and Native Hawaiian or Pacific Islander. In 2020, the percent of persons under 5 years of age was estimated at 5.3 percent, the percent of persons under 18 years of age was estimated at 20.2 percent, and the percent of persons 65 years or older was estimated at 22.6 percent (U.S. Census Bureau 2020).

The average household income for 2015 to 2019 was estimated to be $54,226 annually (U.S. Census Bureau 2020). Statistical and demographic data for 2020 published by the U.S. Census Bureau lists labor force of the county as 38,013 for calendar year 2019, based on the American Community Survey 1-year estimate, with 36,433 employed for an unemployment rate of 4.2 percent (U.S. Census Bureau 2020). The services industry employs the most people followed by manufacturing, trade, government, construction, transportation/utilities, finance/insurance/real estate, and agriculture/forestry/fishing and mining.

The location of Erie County next to Lake Erie and the local attractions make the county a high tourist area. The population in the area increases by 50 percent in the summer. Cedar Point Amusement Park alone draws more than 3.6 million visitors each season. The largest city is Sandusky, with a population of approximately 25,000.

Peak NASA employment at GRC-ATF was approximately 600 people in the mid-1960s. Today's total NASA employment is approximately 170. Of these employees, approximately 24 are civil servants and the remainder are contractor employees (Mullenax 2018). Other government agencies have 20 to 30 personnel stationed onsite.

GRC-ATF is not as significant an employer in its region as the Lewis Field site. Other large employers in the area include the Flex-N-Gate (formerly Ford Motor Company), Kyklos Bearing International, Delco-Chassis NDH, Tenneco (formerly Imperial Clevite), Sandusky Plastics, and Sandusky International (Foundry and Machinery) (SAIC 2013b).

NASA's presence in the area nonetheless provides local economic impacts and benefits. A 2021 study found overall economic benefit to the regional economy from NASA GRC to be as follows: total output of $1.8 billion, employment impact of 8,974, and household earnings impact of $805.7 million (Lendel and Yun 2021). Most of these benefits are associated with Lewis Field; however, GRC actions are felt throughout Ohio. The 2021 report found that GRC activities in fiscal year (FY) 2020 generated an increased demand for products and services used in northeast Ohio valued at $1.8 billion. In FY 2020, GRC awarded $3.9 million in grants to Ohio academic institutions, 66.7 percent of which went to institutions in northeast Ohio. Northeast Ohio received the greatest share of expenditures from GRC when compared to the rest of the state, 96.1 percent of $303.8 million. GRC continues to be a significant influence on the economy and labor force in Ohio, particularly for the knowledge-intensive labor force, which helps provide technological advancement for the country, generate local wealth, and attract skilled and knowledgeable workers to reside in Ohio.

3.8 ECOLOGY

GRC-ATF is part of a regional ecosystem encompassing Sandusky, parts of Lake Erie, and several Lake Erie islands. Several natural areas are found in the general vicinity. The Milan State Wildlife Area is located approximately 3 miles to the south. The Erie Sand Barrens SNP is approximately 1,000 feet to the south. The Sheldon Marsh SNP is approximately 4 miles to the northwest, and the Resthaven Wildlife Area is 6 miles to the northwest. Another local natural area is Old Woman Creek, a National Estuarine Research Reserve (NERR) and SNP, which is east of the city of Huron.

3.8.1 Flora

The ODNR Division of Natural Areas and Preserves (DNAP) conducted a botanical survey of GRC-ATF in 1994. During that survey, 327 species of vascular plants were cataloged, 12 of which were listed by DNAP as Ohio rare species. In 2001, DNAP conducted a follow-up survey in which 312 of the species found in 1994 were identified and 219 new additions were made. During a 2016 field survey, all plant communities previously described throughout 2001 were updated or confirmed to reflect their present ecological condition. The 2016 survey identified 16 formations and 13 alliances at GRC-ATF. Formations and alliances are listed below; descriptions and delineations of the alliances are provided in *Protected Species Management Strategy for NASA Glenn Research Center* (Volume II of EnviroScience 2017). They are identified in Figure 3-12.

<u>Forest Formations</u>

- Formation: I.A.8.N.c. Conical-crowned temperate or subpolar needle-leaved evergreen forest (EFU1)
- Formation: I.B.2.C.b. Orchards and groves (fruit and nut trees) (*eliminated by succession)*
- Formation: I.B.2.N.a. Lowland or submontane cold-deciduous forest
  - *Quercus alba* – (*Quercus rubra*, *Carya* spp.) forest alliance (FU2)
  - *Quercus rubra* – *Acer saccharum* – (*Quercus alba*) forest alliance (FU3)
  - *Quercus velutina* – *Quercus alba* forest alliance (FU4)
  - Mixed (oak-dominated) deciduous successional forest (FU5)
  - Mesic, mixed deciduous successional forest (FU6)
  - Mixed deciduous successional forest (FU7)
  - *Populus deltoides* successional forest (FU8)
- Formation: I.B.2.N.d. Temporarily flooded cold-deciduous forest – successional communities
  - *Fraxinus pennsylvanica* – *Ulmus americana* – *Celtis* (*occidentalis, laevigata*) temporarily flooded forest alliance (FL1)
  - *Salix nigra* temporarily flooded forest alliance (FL2)
- Formation: I.B.2.N.e. Seasonally flooded cold-deciduous forest – successional communities
  - *Acer rubrum* – *Fraxinus pennsylvanica* seasonally flooded forest alliance (FL3)

        - *Quercus palustris* – (*Quercus bicolor*) seasonally flooded forest alliance (FL4)
        - Mixed cold-deciduous seasonally flooded forest (FL5)
    - Woodland Formation: Mixed cold-deciduous seasonally flooded woodland (WL1)

Shrubland Formations

- Formation: III.B.2.N.a. Temperate cold-deciduous shrubland – successional communities
    - Dry mid-successional cold-deciduous shrubland (SU1)
- Formation: III.B.2.N.c. Intermittently flooded cold-deciduous shrubland
    - Intermittently flooded mid-successional cold-deciduous shrubland (SL1)
    - Intermittently flooded late-successional cold-deciduous shrubland (SL2)
- Formation: III.B.2.N.f. Semipermanently flooded cold-deciduous shrubland
    - *Cephalanthus occidentalis* Semipermanently Flooded Shrubland Alliance (SL3)
- Formation: III.B.2.N.g. Saturated cold-deciduous shrubland
    - *Cornus* spp. – *Salix* spp. Saturated Shrubland Alliance (SL4)

Herbaceous Vegetation Formations

- Formation: V.A.5.C.b. Landscaped urban/suburban/rural (residential yards, nurseries)
    - Landscaped/maintained grounds surrounding buildings (LM)
- Formation: V.A.5.N.c. Medium-tall sod temperate or subpolar grassland
    - Maintained grassland (MG)
- Formation: V.A.5.N.k. Seasonally flooded temperate or subpolar grassland
    - *Phalaris arundinacea* Seasonally Flooded Herbaceous Alliance (HL2)
    - *Typha* spp. – (*Scirpus* spp. – *Juncus* spp.) Seasonally Flooded Herbaceous Alliance (HL3)
    - *Phragmites australis* Seasonally Flooded Herbaceous Alliance (HL4)
- Formation: V.B.2.N.a. Tall temperate or subpolar perennial forb vegetation – successional community
    - Dry early successional herbaceous field (HU1)
- Formation: V.B.2.N.c. Intermittently flooded temperate perennial forb vegetation – successional community
    - Intermittently flooded early successional herbaceous field (HL1)
- Formation: V.C.2.N.a. Permanently flooded temperate or subpolar hydromorphic rooted vegetation
    - *Potamogeton* spp. – *Ceratophyllum spp. – Elodea spp. Permanently Flooded Herbaceous Alliance* (HL5)
    - *Nelumbo lutea* permanently flooded herbaceous community (HL6).

Wetlands were formally delineated for all of GRC-ATF in accordance with methods described in the *Corps of Engineers Wetlands Delineation Manual* (USACE 1987) and the *Interim Regional Supplement to the Corps of Engineers Wetland Delineation Manual: Northeast and Northcentral Region* (USACE 2012). A total of 1,050 wetlands totaling 421.958 acres, 373 waterways totaling 308,726 linear feet, and 15 ponds totaling 14.908 acres were delineated.

As part of the wetland delineation effort, 10 upland and wetland vegetative communities were identified at GRC-ATF. Upland and wetland vegetation sample plots were recorded for the delineated wetlands and associated upland areas.

3.8.2 Fauna

Animals censused at GRC-ATF during the 2001 and 2016 surveys for the *Protected Species Management Strategy* (EnviroScience 2017) included birds, amphibians, reptiles, fish, lepidoptera, and bats. One hundred and twenty-five bird species were identified during the 2001 summer birding season at

GRC-ATF. This includes 11 species that were considered late migrants through the area and 7 species that were classified as visitors only. A general analysis of the results indicates little change in the species diversity on the station since the 1994 surveys conducted for the *Biological Inventory of Plum Brook Station* (ODNR 1995). The birds identified in the 2016 survey were similar to those identified in 1994 and 2001. One hundred and twenty species were identified, 6 of which were considered visitors and 11 were classified as migrants (EnviroScience 2017).

In 2001, amphibians and/or reptiles were recorded from 115 localities in GRC-ATF. There were 15 localities from 1994 where animals were no longer found, but animals were found at 29 new locations. Twenty-one species have been found, including two salamanders, six frogs, one lizard, five turtles, and seven snakes. Two new native species, the milk snake and blue-tail skink, were found as well as an introduced species, the red-eared slider. The gray tree frog has been deleted from the list. In addition, the area lies within the range of 19 other species, and it is possible that 1 or more of these may yet be discovered here (ODNR 2002). The 2016 survey detected 20 species at more than 200 localities, which include two salamander species, seven frog species, four turtle species, and seven snake species. Of those 20 species, 2 are listed as species of concern, and 1, the *Opheodrys vernalis* (Smooth Greensnake), is endangered (Table 3-2).

During the fish survey conducted in support of the 1995 *Biological Inventory of Plum Brook Station* (ODNR 1995), 3,028 individuals, representing 13 species and 1 hybrid, were collected. In 2001, 2,156 individuals, representing 15 species and 1 hybrid, were collected. The small, intermittent nature of the streams in the study area, coupled with extensive channel modifications and habitat degradations, have resulted in a lower species diversity than would be found in more pristine headwater streams of similar size. Except for the brook stickleback, all species captured in this study were common species statewide, exhibiting high degrees of tolerance to habitat and water quality degradations. A small population of sticklebacks was discovered in a small, shallow pool below a culvert in one of the tributary ditches feeding into Pipe Creek in 1993. This population was still there in 2001 but was no longer detected in 2016 (ODNR 2002). The 2017 report confirmed the low fish diversity reported in the 1994 and 2001 reports (EnviroScience 2017).

In a 1994 summer survey of GRC-ATF, 41 species of butterflies were recorded. During the summer of 2001, 53 species of butterflies were recorded. Three species observed in 1994 were not seen in 2001. However, 14 species not recorded in 1994 were found in 2001. As of 2001, the surveys conducted that year raised the number of species recorded from Erie County from 59 to 70 (ODNR 2002). The 2016 survey recorded 45 butterfly species, none of which were listed as Federal- or state-listed rare, threatened, or endangered species. Fourteen species were recorded in either 1994 or 2001 that were not seen in 2016, and three new species were recorded in 2016 (EnviroScience 2017).

After an extensive survey of GRC-ATF during the summer of 2001, 450 species of moths were recorded. A previous survey in 1994 recorded 385 species of moths. At the time of the 2001 moth survey, six species were listed as uncommon, three species were rare, and three species were of special interest. One species on the ODNR's Ohio's Endangered Wildlife List was recorded (ODNR 2002). The 2016 survey detected 455 species of moths, 332 of which had been previously detected and 123 that were new to the facility. No Federal- or state-listed rare, threatened, or endangered species were identified during the 2016 survey (EnviroScience 2017).

Distribution, diversity, and relative abundance of the Chiropterans (bats) at GRC-ATF were studied from April through September 2001. Methodology included visual and acoustical surveying of the grounds and buildings; mist netting of wooded, riparian, and open sites; and radio tracking of selected bats within the station. A total of 238 bats, including 8 different species, were captured at 17 of the 21 mist net sites at ATF. No evidence of the Indiana bat was found. Several maternity colonies were located and used by three different species (ODNR 2002).

In 2010 and 2012, additional bat mist netting surveys were conducted. In 2010, bats were captured at each of four mist net sites, with five species of bats recorded. The results of this survey were qualitatively similar to the more extensive mist netting survey conducted in 2001 (West 2010) and described above. In 2012, bat mist netting was conducted at eight sites on GRC-ATF; six bat species were captured during the mist netting effort. Acoustic detection of bat calls was also used during the 2012 bat survey. Similar to the 2010 bat survey, the results of the 2012 survey were similar to those of the 2011 bat mist netting survey conducted at GRC-ATF (West 2012).

In 2009 and 2010, various bird surveys were conducted onsite by USDA's Wildlife Services and National Wildlife Research Center (Seamans et al. 2011). As part of this effort, passerine and diurnal raptors were surveyed during their fall (2009) and spring (2010) migratory periods. In the fall of 2009, 40 species of passerines and 10 species of diurnal raptors were identified. In the spring of 2010, 51 species of passerines and 13 species of diurnal raptors were identified. In addition, in 2010, USDA conducted a breeding bird survey, which identified 54 species of such birds at GRC-ATF (Seamans et al. 2011).

In 2012, a survey for a candidate species for the Federal endangered species list, the Eastern Massasauga rattlesnake (*Sistrurus catenatus*), was conducted. The survey sites chosen for this effort were specific to the habitat requirements of the Eastern Massasauga, so it could not be considered a comprehensive snake or reptile survey. However, although no Eastern Massasaugas were found onsite, three species of snakes were recorded during the survey (Lipps 2012).

In 2017, a bee survey was completed in a milkweed field and the adjacent abandoned prairie at the intersection of Taylor and Maintenance Roads. The results identified eight known species of bees. In addition, 18 bees whose species could not be identified were found during the survey (Eppig 2018).

3.8.3 Unique and Important Habitats

GRC-ATF contains vast natural resources in the form of a complex mosaic of plant communities in various successional stages and hydrologic regimes. Much of GRC-ATF is undeveloped natural areas or recovering natural areas previously used for agriculture. The size and diversity of natural habitats at GRC-ATF support many plant and animal species (EnviroScience 2017, ODNR 1995, ODNR 2002). Many of these areas contain rare plants species and rare plant communities, including rare prairie species and remnant oak savannas. The *Protected Species Management Strategy for NASA Glenn Research Center at Plum Brook Station Volume II: Plant Community Survey* (EnviroScience 2017) divided significant plant communities into four categories:

- Rare plant community restoration areas,
- Specific rare plant sites,
- Intact rare plant communities, and
- Degraded rare plant communities.

At GRC-ATF, eight core sites containing areas of special vegetation significance were identified as priority areas for management in Volume III of the *Protected Species Management Strategy* (EnviroScience 2017, ODNR 2002). The eight areas are identified in Table 3-3 and Figure 3-13, which show management areas at GRC-ATF. These include specific sites with identified populations of rare or state-listed plant species as of the species surveys conducted in 2001 and 2016 in support of the *Protected Species Management Strategy* (EnviroScience 2017, ODNR 2002). They can be small and local or somewhat extensive in area, but in all cases their distinguishing characteristic is that they support a growth of rare plants or can be restored to a condition that supports rare plants. The areas are being managed to protect against loss of the most important sites, which would likely mean the irretrievable loss of the local rare plants, many of which are exceptionally rare or state-listed and found nowhere else in the region or state.

Table 3–2. State-listed Animal Species at GRC-ATF (EnviroScience 2017)*

Endangered	Survey Years Located
Bulbulcus ibis (cattle egret)	1994/2001
Opheodrys vernalis (smooth green snake)	1994/2001/2016
Spartiniphaga inops (moth, no common name)	2001
Threatened	
Bartramia longicauda (upland sandpiper)	1994
Emydoidea blandingii (Blanding's turtle)	1994
Nycticorax nyctcrax (black-crowned night heron)	1994/2001
Myotis septentrionalis (northern long-eared bat)	2001/2010/2012
Special Interest/Concern	
Accipiter striatus (sharp-shinned hawk)	2016
Ammodramus henslowii (Henslow's sparrow)	2016
Casmerodius albus (great egret)	1994/2001/2016
Cistothorus palustris (marsh wren)	2016
Cistothorus platensis (sedge wren)	1994/2001/2016
Colinus virginianus (northern bobwhite)	2001
Emydoidea blandingii (Blanding's turtle)	1994 (*no longer listed*)
Elaphe vulpine gloydi (eastern fox snake)	1994/2001/2016
Empidonax minimus (least flycatcher)	2001/2016
Eptesicus fuscus (big brown bat)	2001/2010/2012/2016
Haliaeetus leucocephalus (bald eagle)	2002/2016 (*federal only*)
Lasiurus borealis (eastern red bat)	2001/2010/2012/2016
Lasiurus cinereus (hoary bat)	2001/2010/2012
Myotis lucifugus (little brown bat)	2001/2010/2012
Oporornis philadelphia (mourning warbler)	2001/2016
*Pantherophis vulpinus (*western foxsnake*)*	2016
Perimyotis subflavus (tri-colored bat)	2001/2012
Rallus limicola (Virginia rail)	2001/2016
Setophaga cerulean (cerulean warbler)	2016
Setophaga fusca (blackburnian warbler)	2016
Setophaga magnolia (magnolia warbler)	2016
Sphyrapicus varius (yellow-bellied sapsucker)	2016

Source: EnviroScience 2017. *Final Protected Species Management Strategy for NASA Glenn Research Center at Plum Brook Station*, Volume I: Biological Surveys. March.

*This table lists fauna that were on Ohio's state-listed protected list at the time they were surveyed at GRC-ATF. Species may be listed in a different category as of 2016, or have been removed from the protected list, and this is reflected in the above table

ATF = Armstrong Test Facility
GRC = John H. Glenn Research Center

Table 3–3. The Eight Species Management Areas at GRC-ATF

Area Name	Category	Acreage
East Patrol Road	Rare Prairie Plant Site	78
Magazine Area	Rare Prairie Plant Site	504
Pentolite Area	Native Forests	227
West Area	Native Forest	55
South Patrol Road and Taft Road	Savanna Areas	90
Pentolite Road	Savanna Area	17
Central	Meadows Area	458
Gateway	Meadow Area	99

ATF = Armstrong Test Facility
GRC = John H. Glenn Research Center

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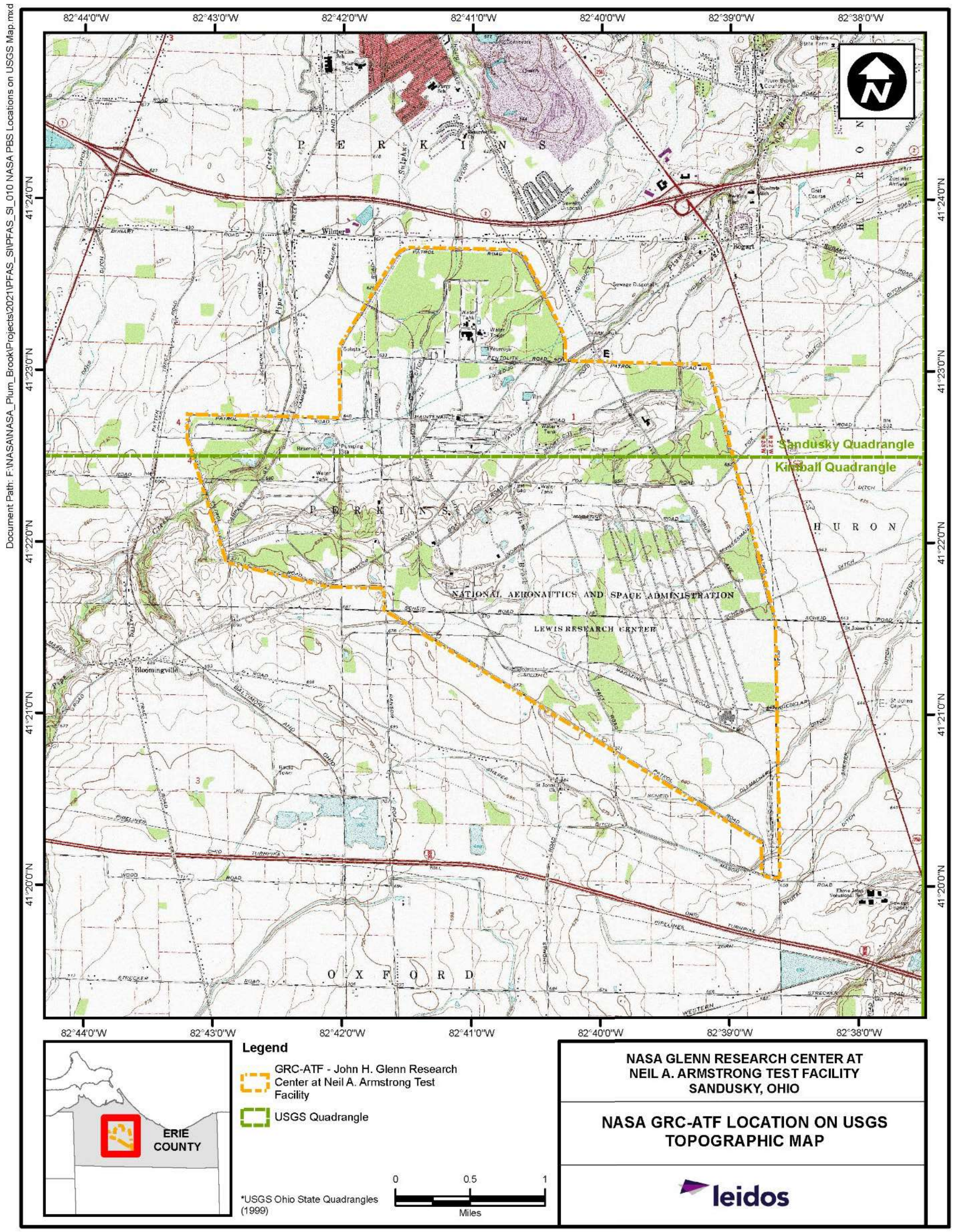

Figure 3-1. NASA GRC-ATF Location on USGS Topographic Map

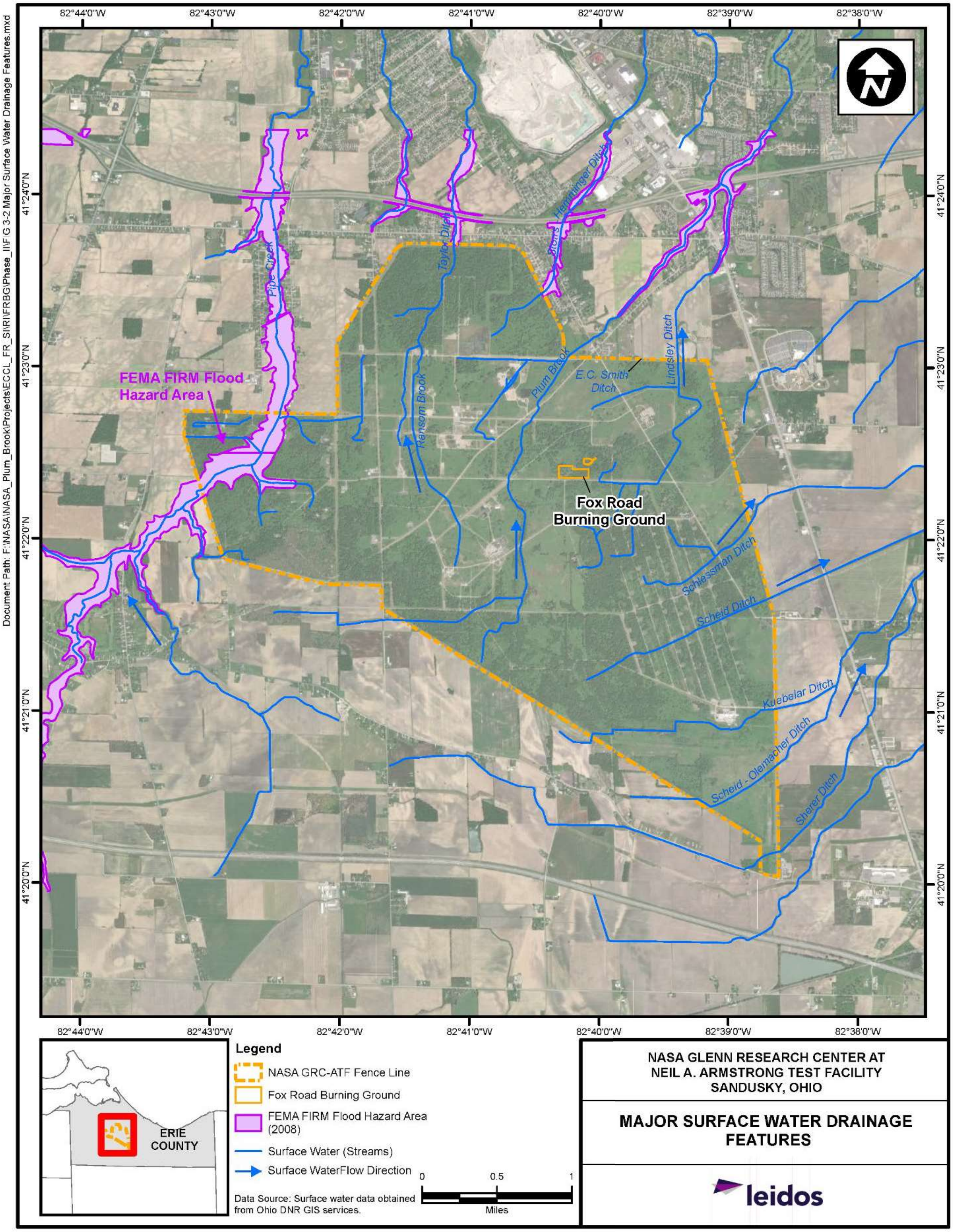

Figure 3-2. Major Surface Water Drainage Features

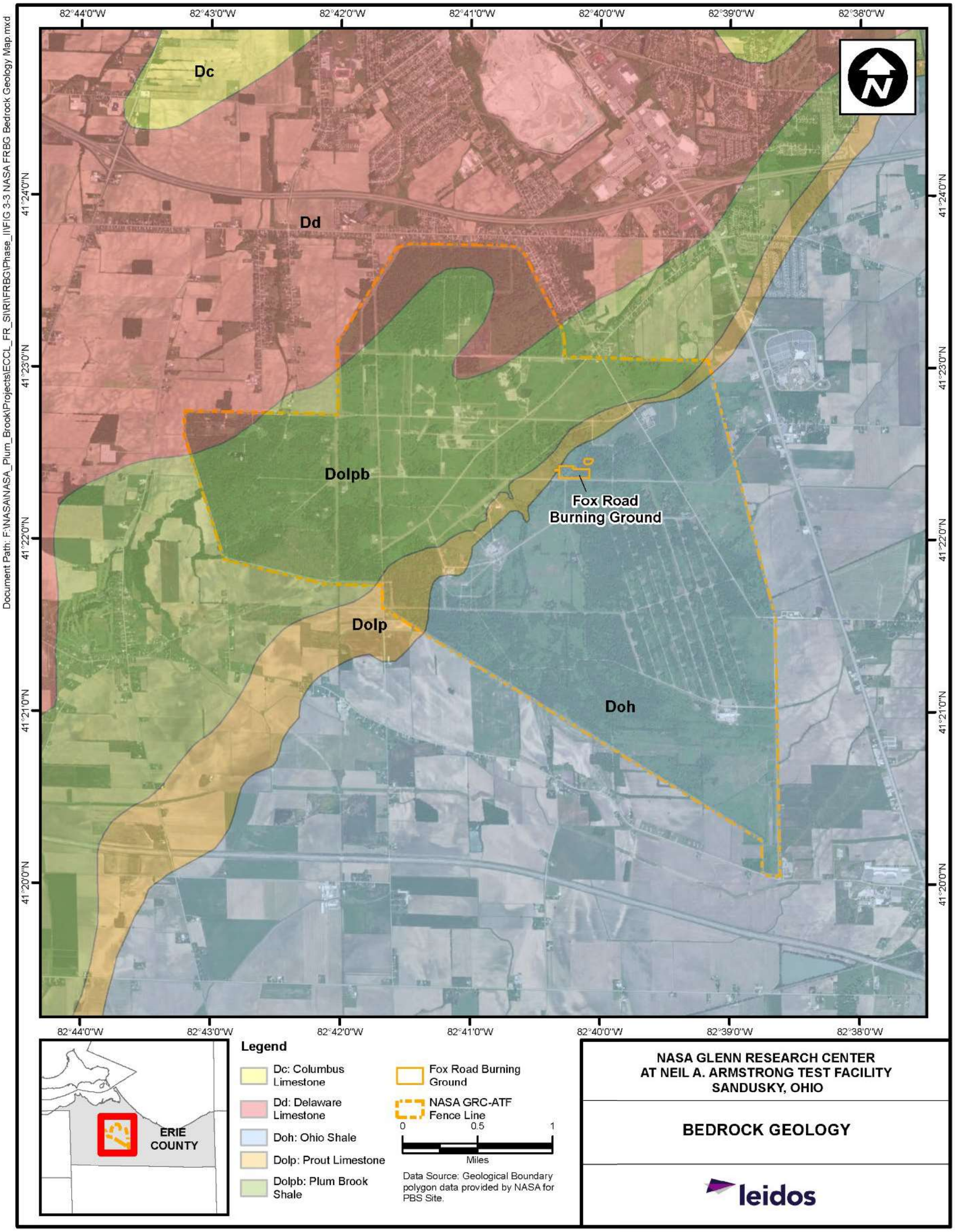

Figure 3-3. Bedrock Geology

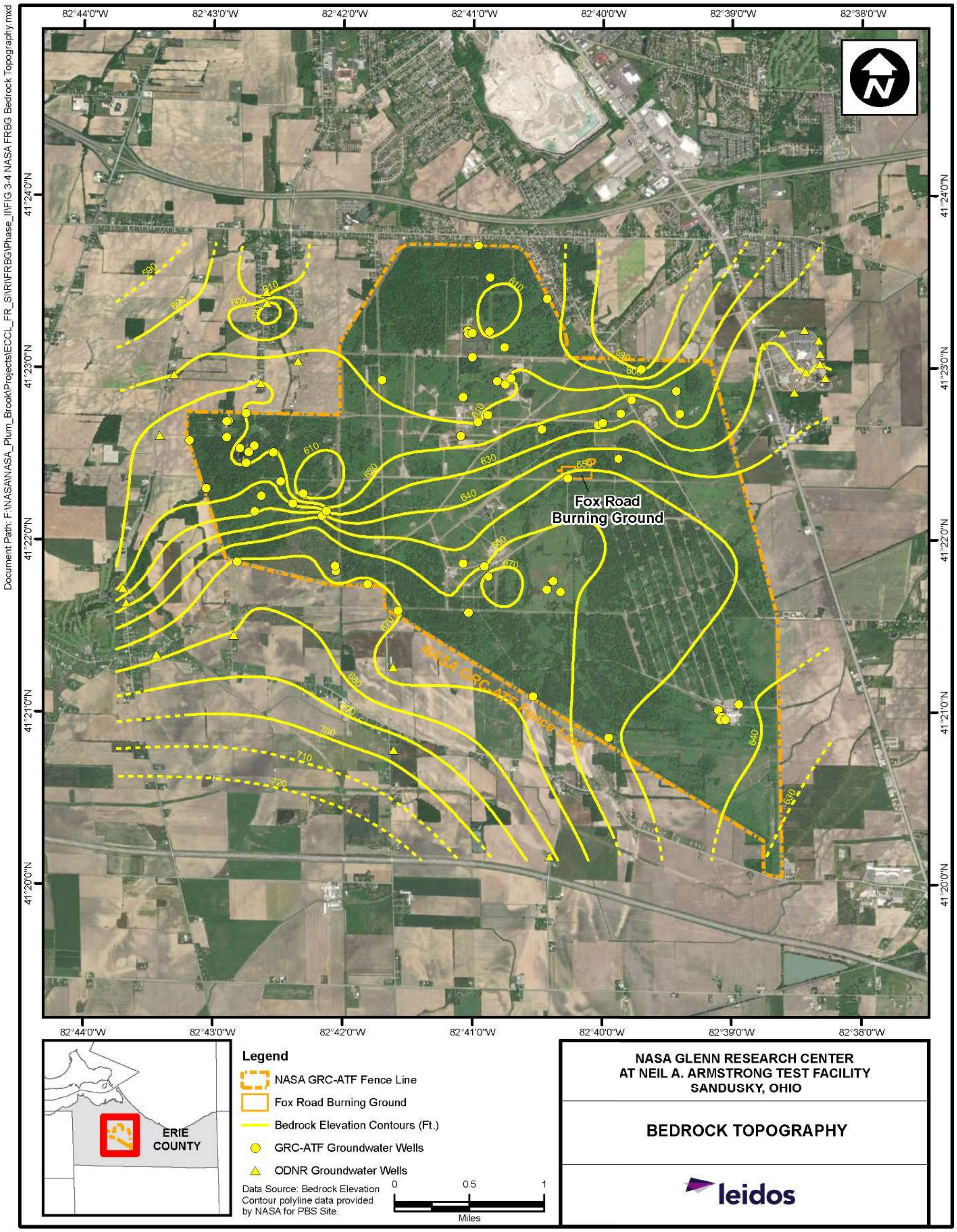

Figure 3-4. Bedrock Topography

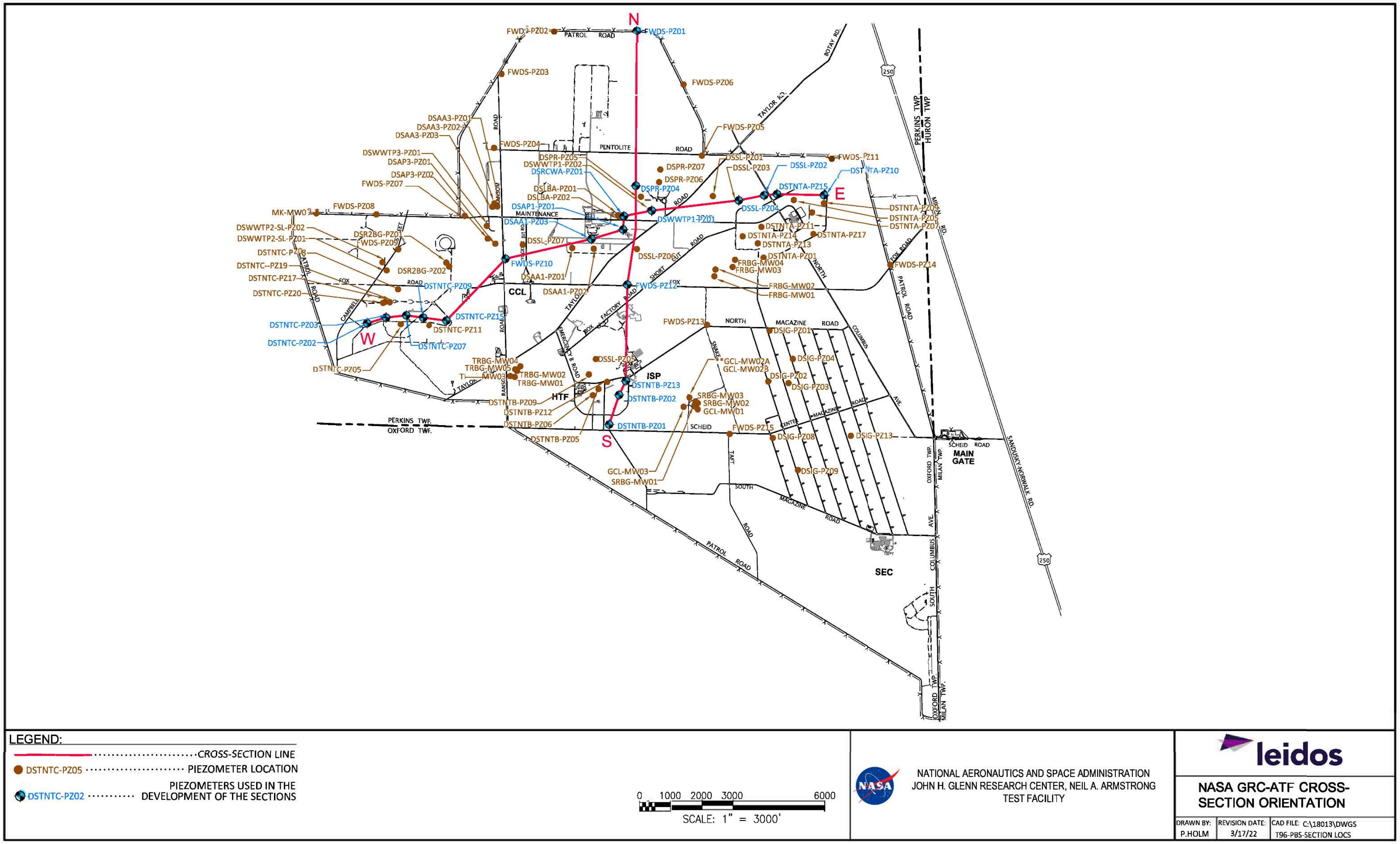

Figure 3-5. NASA GRC-ATF Cross Section Orientation

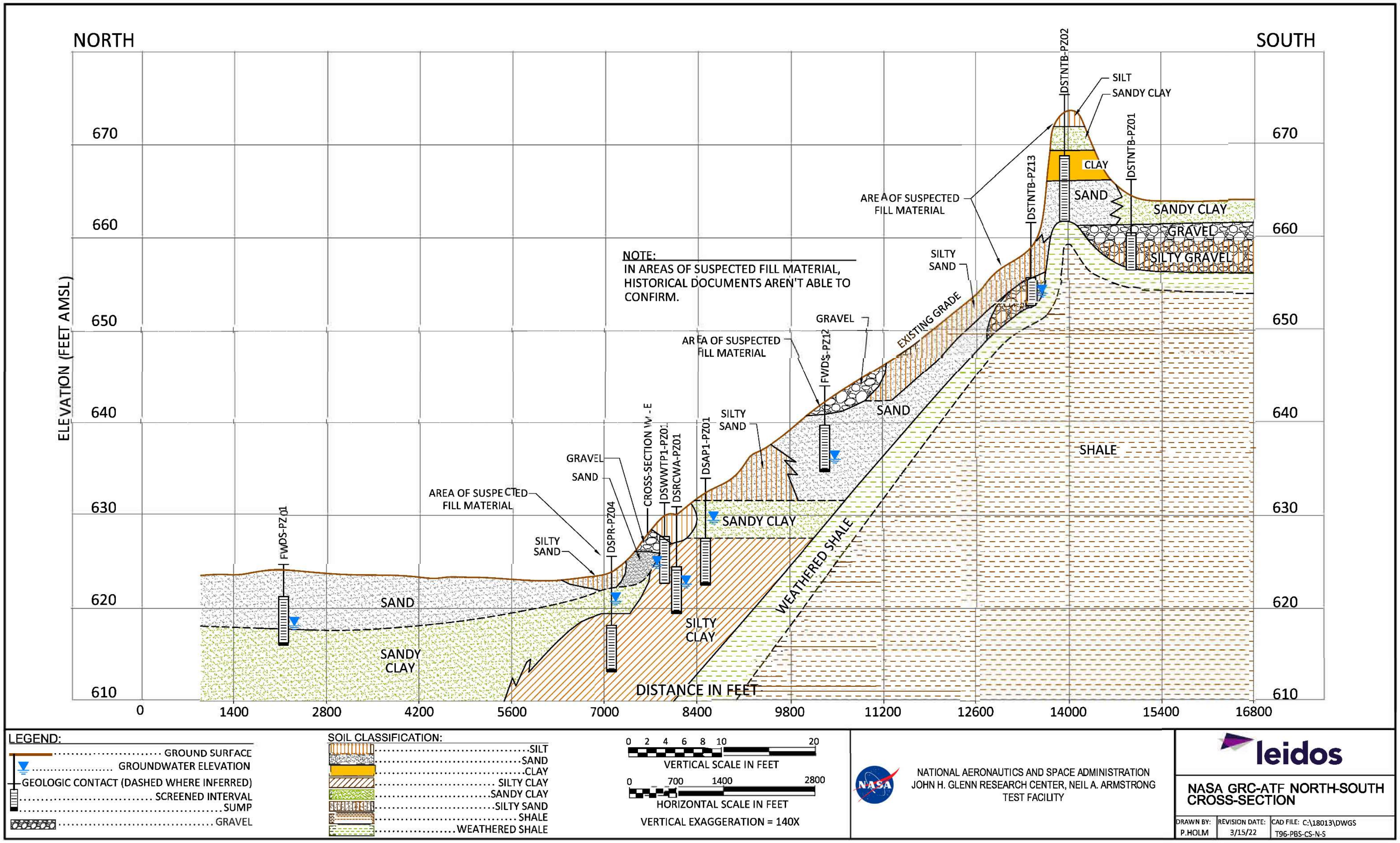

Figure 3-6. NASA GRC-ATF North-South Cross-Section

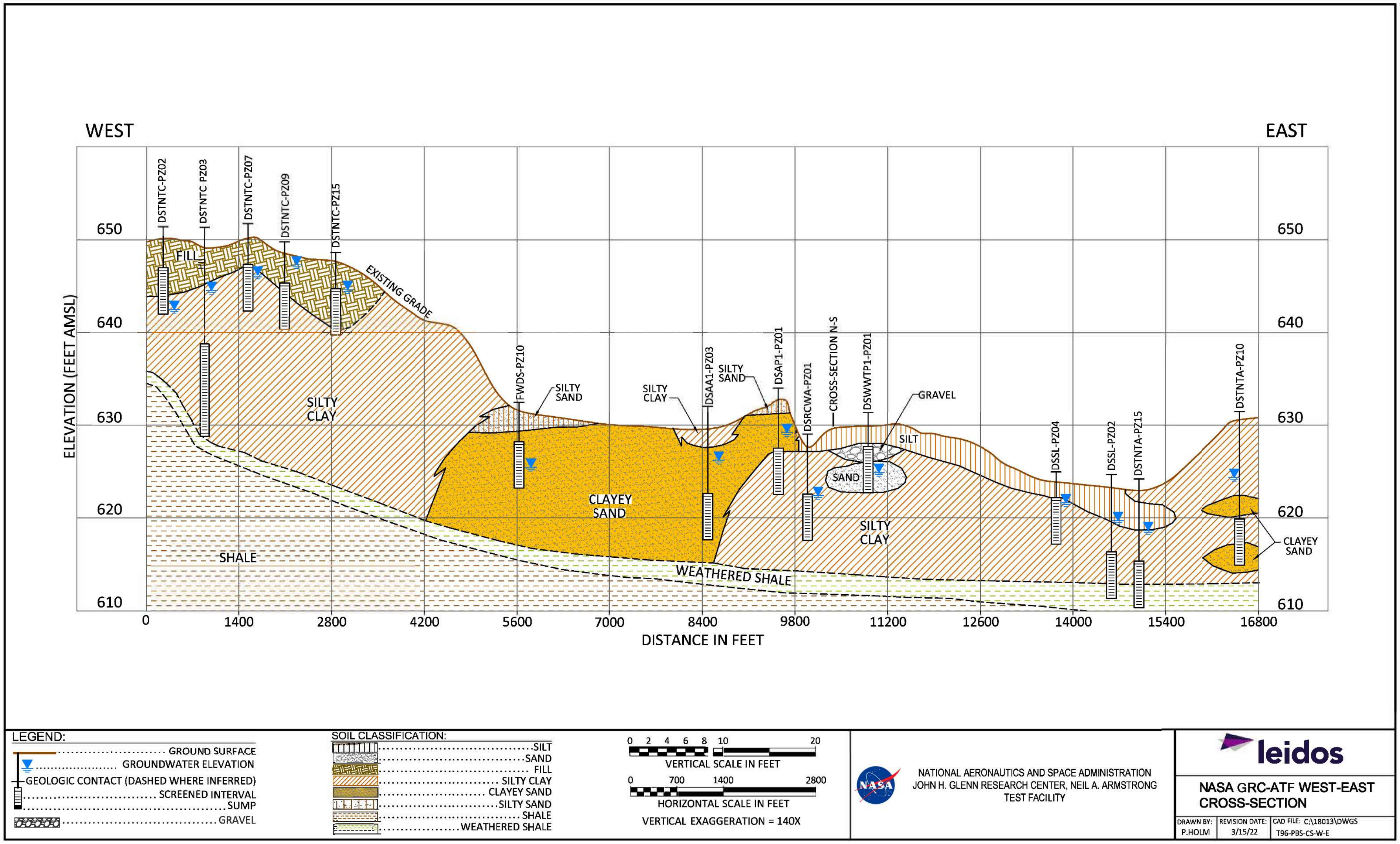

Figure 3-7. NASA GRC-ATF West-East Cross-Section

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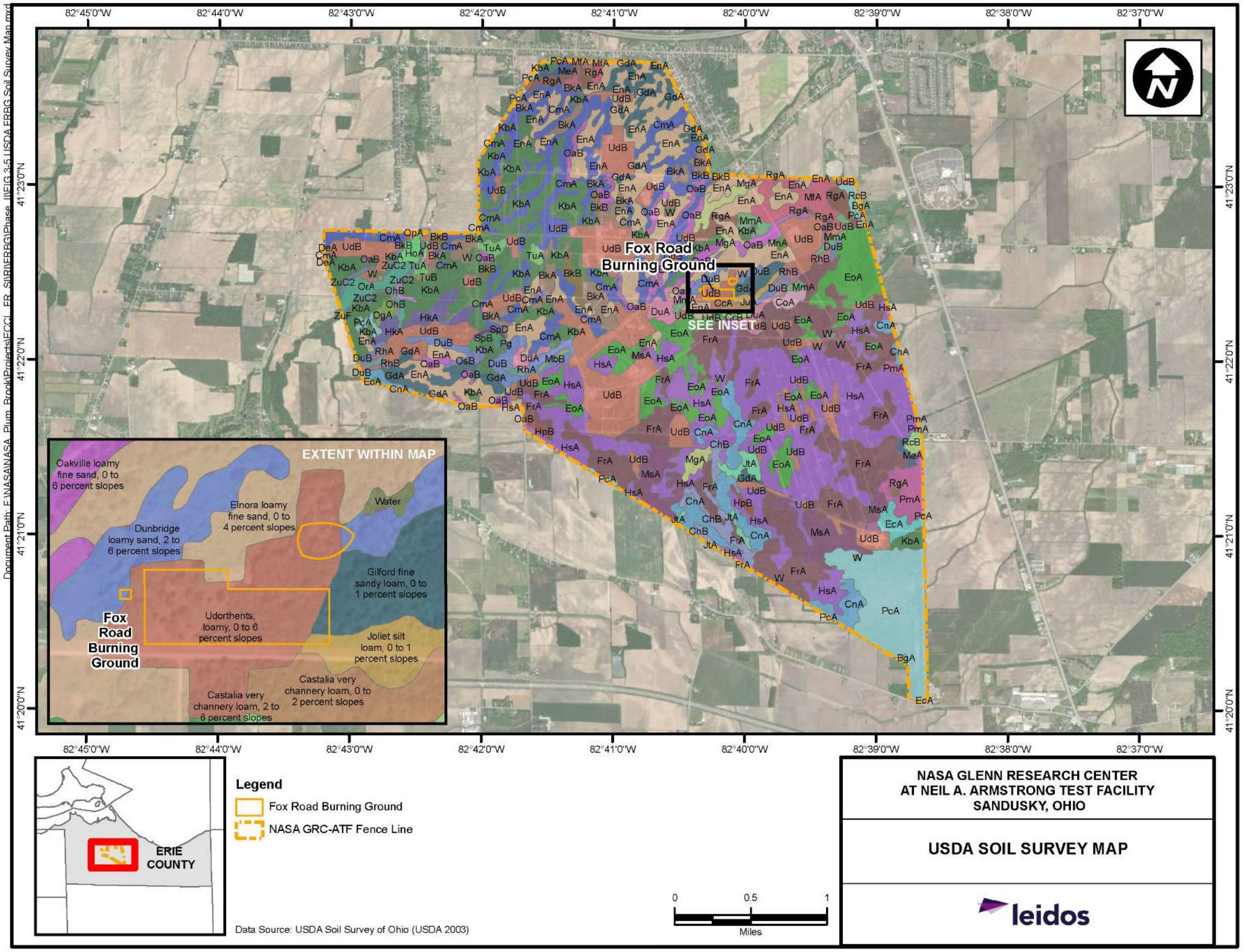

Figure 3-8. USDA Soil Survey Map

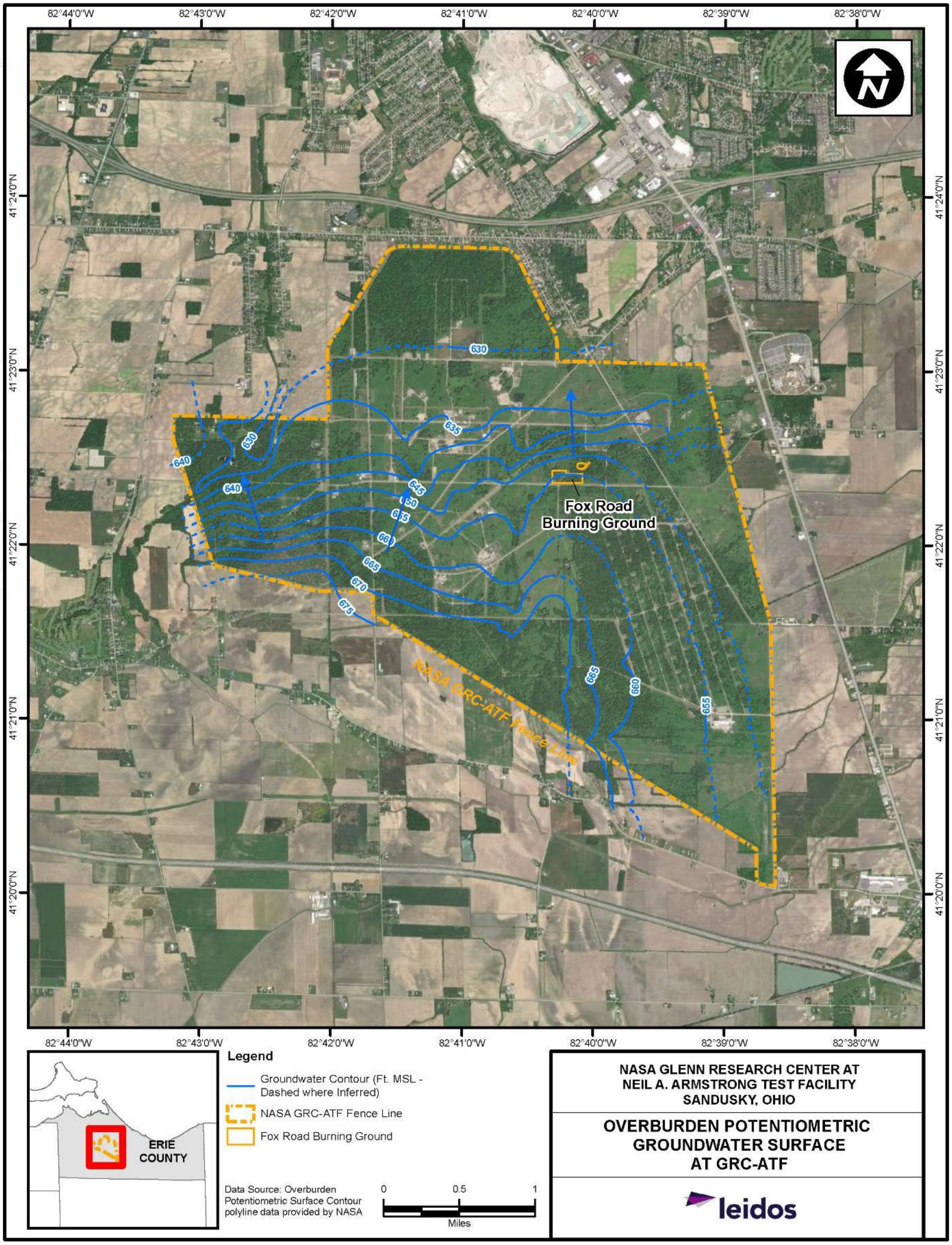

Figure 3-9. Overburden Potentiometric Groundwater Surface at GRC-ATF

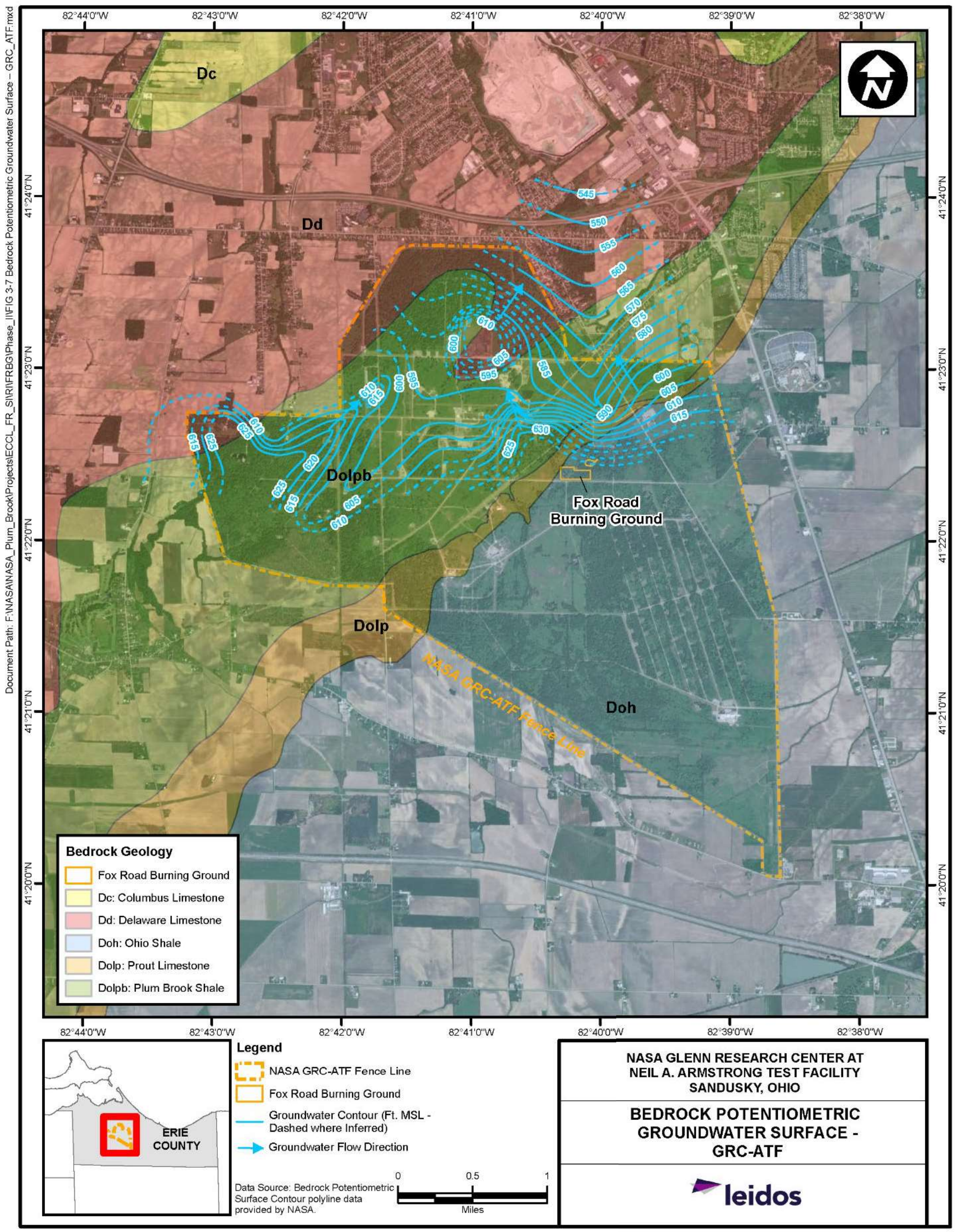

Figure 3-10. Bedrock Potentiometric Groundwater Surface at GRC-ATF

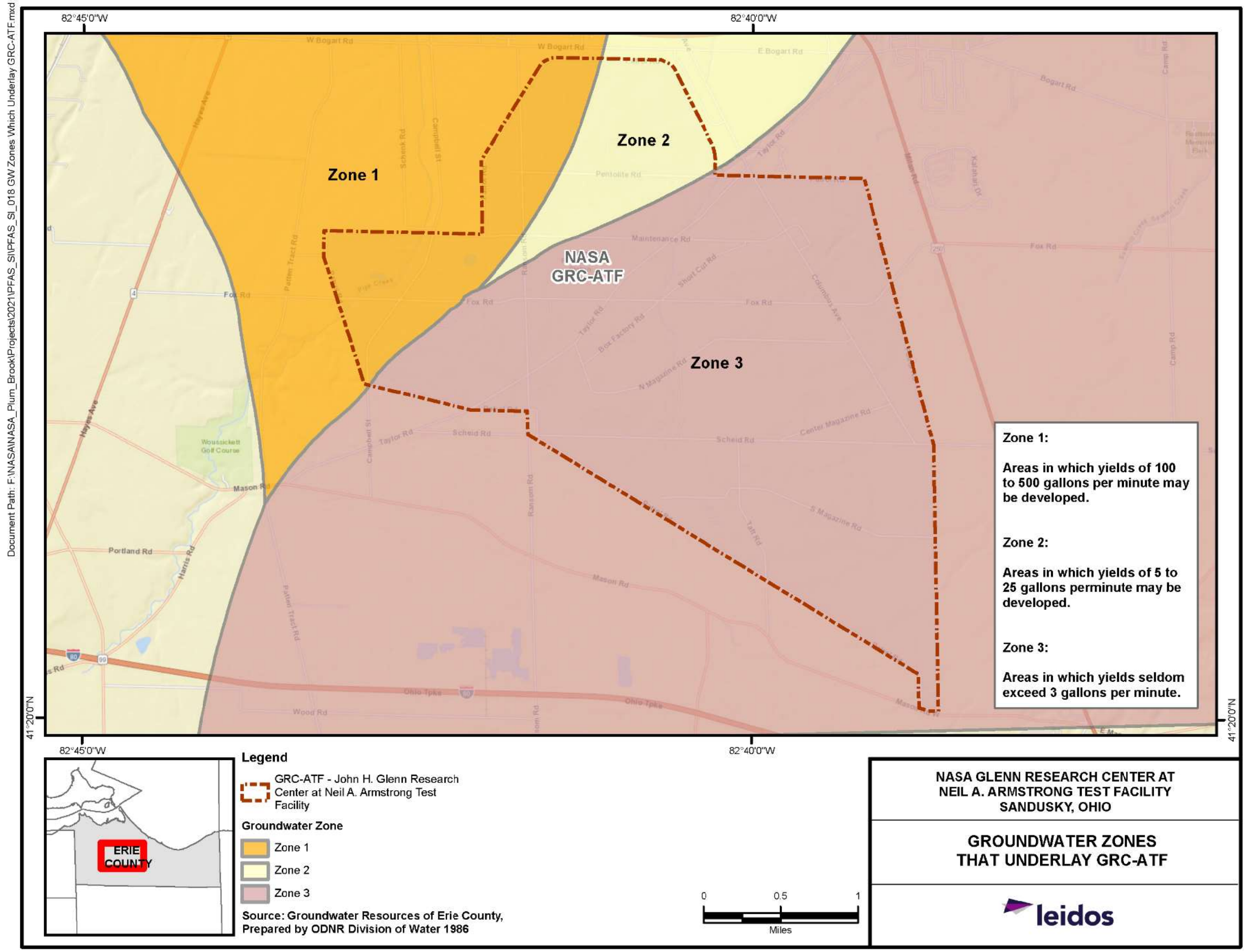

Figure 3-11. Groundwater Zones that Underlay GRC-ATF

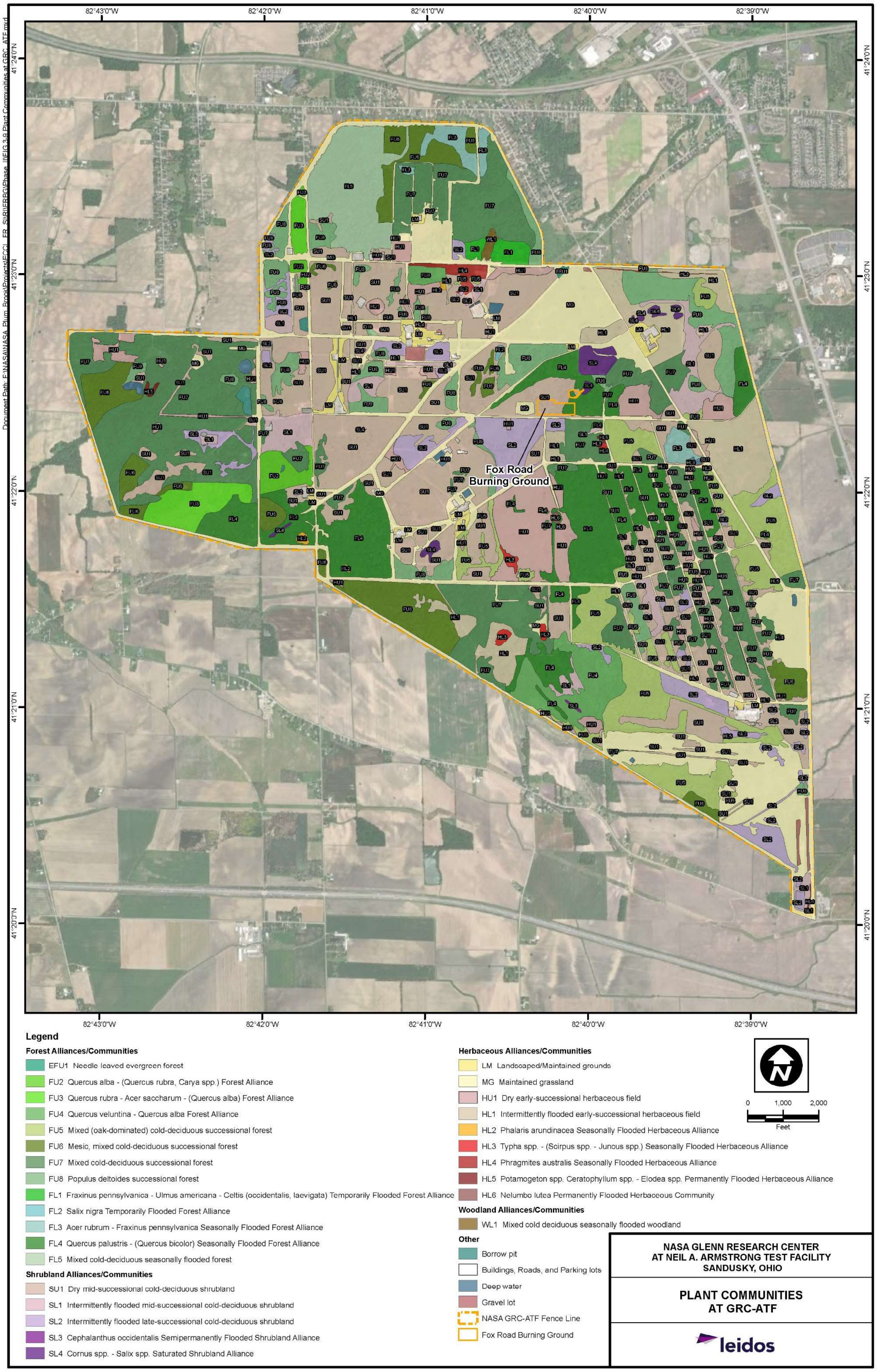

Figure 3-12. Plant Communities at GRC-ATF

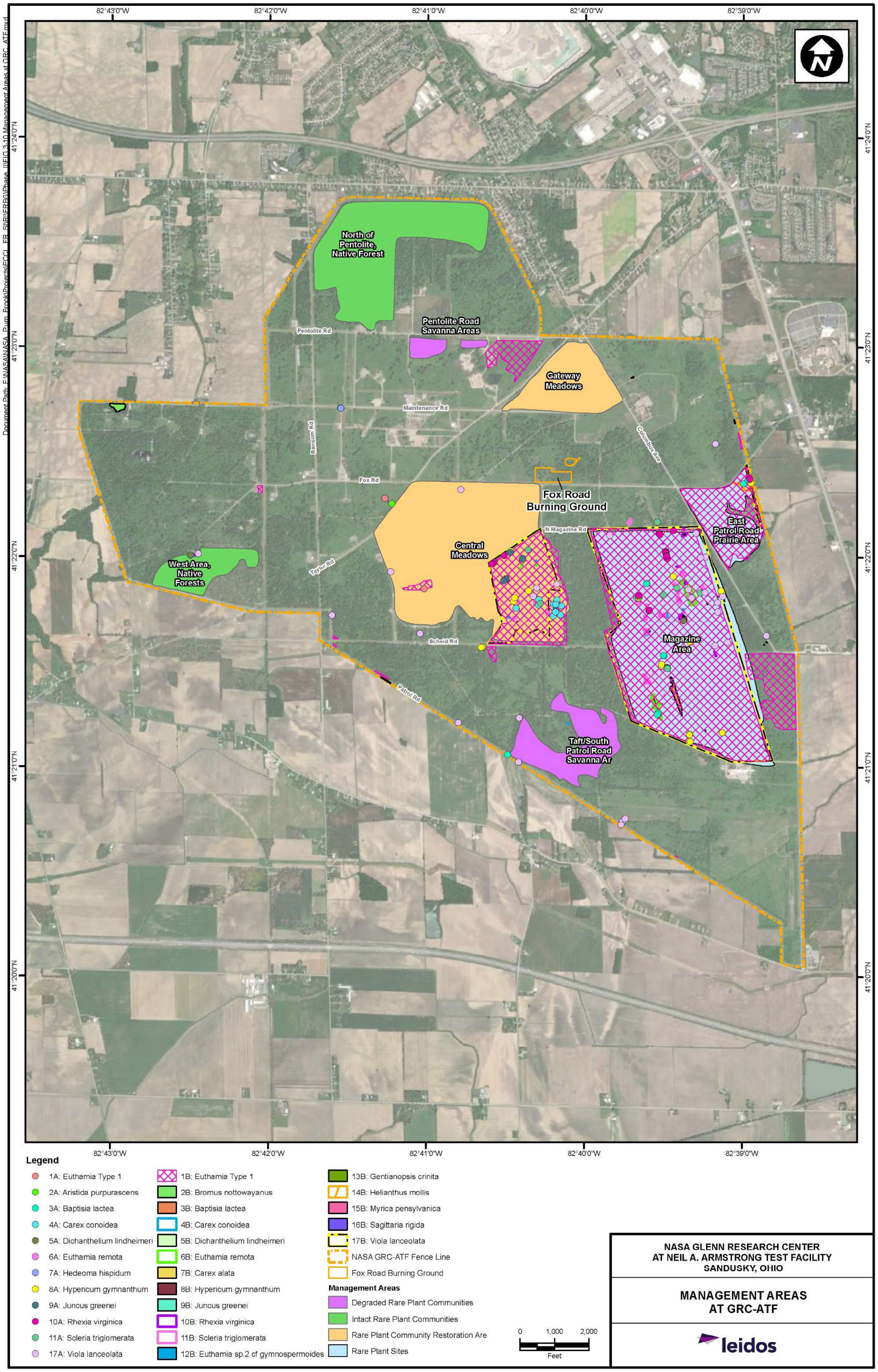

Figure 3-13. Management Areas at GRC-ATF

4. FIELD PROGRAM METHODS

4.1 INTRODUCTION

This section describes the methods used to perform the activities that Leidos completed during the Phase II RI conducted at GRC-ATF in accordance with the CERCLA process. The primary objective of this project was to implement the recommendations of the Phase I RI, which were to complete the Burning Grounds Phase II RI at TRBG, SRBG, and FRBG. The objective of the Phase II RI is to fully characterize the nature and extent and evaluate exposure risk to hazardous substances in groundwater, and if necessary, soil vapor, due to historical activities at the three burning grounds. All field activities were performed in accordance with the *Burning Grounds Phase II Remedial Investigation Sampling and Analysis Plan* (Leidos 2020).

Leidos conducted the following Phase II RI field activities at FRBG from April through December 2021:

- Utility clearance and general access/mobilization activities;
- Installation and development of four permanent groundwater monitoring wells (FRBG-MW01, FRBG-MW02, FRBG-MW03, and FRBG-MW04);
- Two seasonal groundwater sampling events each consisting of the four new wells plus two existing wells sampled for metals, explosives, VOCs, SVOCs, and PCBs;
- Investigation-derived waste (IDW) management; and
- Civil survey.

4.2 DEVIATIONS FROM THE WORK PLAN

Tables 5-1 through 5-3 of the Sampling and Analysis Plan (SAP) (Leidos 2020) stated that samples were proposed for total metals analysis. Leidos issued a field change request to update the sampling plan to collect both total metals (unfiltered) and field filtered metals samples for analysis due to the turbid nature of the groundwater monitoring wells installed. NASA approved the field change request on May 20, 2021. During the groundwater gauging event prior to the fall 2021 sampling activities, FRBG-MW01 and FRBG-MW02 were dry upon gauging and were not sampled. In addition, FRBG-MW03 and FRBG-MW04 were purged and sampled using a disposable bailer due to insufficient groundwater volumes for low-flow purging techniques during the fall event.

4.3 UTILITY LOCATE

Prior to any subsurface investigation, a NASA surveyor located and marked known underground utilities (e.g., water, gas, electric, and telephone). NASA provided an appropriate dig permit prior to the commencement of any intrusive field activities.

Focused geophysical surveys, including ground penetrating radar and ground conductivity meter (e.g., EM-31), were not planned as part of the Phase II RI.

4.4 PERMANENT MONITORING WELL INSTALLATION

During the Phase II RI field activities, four permanent monitoring wells were installed at FRBG to identify the extent of hazardous substances in groundwater due to the historical activities at the burning ground. Monitoring well installations were performed in accordance with the SAP (Leidos 2020) and Ohio EPA's *Technical Guidance Manual for Hydrogeologic Investigations and Ground Water Monitoring – Chapter 7: Monitoring Well Design and Installation* (Ohio EPA 2008). TTL Associates, Inc. conducted all hand augering, hollow-stem auger drilling, and environmental monitoring well installation activities.

All monitoring wells were installed in the uppermost aquifer observed in the overburden. The monitoring wells were installed at each borehole using a Geoprobe® hollow-stem auger rig with a 4.25-inch inside diameter auger. The wells are composed of pre-cleaned 2-inch-diameter Schedule 40 polyvinyl chloride (PVC) and are protected above ground in a 6-inch-diameter iron/steel casing that extends approximately 3 feet above grade. Well construction details for all monitoring wells sampled are provided in Table 4-1, and the locations of the five wells are depicted in Figure 4-1. Lithology from each location was documented, with boring logs and well construction details being provided in Appendix A.

4.5 MONITORING WELL DEVELOPMENT

All four new permanent monitoring wells were developed using the pump and surge method on May 11 and 12, 2021. Each well was developed to ensure that fine-grained particles were removed from the well per Ohio EPA's *Technical Guidance Manual for Hydrogeologic Investigations and Ground Water Monitoring – Chapter 8: Monitoring Well Development, Maintenance, and Redevelopment* (Ohio EPA 2009b). Well development proceeded until all criteria outlined in the *Burning Grounds Phase II Remedial Investigation Sampling and Analysis Plan* (Leidos 2020) were achieved. Final water quality parameters associated with groundwater monitoring well development are detailed in Table 4-2, and well development forms are included in Appendix A.

4.6 WATER LEVEL MEASUREMENT

Due to naturally occurring petroleum at portions of GRC-ATF, static water level measurements were made using an electronic oil-water interface probe. The depth to groundwater and petroleum (if any) were measured from a consistent measuring point, which were surveyed and permanently marked on each monitoring well. Since all probe cords used for measurement are incrementally marked at 0.01-foot intervals, water level measurements were recorded to the nearest 0.01 foot. The proper method for water level measurements were followed in accordance with the *Burning Grounds Phase II Remedial Investigation Sampling and Analysis Plan* (Leidos 2020). Groundwater elevations were measured to the nearest 0.01 foot in each monitoring well prior to sampling and during well purging. Comprehensive groundwater level measurements were collected at FRBG on May 17 and November 23, 2021. No petroleum was measured at the site. Groundwater elevation data are provided in Table 4-3. The groundwater potentiometric elevations for the May 2021 event are depicted in Figure 4-2. Groundwater flow at the site flows radially eastward/northward from the Subsurface Debris Area. This is consistent with general groundwater flow direction at GRC-ATF. Naturally occurring petroleum was not observed at FRBG during the Phase II RI activities.

4.7 GROUNDWATER SAMPLING

Groundwater monitoring wells were sampled using the low-flow drawdown method in accordance with Ohio EPA's *Technical Guidance Manual for Hydrogeologic Investigations and Ground Water Monitoring – Chapter 10: Ground Water Sampling* (Ohio EPA 2012). The purpose of the low flow sampling procedure is to obtain groundwater samples that are representative of the source from which they are collected and to minimize sampler exposure to potential groundwater contaminants as well as minimize the volume of IDW.

Prior to purge and sampling activities, static water level measurements were made using an oil-water interface probe using procedures outlined in Section 4.6. Each monitoring well was purged using low-flow techniques prior to sample collection using a bladder pump. Teflon® materials were not used in low-flow sampling (i.e., tubing, bladder) as the groundwater monitoring wells may be used for future sampling that is sensitive to the use of fluoropolymer products. The pump intake was positioned near the middle of the screened interval of the well to ensure that standing water is removed and fresh formation water is drawn into the well. Low-flow purging techniques were used in conjunction with a flow-through cell to measure the following water quality parameters: pH, temperature, specific conductivity, dissolved oxygen (DO),

Table 4-1. Monitoring Well Construction Details

Monitoring Well Identifier	Casing Type	Installation Date	Northing (ft)	Easting (ft)	Top of Casing Elevation (ft AMSL)	Casing Material	Screen Material	Filter Pack	Total Depth (ft bgs)	Screen Depth (ft bgs)
FRBG-MW01	Stick-up	4/28/22	621849.79	1921782.47	666.16	2-inch PVC	10 slot	#5 Sand	8.0	3.9 – 7.9
FRBG-MW02	Stick-up	4/28/22	622066.41	1921816.78	664.83	2-inch PVC	10 slot	#5 Sand	8.0	3.9 – 7.9
FRBG-MW03	Stick-up	4/28/22	622148.62	1922372.7	675.95	2-inch PVC	10 slot	#5 Sand	11.0	5.9 – 10.9
FRBG-MW04	Stick-up	4/28/22	622380.78	1922450.62	669.15	2-inch PVC	10 slot	#5 Sand	9.0	3.9 – 8.9

Notes: Horizontal datum: Ohio State Plane Coordinate System, using North American Datum of 1983 with units of English feet.
Vertical datum: North American Vertical Datum of 1988 with units of English feet.

AMSL = Above Mean Sea Level
bgs = Below Ground Surface
ft = Feet
PVC = Polyvinyl Chloride

Table 4-2. Well Development Final Water Quality Parameters

Monitoring Well Identifier	Development Date[b]	Volume Purged (gal)	Temperature (°C)	Specific Conductivity (mS/cm)	pH (S.U.)	Turbidity (NTU)	Dissolved Oxygen (mg/L)	ORP (mV)
FRBG-MW01[a]	5/11/21	3.75	8.1	0.55	7.5	>800	6.37	190
FRBG-MW02[a]	5/11/21	4.75	9.35	0.533	7.57	>800	6.42	201
FRBG-MW03	5/11/21	12.25	8.73	0.652	8.22	>800	2.98	33
FRBG-MW04[a]	5/11 – 5/12/21	6.5	9.6	0.34	7.17	>800	6.72	216

[a]Well frequently went dry; sediment removed and a minimum of five well volumes purged; well is considered developed per SAP.
[b]Dates shown are inclusive of all dates during well development; measurements are from final well development measurement.

NTU = Nephelometric Turbidity Unit
ORP = Oxidation-Reduction Potential
S.U. = Standard Unit

Table 4-3. Groundwater Elevation Data

Monitoring Well Identifier	TOC Elevation (ft AMSL)	Depth to Water (ft BTOC)		Groundwater Elevation (ft AMSL)	
Date		5/17/21	11/23/21	5/17/21	11/23/21
FRBG-MW01	666.16	7.00	Dry	659.16	Dry
FRBG-MW02	664.83	6.84	Dry	657.99	Dry
FRBG-MW03	675.95	8.33	11.86	667.62	664.09
FRBG-MW04	669.15	5.92	9.50	663.23	659.65

Note: Vertical datum: North American Vertical Datum of 1988 with units of English feet.

AMSL = Above Mean Sea Level
BTOC = Below Top of Casing
TOC = Top of Casing

oxidation reduction potential (ORP), and turbidity. Water quality measurements and water level drawdown were recorded every 5 minutes. A flow rate that ensures minimal drawdown of the water level is typically 100 to 500 milliliters per minute (mL/min) but was adjusted accordingly to minimize drawdown. Purging was considered complete when the indicator parameters of pH, temperature, conductivity, DO, ORP, and turbidity have stabilized for three successive measurements. Final water quality parameters associated with groundwater monitoring well sampling are detailed in Table 4-4. Copies of the groundwater purge and sample forms are provided in Appendix A.

Following completion of monitoring well purging and stabilization, samples were collected in laboratory-supplied containers using clean, disposable nitrile gloves and immediately cooled with ice to 4°C (±2°C). The samples were submitted to Eurofins/Test America Laboratory in Canton, Ohio, for total and dissolved metals, explosives, VOCs, SVOCs, and PCBs analyses. Explosives samples were submitted to Eurofins/Test America Laboratory in Denver, Colorado. Monitoring wells FRBG-MW01 and FRBG-MW02 were dry in November 2021, and groundwater samples were not collected. Monitoring FRBG-MW04 was purged dry during sampling activities in November 2021 and recharged slowly; therefore, the sample volume for all sampling parameters was collected over 3 days.

Table 4-4. Monitoring Well Sampling Final Water Quality Stabilization Parameters

Monitoring Well Identifier	Sampling Date	ORP (mV)	Temperature (°C)	pH (S.U.)	Specific Conductivity (mS/cm)	Dissolved Oxygen (mg/L)	Turbidity (NTU)
Spring 2021 Phase II RI Water Quality Parameters							
FRBG-MW01	5/26/21	-27	18.89	7.24	0.498	2.65	69.1
FRBG-MW02	5/26/21	142	12.57	7.49	0.514	2.91	46.4
FRBG-MW03	5/25/21	-110	11.36	7.99	0.511	1.08	18.2
FRBG-MW04	5/25/21	-6	15.72	7.2	0.722	0.71	203
Fall 2021 Phase II RI Water Quality Parameters							
FRBG-MW03	11/30/21	59	11.93	7.29	0.516	5.43	>1000
FRBG-MW04	11/30/21	117	10.5	7.26	0.502	6.29	>1000

NTU = Nephelometric Turbidity Unit
ORP = Oxidation-Reduction Potential
S.U. = Standard Unit

4.8 DECONTAMINATION

Equipment and sample collection tools used during sampling activities were decontaminated to prevent potential chemical cross-contamination. Decontamination of drill rig equipment was conducted within a temporary decontamination pad designed so that all decontamination liquids were contained from the surrounding environment and could be recovered for disposal as IDW per the SAP (Leidos 2020). Decontamination of stainless steel tools and equipment used during sampling activities (i.e., water level, bladder pump) were completed per the SAP (Leidos 2020).

4.9 CIVIL SURVEY

Leidos coordinated a survey of the groundwater monitoring wells with NASA's state licensed surveyor. The surveyor provided horizontal and vertical coordinates for site monitoring wells. The horizontal coordinates were surveyed to within 0.1 foot. Horizontal coordinates are in the Ohio State Plane coordinate system. The vertical coordinates are based on North American Datum of 1983 (NAD 83) (elevation) and were surveyed to within 0.01 foot for well casings. The well coordinates of the four new wells and the two existing wells sampled are detailed in Table 4-1, and the survey report is provided in Appendix B.

4.10 INVESTIGATION-DERIVED WASTE MANAGEMENT

IDW generated during performance of the investigation were containerized, managed, and disposed of in accordance with the SAP. The final waste manifests for the solid IDW generated during well installation and the liquid IDW generated during the fall 2021 groundwater sampling event are provided in Appendix C.

Eleven drums of liquid IDW were generated during the May/June 2021 SRBG, TRBG, and FRBG Phase II RIs and GRC-ATF PFAS SI field activities. Per direction of NASA GRC-ATF Waste Management, all IDW drums were transported to the designated drum staging area located at Building 9206. The liquid IDW was classified as non-hazardous, non-regulated waste. Following NASA Headquarters guidance, liquid IDW was treated with a granulated activated carbon (GAC) treatment system on November 11, 2021. Confirmation samples were collected post-treatment to confirm that the treatment was successful in removing PFAS contamination. On December 2, 2021, the city of Sandusky and Erie County provided NASA approval to discharge the post-treatment water to the sanitary sewer. On December 3, 2021, NASA and Waste Management completed discharge of the post-treatment water to the sanitary sewer. A post-treatment confirmation sample was collected from the spent GAC. The post treatment GAC sample exhibited four minor PFAS detections; all other PFAS were non-detect. Currently, NASA has eight 55-gallon drums of spent GAC onsite at Building 9206. NASA plans to use the spent GAC for future treatment events at GRC-ATF.

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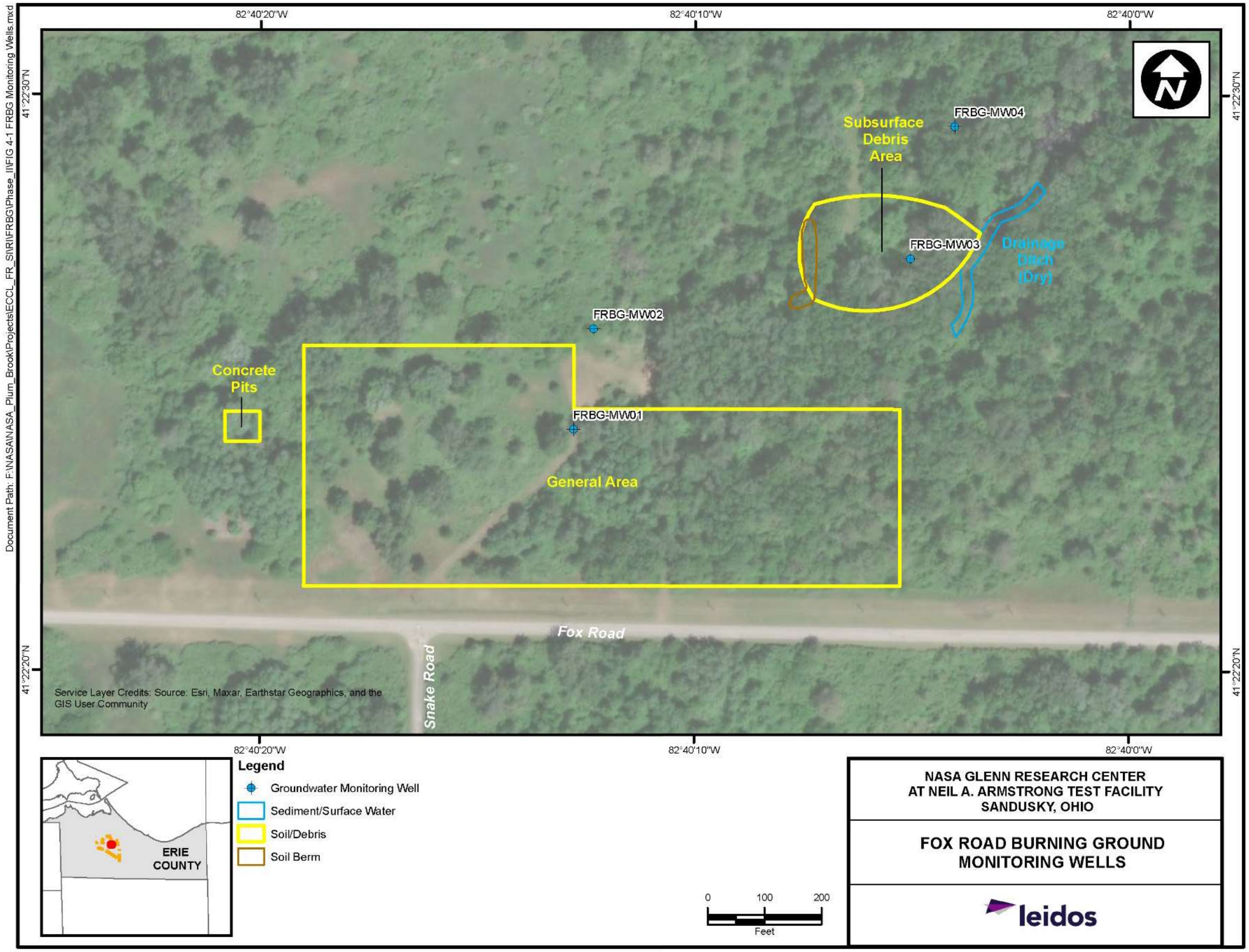

Figure 4–1. Fox Road Burning Ground Monitoring Wells

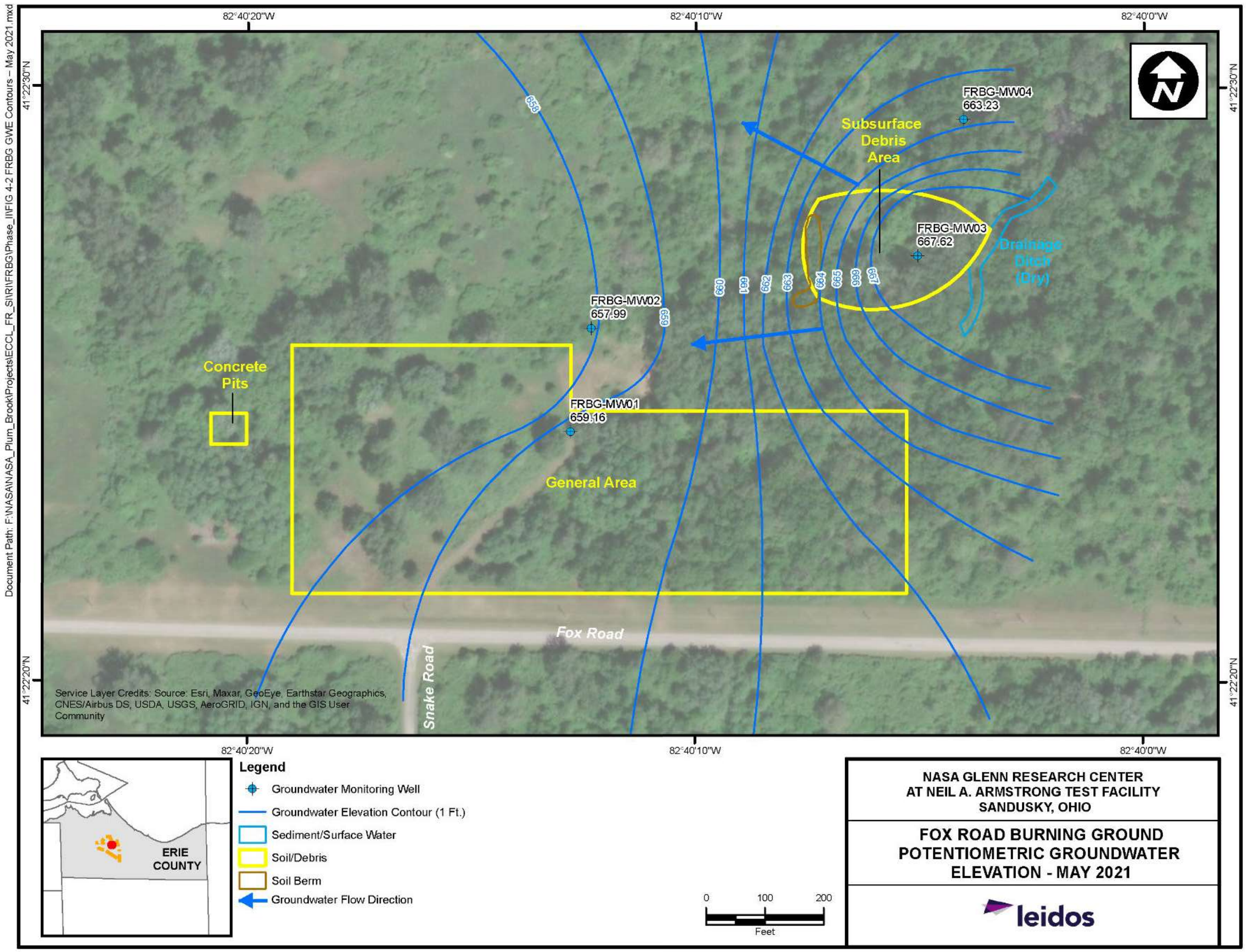

Figure 4–2. Fox Road Burning Ground Potentiometric Groundwater Elevation – May 2021

5. DATA EVALUATION

5.1 DATA USE

The Phase II RI SAP (Leidos 2020) implemented USEPA's DQOs process to ensure that, upon completion of this RI, enough data of sufficient quality and usability would be collected to support the groundwater nature and extent of contamination and HHRA.

RI analytical data were sampled, analyzed, verified, and validated in accordance with the protocols specified in the Phase II RI SAP and Quality Assurance Project Plan (Leidos 2020). Table 5-1 lists the samples collected during the Phase II RI and how they are used in this RI Report. The data quality assessment for the RI data is included in Appendix F and documents the quality and usability of the RI analytical data. The assessment noted that some data were flagged or qualified due to minor analytical issues, but this had limited impact on the data quality. In conclusion, the results are considered usable to support evaluations in this RI, including the nature and extent evaluation and HHRA. The groundwater data collected during the 2017 Phase I RI Report were not used in this Phase II RI Report because of data quality concerns due to nonconforming sample collection techniques.

5.2 ENVIRONMENTAL MEDIA

5.2.1 Groundwater

The scope of the Phase II RI Report includes a full evaluation of groundwater. Four permanent monitoring wells were installed in April 2021 to effectively characterize the downgradient and source area groundwater conditions. Groundwater collection resulted in four samples with an additional duplicate from four monitoring wells during the May 2021 Phase II RI sampling event, but only two samples from two wells during the November 2021 sampling event. During the November 2021 sampling event, FRBG-MW01 and FRBG-MW-02 were dry and representative samples could not be collected. Groundwater data are evaluated site wide and not by EUs like the soils data.

5.2.2 Soil Vapor

Due to the nature of the site (former burning ground), Ohio EPA correspondence stated that if VOCs were not detected as potential COCs for the site, assessing the soil vapor pathway would not be triggered (Ohio EPA 2019). Vapor-forming chemicals were not detected in subsurface soils at FRBG as part of the Phase I RI or groundwater in Phase II. Evidence determined that vapor points were not warranted at FRBG.

5.3 DATA QUALITY

The data used in this RI Report were verified and validated using the methodology described in the SAP (Leidos 2020). Analytical results were loaded into a database. Data qualified during the validation as rejected ("R") were not used in the risk assessments. Field duplicate results were averaged with the primary result. If only one of the duplicate pair had a detectable concentration, just the detected result was used.

5.3.1 Background Evaluation

Background screening levels for naturally occurring inorganics from the *2004 Groundwater Data Summary and Evaluation Report, Former Plum Brook Ordnance Works, Sandusky, Ohio* (Shaw 2005; herein referred to as the 2004 Groundwater Data Summary Report) was used for comparison for determining site-related chemicals (SRCs). An analyte was considered an SRC only if its maximum concentration exceeded the background level.

5.3.2 Risk-Based Comparison

Data screening consisted of comparing site concentrations to risk-based values. The results of the data screens were used to evaluate the nature and extent of site-related contamination and for HHRA. Data are compared to the most recent (May 2022) USEPA tap water RSLs available at the time of this report submission at a target risk (TR) equal to 1E-06 and an HQ equal to 0.1. Data were also compared to the most current MCL if available.

Table 5-1. Data Use Table

Sample Location	Sample ID	Date	Sampling Event	QC	N&E	F&T	HHRA	ERA	Analysis Suite
FRBG-MW01	FRBGGW1001	05/26/2021	2021 Phase II RI	--	X	X	X	--	RCRA Metals (Filtered and unfiltered), Explosives, PCBs, SVOCs, VOCs
FRBG-MW01	FRBGGW9101	05/26/2021	2021 Phase II RI	X	X	X	X	--	RCRA Metals (Filtered and unfiltered), Explosives, PCBs, SVOCs, VOCs
FRBG-MW02	FRBGGW1002	05/26/2021	2021 Phase II RI	--	X	X	X	--	RCRA Metals (Filtered and unfiltered), Explosives, PCBs, SVOCs, VOCs
FRBG-MW03	FRBGGW1003	05/25/2021	2021 Phase II RI	--	X	X	X	--	RCRA Metals (Filtered and unfiltered), Explosives, PCBs, SVOCs, VOCs
FRBG-MW04	FRBGGW1004	05/25/2021	2021 Phase II RI	--	X	X	X	--	RCRA Metals (Filtered and unfiltered), Explosives, PCBs, SVOCs, VOCs
FRBG-MW03	FRBGGW1007	11/30/2021	2021 Phase II RI	--	X	X	X	--	RCRA Metals (Filtered and unfiltered), Explosives, PCBs, SVOCs, VOCs
FRBW-MW04	FRBGGW1008	11/30/2021	2021 Phase II RI	--	X	X	X	--	RCRA Metals (Filtered and unfiltered), Explosives, PCBs, SVOCs, VOCs

Note:
Quality control samples are field duplicates.

ERA = Ecological Risk Assessment
F&T = Fate and Transport
HHRA = Human Health Risk Assessment
ID = Identification
N&E = Nature and Extent
PCB = Polychlorinated Biphenyl
QC = Quality Control
RCRA = Resource Conservation and Recovery Act
RI = Remedial Investigation
SVOC = Semivolatile Organic Compound
VOC = Volatile Organic Compound

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6. NATURE AND EXTENT OF CONTAMINATION

This section evaluates the nature and extent of groundwater contamination at FRBG. The evaluation discusses the nature and extent of SRCs in groundwater at FRBG, using analytical data results obtained during the 2021 Phase II RI. Nature and extent of soil contamination at FRBG is presented in the Phase I RI Report (Leidos 2018a).

6.1 CONTAMINANT EVALUATION METHODOLOGY

The following subsections describe the methodology to screen available data to determine SRCs and the methodology used to assess asbestos content in soil and debris.

6.1.1 Site-Related Chemical Evaluation

The purpose of selecting SRCs is to identify those chemicals that may be present as a result of past site activities and may be of concern to human health. The first step in SRC identification involves evaluating the quality of the analytical data to ensure their acceptability for use. Additional steps involve eliminating chemicals that are considered essential nutrients and comparing the analytical concentrations to GRC-ATF background concentrations.

Identification of SRCs begins with all chemicals detected in an exposure medium (e.g., groundwater). Detected chemicals are eliminated as SRCs based on the following criteria.

Data Quality Assessment – Analytical results were reported by the laboratory in electronic form and loaded into a database. Site data were then extracted from the database so that only one result is used for each station and depth sampled. If laboratory reanalysis or dilutions are performed, only the one appropriate result is used based on data review and validation. Quality control (QC) data, such as sample splits, are not included in the determination of SRCs. However, if a field duplicate was collected, the field duplicate result was averaged with the primary result to provide the result. Samples rejected in the validation process are excluded from the data set.

Essential Nutrients – Chemicals that are considered essential nutrients (i.e., calcium, chloride, iodine, iron, magnesium, potassium, phosphorus, and sodium) are an integral part of the human food supply and are often added to foods as supplements. USEPA recommends these chemicals not be evaluated provided they are present at low concentrations (i.e., only slightly above naturally occurring levels) and toxic at only high doses (i.e., much higher than those that could be associated with contact at the site) (USEPA 1989). Essential nutrients were not carried forward as SRCs.

Background – Background screening levels for naturally occurring inorganics are from the 2004 Groundwater Data Summary and Evaluation Report (Shaw 2005). An analyte was considered an SRC only if its maximum concentration exceeded the background level.

To support the evaluation of nature and extent of contamination, SRC concentrations were compared to the tap water RSL at a target HQ of 0.1 or a TR of 1E-06. Appendix D contains analytical data from the 2021 Phase II RI, and Appendix E provides the complete laboratory data packages. Table 6-1 presents the data summary tables of detected chemicals in groundwater. If a chemical is not detected, it is not presented in the summary table. Figure 6-1 presents chemicals that exceed background concentrations or tap water RSLs of an HQ of 0.1 and a TR of 1E-06. If a chemical did not have a background concentration or screening level, the chemical was not presented in Figure 6-1. The following subsections discuss the exceedances.

6.1.2 Chemical Contamination

Seven groundwater samples were collected at FRBG, including one field duplicate. Four primary samples and one field duplicate were collected during the May 2021 sampling event, and two primary samples were collected during the November 2021 sampling event. Well FRBG-MW04 was sampled over consecutive three days in November/December 2021 to collect sufficient sample volume for all analysis due to slow recharge. The sampling suite associated with groundwater included RCRA metals (filtered and unfiltered), explosives, PCBs, SVOCs, and VOCs.

In groundwater, 21 metals, 6 SVOCs (1-methylnaphthalene; 2-methylnaphthalene; caprolactam; naphthalene; phenanthrene; and phenol), 3 explosives (1,3,5-trinitrobenzene; 2-amino-4,6-DNT; and hexahydro-1,3,5-trinitro-1,3,5-triazine [RDX]) and 4 VOCs (2-butanone; acetone; toluene; and trichloroethene [TCE]) were detected. No PCBs were detected. The explosives, VOCs, and five of the SVOCs were detected at concentrations below the risk screening criteria. Nine of the 21 metals (aluminum, antimony, arsenic, cadmium, iron, lead, manganese, thallium, and vanadium) exceeded their respective background concentrations, MCL, and/or the tap water RSL at an HQ of 0.1 and a TR of 1E-06. Four of the metals (calcium, magnesium, potassium, and sodium) were considered essential nutrients. Table 6-1 presents the data screening results for groundwater at FRBG.

Aluminum – Total aluminum was detected in five of six samples with a maximum detection of 9,800 micrograms per liter (µg/L). Four of the detections were above the background concentration of 309 µg/L, but only two samples (FRBG-MW03: 9,800 µg/L in November 2021 and FRBG-MW04: 7,700 µg/L in December 2021) were above the tap water RSL of 2,000 µg/L. Aluminum was not detected above the laboratory reporting limits in any of the filtered samples.

Antimony – Total antimony was detected in two samples with a maximum estimated detection of 1.3 µg/L. The two samples (FRBG-MW03: 1.3 µg/L in November 2021 and FRBG-MW04: 1.0 µg/L in December 2021) were detected at estimated concentrations and exceeded the tap water RSL of 0.78 µg/L. After filtration, only FRBG-MW03 (1.1 µg/L in November 2021) had an estimated detectable concentration. No concentrations exceeded the USEPA MCL of 6.0 µg/L.

Arsenic – Total arsenic was detected in three samples with a maximum detection of 12.0 µg/L. All three exceeded the tap water RSL of 0.052 µg/L. Only one sample (FRBG-MW03: 12.0 µg/L in November 2021) exceeded the background concentration of 0.74 µg/L and the USEPA MCL of 10.0. Only one filtered sample, FRBG-MW04 (2.9 µg/L in December 2021), had an estimated detectable concentration above the screening criteria but below the MCL.

Cadmium – Total cadmium was detected in one sample (FRBG-MW03 in May 2021) with an estimated concentration of 0.27 µg/L, which exceeded the tap water RSL of 0.18 µg/L. After filtration, no samples had detectable concentrations. However, the detection limit of the filtered analysis exceeded the tap water RSL.

Iron – Total iron was detected in five of six samples with a maximum detection of 19,000 µg/L. Four of the detections were above the tap water RSL of 1,400 µg/L, but only three samples (FRBG-MW02: 3,400 µg/L in May 2021, FRBG-MW03: 19,000 µg/L in November 2021, and FRBG-MW04: 11,000 µg/L in December 2021) were above the background concentration of 1,550 µg/L.

Lead – Total lead was detected in four of six samples with a maximum detection of 19.0 µg/L. Only the maximum detected concentration (FRBG-MW03 in November 2021) exceeded both the tap water RSL and MCL of 15.0 µg/L. After filtration, total lead was detected in two samples; however, both fell below screening levels.

Manganese – Total manganese was detected in all six samples with a maximum detection of 810 µg/L (average of the primary and duplicate sample of FRBG-MW01). All six of the detections were above the tap water RSL of 43.0 µg/L, but only one sample (FRBG-MW01: 810 µg/L in May 2021) was above the background concentration of 636 µg/L. After filtration, manganese was detected in the same six samples and exceeded the tap water RSL screening level with the highest concentration from FRBG-MW01 at 630 µg/L, below the background concentration.

Thallium – Total thallium was detected in two of six samples with a maximum detection of 0.91 µg/L. Both detections (FRBG-MW03: 0.91 µg/L in November 2021 and FRBG-MW04: 0.35 µg/L in December 2021) were above the tap water RSL of 0.02 µg/L. After filtration, thallium was only detected in FRBG-MW01 with a concentration of 2.8 µg/L in May 2021. Thallium was not detected in the FRBG-MW01 unfiltered sample. However, the detection limit of both the total and filtered analysis exceeded the tap water RSL.

Vanadium – Total vanadium was detected in four of six samples with a maximum detection of 31 µg/L. Two of those detections were above the tap water RSL of 8.6 µg/L at 31 µg/L (FRBG-MW03 in November 2021) and 20 µg/L (FRBG-MW04 in December 2021). After filtration, the constituent was detected in only one sample at an estimated concentration of 5.6 µg/L (duplicate sample only) at GRBG-MW01 in May 2021. However, the detection limit of the filtered analysis exceeded the tap water RSL.

Naphthalene – Naphthalene was detected in one of six samples with a maximum detection of 0.24 µg/L. The FRBG-MW03 sample from November 2021 exceeded the tap water RSL of 0.12 µg/L. Naphthalene was not detected in the May 2021 sample at FRBG-MW03; however, the detection limit was above the RSL.

6.2 CONCLUSIONS

During the Phase I RI for FRBG, the site was divided into four EUs to allow for refined evaluation of potential chemical contamination and potential exposure. These EUs were the General Area, Subsurface Debris Area, Drainage Ditch, and Concrete Pits. The sampling rationale for each groundwater sampling location was to assess potential impacts to overburden groundwater within or downgradient from the General Areas and Subsurface Debris Area. Conservative transport modeling in the Phase I RI indicated 11 chemicals may leach from soil and migrate to the groundwater table beneath their respective sources at concentrations exceeding MCLs/RSLs. The 11 chemicals included organic (mercury), explosives (2,4,6-TNT; 2,4-DNT; 2,6-DNT; 2-amino-4,6-DNT; 4-amino-2,6-DNT; and pentaerythritol tetranitrate [PETN]), SVOCs (benzaldehyde and naphthalene), and pesticides (beta-hexachlorocyclohexane and dalapon). A qualitative assessment of the sample results was performed, and the limitations and assumptions of the models were considered to identify if any soil contaminant migration chemicals of concern (CMCOCs) were present in soil at FRBG that may potentially impact groundwater. This qualitative assessment concluded that without available groundwater data, seven initial CMCOCs (2,4,6-TNT; 2,4-DNT; 2,6-DNT; 2 amino-4,6-DNT; 4-amino-2,6-DNT; naphthalene; and beta-hexachlorocyclohexane) should be assessed during future groundwater studies at the site (Leidos 2018a). Of the 11 chemicals from the transport modeling, only naphthalene was detected in groundwater above the tap water RSL. Pesticides were not included in the analytical suite at FRBG because pesticide analyte surface and subsurface soil samples results did not exceed their respective background concentrations or resident regional screening levels.

Only nine total inorganics (aluminum, antimony, arsenic, cadmium, iron, lead, manganese, thallium, and vanadium) exceeded their respective background concentrations and/or the tap water RSL in groundwater at FRBG. Aluminum and antimony exceedances were limited to FRBG-MW03 and FRBG-MW04 located in and to the north the Subsurface Debris Area. Aluminum and antimony were only detected above screening criteria in the November 2021 sampling event at these wells, at which time the turbidity readings were greater than 1,000 nephelometric turbidity units (NTUs) due to purging and sampling with a bailer. Total arsenic exceeded screening criteria at FRBG-MW03 in November 2021 and at FRBG-MW-04 in both events. However, only the November 2021 concentration at FRBG-MW03 exceeded the MCL. The single cadmium (total) exceedance was limited to the November 2021 sample collected at FRBG-MW03 located in the Subsurface Debris Area, but the concentration was below the MCL. Total iron exceeded the screening criteria at three of the four sampling locations: FRBG-MW02 (May 2021), FRBG-MW03 (November 2021), and FRBG-MW04 (November 2021). None of the filtered iron results exceeded the tap water RSL. Total and dissolved lead only exceeded screening criteria at one location (FRBG-MW03 location in the Subsurface Debris Area) in November 2021. Total manganese exceeded the tap water RSL in all sampling locations, but concentrations were only above the corresponding background concentration at FRBG-MW01 in May 2021. Total thallium exceeded screening criteria during the November 2021 event at FRBG-MW03 and FRBG-MW-04. Dissolved thallium only exceeded screening criteria in May 2021 at FRBG-MW01. Vanadium exceedances were limited to two locations (FRBG-MW03 and FRBG-MW04) during the November 2021 event; only total vanadium exceeded screening criteria. Most metal exceedances were at FRBG-MW03, which is located in the Subsurface Debris Area and cross/upgradient of FRBG-MW01 and FRBG-MW02.

Naphthalene was the only organic constituent detected above screening criteria at FRBG. Naphthalene was only detected at FRBG-MW-03 during the November 2021 sampling event at a concentration of 0.24 µg/L, exceeding the tap water RSL of 0.12 µg/L. Naphthalene was not detected in any of the other samples; however, the detection limits ranged from 0.19 to 0.22 µg/L and are above the RSL.

The groundwater in the overburden is in discontinuous pockets during dry time periods, as evidenced by FRBG-MW01 and FRBG-MW-02 being dry in November 2021 and the slow recharge of FRBG-MW-04 also in November 2021. During wet periods, the general flow direction in the overburden water-bearing zone is radially to the west/northwest from FRBG, largely mirroring surface topography (Shaw 2005). Since most metals and the naphthalene concentration exceedances were at FRBG-MW03, which is located to the east of the other wells sampled in the General Area EU, it appears the extent of the contaminants in the FRBG groundwater has been adequately characterized. Naphthalene is the only CMCOC identified in the Phase I RI that was detected in the groundwater above screening criteria. Naphthalene was detected in soil samples collected in the surface and subsurface soil samples at location FRBG-SL-027 during the Phase I RI near FRBG-MW03.

Table 6–1. Data Screening Table – Groundwater

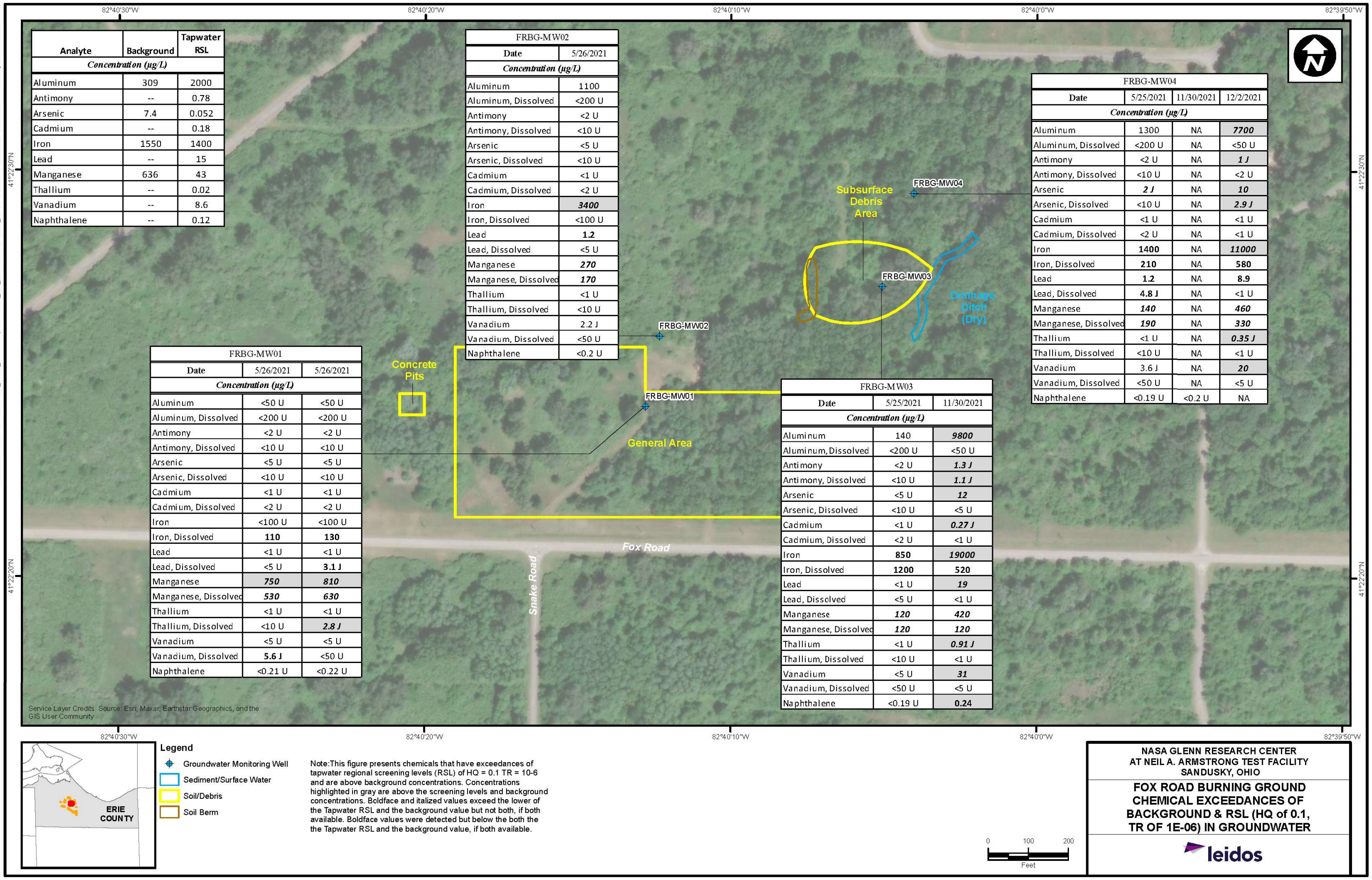
Analysis Type	Analyte (µg/L)	CAS Number	Freq of Detect	Minimum Detect (µg/L)	Maximum Detect (µg/L)	Average Result (µg/L)	Background Criteria (µg/L)	Maximum Exceeds Background?	Number > BKG	Tap Water RSL May 2022 (µg/L)	RSL Type	Maximum Exceeds RSL?	Number > RSL	USEPA MCL (µg/L)	Maximum Exceeds MCL?	Number > MCL	Exceedance Justification
Metals, Total	Aluminum	7429-90-5	5/6	140	9800	3340	309	Yes	4	2000	n	Yes	2	--	--	--	Exceeds screening level
Metals, Total	Antimony	7440-36-0	2/6	1	1.3	1.05	--	--	--	0.78	n	Yes	2	6	No	0	Exceeds screening level
Metals, Total	Arsenic	7440-38-2	3/6	2	12	5.25	7.4	Yes	2	0.052	c	Yes	3	10	Yes	1	Exceeds screening level
Metals, Total	Barium	7440-39-3	6/6	17	78	43.5	11800	No	0	380	n	No	0	2000	No	0	Below background
Metals, Total	Beryllium	7440-41-7	1/6	0.81	0.81	0.552	--	--	--	2.5	n	No	0	4	No	0	Below risk screening criteria
Metals, Total	Cadmium	7440-43-9	1/6	0.27	0.27	0.462	--	--	--	0.18	n	Yes	1	5	No	0	Exceeds screening level
Metals, Total	Calcium	7440-70-2	6/6	78000	150000	106000	316000	No	0	--	--	--	0	--	--	--	Essential Nutrient
Metals, Total	Chromium	7440-47-3	4/6	1.9	15	5.15	--	--	--	2200	n	No	0	100	No	0	Below risk screening criteria
Metals, Total	Cobalt	7440-48-4	6/6	0.22	9.9	3.28	12.1	No	0	0.6	n	Yes	4	--	--	--	Below background
Metals, Total	Copper	7440-50-8	4/6	1.8	36	9.95	19.8	Yes	1	80	n	No	0	1300	No	0	Below risk screening criteria
Metals, Total	Iron	7439-89-6	5/6	850	19000	5950	1550	Yes	3	1400	n	Yes	3	--	--	--	Exceeds screening level
Metals, Total	Lead	7439-92-1	4/6	1.2	19	5.22	--	--	--	15	MCL	Yes	1	15	Yes	1	Exceeds screening level
Metals, Total	Magnesium	7439-95-4	6/6	21000	45000	31800	217000	No	0	--	--	--	0	--	--	--	Essential Nutrient
Metals, Total	Manganese	7439-96-5	6/6	120	780	365	636	Yes	1	43	n	Yes	6	--	--	--	Exceeds screening level
Metals, Total	Nickel	7440-02-0	5/6	1.9	28	10.2	8.6	Yes	2	39	n	No	0	--	--	--	Below risk screening criteria
Metals, Total	Potassium	7440-09-7	6/6	760	5100	2510	116000	No	0	--	--	No	0	--	--	--	Essential Nutrient
Metals, Total	Silver	7440-22-4	1/6	0.084	0.084	0.431	--	--	--	9.4	n	No	0	--	--	--	Below risk screening criteria
Metals, Total	Sodium	7440-23-5	3/6	2450	4300	2890	1390000	No	0	--	--	--	0	--	--	--	Essential Nutrient
Metals, Total	Thallium	7440-28-0	2/6	0.35	0.91	0.543	--	--	--	0.02	n	Yes	2	2	No	0	Exceeds screening level
Metals, Total	Vanadium	7440-62-2	4/6	2.2	31	10.3	--	--	--	8.6	n	Yes	2	--	--	--	Exceeds screening level
Metals, Total	Zinc	7440-66-6	2/6	45	85	28.3	507	No	0	600	n	No	0	--	--	--	Below background
Metals, Dissolved	Antimony, Dissolved	7440-36-0	1/6	1.1	1.1	3.68	--	--	--	0.78	n	Yes	1	6	No	0	Exceeds screening level
Metals, Dissolved	Arsenic, Dissolved	7440-38-2	1/6	2.9	2.9	4.23	--	--	--	0.052	c	Yes	1	10	No	0	Exceeds screening level
Metals, Dissolved	Barium, Dissolved	7440-39-3	6/6	11	110	41.6	--	--	--	380	n	No	0	2000	No	0	Below risk screening criteria
Metals, Dissolved	Calcium, Dissolved	7440-70-2	6/6	76000	140000	101000	--	--	--	--	--	--	0	--	--	--	Essential Nutrient
Metals, Dissolved	Chromium, Dissolved	7440-47-3	2/6	0.81	0.94	1.96	--	--	--	2200	n	No	0	100	No	0	Below risk screening criteria
Metals, Dissolved	Cobalt, Dissolved	7440-48-4	4/6	0.21	1.9	2.42	--	--	--	0.6	n	Yes	3	--	--	--	Exceeds screening level
Metals, Dissolved	Iron, Dissolved	7439-89-6	5/6	120	1200	447	--	--	--	1400	n	No	0	--	--	--	Below risk screening criteria
Metals, Dissolved	Lead, Dissolved	7439-92-1	2/6	3.1	4.8	2.32	--	--	--	15	MCL	No	0	15	No	0	Below risk screening criteria
Metals, Dissolved	Magnesium, Dissolved	7439-95-4	6/6	22500	43000	30400	--	--	--	--	--	--	0	--	--	--	Essential Nutrient
Metals, Dissolved	Manganese, Dissolved	7439-96-5	6/6	120	580	252	--	--	--	43	n	Yes	6	--	--	--	Exceeds screening level
Metals, Dissolved	Nickel, Dissolved	7440-02-0	3/6	2.45	5.5	8.86	--	--	--	39	n	No	0	--	--	--	Below risk screening criteria
Metals, Dissolved	Potassium, Dissolved	7440-09-7	5/6	590	2350	1400	--	--	--	--	--	--	0	--	--	--	Essential Nutrient
Metals, Dissolved	Sodium, Dissolved	7440-23-5	3/6	2500	6000	3400	--	--	--	--	--	--	0	--	--	--	Essential Nutrient
Metals, Dissolved	Thallium, Dissolved	7440-28-0	1/6	2.8	2.8	3.13	--	--	--	0.02	n	Yes	1	2	Yes	1	Exceeds screening level
Metals, Dissolved	Vanadium, Dissolved	7440-62-2	1/6	5.6	5.6	14.3	--	--	--	8.6	n	No	0	--	--	--	Below risk screening criteria

Table 6–1. Data Screening Table – Groundwater (Continued)

Analysis Type	Analyte (µg/L)	CAS Number	Freq of Detect	Minimum Detect (µg/L)	Maximum Detect (µg/L)	Average Result (µg/L)	Background Criteria (µg/L)	Maximum Exceeds Background?	Number > BKG	Tap Water RSL May 2022 (µg/L)	RSL Type	Maximum Exceeds RSL?	Number > RSL	USEPA MCL (µg/L)	Maximum Exceeds MCL?	Number > MCL	Exceedance Justification
Metals, Dissolved	Zinc, Dissolved	7440-66-6	1/6	65	65	29.2	--	--	--	600	n	No	0	--	--	--	Below risk screening criteria
Organics-Semivolatile	1-Methylnaphthalene	90-12-0	1/6	0.39	0.39	0.148	--	--	--	1.1	c	No	0	--	--	--	Below risk screening criteria
Organics-Semivolatile	2-Methylnaphthalene	91-57-6	1/6	0.57	0.57	0.178	--	--	--	3.6	n	No	0	--	--	--	Below risk screening criteria
Organics-Semivolatile	Caprolactam	105-60-2	3/6	0.98	52	10.5	--	--	--	990	n	No	0	--	--	--	Below risk screening criteria
Organics-Semivolatile	Naphthalene	91-20-3	1/6	0.24	0.24	0.123	--	--	--	0.12	c	Yes	1	--	--	--	Exceeds screening level
Organics-Semivolatile	Phenanthrene	85-01-8	1/6	0.17	0.17	0.111	--	--	--	12	n	No	0	--	--	--	Below risk screening criteria
Organics-Semivolatile	Phenol	108-95-2	1/6	0.515	0.515	0.494	--	--	--	580	n	No	0	--	--	--	Below risk screening criteria
Organics-Explosives	1,3,5-Trinitrobenzene	99-35-4	1/6	0.34	0.34	0.151	--	--	--	59	n	No	0	--	--	--	Below risk screening criteria
Organics-Explosives	2-Amino-4,6-DNT	35572-78-2	1/6	0.058	0.058	0.0588	--	--	--	0.19	n	No	0	--	--	--	Below risk screening criteria
Organics-Explosives	RDX	121-82-4	1/6	0.31	0.31	0.146	--	--	--	0.97	c	No	0	--	--	--	Below risk screening criteria
Organics-Volatile	2-Butanone	78-93-3	1/6	1.35	1.35	4.39	--	--	--	560	n	No	0	--	--	--	Below risk screening criteria
Organics-Volatile	Acetone	67-64-1	1/6	8	8	5.5	--	--	--	1800	n	No	0	--	--	--	Below risk screening criteria
Organics-Volatile	Toluene	108-88-3	1/6	0.14	0.14	0.44	--	--	--	110	n	No	0	1000	No	0	Below risk screening criteria
Organics-Volatile	Trichloroethene	79-01-6	1/6	0.19	0.19	0.448	--	--	--	0.28	n	No	0	5	No	0	Below risk screening criteria

Notes:
Average result was calculated using 0.5 times the detection limit for non-detect results.
USEPA MCL – U.S. Environmental Protection Agency maximum contaminant level, May 2022 (USEPA 2022a).
RSL – USEPA Regional Screening Level for tap water for HQ=0.1 and TR=1E-6 May 2022 update (USEPA 2022a).
Background Criteria from 2004 Groundwater Data Summary and Evaluation Report (Shaw 2005).

-- = The screening value is does not exist for the chemical
µg/L = Micrograms per Liter
BKG = Background
C = carcinogenic,
CAS = Chemical Abstracts Service
DNT = Dinitrotoluene
Freq = Frequency
MCL = Maximum Contaminant Level
N = Non-Carcinogenic
RDX = Hexahydro-1,3,5-Trinitro-1,3,5-Triazine
RSL = Regional Screening Level
USEPA = U.S. Environmental Protection Agency



Analyte	Background	Tapwater RSL
	Concentration (µg/L)	
Aluminum	309	2000
Antimony	--	0.78
Arsenic	7.4	0.052
Cadmium	--	0.18
Iron	1550	1400
Lead	--	15
Manganese	636	43
Thallium	--	0.02
Vanadium	--	8.6
Naphthalene	--	0.12

FRBG-MW01

Date	5/26/2021	5/26/2021
	Concentration (µg/L)	
Aluminum	<50 U	<50 U
Aluminum, Dissolved	<200 U	<200 U
Antimony	<2 U	<2 U
Antimony, Dissolved	<10 U	<10 U
Arsenic	<5 U	<5 U
Arsenic, Dissolved	<10 U	<10 U
Cadmium	<1 U	<1 U
Cadmium, Dissolved	<2 U	<2 U
Iron	<100 U	<100 U
Iron, Dissolved	110	130
Lead	<1 U	<1 U
Lead, Dissolved	<5 U	3.1 J
Manganese	750	810
Manganese, Dissolved	530	630
Thallium	<1 U	<1 U
Thallium, Dissolved	<10 U	2.8 J
Vanadium	<5 U	<5 U
Vanadium, Dissolved	5.6 J	<50 U
Naphthalene	<0.21 U	<0.22 U

FRBG-MW02

Date	5/26/2021
	Concentration (µg/L)
Aluminum	1100
Aluminum, Dissolved	<200 U
Antimony	<2 U
Antimony, Dissolved	<10 U
Arsenic	<5 U
Arsenic, Dissolved	<10 U
Cadmium	<1 U
Cadmium, Dissolved	<2 U
Iron	3400
Iron, Dissolved	<100 U
Lead	1.2
Lead, Dissolved	<5 U
Manganese	270
Manganese, Dissolved	170
Thallium	<1 U
Thallium, Dissolved	<10 U
Vanadium	2.2 J
Vanadium, Dissolved	<50 U
Naphthalene	<0.2 U

FRBG-MW03

Date	5/25/2021	11/30/2021
	Concentration (µg/L)	
Aluminum	140	9800
Aluminum, Dissolved	<200 U	<50 U
Antimony	<2 U	1.3 J
Antimony, Dissolved	<10 U	1.1 J
Arsenic	<5 U	12
Arsenic, Dissolved	<10 U	<5 U
Cadmium	<1 U	0.27 J
Cadmium, Dissolved	<2 U	<1 U
Iron	850	19000
Iron, Dissolved	1200	520
Lead	<1 U	19
Lead, Dissolved	<5 U	<1 U
Manganese	120	420
Manganese, Dissolved	120	120
Thallium	<1 U	0.91 J
Thallium, Dissolved	<10 U	<1 U
Vanadium	<5 U	31
Vanadium, Dissolved	<50 U	<5 U
Naphthalene	<0.19 U	0.24

FRBG-MW04

Date	5/25/2021	11/30/2021	12/2/2021
	Concentration (µg/L)		
Aluminum	1300	NA	7700
Aluminum, Dissolved	<200 U	NA	<50 U
Antimony	<2 U	NA	1 J
Antimony, Dissolved	<10 U	NA	<2 U
Arsenic	2 J	NA	10
Arsenic, Dissolved	<10 U	NA	2.9 J
Cadmium	<1 U	NA	<1 U
Cadmium, Dissolved	<2 U	NA	<1 U
Iron	1400	NA	11000
Iron, Dissolved	210	NA	580
Lead	1.2	NA	8.9
Lead, Dissolved	4.8 J	NA	<1 U
Manganese	140	NA	460
Manganese, Dissolved	190	NA	330
Thallium	<1 U	NA	0.35 J
Thallium, Dissolved	<10 U	NA	<1 U
Vanadium	3.6 J	NA	20
Vanadium, Dissolved	<50 U	NA	<5 U
Naphthalene	<0.19 U	<0.2 U	NA

Note: This figure presents chemicals that have exceedances of tapwater regional screening levels (RSL) of HQ = 0.1 TR = 10-6 and are above background concentrations. Concentrations highlighted in gray are above the screening levels and background concentrations. Boldface and italized values exceed the lower of the Tapwater RSL and the background value but not both, if both available. Boldface values were detected but below the both the the Tapwater RSL and the background value, if both available.

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FOX ROAD BURNING GROUND CHEMICAL EXCEEDANCES OF BACKGROUND & RSL (HQ of 0.1, TR OF 1E-06) IN GROUNDWATER

leidos

Figure 6–1. Chemical Exceedances of Background and RSL (HQ of 0.1, TR of 1E-06) in Groundwater

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7. CONTAMINANT FATE AND TRANSPORT

The properties of chemicals and the environment are used to understand and predict chemical fate and transport. An understanding of the fate and transport is part of the overall assessment of the potential for a chemical to cause an adverse human health or environmental effect. This section provides an overview of the fate and transport properties of chemicals previously identified as SRCs in groundwater at FRBG. Based on groundwater sample results discussed in the previous section, the main SRCs that occur in groundwater at FRBG are metals.

Section 7.1 describes physical and chemical properties of SRCs found in groundwater at the site. Section 7.2 presents chemical transport mechanisms. The Phase I RI presented a soil screening analysis to identify the soil SRCs with the potential to migrate from soil to groundwater as initial contaminant migration chemicals of potential concern (CMCOPCs), described fate and transport modeling of final CMCOPCs, and provided an evaluation of the identified initial CMCOCs.

7.1 CHEMICAL MOBILITY AND PERSISTENCE

The mobility and persistence of potential contaminants are determined by their physical, chemical, and biological interaction with the environment. Mobility is the potential for a chemical to migrate from a site, and persistence is a measure of how long a chemical will remain in the environment. Some of the mechanisms controlling mobility and persistence are described as follows:

- *Volatilization* occurs when a compound transfers from the aqueous phase to the gas phase. Measures of a chemical's tendency to volatilize from water and soil moisture include its vapor pressure and Henry's law constant (Kh). Volatilization tends to occur more readily from surface water, sediment, or shallow soil than from deeper soil or groundwater.
- *Sorption* occurs when a constituent adheres to and becomes associated with solid particles. The soil and sediment media likely to sorb chemicals are clays and organic matter. The conventional measure of sorption is the distribution coefficient (K_d). The K_d for organic chemicals is typically the product of the soil organic carbon partition coefficient (K_{oc}) of the chemical and the fraction of organic carbon in the soil. Metals sorption potential is a complex function of pH, organic content, oxide coatings, and other factors; therefore, K_d is not easily estimated by methods other than site-specific testing (USEPA 2010). Generally, adsorption of metals increases with pH and metals most often sorb to clay minerals, organic matter, and iron and manganese oxyhydroxides.
- *Solubility* is a measure of the degree to which a constituent will dissolve in water. Highly soluble chemicals are more likely to be leached from soil by precipitation or runoff that infiltrates into the subsurface.
- *Degradation* is the deterioration or destruction of a chemical, either biologically (through biodegradation) or abiotically (through such processes as abiotic reduction, hydrolysis, and photolysis). Biodegradation of chemicals by microbial organisms occurs through metabolic or enzymatic processes. The rate of degradation is dependent on the chemical, biological, and physical conditions of the medium in which the contaminant is located.
- *Transformation* occurs when the valence state of metals is increased (oxidation) or decreased (reduction). It can be caused by changes in oxidation potential or pH and by microbial or nonmicrobial (abiotic) processes. Transformation may have a significant effect on the mobility of a metal, either increasing or decreasing it.

7.1.1 Explosives

Several explosive compounds were detected in soil and groundwater at FRBG but at low concentrations. The nitro groups of TNT are the most prevalent explosives at the site. TNT can be aerobically biodegraded, reduced by hydrogen under anaerobic conditions, or degraded by biotic cometabolism. TNT can also be degraded abiotically by hydrolysis or reduced by iron.

7.1.2 Organic Chemicals

Organic chemicals, such as SVOCs or VOCs, may be transformed or degraded in the environment by processes including hydrolysis, oxidation/reduction, photolysis, volatilization, biodegradation, or biotransformation. The half-life of organic chemicals in transport media can vary from minutes to years, depending on environmental conditions and chemical structures. The average half-life of naphthalene is 129.5 days. Some types of organic chemicals are stable, and degradation rates can be slow. Organic degradation may either enhance (by producing more toxic byproducts) or reduce (reducing concentrations) the toxicity of a chemical in the environment.

7.1.3 Inorganic Chemicals

Due to the complexity of inorganic chemicals, specifically metals, and their variable forms in the environment, predicting their chemical mobility and persistence can be difficult. Typically, they are not volatile under normal temperature and pressure conditions. Their sorption potential is a complex function of pH, organic content, oxide coatings, and other factors; therefore, K_d is not easily estimated by methods other than site-specific testing (USEPA 2010). Generally, metal adsorption increases with pH. Metals most often sorb to clay minerals, organic matter, and iron and manganese oxyhydroxides. Metals may be sorbed on the surface of the soil or fixed to the interior of the soil, where they are unavailable for release to groundwater. After available sorption sites are filled, most metals are incorporated into the structures of major mineral precipitates as coprecipitates (ERG 2005).

The solubilities of metals are also dependent on several factors. In general, solubility is highly dependent on the oxidation state of the metal. The solubility of cations (positively charged ions) decreases as pH increases. Some cations may complex with oxygen and hydroxide, forming insoluble oxyhydroxides, or with phosphate, sulfate, and carbonate, forming insoluble mineral precipitates. Metal sulfide complexes, which form in reducing environments, are extremely insoluble and tend to reduce the total metals concentrations (ERG 2005).

The solid forms of iron (iron hydroxides) and manganese (manganese oxides) are present in the natural soil matrix. If insufficient amounts of oxygen and nitrate are present in the subsurface, iron hydroxides and manganese oxides will be used as electron acceptors during metabolic activity and dissolve under reducing conditions into soluble forms. Sulfides present in groundwater can also result in the dissolution of iron hydroxides. Several metals, such as arsenic, tend to sorb to these iron hydroxides and manganese oxides. If these iron and manganese compounds are dissolved, the metals that are bound to these hydroxides and oxides, such as chromium and arsenic, will also be released. Iron also becomes more soluble as pH decreases below 7 (ERG 2005).

Subsurface conditions are likely to become more reduced in areas that have substantial carbon available. Several metabolic processes can use naturally occurring organic carbon or anthropogenic organic compound contamination as an electron donor or electron acceptor. Metal concentrations, in particular iron and manganese and those metals that tend to desorb from iron and manganese oxyhydroxides when they are reduced to their more soluble forms, are also frequently higher in areas of organic contamination, such as explosives or VOC plumes, because of the reducing conditions that are created during biodegradation of these chemicals (USEPA 2017).

7.2 CHEMICAL TRANSPORT

Contamination at FRBG is attributed primarily to historical usage as a disposal site and the burning of disposed of materials. The primary source of contamination includes contaminated wastes, including explosives, waste oil, solvents, asbestos, and acids. Except for some scattered debris, the site has no more primary source material.

Migration pathways for potential contaminants at FRBG are further discussed below in the context of their location (i.e., unsaturated zone and saturated zone migrations).

7.2.1 Unsaturated Zone Migration

Contaminants released to the ground surface migrated through the unsaturated zone, as controlled by the chemical and physical differences between the contaminants and the surrounding media, gravity, and pressure (head). Once in the unsaturated zone, contaminants may have sorbed to soil or organic matter, become trapped in residual pore spaces, or continued to leach to the saturated zone. Although the explosives and VOCs have lower K_{oc} values, the contaminants could still sorb to soil in areas of higher clay or total organic carbon content. The high-molecular-weight PCBs have a strong tendency for sorption. Once in the soil, contaminants can enter the gas phase through volatilization of soil contaminants. Higher soil temperatures in the upper few feet of soil occur during the summer and can lead to increased volatilization. Constituents sorbed or complexed to surface soil may be transported to sediment via surface water runoff.

The entire FRBG site is vegetated, and there is little to no restriction for infiltration. VOCs and SVOCs have leached from the unsaturated zone to groundwater. In contrast, due to the high sorption potential and low water solubility of PCBs, these contaminants are largely immobile in the unsaturated zone and unlikely to appreciably leach to groundwater. Based on their moderate volatility, PCBs may evaporate into soil gas and then into the atmosphere.

Most metals at the FRBG are likely naturally occurring in the environment and not associated with a CERCLA release. The mobility of metals in the unsaturated zone is highly dependent on the subsurface conditions. Surface soil and shallow subsurface soil (within the top 2 feet of the ground surface) exist under more oxidizing conditions due to the proximity to outdoor air; therefore, aluminum, manganese, and iron will tend to be in their immobile forms of aluminum hydroxides, manganese oxides, and iron hydroxides. In oxidizing environments, arsenic and chromium are typically present in forms that are more mobile. However, these metals, along with lead, thallium, and zinc, will potentially sorb or complex with clays, organic material, iron hydroxides, or manganese oxides, limiting their mobility.

7.2.2 Saturated Zone Migration

Contaminants have entered groundwater at FRBG primarily by leaching through unsaturated zone soil. A description of regional and site-specific hydrology is provided in Section 3.6 and summarized below:

- The general groundwater flow direction across FRBG is to the west/northeast (Figure 4-2). The approximate hydraulic gradient is 0.00345 ft/ft.
- The upper bedrock surface at FRBG is the Devonian Age Ohio Shale. Based on soil boring logs completed at the site for the wells sampled, depth to bedrock is 5 to 10 feet bgs.

- Based on the 2001 Groundwater RI (USACE 2002), depth to water in the overburden well (ABG-GW-002) at the southeast portion of the site fluctuates throughout the year between approximately 4 and 6 feet bgs. During the Phase II RI field investigation, groundwater in the overburden soil was observed at depths ranging from 3.4 to 4.5 feet bgs in May 2021 and 7.0 to 9.4 feet bgs to dry conditions in November 2021.

Contaminants typically will not move as rapidly as groundwater because of retardation or the adsorption of the contaminant to the solid media. Retardation can be a significant factor for groundwater COPCs within the overburden aquifer, which is composed primarily of clays and silts.

As previously mentioned, organic contamination in groundwater is composed primarily of SVOCs and VOCs. The SVOCs and VOCs in groundwater may volatilize into soil gas overlying the water table. These constituents also have high to moderate aqueous solubilities and have the potential to migrate once dissolved in groundwater. All of the organic groundwater COPCs are subject to biodegradation.

Transport and partitioning of metals in water is dependent on the oxidation state of the metal and on interactions with other materials present. Under reducing conditions, iron and manganese would be expected to be transformed into more soluble forms. Any metals, such as arsenic, which may be naturally bound to iron hydroxides and manganese oxides, can also become more mobile. Arsenic can also coprecipitate in groundwater.

7.3 SUMMARY AND CONCLUSIONS

The Phase I RI fate and transport evaluation identified 2,4,6-TNT; 2,4-DNT; 2,6-DNT; 2 amino-4,6-DNT; 4-amino-2,6-DNT; naphthalene; and beta-hexachlorocyclohexane for future groundwater evaluation to assess the modeling results. The explosives were not detected in groundwater above screening criteria, and samples were not analyzed for beta-hexachlorocyclohexane at FRBG during the Phase II RI because pesticide analyte surface and subsurface soil samples results did not exceed their respective background concentrations or resident regional screening levels. Naphthalene was the only organic constituent detected above screening criteria at FRBG.

Based on the information presented above, contaminant leaching from soil to the water table (vertical migration) and mixing with groundwater beneath the source is the contaminant release mechanism identified at FRBG.

One of the principal migration pathways at the site is percolation through the unsaturated soil to the water table (i.e., vertical leaching of contaminants from soil into groundwater). The rate of percolation is controlled by soil cover, ground slope, saturated conductivity of the soil, and meteorological conditions. Once the contaminant leachate percolates through the soil and reaches the water table, it mixes with groundwater beneath the source. The potential receptor location would be a hypothetical domestic water well located beneath the site. However, because of the heterogeneous nature of the unconsolidated glacial material, groundwater flow patterns within unconsolidated soil are difficult to predict. The presence of inorganics above screening levels in groundwater either leached from soil prior to previous investigations or are naturally occurring. The presence of naphthalene above screening levels, although only at one location and at low concentrations, leached from soil.

8. HUMAN HEALTH RISK ASSESSMENT

This HHRA documents the potential health risks to humans resulting from exposure to contamination within FRBG.

The HHRA was performed consistent with previous GRC-ATF HHRAs and is based on USEPA and Ohio EPA guidance and technical information sources, which include:

- USEPA guidance found in the Risk Assessment Guidance for Superfund Part A (USEPA 1989);
- USEPA guidance regarding evaluation of dermal exposure and toxicity from the Risk Assessment Guidance for Superfund Part E (USEPA 2004);
- Ohio EPA Human Health Cumulative Carcinogenic Risk and Non-carcinogenic Hazard Goals for the Division of Environmental Response and Revitalization (DERR) Remedial Response Program (Ohio EPA 2009a); and
- Toxicity values from the most recent USEPA RSL table (USEPA 2022a).

The HHRA consists of four steps:

- Data evaluation,
- Exposure assessment,
- Toxicity assessment, and
- Risk characterization.

The following sections describe the methods and assumptions used to conduct the HHRA as well as the results of the HHRA.

Section 8.1, Site Background and History. Describes the physical characteristics of the site, its current and plausible future uses, and potential sources of contamination.

Section 8.2, Data Evaluation. Describes data sources, data quality and usability, and selection of COPCs.

Section 8.3, Exposure Assessment. Describes the exposure scenarios and rationale by which plausible receptors are selected, the routes by which receptors may be exposed, the calculation of EPCs for each COPC, and the estimated dose or contact rates for each COPC.

Section 8.4, Toxicity Assessment. Evaluates the potential for COPCs to cause adverse health effects in exposed individuals. Where possible, it provides an estimate of the relationship between the intake or dose of a COPC and the likelihood or severity of adverse health effects resulting from that exposure.

Section 8.5, Risk Characterization. Quantitative risk estimates are calculated for each complete exposure pathway by combining the toxicity values from Section 8.4 with the chemical dose or contact rates estimated in Section 8.3.

Section 8.6, Uncertainty Analysis. Presents the uncertainties associated with the various assumptions and parameters used in the HHRA; their potential effects on the HHRA and its interpretation are addressed qualitatively.

Section 8.7, Summary and Recommendations. Provides a summary and discussion focused on those results and issues that are most directly relevant to the risk assessment conclusions for FRBG, including any COCs identified by the HHRA.

8.1 SITE BACKGROUND AND HISTORY

A detailed description of the site and its history is provided in Section 1.2. Sufficient information is summarized below to support this HHRA.

FRBG is in the eastern central portion of GRC-ATF (Figure 1-2). FRBG was one of the burning grounds that the Army and NASA used for destroying hazardous and non-hazardous material. These burning grounds are considered potential sources of environmental contamination because they were disposal sites for contaminated wastes. The contaminated wastes included explosives, acids, asbestos, waste oil, solvents, and landfilled debris.

8.2 DATA EVALUATION

8.2.1 Data Sets

Groundwater data collected during two sampling events in 2021 (May and November/December) were used in this HHRA. Wells FRBG-MW03 and FRBG-MW04 were sampled during both events. Wells FRBG-MW01 and FRBG-MW02 were sampled only during the May 2021 sampling event. All groundwater data were aggregated into a single exposure unit (EU) due to well locations in the unconsolidated aquifer and potential to be affected by site activities. Samples included in the HHRA data set are listed in Table 8-1. Groundwater samples were analyzed for TAL metals (filtered and unfiltered), explosives, PCBs, VOCs, and SVOCs

Only groundwater is included in this HHRA.

8.2.2 Identification of Chemicals of Potential Concern

The purpose of selecting COPCs is to identify those chemicals that may be present resulting from past site activities and may be of concern to human health.

8.2.2.1 COPCs – Approach

The first step in COPC identification involves evaluating the quality of the analytical data to ensure their acceptability for use in the HHRA (USEPA 1989). Additional steps involve eliminating chemicals that are considered essential nutrients, comparing the analytical concentrations to GRC-ATF background concentrations, and comparing the analytical concentrations to risk-based screening concentrations. This selection process is intended to identify those chemicals presumed to be site-related (i.e., present due to inadvertent or intentional site activity) and determine if those chemicals are potentially harmful to human health.

The selection of COPCs began by identifying those chemicals that were detected at least once in a groundwater sample collected from the monitoring wells at FRBG. Certain chemicals were then eliminated as COPCs based on the following criteria.

Data Quality Assessment – The data used in the risk assessment were verified and validated using the methodology described in the data quality assessment (Appendix F). Analytical results were reported by the laboratory in electronic form and loaded into a database. Site data were then extracted from the database so that only one result is used for each station. If laboratory reanalysis or dilutions were performed, only the appropriate result is used based on data review and validation. QC data, such as a field duplicate, were not used to identify COPCs for this risk assessment. Data qualified during the validation as rejected (“R”) also were not used in the risk assessment. Data qualified as estimated (“J”) are retained and used in the risk assessment.

Essential Nutrients – Chemicals that are considered essential nutrients (i.e., calcium, chloride, iodine, iron, magnesium, potassium, phosphorus, and sodium) are an integral part of the human food supply and are often added to foods as supplements. USEPA recommends these chemicals not be evaluated provided they are present at low concentrations (i.e., only slightly above naturally occurring levels) and toxic at only very high doses (i.e., much higher than those that could be associated with contact at the site) (USEPA 1989). Essential nutrients were not carried forward as COPCs.

Background – Background screening levels for naturally occurring inorganics are from the 2004 Groundwater Data Summary and Evaluation Report (Shaw 2005).

Risk-Based Screening – The objective of this evaluation is to identify COPCs that may pose a potentially significant risk to human health. The risk-based screening values are conservative values published by USEPA. The maximum detected concentration (MDC) of each chemical was compared to appropriate screening values. Chemicals detected below these screening values were screened from further consideration. The risk-based screening values are the most current residential tap water RSLs taken from the May 2022 RSL tables (USEPA 2022a). The RSLs were derived to include the exposure routes of ingestion, dermal contact, and inhalation of chemicals that volatilize during all household uses of tap water.

In addition, a separate data screening was performed to identify volatile chemicals detected in groundwater as COPCs for vapor intrusion into residences. The screening levels used to identify COPCs for this pathway are USEPA's VISLs calculated using USEPA's online VISL calculator (USEPA 2022b) (see Appendix G). VISLs are calculated for only those chemicals that were detected in at least one groundwater sample and that are determined to be volatile, based on a vapor pressure greater than 1 mm Hg or a Henry's Law Constant greater than 1E-05 atm-m^3/mole. To account for the potential effects of multiple chemicals, a target HQ of 0.1 was used for RSLs and VISLs based on non-cancer endpoints and a target cancer risk of 1E-06 was used. These screening values are considered conservative.

Specific details concerning use of the RSLs and VISLs are described below:

- **Chromium** – Detected concentrations were reported by the laboratory for total chromium. RSLs are available for trivalent and hexavalent chromium. There is no known source of hexavalent chromium at FRBG; therefore, chromium was assumed to be represented primarily by the more environmentally stable trivalent form.
- **Manganese** – The RSL for non-diet manganese was used in the screening process to select the groundwater COPCs (USEPA 2022a).
- **Phenanthrene** – The tap water RSL for pyrene was used as a surrogate value for the COPC screening of phenanthrene (NDEP 2006).
- **Acetone** – No VISL is available for acetone. This chemical was detected at a low concentration in only one of six groundwater samples analyzed (including a field duplicate).

8.2.2.2 COPCs – Results

The COPC screening results are presented in Appendix G. This table includes frequency of detection, range of detected concentrations, and comparison to RSLs and background concentrations (where applicable). All detected chemicals and those selected as COPCs are shown in Table 8-2. Table 8-3 presents statistics and EPCs for the COPCs.

Thirty-four chemicals were detected at least once in groundwater: 21 metals, 6 SVOCs, 3 explosives, and 4 VOCs. Of these, nine metals (aluminum, antimony, arsenic, cadmium, iron, lead, manganese, thallium, and vanadium) and one SVOC (naphthalene) were selected as COPCs in groundwater based on data comparisons with RSLs.

For metal COPCs, human health risks were calculated using unfiltered groundwater data as opposed to filtered (i.e., dissolved) data. The dissolved metals results are used as a weight-of-evidence tool to distinguish between metals dissolved in the groundwater versus metals that are in particulate form that are typically eliminated by filtration and to aid in the selection of COCs.

Of the 13 organic chemicals detected in groundwater samples collected from the FRBG, only 5 chemicals are volatile: naphthalene (analyzed as a SVOC), acetone, 2-butanone, toluene, and TCE. VISLs were calculated (see Appendix G) as target groundwater concentrations for all of the volatile chemicals, except for acetone, which currently has no inhalation toxicity criteria available for calculating a VISL. Based on the data comparisons with the VISLs, none of the aforementioned volatiles are identified as groundwater COPCs for the vapor intrusion pathway. Therefore, the vapor intrusion exposure pathway at FRBG is incomplete and is not being evaluated in this HHRA.

8.3 EXPOSURE ASSESSMENT

The objectives of the exposure assessment are to estimate the magnitude, frequency, and duration of potential human exposure to COPCs. The four primary steps of the exposure assessment are:

1. Characterize the exposure setting, including identification of contaminant sources, release mechanisms, and migration and identification of current and future land use;
2. Identify potentially exposed populations, exposure media, and exposure pathways;
3. Calculate EPCs; and
4. Estimate each receptor's potential intake of each COPC.

Steps 1 and 2 are summarized in the conceptual site exposure model (CSEM) summarized in Section 8.3.1 and Figure 1-3. Steps 3 and 4 are described in Sections 8.3.2 and 8.3.3, respectively. The output of the exposure assessment is used in conjunction with the output of the toxicity assessment (Section 8.4) to quantify risks and hazards to receptors in the risk characterization (Section 8.5).

8.3.1 Conceptual Site Exposure Model

The CSEM provides the basis for identifying and evaluating potential risks to human health in the HHRA. The CSEM identifies the receptors appropriate to all plausible site use scenarios and the potential exposure pathways through which the receptors may be exposed to contaminated media. The CSEM includes all sources, release and transport pathways, and exposure routes, thus facilitating a consistent and comprehensive evaluation of risk to human health and preventing potential pathways from being overlooked. The elements of the CSEM include the following:

- Source (i.e., initially contaminated environmental) media and contaminant release mechanism;
- Contaminant migration pathways and media;
- Exposure media;
- Receptors; and
- Routes of exposure (e.g., ingestion, inhalation, and dermal).

A receptor may come into direct contact with a contaminated source medium, in which case the source medium and exposure medium are identical. Figure 1-3 shows the CSEM for FRBG.

8.3.1.1 Contaminant Sources, Release Mechanisms, Migration Pathways, and Exposure Media

Releases to soil and sediment were discussed and evaluated in the Phase I RI (Leidos 2018a). Sources of contamination at FRBG may include releases to surface and subsurface soil from the burning of contaminated wastes, including explosives, waste oil, solvents, asbestos, and acids. With the exception of some scattered debris, the site has no more primary source material. Contaminants released to surface soil also may migrate to the Drainage Ditch via surface runoff and to air via volatilization and fugitive dust. These releases were discussed and evaluated in the Phase I RI. In addition, contaminants released to soil may reach the groundwater through the process of precipitation and infiltration through the soils. This is the pathway evaluated in this RI.

8.3.1.2 Receptor Scenarios and Exposure Routes

FRBG and GRC-ATF, including their physical setting, historical and current use, topography, and demographics of the area, are described in Sections 1 and 3.

An estimated 75 percent of NASA's property at GRC-ATF is considered unused. The remaining land is used for offices, test facilities, roads, and infrastructure. Public access is restricted at GRC-ATF. An 8-foot security fence surrounds approximately 5,000 acres of GRC-ATF, and access to the site is gained through the security office located on East Scheid Road. The main gate and security office are staffed by armed guards 24 hours per day. During each 8-hour shift, a security guard patrols the inside perimeter road (Patrol Road) of the facility. Persons gain access to the station by showing the guard a badge that authorizes entry. GRC-ATF is expected to remain under the control of NASA for the foreseeable future.

FRBG is located on 17.2 acres in the east-central portion of GRC-ATF. The exact locations of historical activities and extents are not certain. FRBG currently comprises forest and shrubland on the eastern portion of the site. The western half of the General Area is a mixture of flat, grassy area with some mature trees, areas of heavy shrub/scrub vegetation, and few soil piles. The three wetlands are independent of each other and are only partially inside the eastern boundaries of the General Area and Drainage Ditch. No groundwater at GRC-ATF is used for drinking water. The GRC Master Plan (NASA 2008) states the following: *"Groundwater underlying PBS shall not be extracted or used for any purpose, potable or otherwise, except for investigation, monitoring or remediation of groundwater, or in conjunction with construction or excavation activities or maintenance of subsurface utilities."*

Although it is unlikely that FRBG will be developed for residential purposes and/or that the groundwater will be used as a source of potable water, a hypothetical onsite residential scenario is evaluated to assess the upper bound for long-term exposure. Generally, sites that "pass" a residential risk assessment can be released for use without restriction. Relevant pathways for groundwater exposure are ingestion, dermal contact, and inhalation of VOCs (during household use of water). The resident is assumed to be exposed 350 days/year for 26 years (20 years as an adult and 6 years as a child). The groundwater receptor scenarios evaluated in the HHRA are summarized in the CSEM (Figure 1-3). Note this figure also includes exposures to soil (from the Phase I RI).

8.3.2 Exposure Point Concentrations

This HHRA evaluates the reasonable maximum exposure (RME) of receptors to groundwater contaminants at FRBG. The intent of the RME is to estimate the highest exposure level that could reasonably be expected to occur but not the worst possible case (USEPA 1989). Exposure parameters selected for an RME scenario for intake rate, exposure frequency, and exposure duration are generally upper bounds. Other variables (e.g., body weight and lifespan) are generally central or average values. The concentration to which a receptor is exposed is called the EPC. The procedure used to calculate EPCs for the COPCs is discussed in this section. The resulting exposure rate, once the components are multiplied, represents a conservative estimate of actual exposure (i.e., intake). A statistical summary of groundwater data (including MDCs, averages, and upper confidence limits [UCLs]) is provided in Table 8-3 for the COPCs. Per USEPA recommendations, the smaller of the 95 percent UCL or the MDC is used to estimate groundwater EPCs (USEPA 2002). The 95 percent UCLs were calculated for chemicals that had at least three detections using ProUCL Version 5.1.002 (USEPA 2016). The ProUCL output for FRBG groundwater data is provided in Appendix G. The EPC for lead is the calculated average concentration as recommended by USEPA (USEPA 2021a).

Field duplicate data from FRBG-MW01 were used in the EPC calculations as follows: primary and duplicate data were averaged, if both results were detected or not detected; if only one of the duplicate pair had a detectable concentration, only the detected result was used.

Wells FRBG-MW01 and FRBG-MW02 were only sampled in May 2021. Wells FRBG-MW03 and FRBG-MW04 were sampled in May 2021 and November/December 2021. For the purposes of deriving EPCs, the data for the two rounds of sampling for FRBG-MW03 and FRBG-MW04 were averaged to give equal statistical weight to the results from each well.

8.3.3 Quantification of Chemical Intake

The magnitude of human exposure to chemicals in environmental media is described differently for each of the primary intake pathways in terms of the average daily intake for ingestion exposure, inhalation exposure concentration, and dermal absorbed dose (DAD). This HHRA used standard intake equations along with default exposure assumptions for a resident from the USEPA RSL User's Guide (USEPA 2022a). The exposure assumptions are shown in Table 8-4, and the equations used to estimate intake and risk are included in Appendix G.

Lead exposures are assessed using models specific to the complex nature of lead partitioning and toxicity within the human body. USEPA has developed the Integrated Exposure Uptake Biokinetic (IEUBK) model (USEPA 2021b), which is used to estimate blood-lead levels in resident children. Adult exposure to lead in groundwater was not evaluated because the Adult Lead Model (also developed by USEPA) is used to evaluate exposure to lead only in soil. USEPA has not developed a model to evaluate adult exposure to lead in water or other media besides soil for adults.

8.4 TOXICITY ASSESSMENT

The purpose of the toxicity assessment is to evaluate the potential for COPCs to cause adverse health effects in exposed individuals. Where possible, it provides an estimate of the relationship between the intake or dose of a COPC and the likelihood or severity of adverse health effects resulting from that exposure. USEPA has extensively evaluated toxic effects. This section provides the results of the USEPA evaluation of the chemicals identified as groundwater COPCs at FRBG.

For carcinogens, risks are estimated as the probability that an individual will develop cancer over a lifetime resulting from exposure to the carcinogen. Cancer risk from exposure to contamination is expressed as excess or incremental cancer risk, which is cancer occurrence in addition to normally expected rates of cancer development. The numeric descriptor of carcinogenic potency for oral and dermal exposures is the cancer slope factor (CSF) expressed in units of milligrams per kilogram of body weight per day $(mg/kg\text{-}day)^{-1}$. The CSF is defined as a plausible upper-bound estimate of the probability of a response (i.e., cancer) per unit intake of a chemical over a lifetime (USEPA 1989).

Non-carcinogenic effects are evaluated by comparing an exposure or intake/dose with a reference dose (RfD) expressed in units of mg/kg-day for oral and dermal exposure. The RfDs are determined using available dose-response data for individual chemicals. Scientists determine the exposure concentration or intake/dose below which no adverse effects are seen and add a safety factor (from 10 to 1,000) to determine the RfD. RfDs are identified by scientific committees supported by USEPA. RfDs are route- and duration-specific. Toxic effects are diverse and measured in various target body organs (e.g., they range from eye irritation to kidney or liver damage). USEPA is currently reviewing methods for accounting for the difference in severity of effects; however, existing RfDs do not address this issue.

Toxicity values for the COPCs are summarized in Table 8-5. Although inhalation toxicity values are provided for the metals and naphthalene, the metals do not volatilize from tap water during bathing/showering and household usage. Therefore, cancer risks and non-carcinogenic hazards will not be calculated for inhalation exposures to metals in groundwater at FRBG.

8.4.1 Oral Toxicity Values

The cancer and non-cancer toxicity values for evaluating risks from oral (ingestion) exposures are identified based on the following three-tiered hierarchy of sources as recommended by USEPA:

- Tier 1 - USEPA's Integrated Risk Information System (IRIS) database.
- Tier 2 - National Center for Environmental Assessment (NCEA) provisional peer-reviewed toxicity values.
- Tier 3 - In the case where NCEA cannot provide any provisional toxicity values, the following resources may be used with priority given to the source providing the most current peer-reviewed information, available to the public, and transparent in the methods and processes used to develop the value:
    - U.S. Centers for Disease Control and Prevention – Agency for Toxic Substances and Disease Registry toxicological profiles.
    - USEPA criteria documents (criteria documents, such as drinking water criteria documents, drinking water health advisory summaries, ambient water quality criteria documents, and air quality criteria documents, may be consulted in the event none of the above sources contain appropriate information).
    - California Environmental Protection Agency Office of Environmental Health Hazard Assessment toxicity criteria database.
    - Screening toxicity values presented in an appendix to a provisional peer-reviewed toxicity values assessment.
    - Health Effects Assessment Summary Table values (the values found in this table are still applicable in cases where the sources listed in the hierarchy above do not contain toxicity values for a constituent).

This is the hierarchy used in the USEPA May 2022 RSL tables (USEPA 2022a).

8.4.2 Dermal Toxicity Values

Because no toxicity values are specific to dermal exposure, USEPA recommends oral toxicity values be used to assess risks from dermal exposure. However, oral toxicity factors relate toxic response to the administered dose of a chemical, only some of which may be absorbed by the body, whereas chemical intake from dermal contact is estimated as an absorbed dose using chemical-specific permeability constants for absorption from water (USEPA 2004). To ensure that dermal toxicity is not underestimated, USEPA recommends adjusting oral toxicity factors by chemical-specific gastrointestinal absorption fractions (GIABS) if the USEPA-recommended GIABS is less than 50 percent. Oral toxicity criteria are adjusted to generate dermal toxicity criteria, as shown in the following equation:

$$CSF_d = \frac{CSF_o}{GIABS} \quad \text{and} \quad RfD_d = RfD_o \times GIABS$$

Where:

CSF_d = cancer slope factor for dermal pathway (mg/kg-day)$^{-1}$
CSF_o = cancer slope factor for oral pathway (mg/kg-day)$^{-1}$
GIABS = gastrointestinal absorption factor (unitless)
RfD_d = reference dose for dermal pathway (mg/kg-day)
RfD_o = reference dose for oral pathway (mg/kg-day)

The GIABSs for two COPCs (cadmium and vanadium) were less than 50 percent. As a result, the RfD_o was multiplied by the GIABS to generate the RfD_d.

When the USEPA-recommended GIABS is greater than 50 percent, USEPA recommends using oral CSFs and RfDs without adjustment to assess potential dermal risks. The GIABS for all COPCs except for cadmium and vanadium are 100 percent; therefore, oral CSF and RfD values were used to evaluate dermal exposure for these COPCs without adjustment.

8.4.3 Chemicals Without USEPA Toxicity Values

No RfD or CSF values are available for evaluation of phenanthrene; however, the toxicity values available for pyrene are used as surrogate values for quantitatively estimating risks and hazards associated with phenanthrene exposures in groundwater.

No suitable dose-response values exist for assessing the risks associated with exposure to lead. USEPA has identified that no child should have greater than a 5 percent probability of having a blood lead level greater than 10 micrograms per deciliter (µg/dL) (USEPA 1994, USEPA 2021b). USEPA has developed the IEUBK model (USEPA 2021b), which is used to estimate blood-lead levels in resident children.

8.5 RISK CHARACTERIZATION

The purpose of the risk characterization is to evaluate the information obtained through the exposure and toxicity assessments to estimate potential risks and hazards. Potential carcinogenic effects are characterized by using projected intakes and chemical-specific, dose-response data (i.e., CSFs) to estimate the probability that an individual will develop cancer over a lifetime. Potential non-carcinogenic effects are characterized by comparing projected intakes of contaminants to toxicity values (i.e., RfDs). The numerical risk and hazard estimates presented in this section must be interpreted in the context of the uncertainties and assumptions associated with the risk assessment process and with the data upon which the risk estimates are based.

Some chemicals may induce both cancer and non-cancer effects; however, the risks for each endpoint are calculated separately.

8.5.1 Risk Characterization Methods

8.5.1.1 Carcinogenic Risk Characterization

For carcinogens, risk is expressed as the probability that an individual will develop cancer over a lifetime resulting from exposure to the carcinogen. Cancer risk from exposure to contamination is expressed as the ILCR or the increased chance of cancer above the normal background rate of cancer. In the United States, the background chance of contracting cancer is a little more than 3 in 10 for women and a little less than 5 in 10 for men, or 3E-01 to 5E-01 (American Cancer Society 2015). The calculated ILCRs are compared to the range specified in the NCP of 1E-06 to 1E-04, or 1 in 1 million to 1 in 10,000 exposed persons developing cancer (USEPA 1990). ILCRs below 1E-06 are considered acceptable; ILCRs above 1E-04 are considered unacceptable. The range from 1E-06 to 1E-04 is of concern, and any decisions to address ILCRs further in this range, either through additional study or engineered control measures, should account for the uncertainty in the risk estimates. The Ohio EPA DERR program has adopted a human health cumulative ILCR goal within this range of 1E-05 to be used as the level of acceptable excess cancer risk and for developing remediation goals. The DERR notes that the defined risk goal should be applied as a goal, recognizing the need to retain flexibility during the evaluation and selection of remedial alternatives.

For each carcinogenic COPC, the ILCR is calculated by multiplying the average daily exposure of the chemical, for each route of exposure, by the appropriate cancer toxicity measure for the chemical/route, as follows:

$$ILCR = Exposure \times Toxicity\ Value$$

Where:

ILCR	=	incremental lifetime cancer risk (unitless);
Exposure	=	daily intake (mg/kg-day), DAD (mg/kg-day), of chemical; and
Toxicity Value	=	oral or dermal CSF $(mg/kg\text{-}day)^{-1}$.

For a given exposure pathway, the total risk to a receptor exposed to several carcinogenic COPCs is the sum of the ILCRs for each carcinogen, as shown below:

$$ILCR_{total} = \Sigma ILCR_i$$

Where:

$ILCR_{total}$	=	total probability of cancer incidence associated with all carcinogenic COPCs; and
$ILCR_i$	=	ILCR for the i^{th} COPC.

In addition to summing risks across all carcinogenic COPCs, risks are summed across all exposure pathways for a given environmental medium (e.g., ingestion, inhalation, and dermal contact).

8.5.1.2 Non-Carcinogenic Risk Characterization

In addition to developing cancer from exposure to contaminants, an individual may experience other toxic effects. The term "toxic effects" is used here to describe a wide variety of systemic effects ranging from minor irritations, such as eye irritation and headaches, to more substantial effects, such as kidney or liver disease and neurological damage. The risks associated with toxic (i.e., non-carcinogenic) chemicals are evaluated by comparing an estimated exposure (i.e., intake or dose) from site media to an acceptable exposure expressed as an RfD. The RfD is the threshold level below which no toxic effects are expected to occur in a population, including sensitive subpopulations. The ratio of intake over the RfD is the HQ (USEPA 1989) and is calculated by dividing the estimated exposure of the constituent over a specific time period by the appropriate non-cancer toxicity value for that constituent, derived for a similar exposure period, as follows:

$$HQ = \frac{\text{Exposure}}{\text{Toxicity Value}}$$

Where:

HQ	=	hazard quotient (unitless);
Exposure	=	daily intake (mg/kg-day), DAD (mg/kg-day), or exposure concentration (milligrams per cubic meter [mg/m^3]) of chemical; and
Toxicity Value	=	oral or dermal RfD (mg/kg-day).

The HQs for each COPC are summed to obtain an HI, as shown below:

$$HI = \Sigma HQ_i$$

Where:

HI = hazard index for all toxic effects; and
HQ_i = hazard quotient for the ith COPC.

An HI greater than 1 has been defined as the level of concern for potential adverse non-carcinogenic health effects (USEPA 1989).

Non-cancer risks have been calculated only for the resident child because the child HIs are greater than the resident adult HIs.

8.5.1.3 Evaluation of Lead

No suitable dose-response values exist for assessing the risks associated with exposure to lead. USEPA has developed the IEUBK model, which is used to estimate blood-lead levels in children 1 to 7 years old following exposure to lead in various environmental media (USEPA 2021b). USEPA has identified a blood-lead level of 10 µg/dL as a level of concern. The technical review workgroup for lead strongly recommends using the $IEUBK_{win}$ defaults; therefore, per this guidance, model defaults are used along with the site-specific EPCs for groundwater and soil (the soil concentration is from the Phase I RI). In accordance with USEPA guidance for the IEUBK model, the site-specific EPC for lead is the arithmetic mean concentration (USEPA 2021a), not the MDC or 95 percent UCL on the mean. Resident child exposures to lead are presented as predicted blood-lead levels and the probability of exceeding a blood-lead level of 10 µg/dL in the modeled population.

8.5.2 Risk Characterization Results

Detailed hazard and risk results are presented in Appendix G for residents exposed to groundwater. Output files for the IEUBK model also are provided in Appendix G. Risk results are summarized in Table 8-6 and the following section.

The hypothetical future onsite resident may be exposed to groundwater via incidental ingestion and dermal contact. Risks are reported for unfiltered groundwater. Dissolved metal concentrations and their potential effect on the risk results are discussed in Section 8.7.

The total HI for groundwater exposure (8) exceeds the target of 1. Because the total HI exceeds 1, the chemicals were segregated according to target organ or system and an HI was calculated for each target organ. The following target organ HIs exceed the target of 1:

- The target organ HI of 2 for neurological effects exceeds the target of 1 (due to manganese [2] and to a lesser extent aluminum [0.2]); and
- The target organ HI of 5 for dermal effects exceeds the target of 1 (due to arsenic [1], thallium [4], and vanadium [0.2]).

The total ILCR for groundwater exposure of 1E-04 is at the upper bound of the target cancer risk range and is associated almost entirely with arsenic. The geometric mean blood-lead concentration for a child resident of 12 to 72 months is 2.6 µg/dL, and the probability that the blood-lead concentration of a child resident would exceed the target of 10 µg/dL is 0.2 percent, which is less than the target (5 percent).

8.6 UNCERTAINTY ANALYSIS

This section qualitatively discusses the sources of uncertainty in this HHRA and their effect on the risk estimates. Uncertainty is a factor in each step of the exposure and toxicity assessments presented in the preceding sections.

8.6.1 Types of Uncertainty

Generally, risk assessments are influenced by two types of uncertainty:

- Measurement uncertainty, and
- Uncertainty arising from data gaps.

Measurement uncertainty includes the usual variance that accompanies scientific measurements (e.g., instrument uncertainty – accuracy and precision) associated with contaminant concentrations and the heterogeneity of the data.

A second type of uncertainty stems from data gaps (i.e., additional information needed to complete the database for the assessment). The data gap is often significant, such as the absence of information on the effects of human exposure to a chemical or the biological mechanism of action of an agent. Models are often used to fill data gaps because they represent a level of understanding to address certain exposure parameters that are impractical or impossible to measure. Assumptions represent an educated estimate of information that is not available (e.g., additivity of non-cancer effects).

Reliance on a simplified numerical presentation of dose and risk without consideration of uncertainties, limitations, and assumptions inherent in the assessment process can be misleading. For example, an ILCR of 1E-06 may be calculated for a given exposure scenario. However, if the uncertainty in this estimate is several orders of magnitude, the real risk may be higher than the risk from another scenario that has a calculated ILCR of 1E-05 but a smaller degree of uncertainty. Alternatively, an ILCR of 1E-03 may be calculated and appears to represent an unacceptable risk. The actual risk, however, may be orders of magnitude smaller. Situations like this occur because the estimated risk reflects conservative assumptions on lifestyles and site use scenarios, maximum or near-maximum values for many modeling and exposure variables, and the derivation of toxicity values.

8.6.2 Sources of Uncertainty

The sources of uncertainty, as well as the bias they impart to the risk assessment (i.e., whether conservatism is increased or decreased), are discussed below.

8.6.2.1 Sampling Limitations

It is not possible to completely characterize the nature and extent of contamination at any site. Uncertainties arise from limits on the media sampled, the total number and specific locations that can be sampled, and the parameters chosen for analysis to characterize the site. Sampling limitations may result in underestimating or overestimating true risk. For FRBG, only six groundwater samples plus one duplicate sample (from FRBG-MW01) were collected. Wells FRBG-MW01 and FRBG-MW02 were sampled only during the May 2021 sampling event. Wells FRBG-MW03 and FRBG-MW04 were sampled during both the May 2021 and November/December 2021 sampling events. For evaluation purposes, the data for the original and duplicate sample from FRBG-MW01 were averaged, and the May 2021 and November/December 2021 data for FRBG-MW03 and FRBG-MW04 were averaged, respectively. This approach to handling the available groundwater data is a source of uncertainty. In addition, the reporting limits for the dissolved metals were elevated, which is another source of uncertainty.

8.6.2.2 Estimation of EPCs

Generally, the UCL on the arithmetic mean is adopted as the EPC and is considered to represent a conservative estimate of the average concentration. This imparts a small but intentional conservative bias to this HHRA, provided the sampling captured the most highly contaminated areas. In cases where the UCL exceeded the MDC or not enough samples were detected to calculate a UCL, the MDC was used as the EPC. This is generally a conservative estimate of the actual concentration to which receptors are exposed to in this HHRA.

8.6.2.3 Selection of Hypothetical Receptors and Potential Exposure Pathways

The hypothetical residential receptor and associated exposure pathways were chosen to represent an unrestricted use scenario. The onsite resident is not a likely receptor for FRBG and is evaluated in this assessment for the additional information it provides. Inclusion of the onsite resident overestimates the risk that may be experienced by actual receptors in the future because groundwater underlying the site is not used as a source of drinking water.

8.6.2.4 Quantification of Intakes

Ingestion rates, exposure durations, and exposure factors are based on upper bound values (USEPA 2022a), even though it is likely that serial multiplication of conservative variable values leads to overestimation of COPC intake rates (Cogliano 1997).

8.6.2.5 Toxicity Assessment

Considerable uncertainty is associated with the qualitative (hazard assessment) and quantitative (dose response) evaluations of a toxicity assessment. Positive animal cancer test data suggest that humans also contain tissue(s) that may manifest a carcinogenic response; however, the animal data cannot necessarily be used to predict the target tissue in humans. In the hazard assessment of non-cancer effects, positive animal data suggest the nature of the effects (i.e., the target tissues and type of effects) anticipated in humans (USEPA 1989). Uncertainty decreases when similar effects are observed across species, strain, sex, and exposure route; when the magnitude of the response is clearly dose-related; when toxicokinetic data indicate a similar fate in animals and humans; when postulated mechanisms of toxicity are similar for humans and animals; and when the COPC is structurally similar to other chemicals for which the toxicity is more completely characterized.

Many sources of uncertainty exist in the dose-response evaluation for cancer (i.e., computation of a slope factor) and non-cancer effects (i.e., computation of an RfD). First, there is uncertainty regarding interspecies (animal-to-human) extrapolation, which, in the absence of quantitative toxicokinetic, dosimetric, or mechanistic data, is usually based on consideration of interspecies differences in the basal metabolic rate. Second, there is uncertainty regarding intraspecies, or individual, variation. Most toxicity experiments are performed with animals that are similar in age and genotype so that intragroup biological variation is minimal; however, the human population of concern may reflect wide heterogeneity, including unusual sensitivity to the COPC. Even toxicity data from human occupational exposure reflect a bias because only those individuals who are sufficiently healthy to attend work regularly and those not unusually sensitive to the COPC are likely to be occupationally exposed. Third, uncertainty arises from the quality of the key study (from which the quantitative estimate is derived) and the database. For cancer effects, the uncertainty associated with some study quality factors (e.g., test group size) is expressed within the 95 percent upper bound of the slope factor. For non-cancer effects, additional uncertainty factors may be applied in deriving the RfD to reflect poor quality of the key study or gaps in the database.

A further source of uncertainty for non-cancer effects arises from the use of a lowest observed adverse effect level in estimating an RfD because this estimation is predicated on the assumption of a threshold below which adverse effects are not expected. Therefore, an additional uncertainty factor is usually applied to estimate a no-observable-adverse-effect level (NOAEL) from a lowest-observable-adverse-effect level (LOAEL). Additional uncertainty arises from estimating RfD values for chronic exposure from less-than-chronic data. Unless empirical data indicate that effects do not worsen with increasing duration of exposure, an additional uncertainty factor is applied to the NOAEL in the less-than-chronic study.

Another source of uncertainty regarding quantitative risk estimation for carcinogenicity is the method by which data from high dose rates in animal studies are extrapolated to the low dose rate range expected for environmentally exposed humans. The linearized multi-stage model that is used in most quantitative estimates of human cancer risk from animal data is based on a non-threshold assumption of carcinogenesis. An impressive body of evidence, however, suggests that epigenetic carcinogens, as well as many genotoxic carcinogens, have a threshold below which they are non-carcinogenic (USEPA 2005); therefore, the use of the linearized multi-stage model is ultraconservative for chemicals that exhibit a threshold for carcinogenicity.

In summary, the USEPA methodology for both cancer and non-cancer toxicity evaluations is intentionally designed to be protective. However, the extent to which toxicity values may overestimate toxicity is not clear, and it is possible that the toxicity values for some compounds may not be adequately protective.

Significant uncertainty regarding toxicity information for this risk assessment arises in the use of provisional toxicity values (e.g., the RfDs for aluminum, cadmium, iron, and thallium are provisional toxicity values). The significance of findings based on provisional toxicity values should be tempered by the understanding that the provisional value represents a lower level of review and certainty than USEPA-verified toxicity values and may not provide an adequate basis for decision making. The use of such toxicity values may either overestimate or underestimate actual risk.

There is added uncertainty for thallium because the RfD is a supplemental screening toxicity value developed in an appendix to a provisional toxicity assessment. For thallium, insufficient data were available to develop a verified toxicity value or to support the derivation of a provisional toxicity value under current guidelines; however, information was available "…which may be of limited use to risk assessors" (USEPA 2012). Although this toxicity value receives external peer review, there is even more uncertainty than that associated with a provisional toxicity value.

Note the oral RfD for vanadium is derived from the IRIS oral RfD for vanadium pentoxide by factoring out the molecular weight (MW) of the oxide ion. This adds uncertainty to the risk estimate for vanadium because the toxicity value used may not accurately reflect the form of vanadium at FRBG.

Acetone was detected in one of the six groundwater samples at a concentration less than the RSL. Acetone is a common laboratory blank contaminant (USEPA 1989) and has the potential to migrate via the vapor intrusion pathway because it is a VOC. USEPA, however, has not developed toxicity values for acetone for the inhalation pathway, and thus, a VISL could not be calculated for acetone. Acetone was not considered to be a concern for the vapor intrusion pathway because it was detected in only one sample at a relatively low concentration of 8 µg/L, which was substantially less than the RSL of 1,800 µg/L.

8.6.2.6 Risk Characterization

Risk characterization is the process of quantifying the cancer risk due to exposure to carcinogens, as well as quantitatively evaluating hazards potentially posed by non-cancer effects. Cancer risk is assumed to be additive for all carcinogens. Non-cancer risk is assumed to be additive for chemicals with similar sites of toxicological action. If any combination of these chemicals results in synergistic effects, risk might be underestimated. Conversely, the assumption of additivity would overestimate risk if a combination of these chemicals acted antagonistically. It is unclear whether the potential for chemical interaction has been inadvertently understated or overstated. It seems unlikely that the potential for chemical interaction contributes significant uncertainty to this HHRA.

8.7 SUMMARY AND RECOMMENDATIONS

The HHRA documents the potential health risks to humans resulting from exposure to groundwater underlying the FRBG. The HHRA was performed consistent with previous GRC-ATF HHRAs and is based on USEPA and Ohio EPA guidance.

Groundwater data collected at FRBG and used in this HHRA were aggregated into a single EU. GRC-ATF is expected to remain under NASA's control for the foreseeable future. Although it is unlikely that FRBG will be developed for residential purposes, a hypothetical onsite residential scenario was included to evaluate the upper bound for long-term exposure and represent an unrestricted reuse scenario. Sites that "pass" a residential risk assessment can be released for use without restriction. FRBG is best classified as an inactive area and plausible receptors include groundskeepers. Hunting is not currently permitted in this area, although hunting is permitted in other areas within GRC-ATF. Neither groundskeepers nor hunters use the groundwater because access is restricted.

Lead exposures were assessed using a model specific to the complex nature of lead partitioning and toxicity within the human body. USEPA has developed the IEUBK model, which is used to estimate blood-lead levels in children. This model was used to evaluate exposure to lead in groundwater. Note the soil lead EPC from the Phase I RI was also input into the model.

The results of the HHRA for hypothetical residential land use are summarized in Table 8-6. For non-cancer effects, HIs were calculated only for the resident child because the child HIs are greater than the resident adult HIs. The total resident child HI for groundwater (8) exceeds the target of 1. Because the total HI exceeds 1, the chemicals were segregated according to target organ or system and an HI was calculated for each target organ. The following target organ HIs exceed the target of 1: the HI of 2 for neurological effects (primarily due to manganese) and for the HI of 5 for dermal effects (primarily due to thallium [4], arsenic [1], and vanadium [0.2]). The total ILCR of 1E-04 for groundwater exposure is at the upper bound of the target cancer risk range and is associated almost entirely with arsenic. Naphthalene, the other carcinogenic COPC, was not selected as a COC due to a cancer risk at the low end of the target risk range. The lead model results for the resident child show that the probability the blood-lead concentration would exceed 10 µg/dL was less only 0.2 percent, which is less than the target of 5 percent.

Although target organ HIs exceeded 1, none of the contributing COPCs were identified as a COC, as discussed below:

- Although the maximum detected concentration of arsenic at FRBG (12 µg/L) exceeds the background screening value (7.4 µg/L), the average (5.25 µg/L) of the detected concentrations was below the background screening value. In addition, the maximum detected concentration was detected in November 2021 from FRBG-MW03, at which time the turbidity readings (greater than 1,000 NTUs) were much greater than the turbidity readings in May 2021 (less than 20 NTUs). The turbidity results indicate particulate matter may have affected the analytical results for the samples collected in November/December 2021. The dissolved arsenic concentration in the same sample was less than the reporting limit (i.e., 5 µg/L). Note that the May 2021 arsenic concentration from the same well was not detected. For these reasons, arsenic was not identified as a groundwater COC at FRBG.
- Manganese was not identified as a COC. Although the maximum detected concentration (780 µg/L) exceeds the background screening value (636 µg/L), manganese concentrations in FRBG groundwater are comparable to background levels. The average concentration (405 µg/L) is below the background screening value. The maximum detected concentration was detected in well FRBG-MW01. This is the only result exceeding the background concentration. The dissolved manganese concentration in the same sample was 580 µg/L, which is below the background concentration.
- Although the thallium HQ of 4 exceeds the target HQ of 1, thallium was not identified as a groundwater COC due to the uncertainty associated with the "limited use" toxicity value and because the maximum detected concentration (0.91 µg/L, an estimated concentration) was below the MCL (2 µg/L).
- Vanadium was not identified as a COC in groundwater due to the HQ below 1 (0.2) and significantly different result seasonally in the well with the highest concentration (i.e., 31 µg/L in November 2021 versus non-detect at the reporting limit of 5 µg/L in May 2021). In addition, the filtered groundwater sample concentration (representing dissolved metals) associated with the maximum detect was also non-detect at the reporting limit of 5 µg/L. There is also uncertainty associated with the use of the toxicity value (which was derived for vanadium pentoxide and altered by factoring out the MW of the oxide ion).

The results of the lead modeling show that the blood lead levels for the resident child are below the USEPA target (i.e., the probability that the blood-lead concentration of a child resident would exceed the target of 10 µg/dL is 0.2 percent, which is less than the target of 5 percent). Therefore, lead was not identified as a COC in groundwater.

Detected concentrations of chemicals were compared to their respective MCLs (Appendix G). The maximum detected concentration of arsenic (12 µg/L from November 2021) was greater than the MCL of 10 µg/L, but the concentration from the same well during the May 2021 sampling event was non-detect at the reporting limit of 5 µg/L. The average concentration (5.25 µg/L) was also less than the MCL. No other chemicals were detected with a maximum concentration that was greater than applicable MCLs. The maximum detected concentration of lead (19 µg/L) exceeded the action level (15 µg/L). Note this detection was from FRBG-MW03 in November 2021. The concentration of lead in the same well in May 2021 was less than the reporting limit (i.e., less than 1 ug/L). The average lead concentration in unfiltered samples was only 5.22 µg/L, which was less than the action level.

In summary, no groundwater COPCs were identified as a COC for hypothetical future residential land use of FRBG.

Table 8–1. Groundwater Samples Included in the HHRA for Fox Road Burning Ground

Station	Sample ID	Date Collected
FRBG-MW01	FRBGGW1001/FRBGGW9101	5/26/2021
FRBG-MW02	FRBGGW1002	5/26/2021
FRBG-MW03	FRBGGW1003	5/25/2021
FRBG-MW03	FRBGGW1007	11/30/2021
FRBG-MW04	FRBGGW1004	5/25/2021
FRBG-MW04	FRBGGW1008A	11/30/2021
FRBG-MW04	FRBGGW1008B	12/1/2021
FRBG-MW04	FRBGGW1008C	12/2/2021

HHRA = Human Health Risk Assessment
ID = Identifier

Table 8–2. COPCs in Groundwater at Fox Road Burning Ground

Detected Chemical	COPC
Metals	
Aluminum	X
Antimony	X
Arsenic	X
Barium	--
Beryllium	--
Cadmium	X
Calcium	NA
Chromium	--
Cobalt	--
Copper	--
Iron	X
Lead	X
Magnesium	NA
Manganese	X
Nickel	--
Potassium	NA
Silver	--
Sodium	NA
Thallium	X
Vanadium	X
Zinc	--
Aluminum	X
SVOCs	
1-Methylnaphthalene	--
2-Methylnaphthalene	--
Caprolactam	--
Naphthalene	X
Phenanthrene*	--
Phenol	--
Explosives	
1,3,5-Trinitrobenzene	--
2-Amino-4,6-DNT	--
RDX	--
VOCs	
2-Butanone	--
Acetone	--
Toluene	--
Trichloroethene	--

*Screening criteria for pyrene are used as surrogate values for screening phenanthrene.

X = Analyte is identified as a COPC in groundwater.
COPC = Chemical of Potential Concern
DNT = Dinitrotoluene
NA = Analyte detected but no toxicity data are available for evaluation or analyte eliminated as essential nutrient
RDX = Hexahydro-1,3,5-Trinitro-1,3,5-Triazine
SVOC = Semivolatile Organic Compound
VOC = Volatile Organic Compound

Table 8–3. Statistical Summary and Exposure Point Concentrations for Groundwater COPCs at Fox Road Burning Ground

COPC	CAS Number	Freq of Detect	Minimum Detect[b]	Average Result[a,b]	Maximum Detect[b]	Dist.	ProUCL Method	95% UCL from ProUCL	EPC	EPC Basis
Aluminum	7429-90-5	3 / 4	1,100	2,650	4,970	N	95% KM (t) UCL	5,710	4,970	MDC<UCL
Antimony	7440-36-0	2 / 4	1	1.04	1.15	D	Number of Detects<3	--	1.15	MDC
Arsenic	7440-38-2	2 / 4	6	4.56	7.25	D	Number of Detects<3	--	7.25	MDC
Cadmium	7440-43-9	1 / 4	0.385	0.471	0.385	D	Number of Detects<3	--	0.385	MDC
Iron	7439-89-6	3 / 4	3,400	4,890	9,925	N	95% KM (t) UCL	10,100	9,925	MDC<UCL
Lead	7439-92-1	3 / 4	1.2	4.13	9.75	N	95% KM (t) UCL	9.59	4.13[c]	Average[c]
Manganese	7439-96-5	4 / 4	270	405	780	X	95% Chebyshev (Mean, Sd) UCL	951	780	MDC<UCL
Thallium	7440-28-0	2 / 4	0.425	0.533	0.705	D	Number of Detects<3	--	0.705	MDC
Vanadium	7440-62-2	3 / 4	2.2	8.31	16.75	N	95% KM (t) UCL	18.2	16.75	MDC<UCL
Naphthalene	91-20-3	1 / 4	0.1675	0.118	0.1675	D	Number of Detects<3	--	0.1675	MDC

Notes:
All units are micrograms per liter (µg/L)
[a]Average calculated using one-half the detection limit for non-detect results
[b] These values reflect the averaging of duplicates and averaging of samples collected from the same well during different sampling events
[c]The EPC for lead is the calculated average concentration as recommended by USEPA (USEPA 2021a)

-- = No value available
CAS = Chemical Abstracts Service
COPC = Chemical of Potential Concern
EPC = Exposure Point Concentration
KM = Kaplan-Meier statistical method
MDC = Maximum Detected Concentration
UCL = 95% Upper Confidence Limit
USEPA = U.S. Environmental Protection Agency

Distributions:
D = too few detects to determine a distribution
N = normal distribution
X = nonparametric distribution
< = less than

Table 8–4. Exposure Assumptions for HHRA at Fox Road Burning Ground

Exposure Factor	Assumed Value for Resident	
	Adult	Child
Chemical concentration in groundwater (Cgw) (µg/L)	Chemical-specific	
Ingestion rate of groundwater (IR) (L/day)	2.5	0.78
Skin surface area exposed to groundwater (SA) (cm^2)	19,652	6,365
Permeability coefficient (Kp) (cm/hr)	Chemical-specific	
Exposure frequency (EF) (days/year)	350	350
Exposure duration (ED) (years)	20	6
Exposure time (ET) (hours/event)	0.71	0.54
Inhalation exposure time (ET) (hours/day)	24	24
Events (EV) (events/day)	1	1
Body weight (BW) (kg)	80	15
Averaging time – non-cancer (ATn) (days)	NA	2,190
Averaging time – cancer (ATc) (days)	25,550	25,550

Note:
Conversion factors are included in the Appendix G equations

µg = Microgram
HHRA = Human Health Risk Assessment
cm = Centimeter
Hr = Hour
kg = Kilogram
L = Liter
NA = Not Applicable

Table 8–5. Chemical-Specific Exposure and Toxicity Factors

COPC	K_p (cm/hr)	Mutagen	GIABS	SFo $(mg/kg\text{-}day)^{-1}$	IUR $(\mu g/m^3)^{-1}$	RfDo* (mg/kg-day)	Critical Effect/System for RfDo	RfC (mg/m^3)	Critical Effect/System for RfC
Aluminum	1.00E-03	No	1.00E+00	--	--	1.00E+00	Neurological	5.00E-03	Neurological
Antimony	1.00E-03	No	1.50E-01	--	--	4.00E-04	Blood glucose and cholesterol/whole body	3.00E-04	Respiratory
Arsenic	1.00E-03	No	1.00E+00	1.50E+00	4.30E-03	3.00E-04	Cardiovascular and dermal	1.50E-05	--
Cadmium	1.00E-03	No	5.00E-02	--	1.80E-03	1.00E-04	Urinary	1.00E-05	Urinary
Iron	1.00E-03	No	1.00E+00	--	--	7.00E-01	Gastrointestinal	--	--
Lead	NA								
Manganese	1.00E-03	No	4.00E-02	--	--	2.40E-02	Nervous	5.00E-05	Nervous
Thallium	1.00E-03	No	1.00E+00	--	--	1.00E-05	Skin	--	--
Vanadium	1.00E-03	No	2.60E-02	--	--	5.04E-03	Decreased hair cystine/dermal	1.00E-04	--
Naphthalene	4.66E-02	No	1.00E+00	1.20E-01	3.50E-05	2.00E-02	Decreased body weight	3.00E-03	Nervous, respiratory

Note:
All values are from the USEPA RSL table dated May 2022 unless otherwise noted
*RfD_o adjusted based on GIABS to derive RfD

-- = No value available
$\mu g/m^3$ = Micrograms per Cubic Meter
cm/hr = Centimeters per Hour
COPC = Chemical of Potential Concern
GIABS = Gastrointestinal Absorption Factor
IUR = Inhalation Unit Risk
Kp = Permeability Coefficient
mg/kg-day = Milligrams per Kilogram per Day
mg/m^3 = Milligrams per Cubic Meter
NA = Not Available
RfC = Reference Concentration
RfDo = Reference Dose (oral)
RSL = Regional Screening Level
SFo = Cancer Slope Factor (oral)
USEPA = U.S. Environmental Protection Agency

Table 8–6. Risk Characterization for Groundwater at Fox Road Burning Ground Future Hypothetical Resident

COPC	EPC	HQ	ILCR	Was Chemical Identified as a COC	Rationale
Aluminum	4,970	0.2	--	No	HQ < 1; minor contributor to the neurological HI.
Antimony	1.15	0.1	--	No	HQ < 1
Arsenic	7.25	1	1E-04	No	Dissolved results (only one detection) indicate that most of the total concentration is due to particulate matter; maximum dissolved concentration (3.95 µg/L) < total maximum concentration (7.25 µg/L)[a]. In addition, the maximum dissolved result < background criterion and < MCL.
Cadmium	0.385	0.2	--	No	HQ < 1
Iron	9,925	0.7	--	No	HQ < 1
Lead	4.13	--	--	No	IEUBK Lead Model results below benchmark (i.e., <5% probability of exceeding 10 µg/dL blood lead level).
Manganese	780	2	--	No	Dissolved results indicate that particulate matter in the samples contribute to the total concentration; maximum dissolved concentration (580 µg/L) < total maximum concentration (780 µg/L). In addition, the maximum dissolved result < background criterion.
Thallium	0.705	4	--	No	Although total thallium is a predominant contributor to the dermal target organ HI of 5, the maximum concentration is < MCL.
Vanadium	16.75	0.2	--	No	HQ < 1; minor contributor to dermal target organ HI; vanadium was not detected in corresponding filtered sample and not detected in sample collected from same well during different sampling round.
Naphthalene	0.1675	0.03	1E-06	No	HQ<1; cancer risk at the low end of the target risk range.
Total All Chemicals		8	1E-04	--	--

[a]Before the maximum concentrations were determined, duplicate sample results were averaged and samples collected from the same well also were averaged.

-- = Not Applicable
µg/L = Micrograms per Deciliter
COC = Chemical of Concern
COPC = Chemical of Potential Concern
EPC = Exposure Point Concentration
HI = Hazard Index
HQ = Hazard Quotient
ILCR = Incremental Lifetime Cancer Risk
MCL = Maximum Contaminant Level
< = Less than

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9. ECOLOGICAL RISK ASSESSMENT

An ERA was included in the Phase I RI Report. FRBG is approximately 17.2 acres and is vegetated with deciduous shrubland and forest, with portions of three wetlands present on the eastern boundary of the site. Wetlands are considered important ecological resources, and there is documentation of contamination at FRBG, so further analysis was conducted in a Level II ERA. Surface soil data were screened against ESVs recommended in Ohio EPA guidance, and preliminary COPECs were identified for each EU. Preliminary COPECs were further analyzed to determine if ecological risk was probable with the information available. Frequency of detection, average concentration, sample location, migration to wetlands, and impact of recommended human health remediation were considered applicable for each EU. Using this combination of factors, it was determined that there were no final COPECs at FRBG. Consequently, the ERA for FRBG concluded with a Level II Screening ERA, and NFA was recommended to be protective of important ecological resources (Leidos 2018a).

Ecological receptors are not typically exposed to groundwater, with the exception of caves and when groundwater daylights to surface water. No known caves are present at GRC-ATF, and this site does not contain surface water bodies. As a result, ecological exposures to chemicals in the groundwater is not a concern.

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10. CONCLUSIONS

This Phase II RI Report for FRBG presents a detailed analysis of historical site operations and environmental data to assess environmental groundwater impacts of these historical operations. The following sections summarize the site history and description and the major findings of the nature and extent of contamination, contaminant fate and transport, HHRA, and ERA.

A CSM incorporating all pertinent information is presented. The CSM denotes, based on current data, where source areas occur, the mechanisms for contaminant migration from source areas to receptor media (e.g., groundwater), exit pathways from the site, and if COCs occur that may require further evaluation in an FS. This section concludes with recommendations for any further characterization under the RI phase of work and, for groundwater evaluated in this RI, whether to proceed to the FS phase of the RI/FS process.

10.1 SITE HISTORY AND DESCRIPTION

FRBG is located in the east-central portion of GRC-ATF on the northern side of the intersection of Fox Road and Snake Road. (Figure 1-2). FRBG is approximately 17.2 acres, although the exact locations of historical activities and extents are not certain. FRBG currently comprises forest and shrubland on the eastern portion of the site. The western half of the General Area was a mixture of flat, grassy area with some mature trees, areas of heavy shrub/scrub vegetation, and few soil piles. The three wetlands are independent of each other and are only partially inside the eastern boundaries of the General Area and Drainage Ditch. This drainage ditch was dry during the 2015 SI and 2017 Phase I RI and the 2021 Phase II RI field activities.

In addition to being used as burning grounds, FRBG was documented to have also been used as a landfill (SAIC 1991). Referred to as Disposal Area 1B, it is located to the north of the burning ground area, is accessible by a gravel road, and is approximately 5 acres (SAIC 1991). Disposal Area 1B was created by NASA in the 1960s and was not used by the Army. For the purpose of this investigation, FRBG includes Disposal Area 1B. Various types of waste has been observed in this area, including wood, several empty rusted drums, drum bands, transformer insulators, broken glass, nuts, bolts, and gaskets.

The 1995 Record Review (DM 1995) indicates that FRBG was used for “decontamination of Flume Lines on July 10, 1963.” The report also indicates that large numbers and lengths of pipe and other materials were burned during decontamination efforts in the 1960s and that the site, along with others, was used for decontaminating TNT-contaminated pipes.

The 2016 SI Report indicated that decontamination efforts were conducted from approximately 1954 to 1958. The 2016 SI Report (Leidos 2016b) also confirms that decontamination efforts continued from 1963 to 1964. In addition to use as a burning ground, the PBS PA identified FRBG as a landfill. Reportedly, waste was deposited randomly within this area, although NASA personnel questioned about this disposal area were unfamiliar with its use and sources contributing to its use.

FRBG currently has no structures. However, the remains of a suspected maintenance area (large concrete slab, two shallow pits with steps) are located in the forested area at the western portion of the site.

10.2 SUMMARY OF PREVIOUS INVESTIGATIONS AND DATA USE

The following assessments and evaluations included FRBG:

- PBS PA (SAIC 1991), which included FRBG as part of the OU4 Burning Grounds evaluation, as well as OU11 Disposal Area 1B;

- 1994 SI (MK 1994), which included FRBG as part of PMU 4 Lindsley Ditch; and
- 1995 Records Review Report (DM 1995), which provided the site history, potential sources, and environmental investigations of FRBG, which was identified as the "Additional Burning Ground."

The GRC-ATF Multi-site SI was conducted in August 2015. The SI activities at FRBG included drilling 18 soil borings and collecting 27 surface soil samples and 29 subsurface soil samples. All soil samples were analyzed for VOCs, SVOCs, herbicides, pesticides, PCBs, explosives, and TAL metals. Surface soil was also analyzed for asbestos.

To supplement the 2015 SI, a Phase I RI was conducted in January 2017 to complete a data set that fully characterizes the nature and extent of soil, surface water, and sediment contamination; assesses potential soil to groundwater impacts; and provides data to update and complete the HHRA and ERA.

Sixteen surface soil samples were collected (FR-1 to FR-16). No additional sediment or surface water samples were planned. Consistent with the observations during the 2015 SI, surface water was not present in the drainage ditch. Two temporary wells (FR-MW-1 and FR-MW-2) were installed to 10 feet bgs during field activities. Groundwater was collected from these wells and analyzed for SVOCs, TAL metals, pesticides, and PCBs. In addition, an Asbestos Hazard Evaluation Specialist conducted a site assessment. Thirteen surface soil samples were analyzed for asbestos content. Non-detectable concentrations of asbestos were detected at all sample locations. In addition, black tar was identified within this EU. The field reconnaissance determined this material to be non-friable, and the laboratory analytical results showed that non-detectable asbestos fibers were within this material.

Based on the Phase I RI results, FRBG was adequately characterized, and further investigation was not warranted to complete the RI for surface and subsurface soil. No COCs are identified at the General Area. No COPCs were identified at the Concrete Pits; therefore, no COCs were identified. No COCs were identified in surface soil at the Drainage Ditch under both the residential and industrial scenarios.

The ERA determined that there are no final COPECs at FRBG.

The Phase I RI concluded NFA is required to address chemical contamination within soil at FRBG. Asbestos sampling at FRBG indicated 1 of 27 samples contained chrysolite asbestos at less than 1 percent. No other asbestos was detected. Based on sampling results, additional ACM assessment is not warranted and NFA was recommended for ACM. However, it is NASA's policy to assess and remove all detectable asbestos at GRC-ATF.

The Phase I RI Report recommended a Phase II RI be conducted to collect and assess groundwater data at FRBG. In addition, various types of waste and debris was observed at FRBG, including a rusty steel drum and vertical pipe, primarily in the areas of sample locations FRBG-SL-016 and FRBG-SL-017. Although this area was not identified as having chemical contamination posing a risk to human health or the environment, it was recommended that the removal and disposal of this debris be included in site remedial activities.

10.3 SUMMARY OF NATURE AND EXTENT OF GROUNDWATER CONTAMINATION

Seven groundwater samples were collected at FRBG, including one field duplicate. Four primary samples and one field duplicate were collected during the May 2021 sampling event and two primary samples were collected during the November 2021 sampling event. Section 6 summarizes the nature and extent of contamination.

In groundwater, 21 metals, 6 SVOCs, 3 explosives, and 4 VOCs were detected. No PCBs were detected. The explosives, VOCs, and five of the six SVOCs were detected at concentrations below the risk screening criteria. Nine of the 21 metals (aluminum, antimony, arsenic, cadmium, iron, lead, manganese, thallium, and vanadium) and one SVOC (naphthalene) exceeded their respective background concentrations, MCL, and/or the tap water RSL at an HQ of 0.1 and a TR of 1E-06.

The sampling rationale for each groundwater sampling location was to assess potential impacts to overburden groundwater within or downgradient from the soil EU source area. During the Phase I RI, conservative transport modeling indicated 11 chemicals may leach from soil and migrate to the groundwater table beneath their respective sources at concentrations exceeding MCLs/RSLs. A qualitative assessment of the sample results was performed during the Phase I RI and concluded that without available groundwater data, seven CMCOCs (2,4,6-TNT; 2,4-DNT; 2,6-DNT; 2 amino-4,6-DNT; 4-amino-2,6-DNT; naphthalene; and beta-hexachlorocyclohexane) should be assessed during future groundwater studies at the site (Leidos 2018a). Of the 11 chemicals from the transport modeling, only naphthalene was detected in groundwater above the tap water RSL. Pesticides were not included in the analytical suite at FRBG because pesticide analyte surface and subsurface soil samples results did not exceed their respective background concentrations or resident regional screening levels.

Nine inorganics (aluminum, antimony, arsenic, cadmium, iron, lead, manganese, thallium, and vanadium) exceeded their respective background concentrations and/or the tap water RSL in groundwater at FRBG. Aluminum and antimony exceedances were limited to FRBG-MW03 and FRBG-MW04 located in and to the north of the Subsurface Debris Area. Aluminum and antimony were only detected above screening criteria during the November 2021 sampling event at these wells. Total arsenic exceeded screening criteria at FRBG-MW03 in November 2021 and at FRBG-MW-04 during both events, however, only the November 2021 concentration at FRBG-MW03 exceeded the MCL. The single cadmium (total) exceedance was limited to the November 2021 sample collected at FRBG-MW03 located in the Subsurface Debris Area, but the concentration was below the MCL. Total iron exceeded the screening criteria at three of the four sampling locations: FRBG-MW02 (May 2021), FRBG-MW03 (November 2021), and FRBG-MW04 (November 2021). None of the filtered iron results exceeded the tap water RSL. Total and dissolved lead only exceeded screening criteria at one location (FRBG-MW03 location in the Subsurface Debris Area) in November 2021. Total manganese exceeded the tap water RSL in all sampling locations, but concentrations were only above the corresponding background concentration at FRBG-MW01 in May 2021. Total thallium exceeded screening criteria during the November 2021 event at FRBG-MW03 and FRBG-MW-04. Dissolved thallium only exceeded screening criteria in May 2021 at FRBG-MW01. Vanadium exceedances were limited to two locations (FRBG-MW03 and FRBG-MW-04) during the November 2021 event; only total vanadium exceeded screening criteria. Most metal exceedances were at FRBG-MW03, which is located in the Subsurface Debris Area and cross/upgradient of FRBG-MW01 and FRBG-MW02.

Naphthalene was the only organic constituent detected above screening criteria at FRBG. Naphthalene was only detected at FRBG-MW-03 during the November 2021 sampling event at a concentration of 0.24 µg/L, exceeding the tap water RSL of 0.12 µg/L. Naphthalene was not detected in any of the other samples; however, the detection limits ranged from 0.19 to 0.22 µg/L, which are above the RSL.

The groundwater in the overburden is in discontinuous pockets during dry time periods. Since most metals and the naphthalene concentration exceedances were at FRBG-MW03, which is located to the east of the other wells sampled in the General Area EU, it appears the extent of the contaminants in the FRBG groundwater has been adequately characterized. Naphthalene is the only CMCOC identified in the Phase I RI that was detected in the groundwater above screening criteria.

10.4 SUMMARY OF CONTAMINANT FATE AND TRANSPORT

During the Phase I RI, SRCs were evaluated through the stepwise fate and transport evaluation. Evaluation of modeling results identified the following initial CMCOCs for soil: mercury; 2,4,6-TNT; 2,4-DNT; 2,6-DNT; 2-amino-4,6-DNT; 4-amino-2,6-DNT; PETN; benzaldehyde; naphthalene; beta-hexachlorocyclohexane; and dalapon. These chemicals were predicted to exceed the screening criteria in groundwater beneath the source area. The qualitative assessment eliminated mercury, PETN, benzaldehyde, and dalapon as final CMCOCs. The other seven initial CMCOCs (2,4,6-TNT; 2,4-DNT; 2,6-DNT; 2 amino-4,6-DNT; 4-amino-2,6-DNT; naphthalene; and beta-hexachlorocyclohexane) were retained for consideration, and groundwater sampling was recommended to fully characterize FRBG (Leidos 2018a).

Explosives were not detected in groundwater above screening criteria, and samples were not analyzed for beta-hexachlorocyclohexane at FRBG during the Phase II RI because pesticide analyte surface and subsurface soil samples results did not exceed their respective background concentrations or resident regional screening levels. The only SRCs present in groundwater at FRBG include metals and naphthalene. Based on the information presented in Section 7, contaminant leaching from soil to the water table (vertical migration) and mixing with groundwater beneath the source is contaminant release mechanism and migration pathway identified at FRBG.

One of the principal migration pathways at the site is percolation through the unsaturated soil to the water table (i.e., vertical leaching of contaminants from soil into groundwater). The rate of percolation is controlled by soil cover, ground slope, saturated conductivity of the soil, and meteorological conditions. Once the contaminant leachate percolates through the soil and reaches the water table, it mixes with groundwater beneath the source. The potential receptor location would be a hypothetical domestic water well beneath the site. However, because of the heterogeneous nature of the unconsolidated glacial material, groundwater flow patterns within unconsolidated soil are difficult to predict. The presence of inorganics above screening levels in groundwater either leached from soil prior to previous investigations or are naturally occurring. The presence of naphthalene above screening levels, although only at one location and at low concentrations, leached from soil.

10.5 SUMMARY OF HUMAN HEALTH RISK ASSESSMENT

The HHRA documents the potential health risks to humans resulting from exposure to groundwater contamination within FRBG. The HHRA was performed consistent with previous GRC-ATF HHRAs and is based on USEPA and Ohio EPA guidance.

GRC-ATF is expected to remain under NASA's control for the foreseeable future. Although it is unlikely that FRBG will be developed for residential purposes, a hypothetical onsite residential scenario was included to represent unrestricted use and evaluate the upper bound for long-term exposure. Generally, sites that "pass" a residential risk assessment can be released for use without restriction. FRBG is best classified as an inactive area and plausible receptors include groundskeepers and hunters. No groundwater at GRC-ATF is used for drinking water under current or planned future use. The GRC Master Plan (NASA 2008) states the following: *"Groundwater underlying PBS shall not be extracted or used for any purpose, potable or otherwise, except for investigation, monitoring or remediation of groundwater, or in conjunction with construction or excavation activities or maintenance of subsurface utilities."*

The groundwater exposure routes evaluated in the HHRA include ingestion, dermal contact, and inhalation (associated with the household use of water). Groundwater data for VOCs also were screened for potential impacts associated with the vapor intrusion pathway. Risks were calculated for both cancer and non-cancer effects. Lead exposures were evaluated for the resident child using USEPA's IEUBK model, which is used to predict the relative increase in blood lead concentration that might result from environmental exposure.

For hypothetical residential land use, the total resident child HI for groundwater (8) exceeds the target of 1. Because the total HI exceeds 1, the chemicals were segregated according to target organ or system and an HI was calculated for each target organ. The following target organ HIs exceed the target of 1 for the resident child: the HI of 2 for neurological effects (due to manganese and to a lesser extent aluminum) and for the HI of 5 for dermal effects (due to thallium [4], arsenic [1], and vanadium [0.2]). The total ILCR of 1E-04 for groundwater exposure is at the upper bound of the target cancer risk range and is associated almost entirely with arsenic. The lead model results for the resident child show that there would be a 0.2 percent probability that the blood-lead concentration would exceed 10 µg/dL, which is less than the USEPA target.

Upon further evaluation of the groundwater data by comparing detected concentrations with background levels and the concentrations detected in filtered samples, none of the COPCs were identified as a COC for groundwater.

10.6 SUMMARY OF ECOLOGICAL RISK ASSESSMENT

An ERA was included in the Phase I RI Report. FRBG is approximately 17.2 acres and is vegetated with deciduous shrubland and forest, with portions of three wetlands present on the eastern boundary of the site. Wetlands are considered important ecological resources, and there is documentation of contamination at FRBG, so further analysis was conducted in a Level II ERA. It was determined that there were no final COPECs at FRBG. Consequently, NFA was recommended to be protective of important ecological resources (Leidos 2018a).

Ecological receptors are not typically exposed to groundwater except for caves and when groundwater daylights to surface water. No known caves are at GRC-ATF, and this site does not contain surface water bodies. As a result, ecological exposures to chemicals in the groundwater is not a concern.

10.7 CONCEPTUAL SITE MODEL

Section 1.3 presents the CSM associated with FRBG, including the contamination sources, exposure pathways, human receptors, and ecological resources. In addition, Figure 1-3, providing the pathway network receptor diagram, was updated to support the groundwater HHRA. This section updates the CSM and discusses potential risk identified, data gaps, and uncertainties.

10.7.1 Groundwater Contaminant Migration Pathways and Exit Points

The general flow of groundwater in overburden is to the north toward Lake Erie, largely mirroring surface topography. The flow also corresponds generally to the topography of the top of the bedrock. In contrast, the Delaware Limestone water-bearing zone is saturated year-round but also flows to the north-northeast toward Lake Erie. Saturated soil occurs within unconsolidated glacial overburden at an estimated range of 3.4 to 4.5 feet bgs. Groundwater discharge to surface water features (e.g., via base flow to streams or springs) does not occur within the site boundary.

Contaminant leaching pathways from soil to the water table are through silty clay loam and loamy sand unconsolidated soil. Groundwater sampling results indicated that only one of the seven initial CMCOCs (2,4,6-TNT; 2,4-DNT; 2,6-DNT; 2 amino-4,6-DNT; 4-amino-2,6-DNT; naphthalene; and beta-hexachlorocyclohexane) were not detected in groundwater above screening criteria. Explosives were not detected in groundwater above screening criteria and samples were not analyzed for beta-hexachlorocyclohexane at FRBG during the Phase II RI because pesticide analyte surface and subsurface soil samples results did not exceed their respective background concentrations or resident regional screening levels. Naphthalene is the only CMCOC identified in the Phase I RI that was detected in the groundwater above screening criteria. Nine inorganics (aluminum, antimony, arsenic, cadmium, iron, lead, manganese, thallium, and vanadium) and naphthalene exceeded their respective background concentrations and tap water RSLs in groundwater at FRBG. Based on the results of the HHRA, no COCs were identified in groundwater.

10.7.2 Potential Receptors

GRC-ATF is expected to remain under the control of NASA for the foreseeable future. Although it is unlikely that FRBG will be developed for residential purposes, a hypothetical onsite residential scenario was included to evaluate the upper bound for long-term exposure. Generally, sites that "pass" a residential risk assessment can be released for use without restriction.

No groundwater at GRC-ATF is used for drinking water, and no injection wells are onsite. The Erie County Health Department does not allow the use of surface water as private drinking water. Prior to transfer or conveyance of GRC-ATF or any portion thereof, the General Services Administration and NASA shall ensure that the prospective purchaser or transferee: i) is aware of the environmental conditions of the property; and ii) agrees, as a condition of the purchase/transfer, to enter into an environmental covenant with the state of Ohio prohibiting the extraction or use of groundwater underlying GRC-ATF for any purpose, potable or otherwise, except for investigation, monitoring, or remediation of groundwater, or in conjunction with construction or excavation activities or maintenance of subsurface utilities.

10.7.3 Uncertainties

Uncertainties are inherent in the CSM depending on the density and availability of data. The CSM for FRBG groundwater is overall well defined using existing data, and no major data gaps remain to be resolved. However, some uncertainties for the CSM for FRBG include some SRCs were identified due to the lack of background concentration data available or having limited or slight exceedances of established background concentrations.

10.8 EMERGING CONTAMINANTS

As presented in Section 2.4, FRBG was one of the eight AOPCs at GRC-ATF where NASA is assessing potential PFAS contamination. The assessment is being conducted under a separate investigation; therefore, a PFAS evaluation is not included in this RI. The results of the investigation can be viewed in the PFAS SI Report (Leidos 2022).

10.9 RECOMMENDATIONS OF THE PHASE II REMEDIAL INVESTIGATION

This Phase II RI only evaluated groundwater at FRBG as soil was evaluated in the Phase I RI. Based on the Phase II RI results, FRBG groundwater has been adequately characterized, and further investigation is not warranted to complete the RI for groundwater. The nature and extent of potentially impacted media has been sufficiently characterized. Emerging contaminants will continue to be evaluated separately.

The HHRA did not identify any COCs with residential use of groundwater at FRBG. Ecological exposures to chemicals in the groundwater is not a concern.

NFA was recommended to address chemical contamination within soil at FRBG. Since no COCs were identified with residential use of groundwater at FRBG, NFA is also recommended for groundwater.

However, it is recommended that the soil RSLs used in the Phase I RI be compared to current RSLs to determine if any additional COCs are present in surface and subsurface soils.

During the 2015 SI, an Asbestos Hazard Evaluation Specialist performed a site assessment. The assessment soil sample results indicated 1 of the 25 soil samples collected contained asbestos, which had a concentration of 0.5 percent chrysotile. Asbestos sampling during the 2017 Phase I RI at FRBG indicated 1 of 27 samples contained chrysolite asbestos at less than 1 percent. No other asbestos was detected. Based on sampling results, additional ACM assessment is not warranted, and NFA was recommended for ACM. However, it is NASA's policy to assess and remove all detectable asbestos at GRC-ATF. Therefore, it is recommended that an FS be completed for the asbestos contamination at FRBG.

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