FINAL

PHASE II REMEDIAL INVESTIGATION REPORT FOR SNAKE 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

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8866 Commons Boulevard, Suite 201
Twinsburg, Ohio 44087

October 13, 2022

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LIST OF ACRONYMS

µg/dL	Micrograms per Deciliter
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
BHC	Hexachlorocyclohexane
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Register
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
FR	Federal Register
FRBG	Fox Road Burning Ground
FS	Feasibility Study
GAC	Granulated Activated Carbon
GIABS	Gastrointestinal Absorption Fraction
gpm	Gallons per Minute
GRC	Glenn Research Center
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
LBP	Lead-based Paint
LOAEL	Lowest-Observable-Adverse-Effect Level
MCL	Maximum Contaminant Level
MDC	Maximum Detected Concentration
MS	Matrix Spike
MSD	Matrix Spike Duplicate
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
ODNR	Ohio Department of Natural Resources
Ohio EPA	Ohio Environmental Protection Agency
ORP	Oxidation Reduction Potential
OU	Operable Unit
PA	Preliminary Assessment
PBOW	Plum Brook Ordnance Works
PBS	Plum Brook Station
PCB	Polychlorinated Biphenyl
PFAS	Per- and Polyfluoroalkyl Substances
PMU	Project Management Unit
ppb	Parts per Billion
PVC	Polyvinyl Chloride
QC	Quality Control
RCRA	Resource Conservation and Recovery Act
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
SVOC	Semivolatile Organic Compound

LIST OF ACRONYMS (Continued)

TAL	Target Analyte List
TNB	Trinitrobenzene
TNT	Trinitrotoluene
TPH	Total Petroleum Hydrocarbons
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

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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 Snake Road Burning Ground (SRBG) and provides conclusions and recommendations regarding the evaluation of groundwater data collected from the investigation activities.

Groundwater was not previously evaluated at SRBG 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 2020b).

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

- Installation and development of three permanent groundwater monitoring wells (SRBG-MW01, SRBG-MW02, and SRBG-MW03);
- Development of two existing monitoring wells (GCL-MW01 and GCL-MW03); and
- Two seasonal groundwater sampling events, each consisting of the three new wells plus two existing wells sampled for metals, explosives, volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), pesticides, 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 identified in subsurface soils at SRBG as part of the Phase I RI or groundwater in Phase II. Evidence determined that vapor points were not warranted at SRBG.

ES-1 SUMMARY OF NATURE AND EXTENT

During the Phase I RI for SRBG, the site was divided into three exposure units (EUs) to allow for refined evaluation of potential chemical contamination and potential exposure. These EUs were the Primary Burn Area, Secondary Burn Area, and Drainage Ditch. In addition, the area identified as the Fire Training Pit had its own focused evaluation. The sampling rationale for each groundwater sampling location was to assess potential impacts to overburden groundwater within or downgradient from the EU source area. Conservative transport modeling in the Phase I RI indicated 13 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 13 chemicals included inorganics (silver), explosives (2,4,6-trinitrotoluene [TNT]; 2,4-dinitrotoluene [DNT]; 2,6-DNT; 2-amino-4,6-DNT; and 4-amino-2,6-DNT), SVOCs (1,1'-biphenyl, benzaldehyde, caprolactam, hexachloroethane, and naphthalene), and pesticides (alpha-hexachlorocyclohexane and beta-hexachlorocyclohexane). A qualitative assessment of the sample results was performed, and the limitations and assumptions of the models were considered to determine if any soil contaminant migration chemicals of concern (CMCOCs) were present in soil at SRBG that may potentially impact groundwater. This qualitative assessment concluded that without available groundwater data, two initial CMCOCs (hexachloroethane and naphthalene) should be assessed during future groundwater studies at the site (Leidos 2018a). Of the 13 chemicals from the transport modeling, only caprolactam was detected in groundwater, but concentrations were below the tap water RSL.

Only seven total inorganics (aluminum, arsenic, cadmium, iron, lead, thallium, and vanadium) exceeded their respective background concentrations and/or the tap water RSL in groundwater at SRBG. Total and filtered aluminum exceedances were limited to GCL-MW03 located in the Secondary Burn Area. Total arsenic only exceeded screening criteria at GCL-MW03 in November 2021. All seven detected dissolved arsenic results exceeded the RSL, but only the June 2021 sample at SRBG-MW02 exceeded the background concentration. The single cadmium (total) exceedance was limited to the November 2021 sample collected at SRBG-MW01 located in the Primary Burn Area. None of the total cobalt concentrations were above background concentrations, and 9 of the 10 dissolved cobalt concentrations exceeded the tap water RSL but were below the corresponding background concentration. Total iron exceeded the screening criteria at four of the five sampling locations: GCL-MW03 (May and November 2021), SRBG-MW01 (June 2021), SRBG-MW02 (December 2021), and SRBG-MW03 (June and December 2021). Four filtered iron results exceeded the tap water RSL at GCL-MW03 (November 2021), SRBG-MW-02 (December 2021), and SRBG-MW03 (December 2021). Total and dissolved lead only exceeded screening criteria at one location (GCL-MW03 location to the west of the Primary Burn Area) in November 2021. Dissolved manganese exceeded the tap water RSL in at least one sample at all sampling locations, but all concentrations were below the corresponding background concentration. Total thallium exceeded screening criteria during both events at GCL-MW03 and only in December 2021 at SRBG-MW01, SRBG-MW02, and SRBG-MW03. Dissolved thallium exceeded screening criteria in May 2021 at GCL-MW01, in November 2021 at GCL-MW03, and in December 2021 at SRBG-MW02 and SRBG-MW03. Vanadium exceedances were limited to one location (GCL-MW03) during both events; both total and dissolved vanadium exceeded screening criteria in November 2021, and only total vanadium exceeded criteria in May 2021. Most metal exceedances were at GCL-MW03, which is located west of the site and cross/upgradient of the other wells.

The groundwater in the overburden is in discontinuous pockets during dry time periods. During wet periods, the general flow direction in the overburden water-bearing zone is radially to the north from SRBG, largely mirroring surface topography (Shaw 2005). Since most metal concentration exceedances were at GCL-MW03, which is located to the west-southwest of the other wells sampled, it appears the extent of the contaminants in the SRBG groundwater has been adequately characterized. In addition, none of the CMCOCs identified in the Phase I RI were detected in the groundwater above screening criteria.

ES-2 SUMMARY OF FATE AND TRANSPORT

The Phase I RI fate and transport evaluation identified hexachloroethane and naphthalene for future groundwater evaluation to assess the modeling results. Hexachloroethane and naphthalene were not detected in groundwater at SRBG during the Phase II RI. Only inorganic site-related chemicals (SRCs) exist in groundwater at SRBG. Contaminant leaching from soil to the water table (vertical migration) and mixing with groundwater beneath the source is the contaminant release mechanism identified at SRBG.

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. In addition, the CMCOCs identified in the Phase I RI were not detected in groundwater above screening criteria. The presence of the inorganic chemicals above screening levels in groundwater either leached from soil prior to previous investigations or are naturally occurring.

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 SRBG. The HHRA was performed consistent with previous Plum Brook Station (PBS) 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 SRBG 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. SRBG is best classified as an inactive area, and plausible receptors include groundskeepers and hunters. No groundwater at PBS 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 and dermal contact. Risks were not calculated for the inhalation pathway because none of the chemicals of potential concern (COPCs) has sufficient information to develop a toxicity value for inhalation effects. 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 (9) 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 aluminum) and the HI of 6 for dermal effects (due to arsenic [0.9], thallium [4], 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 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.

No COCs were identified with residential use of groundwater at SRBG. Although arsenic is associated with a cancer risk at the upper bound of the target cancer risk range (i.e., 1E-04) and a hazard quotient (HQ) close to the target of 1, it was not identified as a COC due to its presence at levels comparable to background. Aluminum and vanadium also were not identified as COCs due to lower concentrations detected seasonally in the same well, significant reduction of concentrations in the filtered samples, uncertainty associated with use of a provisional toxicity value, and/or low HQ (0.2 for vanadium). Thallium was not identified as a COC due to uncertainty associated with the toxicity value and because the maximum detected concentration is below the MCL.

Since no vapor forming COCs were detected in soil and vapor forming chemicals were not detected above vapor intrusion screening levels (VISLs) during the first or second round of groundwater sampling, soil gas in not a concern at SRBG.

ES-4 SUMMARY OF ECOLOGICAL RISK ASSESSMENT

An ecological risk assessment (ERA) was completed and detailed in the Phase I RI Report. SRBG is approximately 9.9 acres and is vegetated with dry herbaceous field, with four small wetlands scattered in the interior of the site. A plant management area (Central Meadows) and a rare plant species and its habitat also occur within SRBG. Wetlands, rare species and their habitat, and specially designated natural areas are considered important ecological resources; since documentation of contamination at SRBG exists, further analysis was conducted in a Level II ERA. It was determined that cadmium; lead; mercury; PCB-1260; and 2,6-DNT were final chemicals of potential ecological concern (COPECs) at the Primary Burn Area EU at SRBG (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 exposure 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 SRBG, since soil was evaluated in the Phase I RI. Based on the Phase II RI results, SRBG 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 SRBG. Ecological exposures to chemicals in the groundwater is not a concern.

A Feasibility Study (FS) addressing soil contamination at SRBG was prepared in 2018 (Leidos 2018c). The recommended alternative was excavation and offsite disposal. Since no COCs were identified with residential use of groundwater at SRBG, no additional recommendations are warranted for the FS 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 and if the remedial cleanup goals in the FS need to be updated.

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 Snake Road Burning Ground (SRBG) 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 SRBG 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 1992, a Phase I Site Characterization was performed at SRBG, at the time identified as "Disposal Area Three." This Phase I Site Characterization was summarized in the *Phase I Site Characterization of Disposal Area Three, Plum Brook Station, Ohio* (H+GCL 1992; herein referred to as the Phase I Site Characterization Report), which also provides the most detailed site history of SRBG to date.

In August 2015, a Site Investigation (SI) of soil, sediment, and surface water was performed at SRBG. 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 SRBG.

In March 2018, the Phase I RI Report (Leidos 2018a) evaluated soil, sediment, and surface water at SRBG. The Phase I RI Report recommended a Phase II RI be conducted to collect and assess groundwater data at SRBG. This Phase II RI report evaluates groundwater and soil gas at SRBG. Two rounds of groundwater sampling were performed in May and December 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 two 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 was 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).

NASA currently operates GRC-ATF as a space research facility in support of GRC. Most of the aerospace testing facilities built in the 1960s at 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 Snake Road Burning Ground

1.2.2.1 Site Description

SRBG is west of the current Snake Road and north of West Scheid Road (Figure 1-2). During operational activities, Snake Road (herein referred to as Old Snake Road) went through SRBG. Since operational activities, Snake Road was re-routed and is now 810 feet east of the eastern edge of the Secondary Burn Area.

As noted in the U.S. Army Corps of Engineers (USACE) *Records Review Report for Plum Brook Ordnance Works* (DM 1995; herein referred to as the 1995 Records Review Report), a 1944 historical drawing describes SRBG as being 100 feet wide by 200 feet long and oriented in a north-south direction. The southwestern corner of the burn ground was located approximately 800 feet north of the intersection of West Scheid Road and Old Snake Road. The drawing indicates the burn ground was accessed by a 10-foot wide driveway at its northwestern corner extending 50 feet due west to the unpaved Old Snake Road, and a 4-foot berm surrounded the burn area with an 8-inch-diameter drainage tile in the northeastern corner. Drainage was indicated to be to a ditch flowing north from the burn area to “sufficient outlet.” The drawing shows a graded slope within the burn pit of 0.4 percent south to north and 4 percent east and west to the centerline. Proposed burning spots were specified as having a 4-inch sand base and a 4-inch cinder top.

SRBG is currently vegetated with dry herbaceous field, with four small wetlands scattered in the interior of the site. A plant management area (Central Meadows) and a rare plant species and its habitat also occur within SRBG. One drainage ditch exists at the site, northeast of the former burn area (Figure 1-2). The drainage ditch was dry in the 2015 SI and 2017 RI field activities.

SRBG currently has no structures. However, as discussed in subsequent sections, debris was identified at the site. Metal debris (shredded steel drum, steel drum lid, and steel posts) and cinder blocks were observed, and some asbestos-containing material (ACM) identified as transite (off-white fibrous material and tan cementitious material) were identified.

1.2.2.2 Historical Usage

(Note: Of the identified historical documents associated with SRBG, the Phase I Site Characterization Report [H+GCL 1992] provides the most detailed site history of SRBG. This section was taken, in large part, from this report.)

SRBG had two distinct uses, as summarized below. These two uses were for burning in the Primary Burn Area and Secondary Burn Area and fire training in a Fire Training Pit. Figure 1-3 was provided in the Phase I Site Characterization Report (H+GCL 1992) and illustrates the configuration of the historical use based on a 1964 aerial photograph, 1970 domestic water system section map, and 1944 Scheid Road Burning Ground reference drawing.

Burn Area

The Army used the area east of Old Snake Road from 1941 to 1963 for burning explosives during PBOW decommissioning. This area was assumed to be contained by a dike around the perimeter. The volume of explosives destroyed in this area is unknown; however, hazardous substances that the Army destroyed at the burning grounds included materials contaminated with DNT, TNT, pentolite, and asbestos.

The NASA burnable dump area was on the eastern side of Old Snake Road and was surrounded by a diked containment area, which is no longer present. Waste generated during NASA's decontamination and decommissioning (D&D) efforts that was contaminated or potentially contaminated with explosives or acids was also burned at SRBG. Other hazardous materials that NASA disposed of at SRBG may have included waste oils, solvents, and other chemicals. Common practice was to accumulate combustible/explosive waste in the burn pit and douse it with chemical waste prior to setting the waste pile on fire. The types and volumes of waste disposed of in this manner were not documented.

On May 14, 1973, a fire occurred at SRBG. The probable cause was stated to be either spontaneous combustion due to chemicals and oils dumped together or discarded smoking materials.

This area was also used during NASA's tenure for destroying combustible, non-contaminated solid waste (e.g., wood and paper-type debris). A wire cage, which was onsite during the Phase I Site Characterization but has since been removed, was reportedly used to store combustible materials such as paper and cardboard prior to burning. It was also reported that metal, electrical equipment, wiring, rags, cardboard, and paper were burned in this area. The NASA burnable dump was used throughout the 1960s and possibly to the mid-1970s; leftover unburned debris was periodically removed from the site. In the late 1970s, ash was removed from the burn pit and buried near Line Road 16 and North Magazine Road; the burn pit was then backfilled.

Fire Training Area

The Fire Training Pit, which was located on the western side of Old Snake Road, was constructed in the early 1960s and was used by onsite personnel during fire training exercises. These exercises were performed by partially filling the training pit with water and waste oil and/or diesel fuel. The oil was ignited, and the fire was extinguished with either dry powder or carbon dioxide. The *Plum Brook Station Preliminary Assessment* (SAIC 1991; herein referred to as the PBS Preliminary Assessment [PA]) indicated foam was also used to suppress the fire. The Fire Training Pit was also used to extinguish materials that were ignited in small metal pans to simulate small-scale fires. Solvents were also reportedly placed in the pit and burned. The volumes and types of solvents and waste oils disposed of in this manner were not documented, and this practice was typically in conjunction with onsite firefighting training conducted in the pit.

In addition to fire training, the pit was used on at least two occasions to dispose of solid and explosive waste. On one occasion, the pit was used to dispose of fuel oil filters. The filters were placed in the pit and set on fire to burn the fuel off. Remaining metal pieces associated with the filters were removed from the pit and disposed of as landfill waste. On the other occasion, in approximately 1971, the pit was used to dispose of a small amount of Class C explosives. Some metal pieces, which were not detonated during the process, remained after the explosives were burned and were removed from the pit for disposal as landfill waste.

1.3 CONCEPTUAL SITE MODEL

This section provides additional information to support and present the CSM for use in the assessment and cleanup of SRBG. This CSM presents the contamination sources, exposure pathways, human receptors, and ecological resources. Section 1.2.2.1 presents the site descriptions (history and current conditions), Section 2.0 presents environmental assessments and how data gaps were filled to complete the RI, and Section 3.0 presents the GRC-ATF and site-specific physical characteristics.

1.3.1 Potential Sources

SRBG 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.

The source medium or secondary source is surface and subsurface soil that was potentially contaminated from burning the primary source material. It was noted in historical documents that ash was previously removed from the burn pit, and the burn pit was then backfilled.

1.3.2 Potential Receptors

The following sections discuss potential human and ecological resources at SRBG. Figure 1-4 presents the pathway network receptor diagram to support the SRBG human health risk assessment (HHRA) and ecological risk assessment (ERA).

1.3.2.1 Human Receptors

SRBG 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 SRBG 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 SRBG 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 SRBG.

1.3.2.2 Ecological Resources

SRBG is dominated by terrestrial resources and primarily consists of a large grass field with areas of thick shrub/scrub vegetation and a large grass field with areas of thick shrub/scrub vegetation.

SRBG 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, thus the medium in the ditch was classified as soil instead of sediment. The wetlands at the site are ephemeral in nature.

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 2.0 summarizes previous assessments, evaluations, and investigations at the site.
- Section 3.0 describes the environmental setting, including the topography, meteorology, hydrology, geology, soil, hydrogeology, demography, water resources, and ecology.
- Section 4.0 describes the methods used to perform the Phase II data collection activities.
- Section 5.0 presents the data use, quality, and evaluation methods to support this Phase II RI.
- Section 6.0 discusses the occurrence and distribution of groundwater contamination at the site.
- Section 7.0 presents an evaluation of contaminant fate and transport.
- Section 8.0 includes the methods and results of the HHRA.
- Section 9.0 includes a discussion of the ERA.
- Section 10.0 provides the conclusions and recommendations of this Phase II RI.
- Section 11.0 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

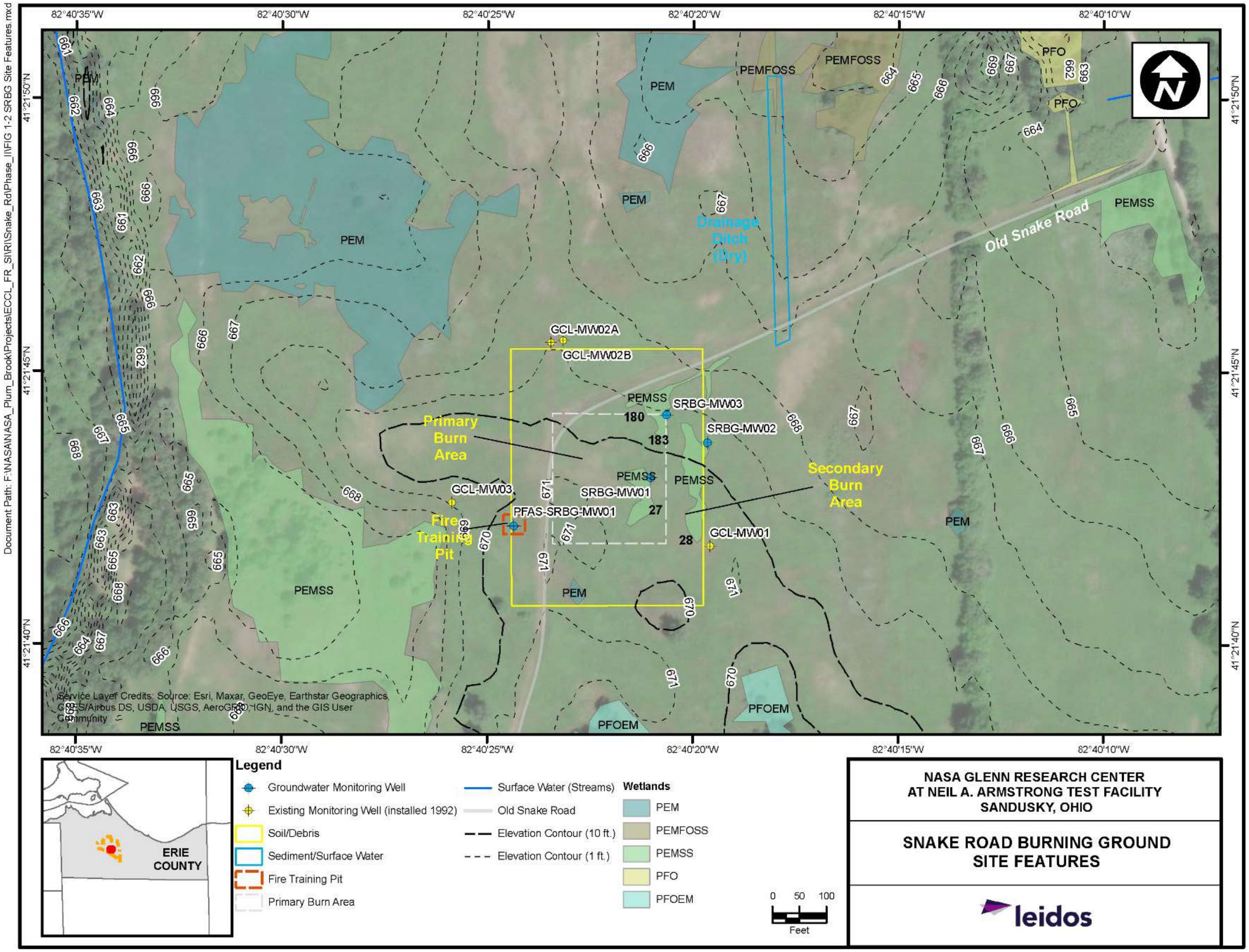


Figure 1–2. Snake Road Burning Ground Site Features

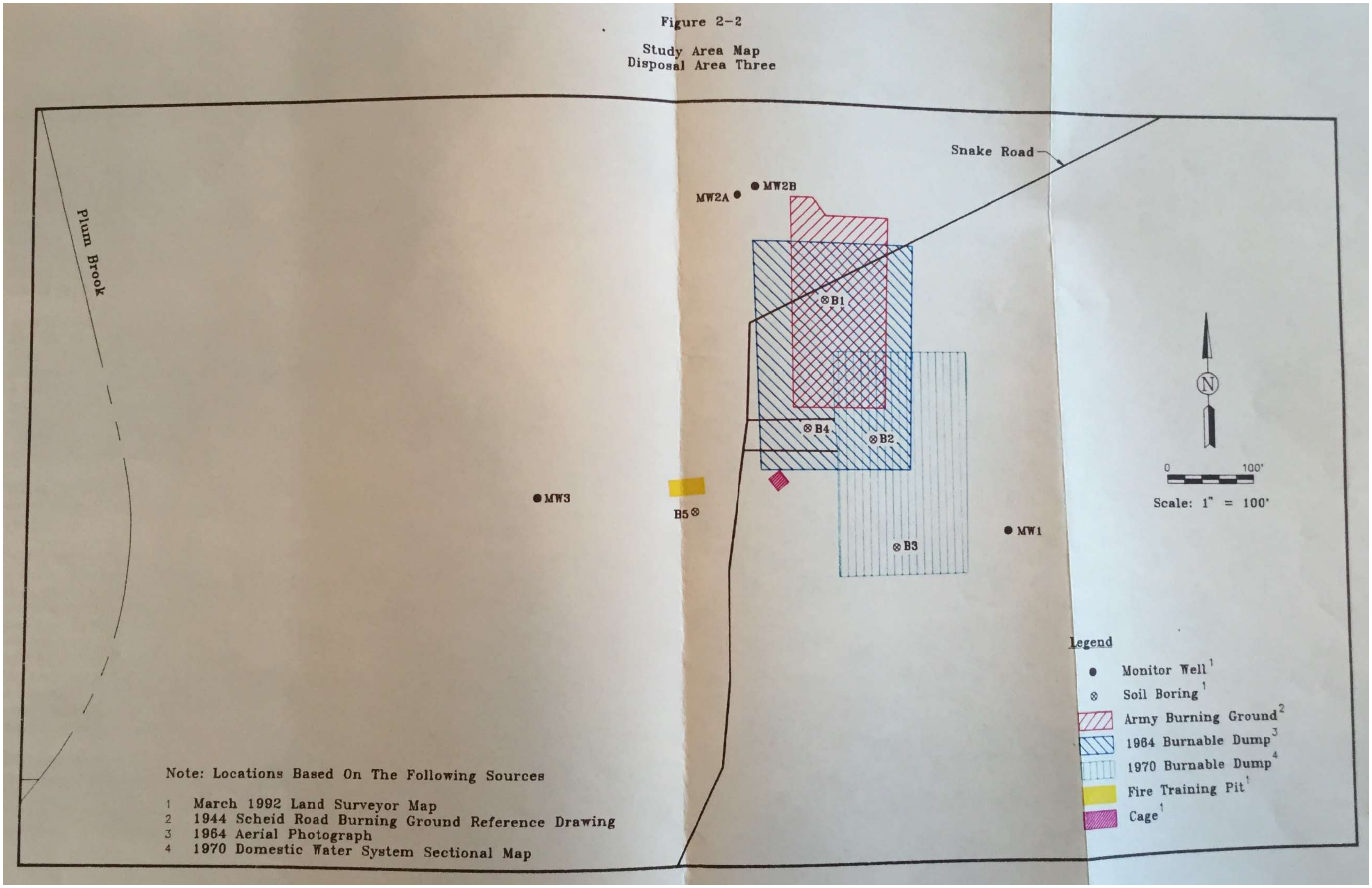


Figure 1–3. Study Area Map from 1992 Phase I Site Characterization Report (H+GCL 1992, Figure 2-2)

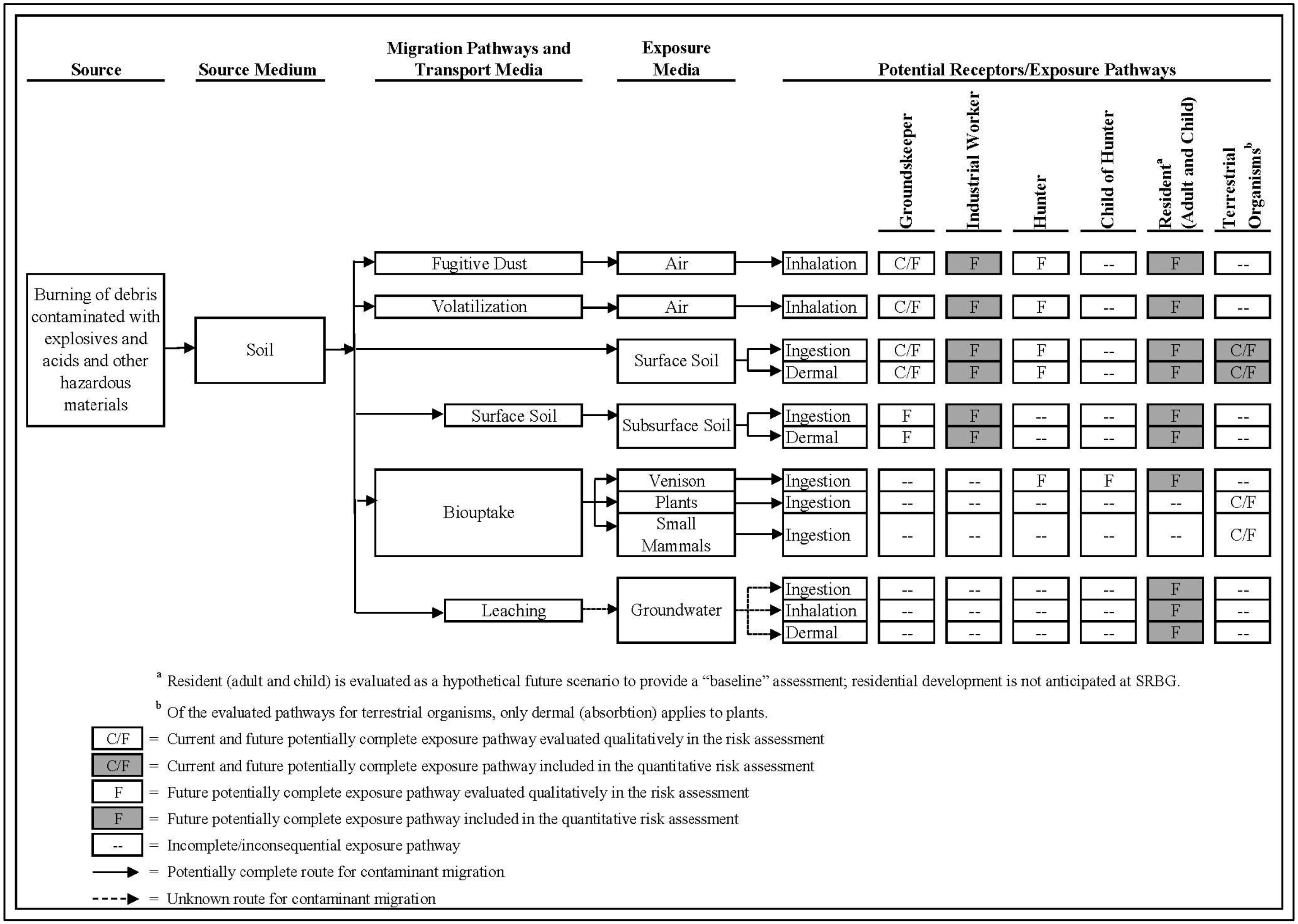


Figure 1–4. Snake Road Burning Ground Pathway Network Receptor Diagram

2. STUDY AREA INVESTIGATION

2.1 PREVIOUS ASSESSMENT AND EVALUATIONS

This section summarizes previous assessments and evaluations conducted at SRBG. 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 1990 Contamination Evaluation of Plum Brook Station

The Army conducted a study of the environmental impact of suspected hazardous waste sites at previously owned U.S. Department of Defense (DoD) properties. The *Engineering Report for the Contamination Evaluation at the Former Plum Brook Station Ordnance Works* (IT Corporation 1991) summarized a records review and evaluation to identify the types of potential hazardous waste and disposal facilities associated with the operation, maintenance, and deactivation of the site, including containerized facilities, landfill disposals, and seepage lagoons (IT Corporation 1991).

Four specific sites were targeted for investigation to confirm or deny the presence or absence of residual chemical contamination from DoD operational activities:

- Waste Disposal Area 1;
- Waste Disposal Area 2;
- Scheid Road Burning Ground (now known as SRBG); and
- Rubbish Burning Grounds (now known as Taylor Road Burning Ground [TRBG]).

The following summarizes the 1990 Contamination Evaluation, as provided in the *Site Inspection Report for Plum Brook Station* (MK 1994; herein referred to as the 1994 SI Report):

> *"IT (IT Corporation) conducted a site investigation focusing on the areas associated with past Army operations, the Red Water Ponds and the Burning Grounds. IT installed six shallow monitoring wells to sample groundwater and collected subsoil samples from the Red Water Ponds and the Burning Grounds. IT also calculated in-situ hydraulic conductivity for the monitoring well zones and collected surface water samples from the streams that drain the site. Although several different volatile, semivolatile, nitroexplosive and metal compounds were found in the samples, IT preliminarily calculated the HRS to be zero (0.0)."*

The summary of the 1990 Contamination Evaluation provided below was in the 1995 Records Review Report (DM 1995). In addition, Figure 2-1 presents the sample locations identified.

> *"As part of IT's Contamination Evaluation, four soil borings (SB-03, SB-04, SB-05, and SB-06) were installed at the Snake Road Burn Ground (referred to by IT as "Scheid Road Burning Grounds"). Borings were advanced from 0 to 6 feet with samples being collected from the 4 to 6 foot interval. Samples were analyzed for VOCs, SVOCs, total recoverable metals (silver, barium, cadmium, chromium, and lead), arsenic, selenium, mercury, total sulfates, PH, nitrates, and nitro-aromatic compounds.*
>
> *Analysis of the samples indicated the presence of nitro-aromatic compounds. 1,3,5-Trinitrobenzene was detected in one soil boring (SB-03) at the burning ground. Other contamination detected (acetone, methylene chloride) was attributed to laboratory contamination, and field decontamination procedures."*

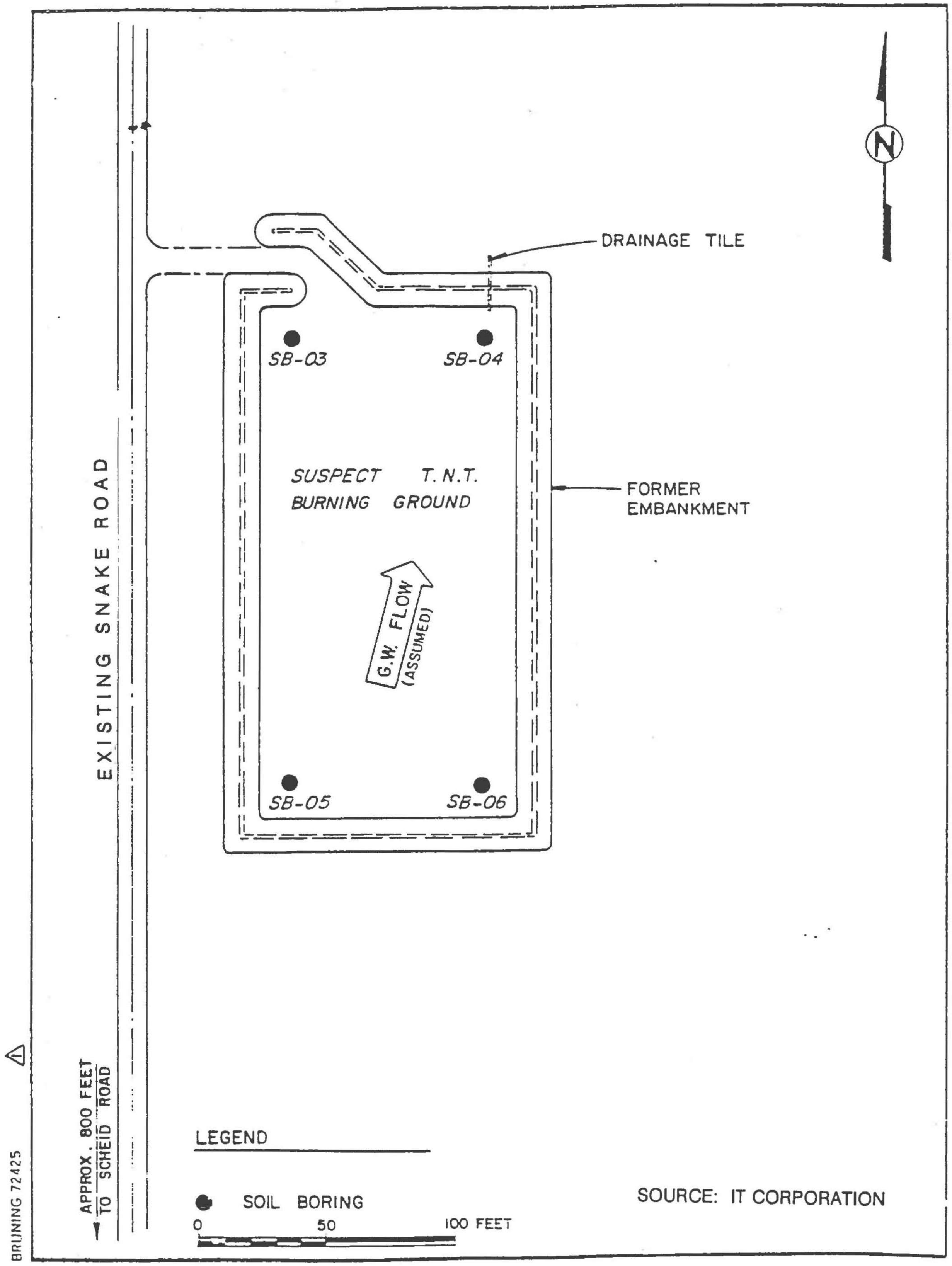


Figure 2–1. Contamination Evaluation Sample Locations at SRBG (SAIC 1991, Figure 5-10)

2.1.2 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 2-2 shows the locations of these disposal areas, as presented in the PBS PA. Disposal Areas 1B and 3 were associated with Fox Road Burning Ground (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.

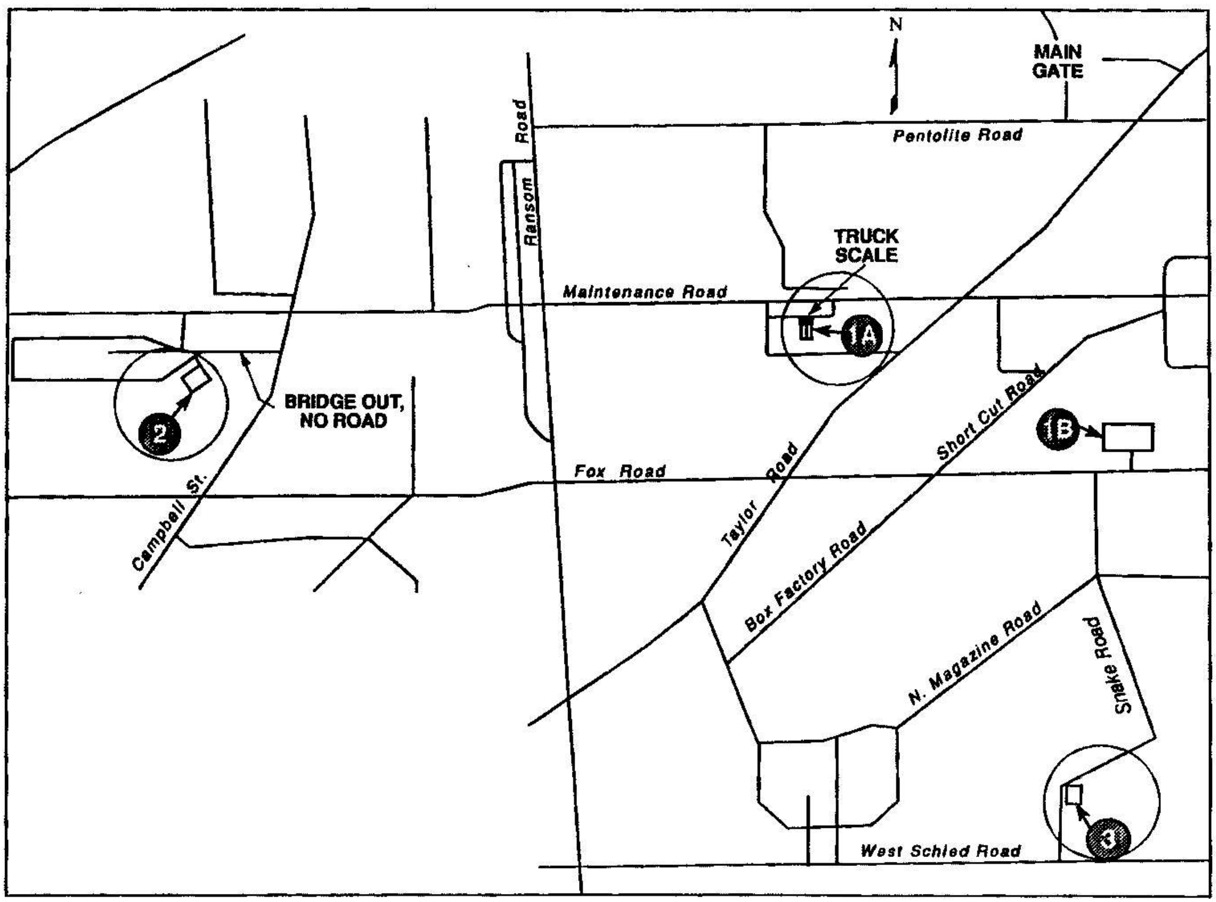


Figure 2–2. Distinct Disposal Areas for Solid Waste (SAIC 1991, Figure 4-1)

2.1.2.1 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.

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 2-3:

- 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.

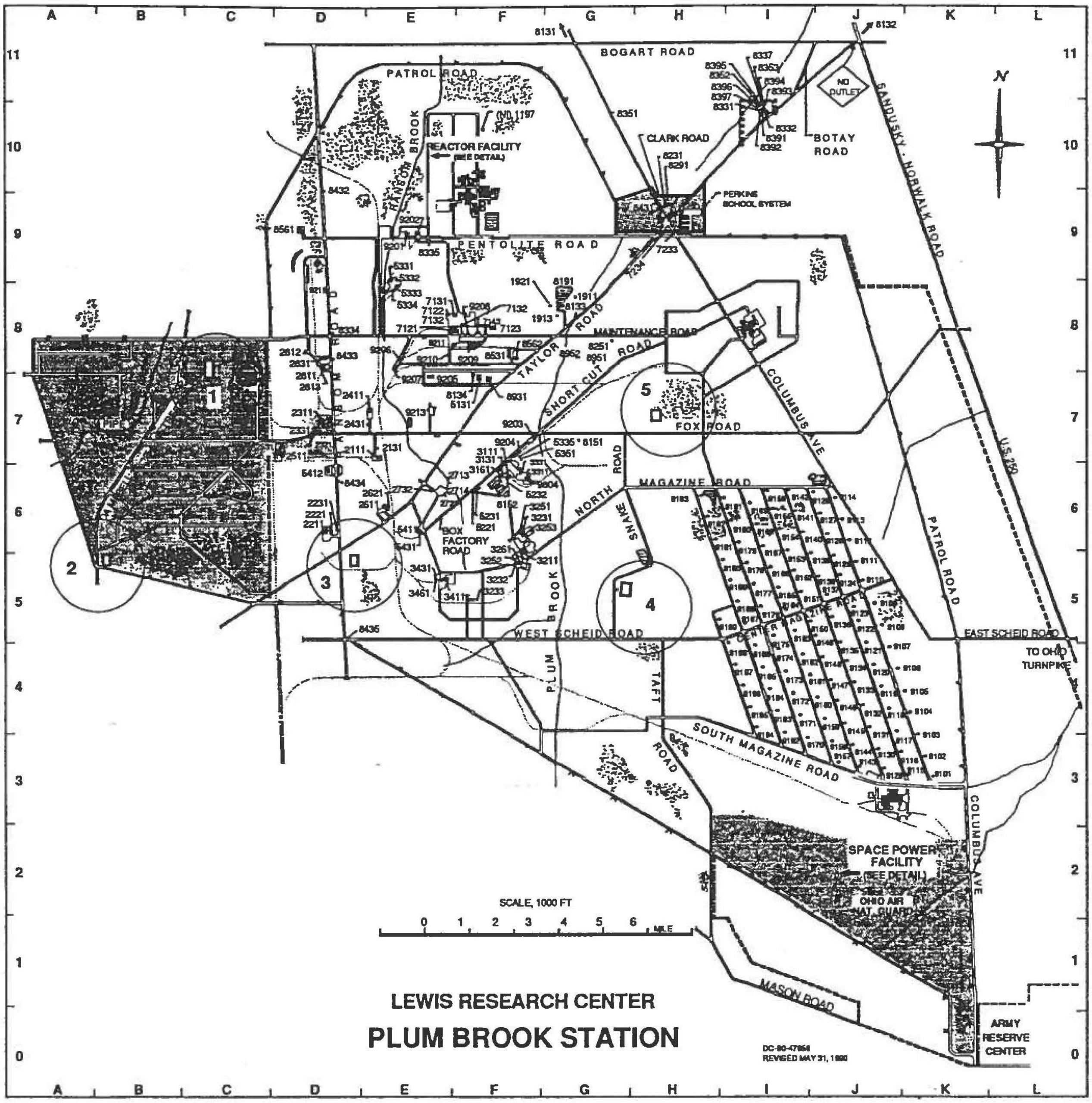
The Army used burning grounds during the D&D of PBOW. Five burning grounds formerly used by the Army were identified, although the PBS PA suspected that additional burning grounds may have been used. These grounds were used for destroying explosives-contaminated wastewater flumes, intermediate settling 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.

2.1.2.2 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. A fire report dated May 14, 1973, noted that a fire at SRBG may have been caused by the spontaneous combustion of chemicals and oils dumped together.

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.



PBF-11

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 2–3. Locations of GRC-ATF Burning Grounds (SAIC 1991, Figure 4-2)

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. These samples were used in the PBS PA to evaluate potential environmental impacts associated with the entire OU4. Samples were not collected or assessed from the other three locations included in OU4. Two samples (SB-01 and SB-02) were collected from TRBG, and four samples (SB-03 to SB06) were collected from SRBG. Figure 2-1 shows the SRBG sample locations, and Table 2-1 presents the partial summary of SRBG soil sample results as summarized in the PBS PA.

Acetone was detected in concentrations up to 4,300 parts per billion (ppb) at SRBG. IT Corporation suspected that the elevated acetone concentrations could be attributed to the use of isopropyl alcohol that was used as a final rinse during decontamination of sampling equipment. However, acetone was also detected in groundwater monitoring wells installed to establish background concentrations.

The only other detected contaminant was a minor amount of 1,3,5-trinitrobenzene (TNB) (0.093 ppb) in a single sample from SRBG. Installation of groundwater monitoring wells had been planned for these two burning ground areas. Based on soil sampling results that suggested minimal subsurface contamination, groundwater monitoring wells were not installed.

Table 2–1. SRBG: Partial Summary of 1989 Soil Sample Results (SAIC 1991, Table 5-5)

Sample No./Media	Volatile Organic Compounds	Semivolatile Organic Compounds	Nitroexplosives	Metals
SB-03/Soil	Acetone, 990 ppb Methylene chloride, 10 ppb	Bis(2-ethylhexyl)phthalate, 380 ppb	1,3,5-Trinitrobenzene, 0.093 ppm	Barium, 31.6 ppm Chromium, 10 ppm Iron, 15,600 ppm Lead, 50 ppm Manganese, 71.3 ppm Sodium, 76 ppm
SB-04/Soil	Acetone, 65 ppb Methylene chloride, 8 ppb	Bis(2-ethylhexyl)phthalate, 1,200 ppb	None detected	Barium, 41.0 ppm Chromium, 7 ppm Iron, 11,000 ppm Lead, 16 ppm Manganese, 14.5 ppm Silver, 0.5 ppm Sodium, 45 ppm
SB-05/Soil	Acetone, 4,300 ppb	Bis(2-ethylhexyl)phthalate, 420 ppb	None detected	Arsenic, 2 ppm Barium, 21.1 ppm Chromium, 4 ppm Iron, 4,940 ppm Lead, 9 ppm Manganese, 35.0 ppm Sodium, 52 ppm
SB-06/Soil	Acetone, 2,300 ppb	Bis(2-ethylhexyl)phthalate, 470 ppb	None detected	Barium, 58.9 ppm Chromium, 6 ppm Iron, 6,420 ppm Lead, 16 ppm Manganese, 129 ppm Sodium, 80 ppm

ppb = Parts per Billion
ppm = Parts per Million
SRBG = Snake Road Burning Ground

2.1.2.3 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.

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:

- 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.

2.1.3 1992 Phase I Site Characterization

In 1992, H+GCL conducted a Phase I Site Characterization of SRBG (identified as "Disposal Area Three" in the Phase I Site Characterization Report). Refinement of potentially impacted areas, soil sample locations, and monitoring well locations are shown in Figure 1-3.

The Phase I Site Characterization consisted of the following:

- Research historical use of SRBG to confirm the chemicals potentially released at the site;
- Complete a soil boring program to determine the presence of possible soil contamination at the burnable dumps and the Fire Training Pit; and
- Complete a groundwater sampling program to determine the impact, if any, of the Fire Training Pit and burnable dumps on the upper aquifer.

The Phase I Site Characterization included interviews with NASA employees, contractors, and tenants. In addition, historical aerial photographs were reviewed to confirm that the confines of the pit did not migrate beyond the area of investigation and that burn activities were concentrations to that same area.

2.1.3.1 Soil Sampling

During this Phase I Site Characterization, nine soil borings were completed, with four being converted to monitoring wells. Soil samples were analyzed for target analyte list (TAL) metals, VOCs, semivolatile organic compounds (SVOCs), explosives, polychlorinated biphenyls (PCBs), total petroleum hydrocarbons (TPH), pesticides, and herbicides. Except for sample location B-1, the soil from the entire boring was composited for analysis (with the exception of the VOC analysis). One sample interval from each boring was submitted for VOC analysis based on field screening activities.

Soil analysis results were compared to toxicity characteristic leaching procedure toxicity characteristics thresholds set forth in 40 Code of Federal Regulations (CFR) Part 261; background metal concentrations defined in U.S. Geological Survey (USGS) Professional Paper 1270; proposed Resource Conservation and Recovery Act (RCRA) soil action levels set forth in 55 Federal Register (FR) 30708; and PCB cleanup standards in 40 CFR Part 761. Soil concentrations at SRBG contained low concentrations of VOCs, SVOCs, and TPH; however, soil samples from background locations also exhibited low concentrations of some SVOCs, TPH, and acetone. Metals were detected in concentrations below RCRA thresholds for characteristic hazardous waste. Two borings had detectable concentrations of PCBs, with a maximum concentration of 980 µg/kg detected for PCB-1248. Explosives, pesticides, and herbicides were not detected in the soil samples.

2.1.3.2 Groundwater Sampling

During field activities, four monitoring wells were installed at SRBG to evaluate the shallow aquifer. Monitoring well GCL-MW01 was considered a background well specifically for evaluating SRBG and was screened from 6 to 11 feet below ground surface (bgs) in the unconsolidated zone. Monitoring wells GCL-MW02A and GCL-MW02B were installed adjacent to the burn areas and installed to evaluate burning activity impacts to groundwater. Monitoring well GCL-MW02A was screened from 12 to 22 feet bgs in shale, and MW-2B was screened from 4.8 to 9.8 feet bgs in the unconsolidated zone.

In addition, GCL-MW03 was installed and screened from 4.6 to 9.6 feet bgs in the unconsolidated zone. Monitoring well GCL-MW03 was installed adjacent to the Fire Training Pit to evaluate the potential impact on groundwater quality resulting from fire training activities. The Phase I Site Characterization Report (H+GCL 1992) noted that the final location of GCL-MW03 was not directly downgradient from the fire training area.

No free product was observed during the well development activities. Groundwater samples were analyzed for VOCs, SVOCs, TAL metals, TPH, pesticides, PCBs, herbicides, and explosives. The groundwater samples contained low concentrations of benzene, total chromium, lead, silver, and zinc. Explosives, pesticides, and herbicides were not detected in groundwater samples.

2.1.3.3 Conclusions

A risk assessment was performed on soil and groundwater to determine potential exposure pathways. The risk assessment was performed by assessing GRC-ATF as an access-controlled facility where exposure to ingestion, dermal contact, or inhalation by the general public is prevented. The risk assessment was performed with a minimized exposure of airborne emissions and/or direct contact because the site was decommissioned as an active burning ground and the area was regraded with fill. The greatest potential exposure evaluated was via surface water or groundwater transport.

It was determined that the presence of chemicals detected in soil and groundwater pose a minor risk to public health and welfare and natural resources. The Phase I Site Characterization Report (H+GCL 1992) did not recommend any further site characterization or remediation. However, because some chemicals (SVOCs, PCBs, lead, and 1,1-dichloroethane) had a high hazard ranking, the following was recommended as a precaution:

- The area should be posted and access restricted to "Authorized Personnel Only."
- Personnel authorized to access the area should be informed in writing of the potential exposures to air emissions and dermal contact if the surface cover is disturbed.
- Written procedures should be developed before the area can be disturbed, and restrictions should be recorded with the property deed and title.
- Damage to the surface cover caused by the drilling operations should be repaired with relatively impermeable fill material.
- The depression where the old Fire Training Pit was located has been surveyed and should be filled in with impermeable material.
- Open burning activities should not be allowed in this area.

2.1.4 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.

SRBG (identified as "Snake Road Burning Ground" in the 1994 SI Report) was in PMU 3 – Plum Brook. As shown in Figure 2-4, the eastern boundary of PMU 3 is a north-south running line through the intersection of Maintenance Road and Columbus Road. Patrol Road is the northern and southern border of the PMU.

PMU 3 covers approximately 1,000 acres. The northern and southern portions are covered with mature growth of hardwood trees. The remaining area is dominated by tall grasses.

The 1994 SI Report referenced the PBS PA (SAIC 1991) report to identify six points of potential contamination for PMUs. These areas are SRBG, two possible fly ash disposal areas, a set of toluene tanks referred to as "Upper Toluene Tanks," and a red water pond area known as "Pentolite Red Water Pond." The pond has been backfilled and is no longer present.

All sources of contamination from PMU 3 flow into Plum Brook. This contamination could be potentially sourced from groundwater or surface soil/water contamination.

The 1994 SI Report used the Preliminary Ranking Evaluation Score Version 2.0 computer program to assist in HRS site scoring of GRC-ATF. The following is the HRS results for PMU 3 (numbers in parentheses results are of PMU 3 without SVOCs):

- Groundwater migration = 0.65 (0.065),
- Surface water migration = 42.84 (4.38),
- Soil exposure = 12.88 (12.88),
- Air migration = 5.88 (5.88), and
- Site score = 22.52 (7.29).

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.

2.1.5 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 (DM 1995) summarizes the use of SRBG. The information is primarily drawn from the Phase I Site Characterization Report (H+GCL 1992). Text from that report follows:

> *"H+GCL's review of the IT's draft report indicated that the Army used an area on the east side of Snake Road for the destruction of explosives during the DoD actions performed between 1941 and 1963. Historical Drawing No. 1669-T-603-12 (TPC, 1944), the proposed plan for the "Scheid Road Burning Ground" (Snake Road Burn Ground), is dated November 22, 1944. This indicates that destruction (burning) of ordnance and other hazardous materials in this area may have been performed for several years before the construction of a formal containment area. It is possible that these activities extended beyond the boundaries of the burn ground. No records regarding the volume of materials destroyed at the Snake Road Burn Ground by the DoD were found. However, materials contaminated with DNT, TNT, pentolite and asbestos were allegedly destroyed here."*

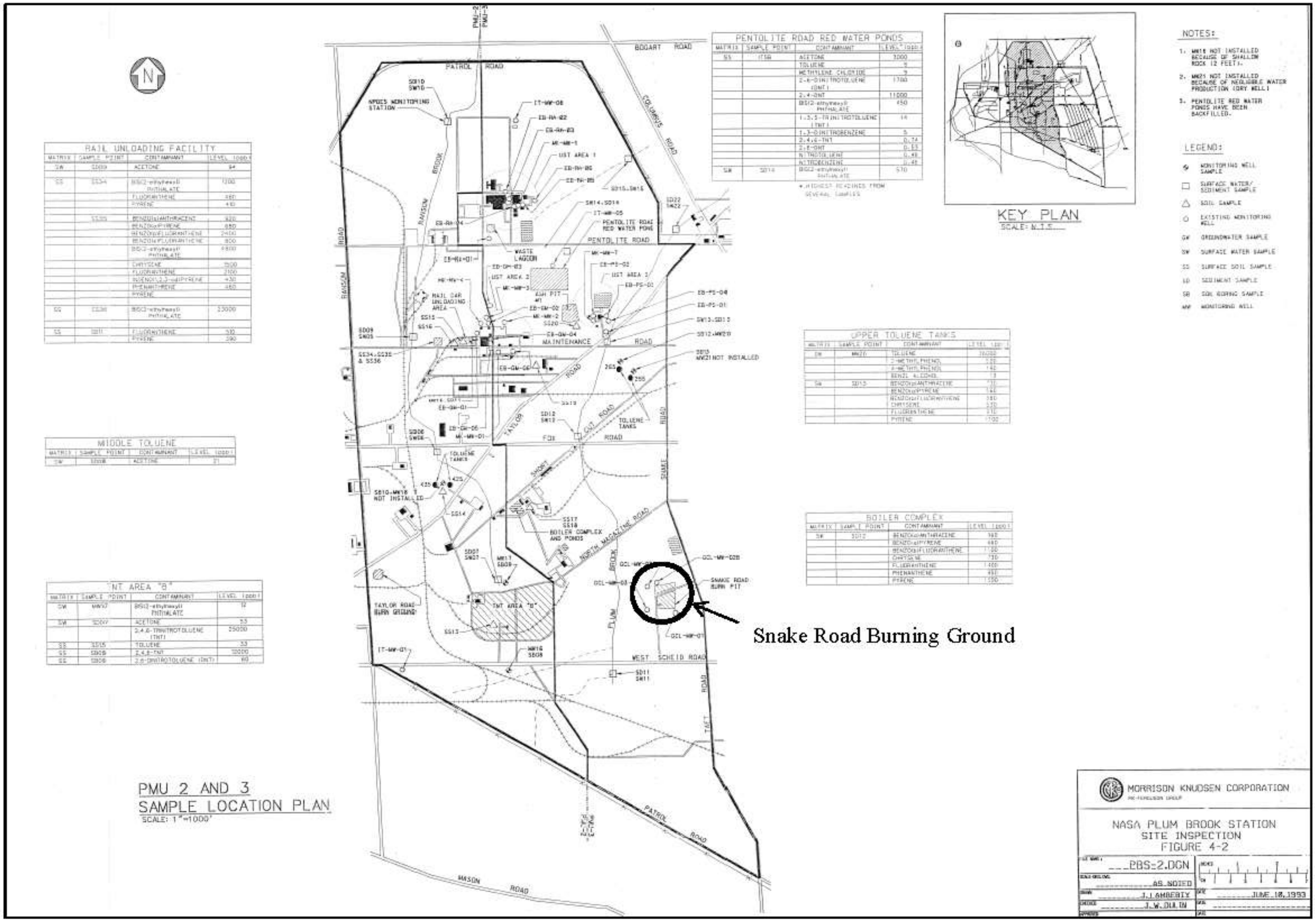


Figure 2–4. PMUs 2 and 3 (MK 1994, Figure 4-2)

The 1995 Records Review Report indicated that NASA expanded the burn grounds beyond those used by DoD. Initial expansion was toward the south, east, and west of the original area. Further expansion in 1970 was in southerly and easterly directions. NASA used the burning ground to dispose of materials contaminated or potentially contaminated by explosives, acids, waste oil, solvents, and other chemicals; however, no documentation has been found regarding the exact volumes of waste burned.

As of the 1995 report, no records were found regarding the closure date of the burning ground and associated areas. The report indicates that it may have been in the late 1970s, as that was when ash was removed from the burn pits, buried, and then the pits were backfilled.

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.

Figure 2-5 presents all locations for samples collected during these investigations and is divided into subsites (Primary Burn Area, Secondary Fire Training Area, and Drainage Ditch) depicted in the *Final Multi-site Investigation Report* (Leidos 2016b; herein referred to as the 2016 SI Report) and *Multi-site Remedial Investigation Sampling and Analysis Plan* (Leidos 2016a). A re-evaluation of the exposure units (EUs) was performed and presented in the Phase I RI Report (Leidos 2018a).

The Phase I RI Report (Leidos 2018a) provides site photographs (Appendix D), boring logs and field forms (Appendix E), and analytical data (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 SRBG, 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 11 different locations, including 2 borings on top of accessible soil piles. Surface soil (0 to 2 feet bgs) samples were collected at all soil borings, and subsurface soil samples were collected to 10 feet bgs. All soil samples were analyzed for VOCs, SVOCs, herbicides, pesticides, PCBs, explosives, and TAL metals. Surface soil was also analyzed for asbestos. Table 2-2 lists the soil samples collected and the analyses conducted for each sample during the 2015 SI.

No surface water was identified in the Drainage Ditch; therefore, no surface water samples were collected at the site. Three sediment samples (SRBG-SDSW-001 to SRBG-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.

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

Sample Location	Sample ID	Depth (ft)	Analyses Suite
SRBG-SL-001	SRBGSL0001	0–2	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs, Asbestos
	SRBGSL0002	2–6	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs
	SRBGSL0003	6–8	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs
SRBG-SL-002	SRBGSL0004	0–2	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs, Asbestos
	SRBGSL0005	2–6	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs
	SRBGSL0006	6–10	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs
SRBG-SL-003	SRBGSL0007	0–2	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs, Asbestos
	SRBGSL0008	2–6	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs
	SRBGSL0009	6–9	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs
SRBG-SL-004	SRBGSL0010	0–2	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs, Asbestos
	SRBGSL0011	2–6	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs
	SRBGSL0012	6–9	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs
SRBG-SL-005	SRBGSL0013	0–2	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs, Asbestos
	SRBGSL0014	2–6	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs
	SRBGSL0015	6–10	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs
SRBG-SL-006	SRBGSL0016	0–2	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs, Asbestos
	SRBGSL0017	2–6	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs
	SRBGSL0018	6–8.5	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs
SRBG-SL-007	SRBGSL0019	0–2	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs, Asbestos
	SRBGSL0020	2–6	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs
	SRBGSL0021	6–8	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs
SRBG-SL-008	SRBGSL0022	0–2	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs, Asbestos
	SRBGSL0023	2–6	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs
	SRBGSL0024	6–8.5	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs
SRBG-SL-009	SRBGSL0025	0–2	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs, Asbestos
	SRBGSL0026	2–6	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs
	SRBGSL0027	6–9	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs
SRBG-SL-010	SRBGSL0028	0–2	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs, Asbestos
	SRBGSL0029	2–6	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs
	SRBGSL0030	6–10	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs
SRBG-SL-011	SRBGSL0031	0–2	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs, Asbestos
	SRBGSL0032	2–6	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs
	SRBGSL0033	6–7.5	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs

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

Sample Location	Sample ID	Depth (ft)	Analyses Suite
SRBG-SDSW-001	SRBGSD0001	0–2	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs, Asbestos
SRBG-SDSW-002	SRBGSD0002	0–2	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs, Asbestos
SRBG-SDSW-003	SRBGSD0003	0–2	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs, Asbestos

ft = feet
ID = Identification
PCB = Polychlorinated biphenyl
SI = Site investigation
SVOC = Semivolatile organic compound
TAL = Target analyte list
VOC = Volatile organic compound

Multiple compounds were detected in each medium sampled. In addition, each medium sampled contained one or more compounds at concentrations greater than relevant screening criteria. Sample results indicate SRBG has been impacted by historical site use.

A site walk was performed to identify any painted debris. No painted debris was identified; therefore, no X-ray fluorescence screening was performed for lead-based paint (LBP). Metal debris (e.g., shredded steel drum, steel drum lid, and steel posts) and cinder blocks were observed. In addition, an Asbestos Hazard Evaluation Specialist performed a site assessment. This assessment included collecting 14 soil samples to analyze asbestos content and identifying 6 pieces of ACM. Chrysotile and/or amosite asbestos were detected in 4 of 14 soil samples, but all detected concentrations were less than 1 percent. Two samples of the transite material contained 25 percent chrysotile.

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, metals, and PCBs as COPCs for surface soil. No COPCs were identified 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 sediment. Surface water was not identified at the site and was not considered a medium of concern.

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

Based on the asbestos sampling results, additional ACM assessment is not warranted, including cementitious material and soil. Based on the asbestos sampling results, the SI recommended addressing the presence of ACM to mitigate potential risks to human health and ecological receptors, and recommended an interim removal action for the debris observed during the SI.

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*

Five surface soil samples were collected using a Geoprobe® 66DT from five locations (SR-1 to SR-5), as presented in Figure 2-5. Soil samples were collected with Geoprobe® direct-push sampling equipment using a dual-tube sampler with a diameter of 2.25 inches. Soil collected from each sample interval was transferred into a stainless steel bowl for homogenization. Table 2-3 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.

Two groundwater samples were proposed for collection in the 2015 RI Sampling and Analysis Plan (SAP) from the existing wells. However, due to inaccessibility of these wells, groundwater samples were not collected during the field activities.

Table 2–3. Soil Samples Collected During the 2017 Remedial Investigation

Sample Location	Sample ID	Depth (ft)	Analysis Suite
SR-1	SRBGSL0034	0–2	TAL Metals, Explosives, PCBs, Pesticides, SVOCs
SR-2	SRBGSL0035	0–2	TAL Metals, Explosives, PCBs, Pesticides, SVOCs
SR-3	SRBGSL0036	0–2	TAL Metals, Explosives, PCBs, Pesticides, SVOCs
SR-4	SRBGSL0037	0–2	TAL Metals, Explosives, PCBs, Pesticides, SVOCs
SR-5	SRBGSL0038	0–2	TAL Metals, SVOCs

ft = Feet
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).

A plant management area (Central Meadows) and a rare plant species and its habitat also occur within SRBG. Wetlands, rare species and their habitat, and specially designated natural areas are considered important ecological resources, and contamination at SRBG has been documented, so further analysis was conducted in a Level II ERA. 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. Using this combination of factors, cadmium; lead; mercury; PCB-1260; and 2,6-DNT were determined to be final COPECs at the Primary Burn Area EU at SRBG. Removal of surface soil in two sample locations (SRBG-SL-001 and SRBG-SL-003) in the primary Burn EU (Figure 2-5) was recommended to protect ecological resources at SRBG.

The HHRA documented the potential health risks to humans resulting from exposure to contamination within SRBG. 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 at the Primary Burn Area, the two PCBs (1248 and 1260) and silver were identified as COCs for surface soil and no COCs were identified for subsurface soil. Under the industrial scenario, no COCs were identified for surface or subsurface soil.

Under the residential scenario at the Secondary Burn Area, no COCs were identified for surface soil. Although not identified specifically as a COC requiring remediation in the Secondary Burn Area, the concentration of PCB-1254 (1.4 mg/kg) in SRBG-SL-002 is within the range of PCB-1248 and PCB-1260 concentrations in SRBG-SL-004 and SRGB-SL-009 (1.2 and 3 mg/kg, respectively) that were recommended for remediation in the Primary Burn Area. Conservatively, SRBG-SL-002 was also recommended for remediation for PCB-1254. No carcinogenic COPCs were identified for subsurface soil; therefore, no risk was calculated. A specific evaluation of the Fire Training Pit located within the Secondary Burn Area EU was sampled by SRBG-SL-008 resulted in no COCs in this area. Under the industrial scenario, no COCs were identified for the surface or subsurface soil.

No COCs were identified in surface soil at the Drainage Ditch under both the residential and industrial scenarios.

Based on the asbestos evaluation, only 4 of 14 soil samples analyzed had detectable asbestos content, all below 1 percent asbestos. Three of these samples at SRBG-SL-002, SRBG-SL-003, and SRBG-SL-004 also coincide with locations recommended for remedial actions. In addition, the one piece of ACM (off-white transite at SRBG-DD-001) was considered friable and contained 25 percent chrysotile; however, there was only a small piece of this transite, and it is assumed all identified material was removed for sampling.

2.2.2.3 Recommendations

The Phase I RI recommended an assessment in an FS for the COCs and COPECs identified. The HHRA identified the following EUs, sample locations, and COCs:

- Two PCBs (1248 and 1260) and silver were identified as COCs for surface soil in the Primary Burn Area at sample locations SRBG-SL-004 and SRBG-SL-009.
- PCB-1254 (1.4 mg/kg) in SRBG-SL-002 in the Secondary Burn Area is within the range of PCB-1248 and PCB-1260 concentrations in SRBG-SL-004 and SRGB-SL-009. This location within the Secondary Burn Area is recommended for remediation for PCB-1254.

The ERA identified the following sample locations and COPECs:

- Cadmium; lead; mercury; PCB-1260; and 2,6-DNT are final COPECs at the Primary Burn Area EU in surface soil at two sample locations in the Primary Burn Area EU (SRBG-SL-001 and SRBG-SL-003).

Remediation of these locations will address the three sample locations (SRBG-SL-001, SRBG-SL-002, and SRBG-SDSW-004) that had detected asbestos in soil (less than 1 percent). In addition, the one piece of ACM (off-white transite at SRBG-DD-001) was considered friable and greater than 1 percent asbestos (chrysotile). However, there was only a small piece of this transite, and it is assumed all identified material was removed for sampling. All detectable asbestos is recommended for assessment in the FS. Consistent with the conclusions of the 2015 SI, additional ACM assessment is not warranted and the 2018 Phase I RI concluded NFA was recommended for ACM. However, it is NASA's policy to assess and remove all detectable asbestos at GRC-ATF.

In addition, metal fragments, debris, and piping were identified southeast of the Primary Burn Area. 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 SRBG in accordance with the *Final Burning Grounds Phase II Remedial Investigation Sampling and Analysis Plan* (Leidos 2020b). The Phase II RI activities were performed from April 26 through December 1, 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 13 chemicals had 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 SRBG. 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:

- Developing existing monitoring wells at SRBG;
- Installing three new monitoring wells at SRBG;
- Sampling the existing and newly installed monitoring wells during two seasonal events; and
- Analyzing groundwater samples for RCRA metals, explosives, VOCs, SVOCs, pesticides, and PCBs.

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

Sample Location	Sample IDs	Sample Dates	Analysis Suite
SRBG-MW01	SRBGGW1001 SRBGGW1006	06/01/2021 11/30/2021	RCRA Metals (filtered and unfiltered), Explosives, PCBs, Pesticides, SVOCs, VOCs
SRBG-MW02	SRBGGW1002 SRBGGW1007	06/01/2021 12/01/2021	RCRA Metals (filtered and unfiltered), Explosives, PCBs, Pesticides, SVOCs, VOCs
SRBG-MW03	SRBGGW1003 SRBGGW1008/SRBGGW9103	06/06/2021 12/01/2021	RCRA Metals (filtered and unfiltered), Explosives, PCBs, Pesticides, SVOCs, VOCs
GCL-MW01	SRBGGW1004/SRBGGW9102 SRBGGW1009/SRBGGW9104	05/27/2021 11/30/2021	RCRA Metals (filtered and unfiltered), Explosives, PCBs, Pesticides, SVOCs, VOCs
GCL-MW03	SRBGGW1005 SRBGGW1010	05/27/2021 11/30/2021	RCRA Metals (filtered and unfiltered), Explosives, PCBs, Pesticides, 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. SRBG 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 SRBG under a separate investigation; therefore, PFAS are not included in this RI.

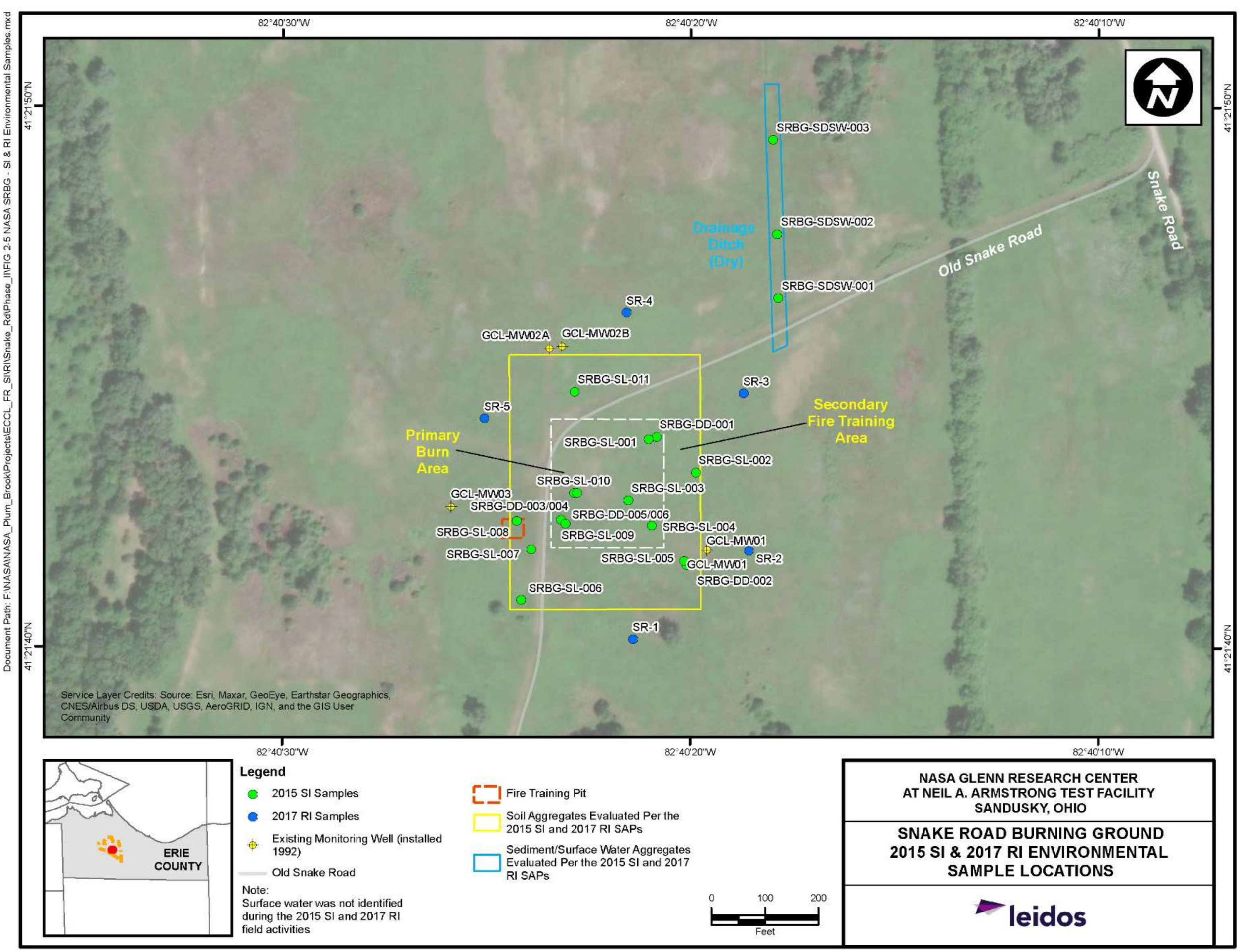


Figure 2–5. Snake Road Burning Ground 2015 SI and 2017 RI Environmental Sample Locations

3. PHYSICAL CHARACTERISTICS

This section describes the physical features, topography, geology, hydrogeology, and environmental characteristics of SRBG 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 drainages 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 USGS 7.5-minute series topographic maps: Sandusky Quadrangle (northern portion of facility) and Kimball Quadrangle (southern portion of facility).

3.1.2 Snake Road Burning Ground

SRBG is in the central portion of GRC-ATF, west of Snake Road and north of West Scheid Road (Figure 1-2). Old Snake Road bisects the site. The topography at the site is flat. Within the burn areas, the site has a maximum elevation of approximately 671 feet AMSL in the southwestern corner of the Primary Burn Area to the lowest elevation of 668 feet AMSL in the northeastern corner of the Secondary Burn Area. The dry ditch northeast of the site has a maximum elevation of approximately 667 feet AMSL, sloping to approximately 665 feet AMSL.

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 2020b). 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 6.4 cm (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 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 station 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 Snake Road Burning Ground

SRBG is in the headwater areas for Lindsley Ditch (Figure 3-2). Surface drainage at the site flows over preferential pathways and into the Drainage Ditch on the eastern portion of the site. The Drainage Ditch at SRBG is routinely dry and appears to only be active during significant precipitation events resulting in runoff in which it flows northward to Lindsley Ditch. The four wetlands at the site are isolated, small (0.02 to 0.14 acres), and ephemeral. All four wetlands at SRBG have moderately low wetland quality with some degradation of wetland functions and conditions.

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. SRBG is located to the east of the southern portion of the north-south cross-section.

3.4.2 Snake Road Burning Ground

The upper bedrock surface at SRBG is the Devonian Age Ohio Shale. Based on soil boring logs completed at the site, depth to gray to black shale bedrock is approximately 7.5 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 3-8presents 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). Detailed cross-sections, Figures 3-5, 3-6, and 3-7, show a detailed lithology of GRC-ATF. SRBG is located to the east of the southern portion of the north-south cross-section.

3.5.2 Snake Road Burning Ground

Soil at SRBG is composed primarily of the Hornell silty clay loam (0 to 2 percent slopes) and Elnora loamy fine sand, bedrock substratum (0 to 4 percent slopes). Minor soil types at the site include Colwood silt loam, bedrock substratum (0 to 1 percent slopes); Fries silty clay loam (0 to 1 percent slopes); and Udorthents-disturbed land. Distributions of soil at the site are illustrated in Figure 3-8.

The Hornell silty clay loam (0 to 2 percent slopes) are from a till parent material developed over residuum weathered from shale. Bedrock is typically encountered within 5 feet of ground surface. The Hornell silty clay loam is somewhat poorly drained, non-hydric soil. The Elnora loamy fine sand, bedrock substratum (0 to 4 percent slopes) consists of loamy fine sand from glaciolacustrine deposits with bedrock typically encountered within 5 feet of the surface. It is moderately well drained and does not exhibit flooding or ponding of 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 recent 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 Snake Road Burning Ground

Discontinuous saturated zones in overburden soil were observed at depths ranging from 3.3 to 6.3 feet bgs during field investigation. During the 1992 Phase I Site Characterization, four monitoring wells were installed at SRBG. Monitoring well GCL-MW01 was considered a background well specifically for evaluating SRBG and was screened from 6 to 11 feet bgs in the unconsolidated zone. Monitoring wells GCL-MW02A and GCL-MW02B were installed adjacent to the burn areas and installed to evaluate burning activity impacts to groundwater. Monitoring well GCL-MW02A was screened from 12 to 22 feet bgs in shale, and GCL-MW02B was screened from 4.8 to 9.8 feet bgs in the unconsolidated zone. In addition, GCL-MW03 was installed and screened from 4.6 to 9.6 feet bgs in the unconsolidated zone. Monitoring well GCL-MW03 was installed adjacent to the Fire Training Pit to evaluate the potential impact on groundwater quality resulting from fire training activities. No free product was observed during the well development activities.

During the Phase II RI, three new permanent monitoring wells were installed (SRBG-MW01, SRBG-MW02, and SRBG-MW03) to total depths ranging from approximately 7 to 9.5 feet bgs. Discontinuous saturated zones were observed from 5 to 8 feet bgs during the field investigations. No free product was observed during the well development or groundwater sampling activities.

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 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 2020).

The average household income for 2015 to 2019 was estimated to be $54,226 annually (U.S. Census 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 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 et al. 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. The 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>

- o Formation: I.A.8.N.c. Conical-crowned temperate or subpolar needle-leaved evergreen forest (EFU1)
- o 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 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 2002, ODNR 1995). 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

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

Special Interest/Concern	Survey Years Located
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

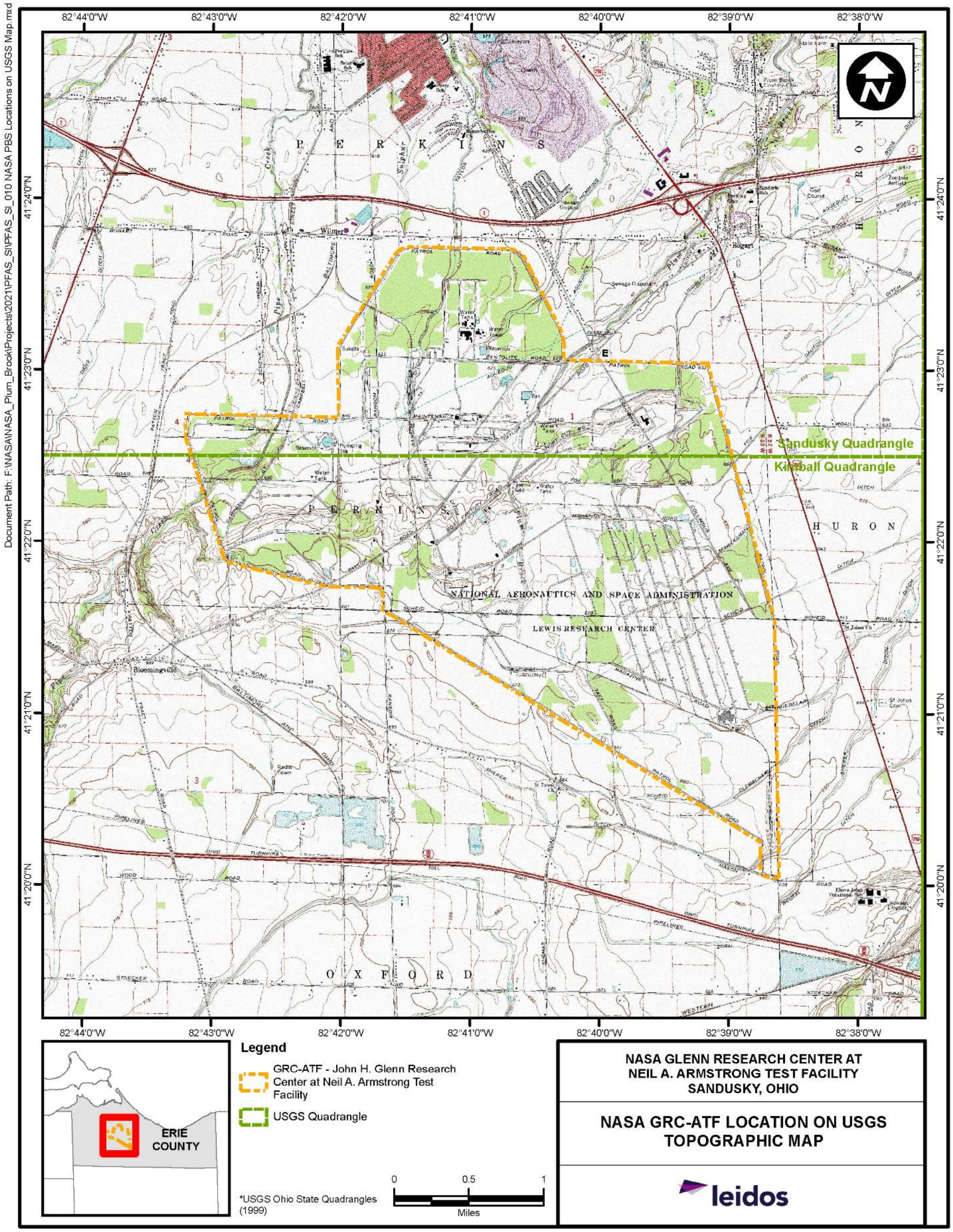


Figure 3–1. NASA GRC-ATF Location on USGS Topographic Map

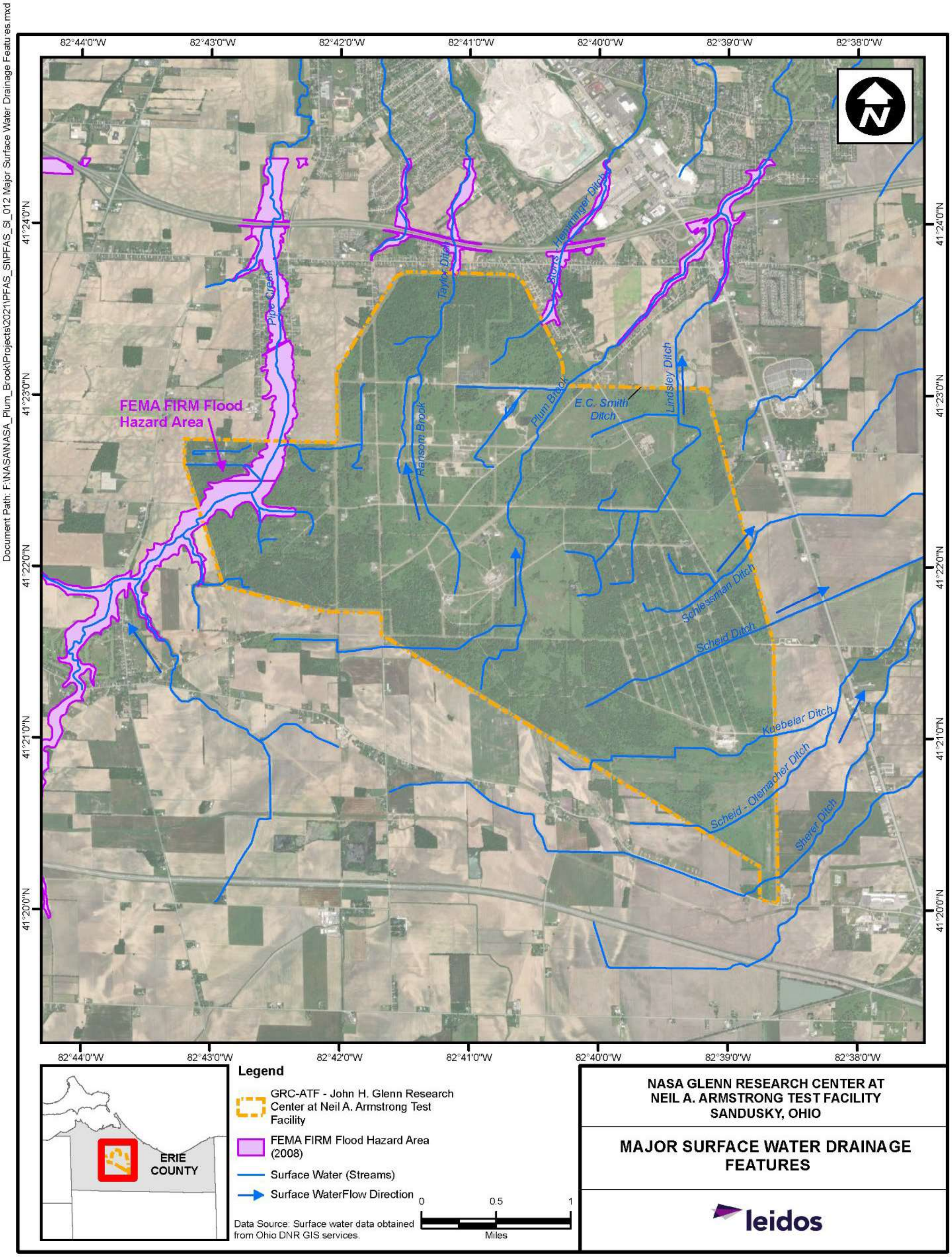


Figure 3–2. Major Surface Water Drainage Features

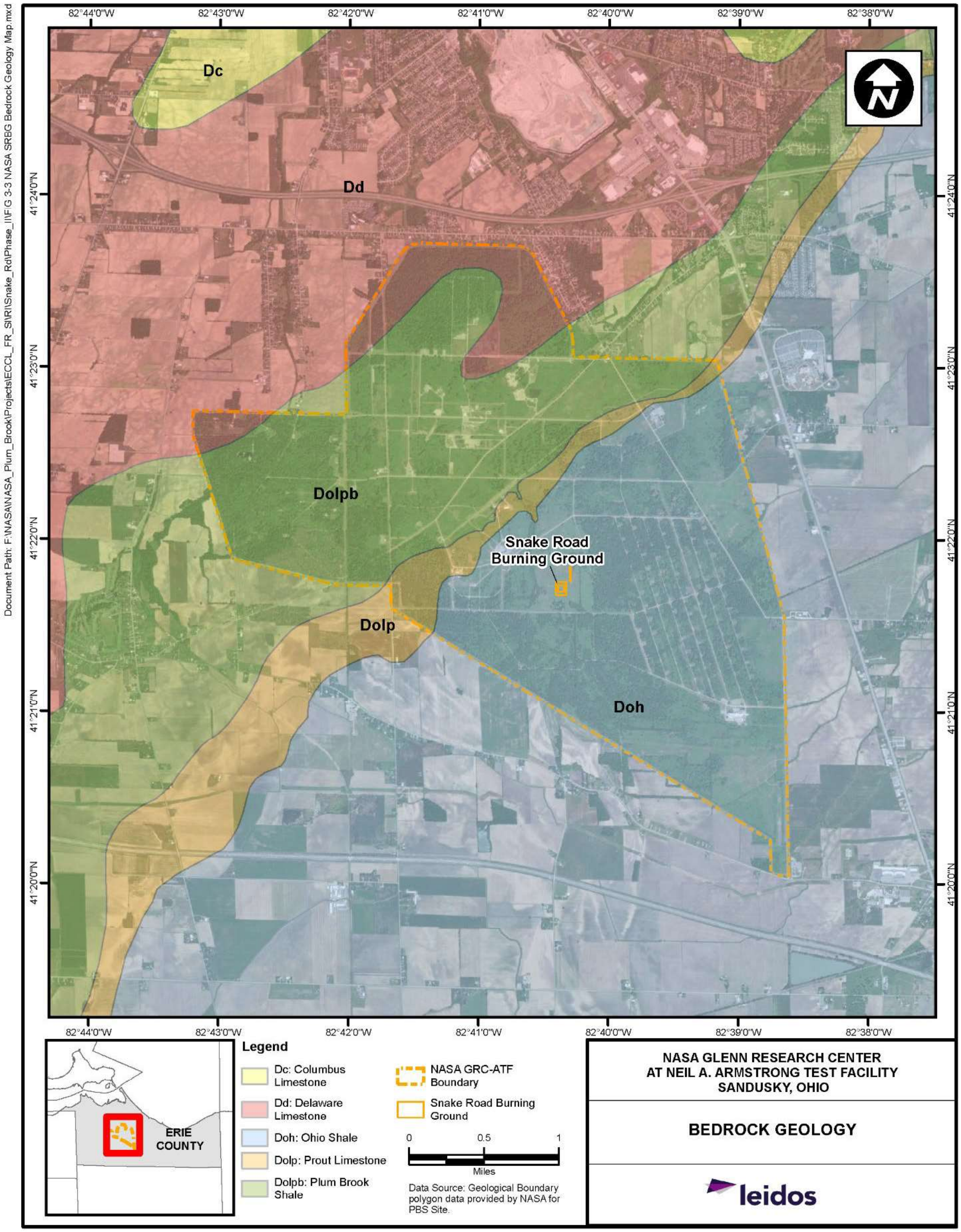


Figure 3–3. Bedrock Geology

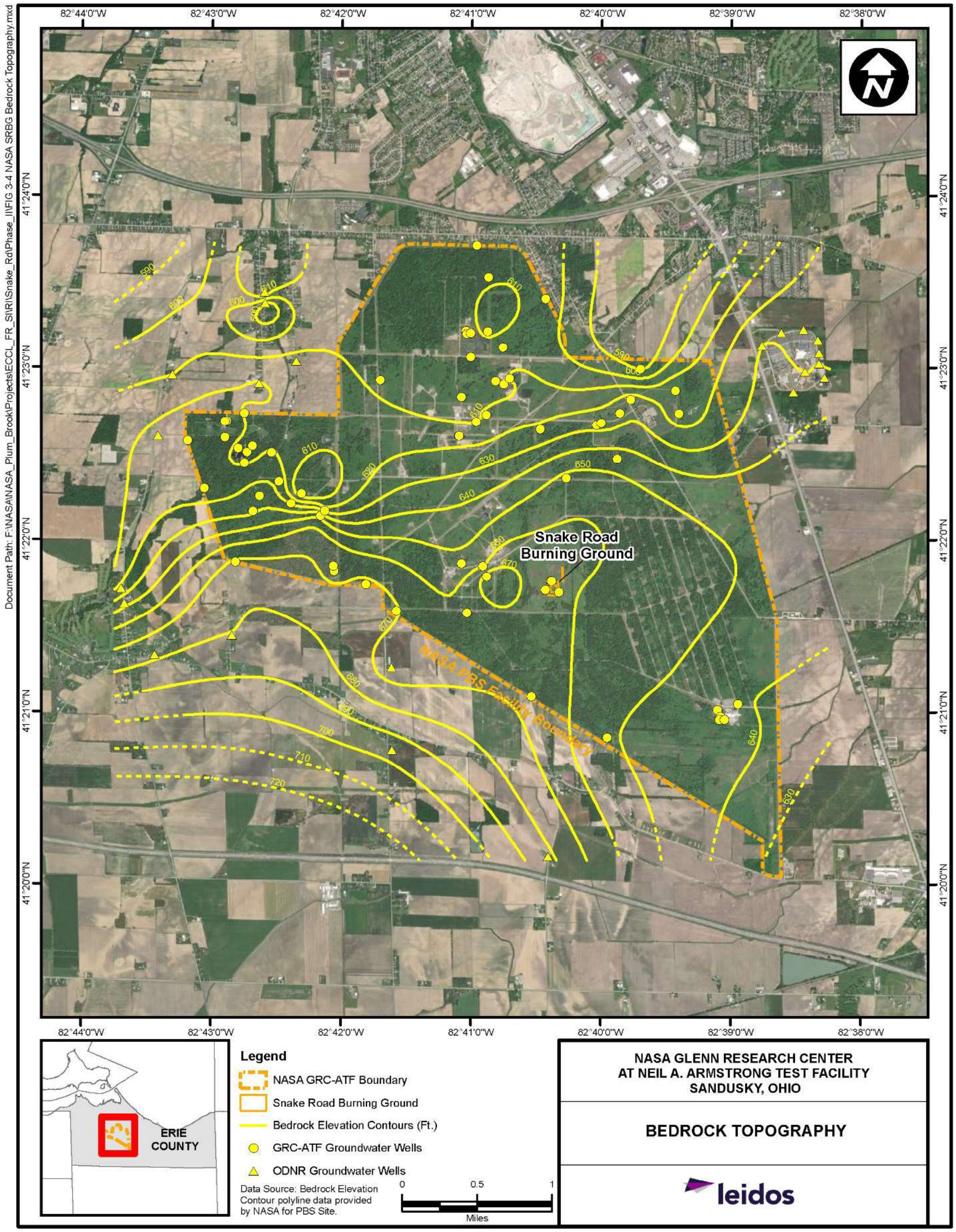


Figure 3–4. Bedrock Topography

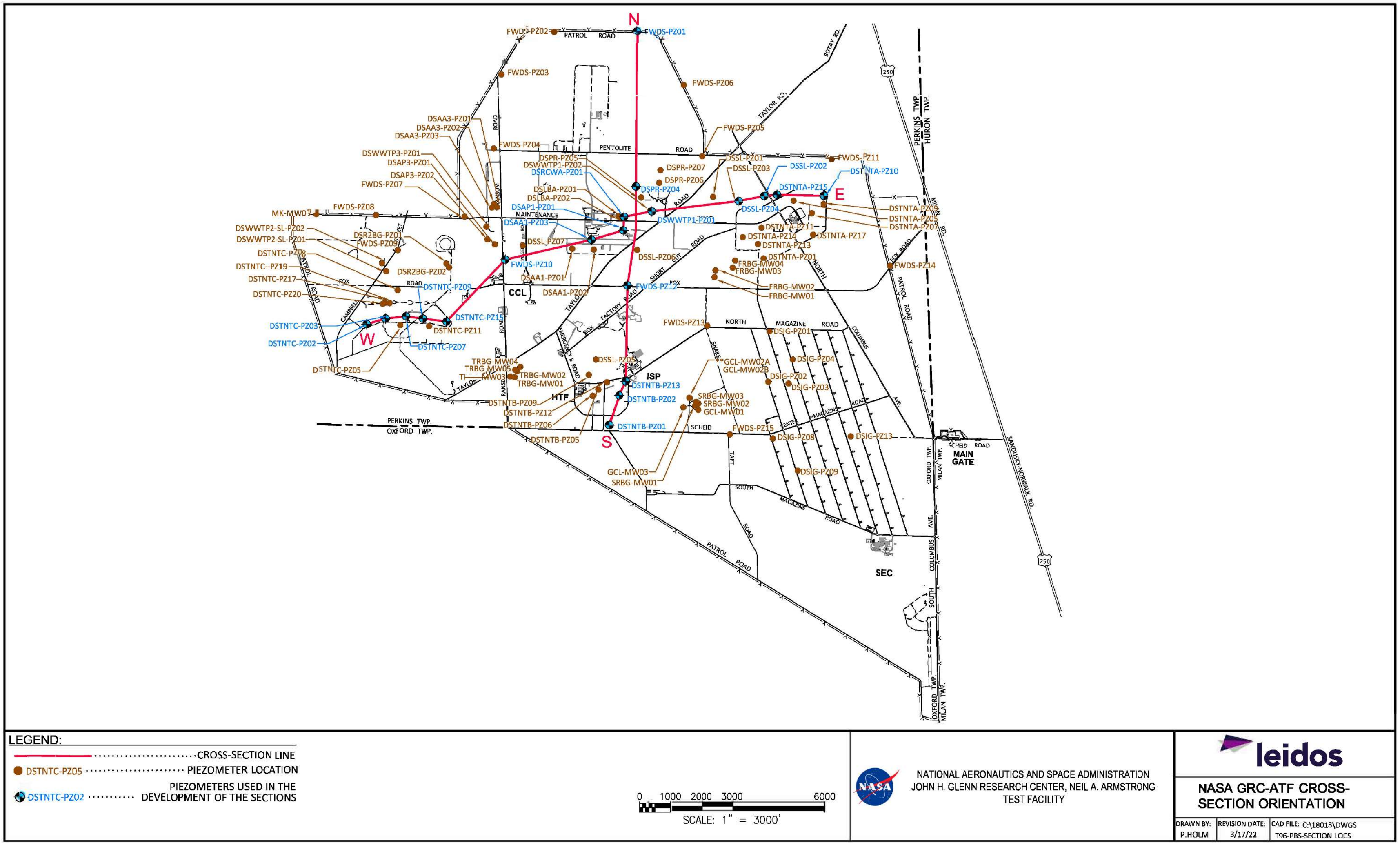


Figure 3–5. NASA GRC-ATF Cross Section Orientation

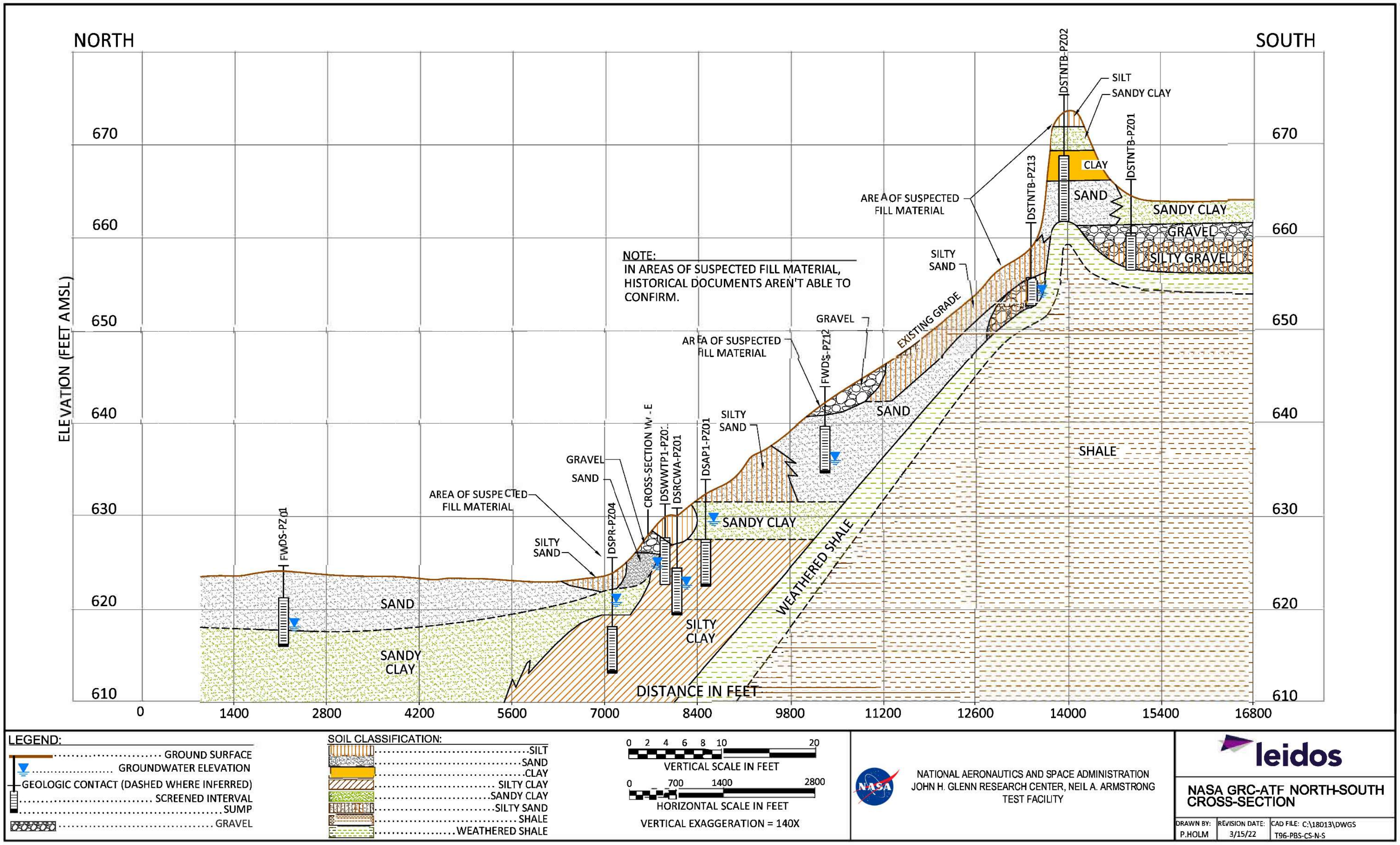


Figure 3–6. NASA GRC-ATF North-South Cross-Section

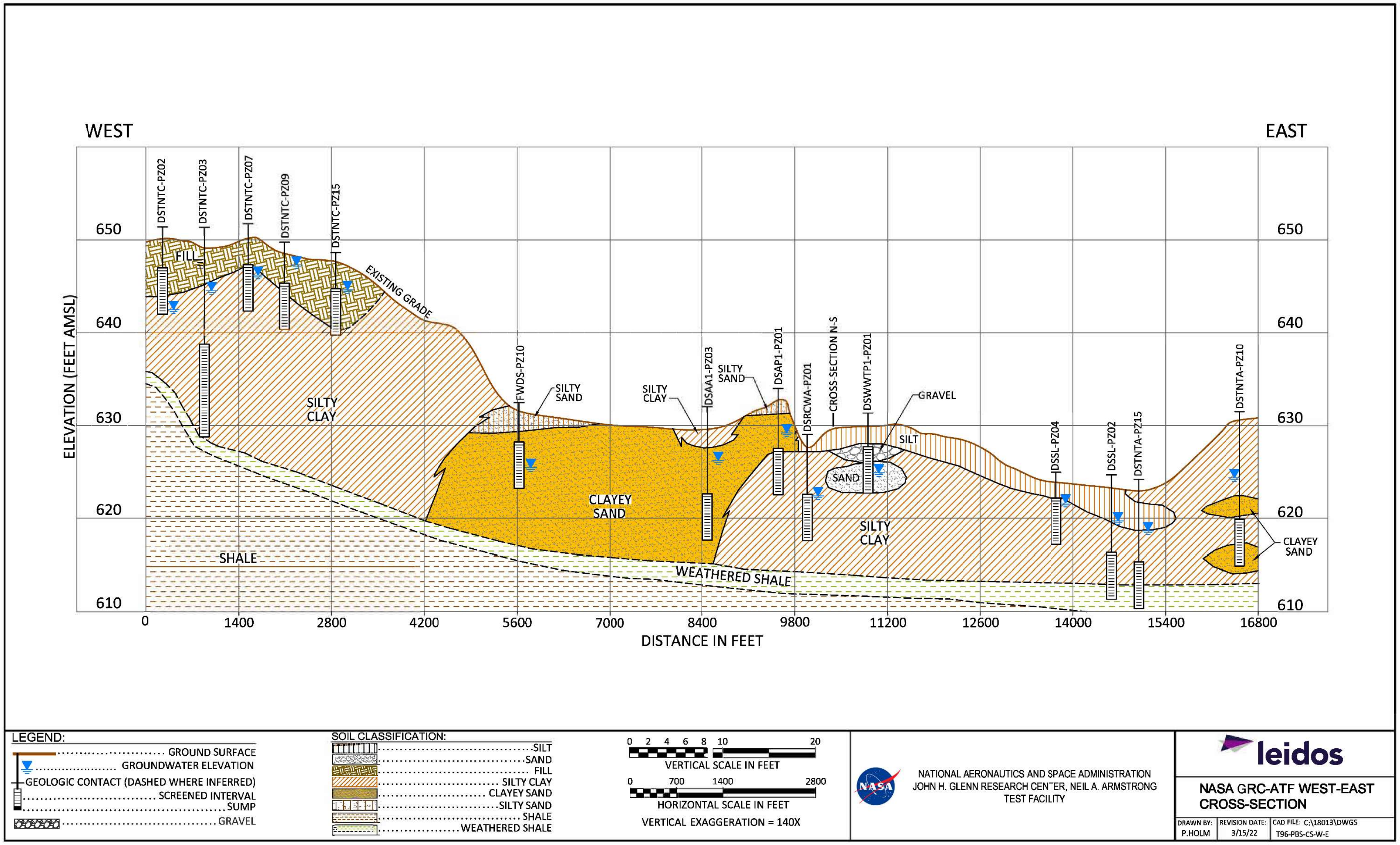


Figure 3–7. NASA GRC-ATF East-West Cross-Section

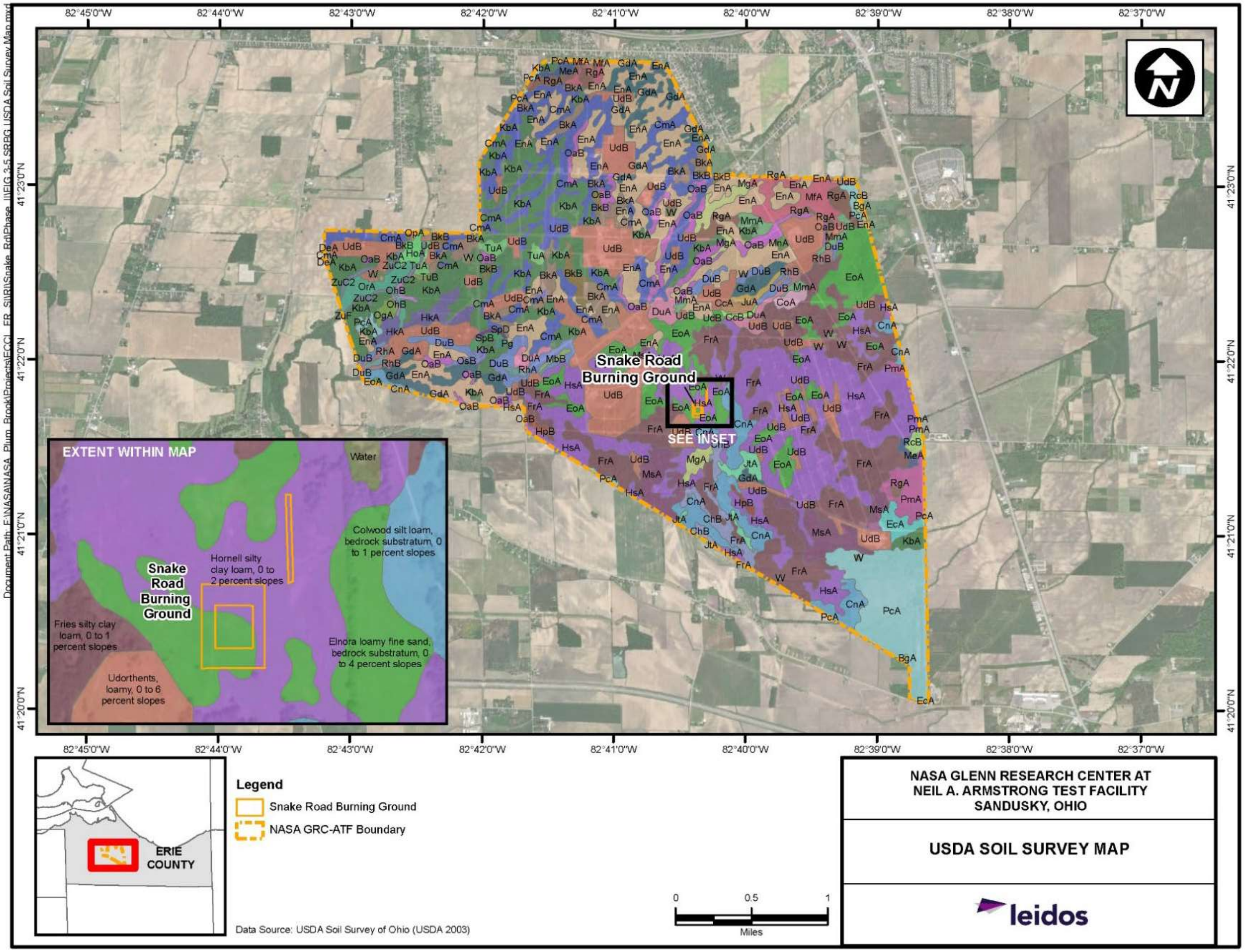


Figure 3–8. USDA Soil Survey Map

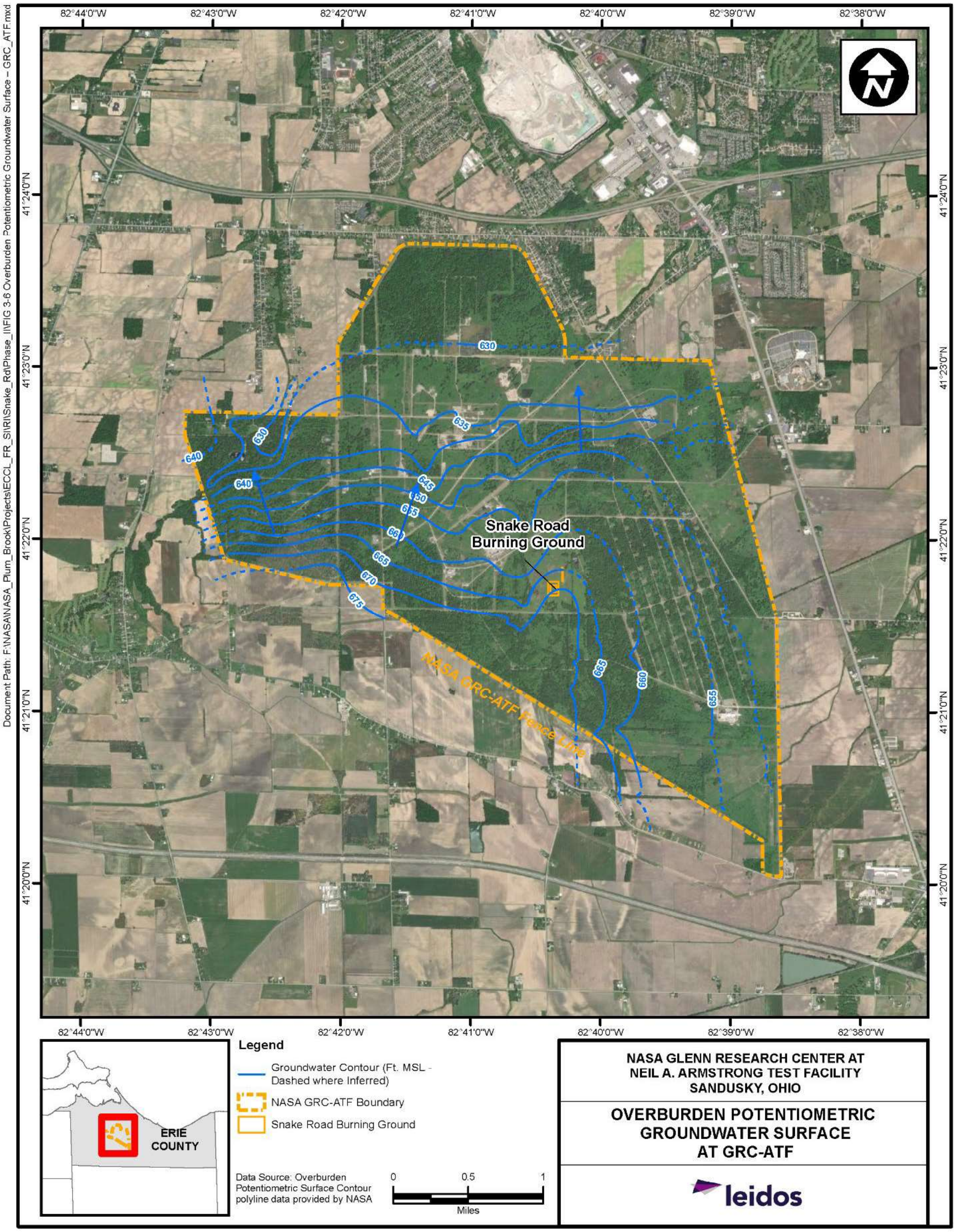


Figure 3–9. Overburden Potentiometric Groundwater Surface at GRC-ATF

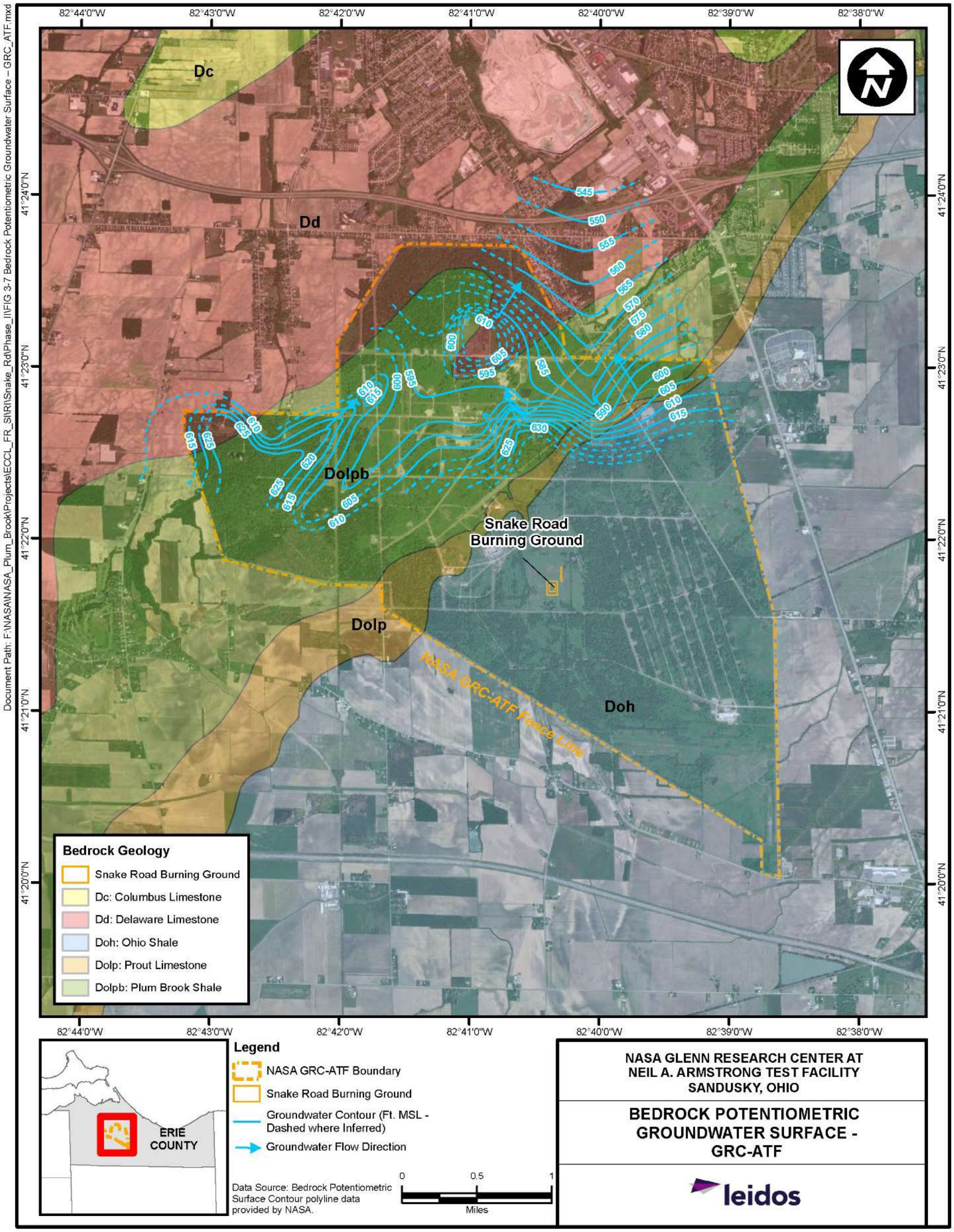


Figure 3–10. Bedrock Potentiometric Groundwater Surface at GRC-ATF

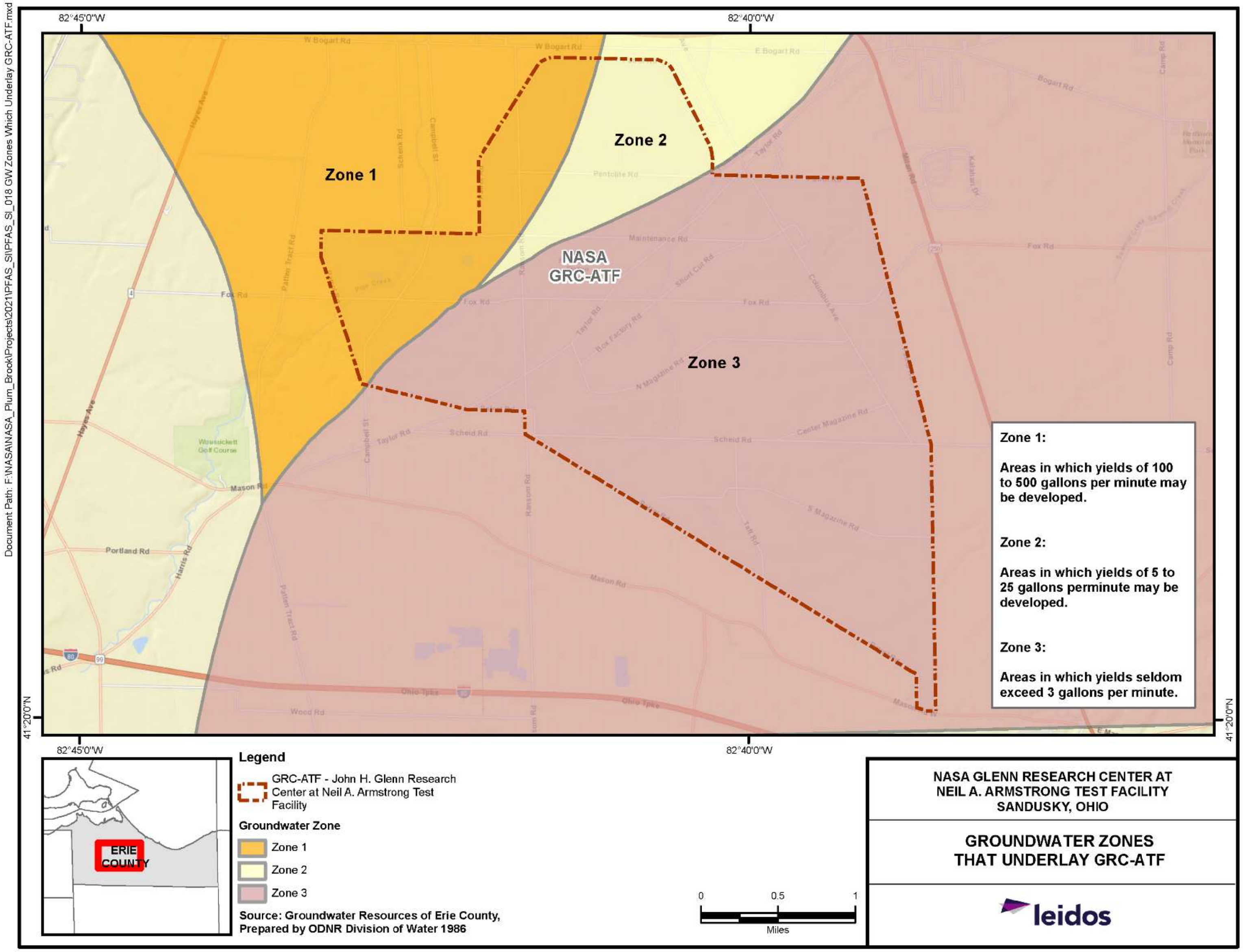


Figure 3–11. Groundwater Zones that Underlie GRC-ATF

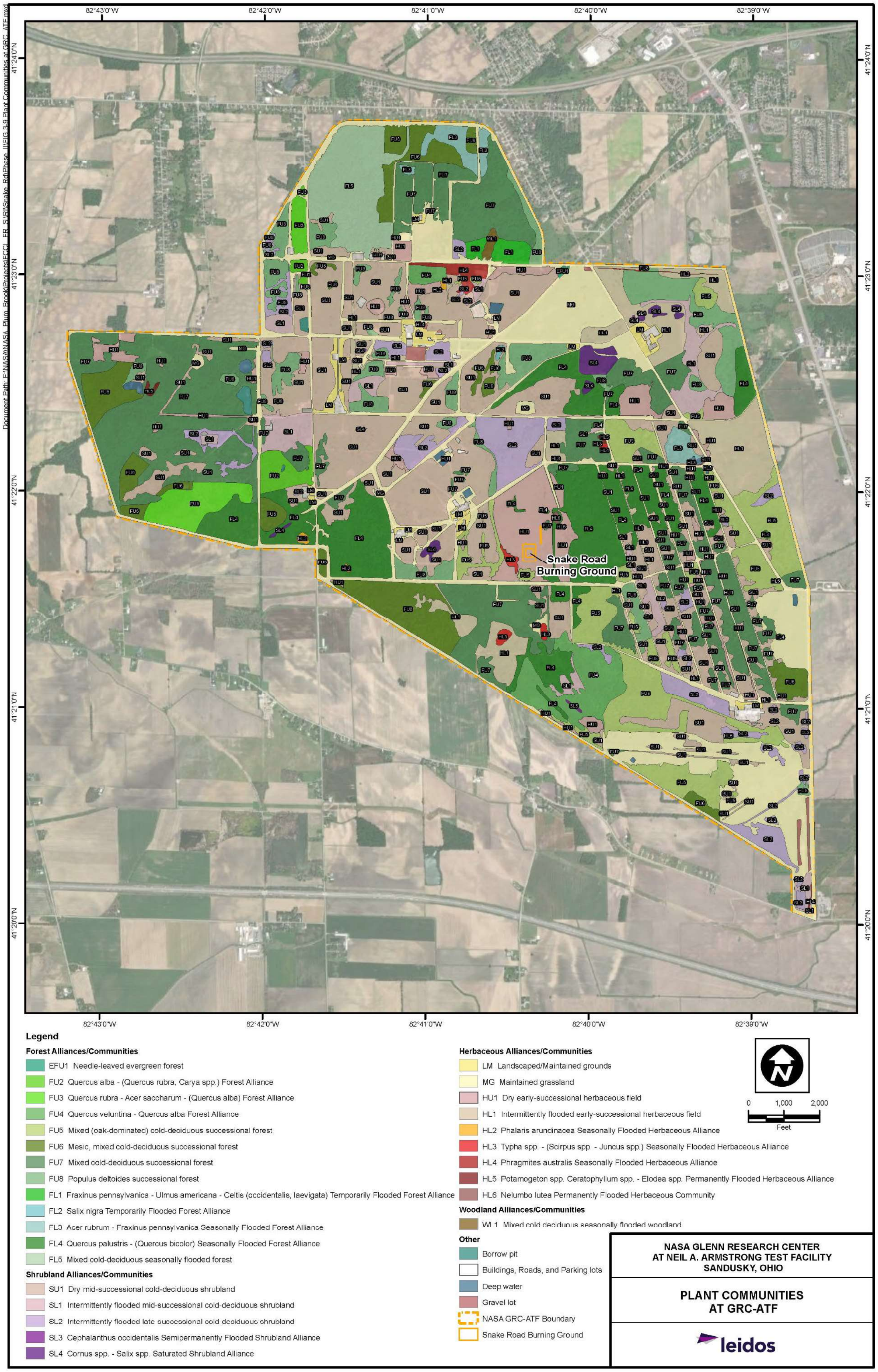


Figure 3–12. Plant Communities at GRC-ATF

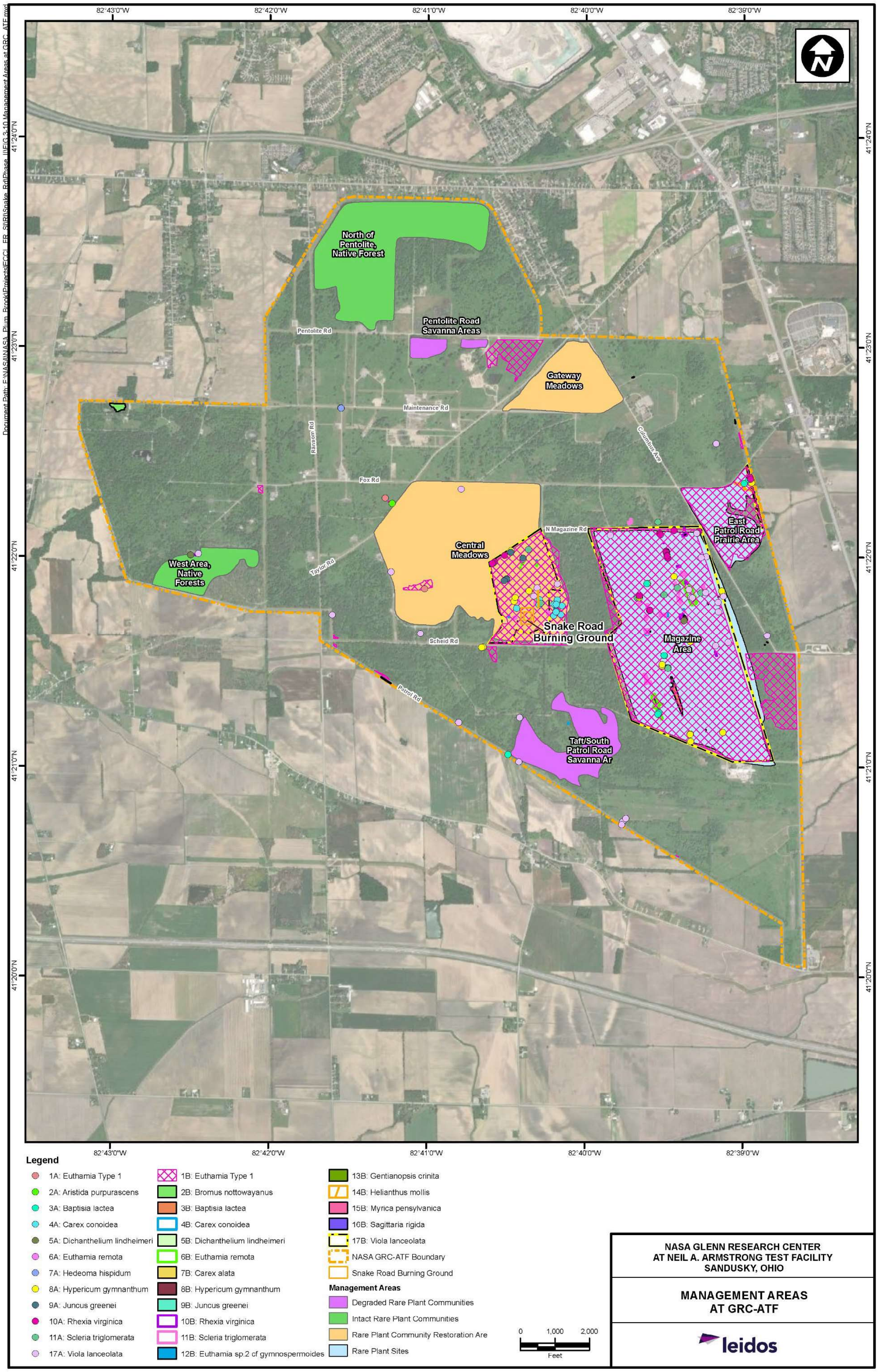


Figure 3–13. Management Areas at GRC-ATF

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 2020b).

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

- Utility clearance and general access/mobilization activities;
- Installation and development of three permanent groundwater monitoring wells (SRBG-MW01, SRBG-MW02, and SRBG-MW03);
- Development of two existing monitoring wells (GCL-MW01 and GCL-MW03);
- Two seasonal groundwater sampling events each consisting of the three new wells plus two existing wells sampled for metals, explosives, VOCs, SVOCs, pesticides, 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 SAP (Leidos 2020b) 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.

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, a total of three permanent monitoring wells were installed at SRBG 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 2020b) 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 three new permanent monitoring wells were developed using the pump and surge method on May 10, 2021. Existing site wells (GCL-MW01 and GCL-MW03) were redeveloped on May 12 and 13, 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 2020b) 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 2020b). 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 SRBG on May 17 and November 23, 2021. Groundwater elevation data are provided in Table 4-3. The groundwater potentiometric elevations for the November 2021 event are depicted in Figure 4-2. Groundwater flow at the site flows radially northward from the Primary Burn Area. This is consistent with general groundwater flow direction at GRC-ATF.

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.

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)
GCL-MW01	Stick-up	3/10/92 – 3/12/92	617559.0743	1921255.401	675.46	5-inch steel	10 slot	Ottawa Sand	11.0	5.99 – 10.97
GCL-MW03	Stick-up	3/12/92	617640.0608	1920776.792	672.74	5-inch steel	10 slot	Ottawa Sand	10.6	4.56 – 9.45
SRBG-MW01	Stick-up	4/27/21	617686.99	1921145.42	674.60	2-inch PVC	10 slot	#5 Sand	9.4	4.3 – 9.3
SRBG-MW02	Stick-up	4/26 – 4/27/21	617751.88	1921251.00	672.93	2-inch PVC	10 slot	#5 Sand	7.4	4.3 – 7.3
SRBG-MW03	Stick-up	4/26/21	617803.52	1921175.01	672.14	2-inch PVC	10 slot	#5 Sand	7.0	3.9 – 6.9

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)
New Wells								
SRBG-MW01	5/10/21	16.50	9.44	0.657	7.18	>800	2.98	71
SRBG-MW02	5/10/21	13.75	9.50	0.582	7.18	>800	3.65	51
SRBG-MW03	5/10/21	10.25	10.15	0.696	7.33	>800	3.29	6
Existing Wells								
GCL-MW01[a]	5/12 – 5/13/21	33	9.29	0.356	6.88	>800	3.42	14
GCL-MW03[a]	5/12 – 5/13/21	32	14.28	0.145	7.25	>800	12.69	102

[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
SRBG-MW01	674.60	5.51	6.28	669.09	668.32
SRBG-MW02	672.93	4.67	4.87	668.26	668.06
SRBG-MW03	672.14	4.05	4.19	668.09	667.95
GCL-MW01	675.46	6.19	7.15	669.27	668.31
GCL-MW03	672.74	5.10	4.96	667.64	667.78

Notes: 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

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 fluoro-polymer 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), 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, VOCs, SVOCs, pesticides, and PCBs analyses. Explosives samples were submitted to Eurofins/Test America Laboratory in Denver, Colorado.

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							
SRBG-MW01	6/07/21	-53	19.65	7.24	0.601	1.29	209
SRBG-MW02	6/01/21	-31	15.81	6.94	0.563	0.6	9.6
SRBG-MW03	6/07/21	-84	17.38	7.37	0.682	1.2	19.4
GCL-MW01	5/27/21	23	11.1	6.77	0.314	1.33	0.0
GCL-MW03	5/27/21	130	13.97	5.92	0.052	1.69	68

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

Monitoring Well Identifier	Sampling Date	ORP (mV)	Temperature (°C)	pH (S.U.)	Specific Conductivity (mS/cm)	Dissolved Oxygen (mg/L)	Turbidity (NTU)
Fall 2021 Phase II RI Water Quality Parameters							
SRBG-MW01	11/30/21	13	11.40	6.45	0.717	0.00	0.0
SRBG-MW02	12/01/21	-22	10.73	6.64	0.631	0.29	3.2
SRBG-MW03	12/01/21	-73	9.94	6.68	0.757	0.00	19.0
GCL-MW01	11/30/21	69	9.56	6.75	0.307	4.13	4.4
GCL-MW03	11/30/21	219	10.59	5.58	0.001	3.03	65.1

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 2020b). Decontamination of stainless-steel tools and equipment used during sampling activities (i.e., water level, bladder pump) were completed per the SAP (Leidos 2020b).

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 three 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 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.

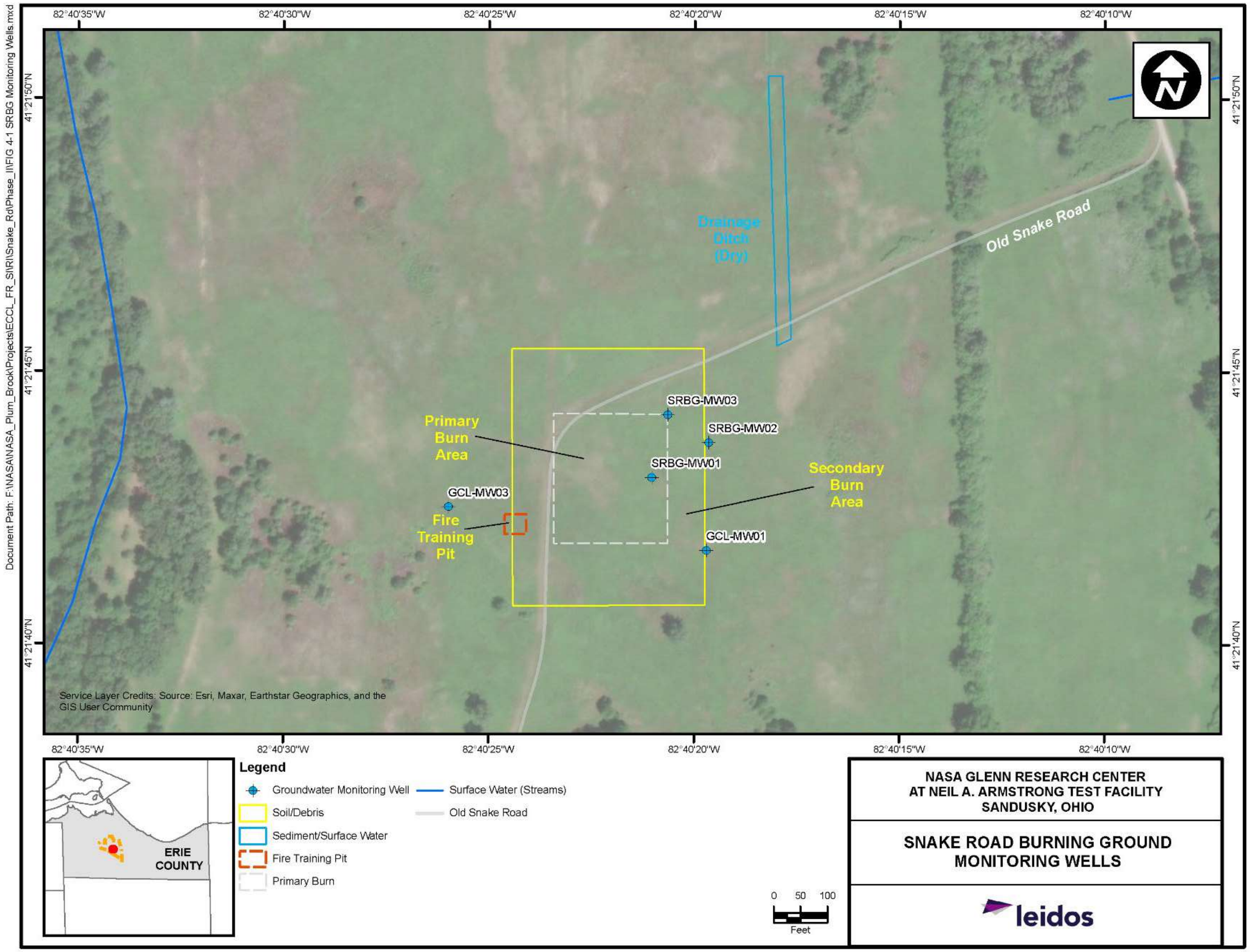


Figure 4–1. Snake Road Burning Ground Monitoring Wells

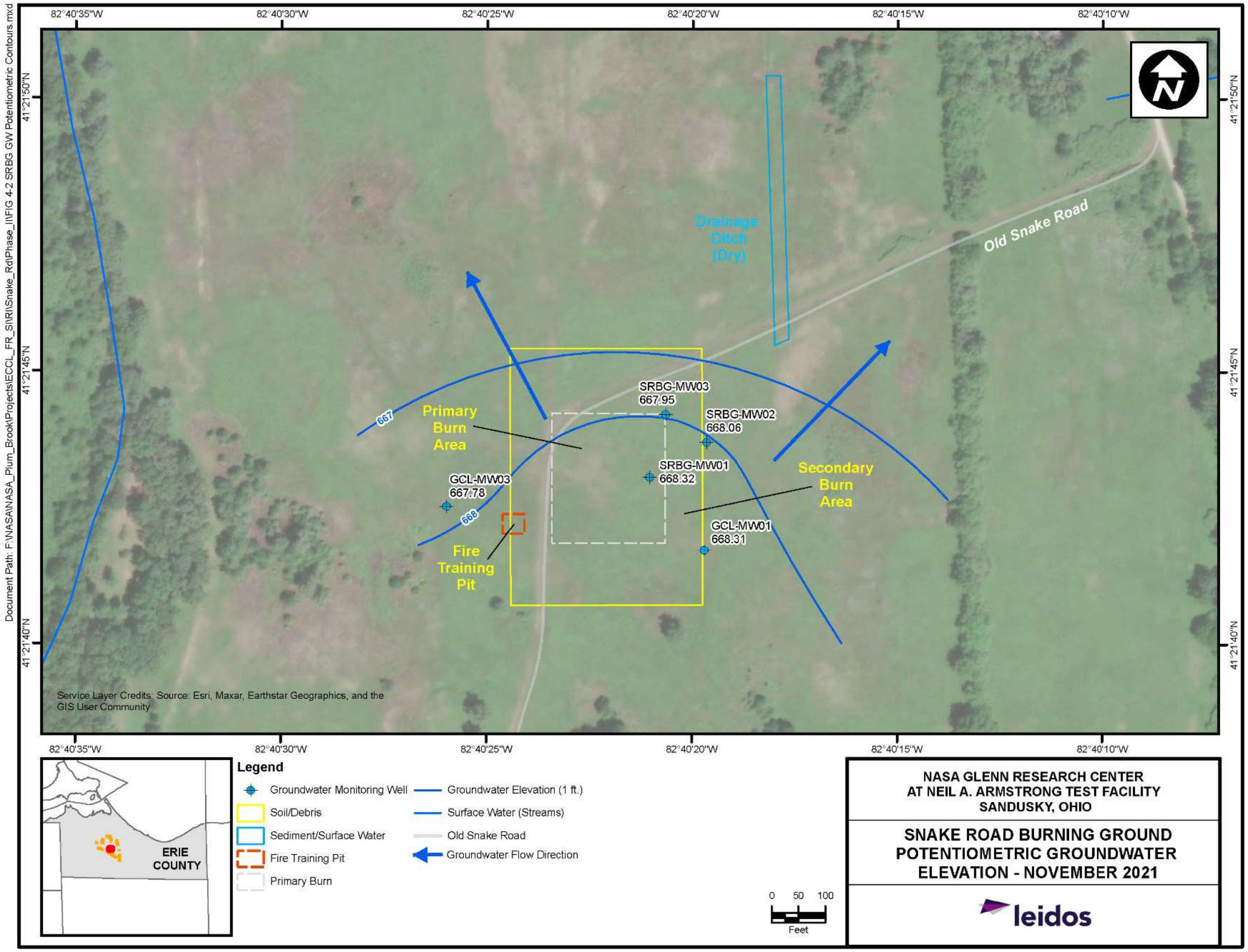


Figure 4–2. Snake Road Burning Ground Potentiometric Groundwater Elevation – November 2021

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5. DATA EVALUATION

5.1 DATA USE

The Phase II RI SAP Plan (Leidos 2020b) 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 2020b). 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.

5.2 ENVIRONMENTAL MEDIA

5.2.1 Groundwater

The scope of the Phase II RI Report includes a full evaluation of groundwater. Three permanent monitoring wells were installed in April 2021 to supplement two existing monitoring wells to effectively characterize the downgradient and source area groundwater conditions. Groundwater collection resulted in five samples with an additional duplicate and matrix spike/matrix spike duplicate (MS/MSD) from five monitoring wells for each of the Phase II RI sampling events. 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 identified in subsurface soils at SRBG as part of the Phase I RI or groundwater in Phase II. Evidence determined that vapor points were not warranted at SRBG.

5.3 DATA QUALITY

The data used in this RI Report were verified and validated using the methodology described in the SAP (Leidos 2020b). 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 a hazard quotient (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
SRBG-MW01	SRBGGW1001	6/7/2021	2021 Phase II RI	--	X	X	X	--	RCRA Metals (Filtered and unfiltered), Explosives, PCBs, Pesticides, SVOCs, VOCs
SRBG-MW02	SRBGGW1002	6/1/2021	2021 Phase II RI	--	X	X	X	--	RCRA Metals (Filtered and unfiltered), Explosives, PCBs, Pesticides, SVOCs, VOCs
SRBG-MW03	SRBGGW1003	6/7/2021	2021 Phase II RI	--	X	X	X	--	RCRA Metals (Filtered and unfiltered), Explosives, PCBs, Pesticides, SVOCs, VOCs
GCL-MW01	SRBGGW1004	5/27/2021	2021 Phase II RI	--	X	X	X	--	RCRA Metals (Filtered and unfiltered), Explosives, PCBs, Pesticides, SVOCs, VOCs
GCL-MW01	SRBGGW9102	5/27/2021	2021 Phase II RI	X	X	X	X	--	RCRA Metals (Filtered and unfiltered), Explosives, PCBs, Pesticides, SVOCs, VOCs
GCL-MW03	SRBGGW1005	5/27/2021	2021 Phase II RI	X	X	X	X	--	RCRA Metals (Filtered and unfiltered), Explosives, PCBs, Pesticides, SVOCs, VOCs
SRBG-MW01	SRBGGW1006	11/30/2021	2021 Phase II RI	--	X	X	X	--	RCRA Metals (Filtered and unfiltered), Explosives, PCBs, Pesticides, SVOCs, VOCs
SRBG-MW02	SRBGGW1007	12/1/2021	2021 Phase II RI	--	X	X	X	--	RCRA Metals (Filtered and unfiltered), Explosives, PCBs, Pesticides, SVOCs, VOCs
SRBG-MW03	SRBGGW1008	12/1/2021	2021 Phase II RI	--	X	X	X	--	RCRA Metals (Filtered and unfiltered), Explosives, PCBs, Pesticides, SVOCs, VOCs
SRBG-MW03	SRBGGW9103	12/1/2021	2021 Phase II RI	X	X	X	X	--	RCRA Metals (Filtered and unfiltered), Explosives, PCBs, Pesticides, SVOCs, VOCs
GCL-MW01	SRBGGW1009	11/30/2021	2021 Phase II RI	--	X	X	X	--	RCRA Metals (Filtered and unfiltered), Explosives, PCBs, Pesticides, SVOCs, VOCs
GCL-MW01	SRBGGW9104	11/30/2021	2021 Phase II RI	X	X	X	X	--	RCRA Metals (Filtered and unfiltered), Explosives, PCBs, Pesticides, SVOCs, VOCs
GCL-MW03	SRBGGW1010	11/30/2021	2021 Phase II RI	--	X	X	X	--	RCRA Metals (Filtered and unfiltered), Explosives, PCBs, Pesticides, 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 SRBG. The evaluation discusses the nature and extent of SRCs in groundwater at SRBG, using analytical data results obtained during the 2021 Phase II RI. Nature and extent of soil contamination at SRBG 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 TR of 1E-06. Appendix E contains analytical data from the 2021 Phase II RI. 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

Thirteen groundwater samples were collected at SRBG, including three field duplicates and five primary samples from each of the two sampling events. The sampling suite associated with groundwater included RCRA metals (filtered and unfiltered), explosives, PCBs, pesticides, SVOCs, and VOCs.

In groundwater, 22 metals, 1 SVOC (caprolactam), and 8 VOCs (1,1-dichloroethane; chloromethane; cyclohexane; m + p xylene; methylcyclohexane; o-xylene, toluene; and total xylenes [m- + p- and o-]) were detected. The SVOC and six of the VOCs were detected at concentrations below the risk screening criteria. No risk screening criteria were available for the VOC methylcyclohexane. Seven of the 22 metals (aluminum, arsenic, cadmium, iron, lead, 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 SRBG.

Aluminum – Total aluminum was detected in 7 of the 10 samples with a maximum detection of 39,000 micrograms per liter (µg/L). Four of the detections were above the background concentration of 309 µg/L, but only two samples were above the tap water RSL of 2,000 µg/L. Both exceedances were from samples collected at GCL-MW03 (8,000 µg/L in May 2021 and 39,000 µg/L in November 2021). Aluminum was detected in 2 of the 10 samples that were filtered, both at GCL-MW03. Only the November 2021 filtered sample at a concentration of 10,000 µg/L exceeded the RSL.

Arsenic – Total arsenic was detected in 9 of the 10 samples with a maximum detection of 9.6 µg/L. All nine detections exceeded the RSL of 0.052 µg/L, but only one sample result exceeded the background concentration of 7.4 µg/L. The exceedance was from the November 2021 sample collected at GCL-MW03 at a concentration of 9.6 µg/L. However, this concentration is below the MCL of 10 µg/L. Arsenic was detected in 7 of the 10 filtered samples, with an average concentration of 3.95 µg/L and a maximum concentration of 7.7 µg/L from the June 2021 sample at SRBG-MW02. All seven detected sample results exceeded the RSL but were below the MCL.

Cadmium – Total cadmium was only detected in 1 of the 10 samples at an estimated concentration of 0.3 µg/L in the November 2021 sample at SRBG-MW01. The result exceeded the RSL of 0.18 µg/L but below the MCL of 5 µg/L. Cadmium was not detected in the filtered samples. The detection limits of the total and filtered samples were above the RSL but below the MCL.

Cobalt – Total and dissolved cobalt was detected in all 10 samples with a total cobalt maximum concentration of 9 µg/L and a dissolved cobalt maximum concentration of 4.4 µg/L, which is below the background concentration of 12.1 µg/L. All but one total and dissolved sample results were above the RSL of 0.6 µg/L.

Iron – Total iron was detected in 9 of the 10 samples with a maximum concentration of 14,000 µg/L. Six of the sample results exceeded the background concentration of 1,550 µg/L and the RSL of 1,400 µg/L at GCL-MW03 (2,700 µg/L in May and 14,000 µg/L in November 2021), SRBG-MW01 (3,100 µg/L in June 2021), SRBG-MW-02 (2,000 µg/L in December 2021), and SRBG-MW03 (2,700 µg/L in June and 3,200 µg/L in December 2021). Dissolved iron was also detected in 9 of the 10 filtered samples. Only four results exceeded the RSL at GCL-MW03 (3,400 µg/L in November 2021), SRBG-MW-02 (1,800 µg/L in December 2021), and SRBG-MW03 (2,800 µg/L in June and 3,000 µg/L in December 2021).

Lead – Total lead was detected in 4 of the 10 samples. Only one sample result exceeded the tap water RSL and MCL of 15 µg/L in the sample collected at GCL-MW03 in November 2021 at a concentration of

26 µg/L. Dissolved lead was only detected in one sample location (GCL-MW03) in November 2021 at a concentration of 6.3 µg/L, which is below the RSL and MCL.

Manganese – Total and dissolved manganese was detected in all 10 samples with a total manganese maximum concentration of 505 µg/L and a dissolved manganese maximum concentration of 520 µg/L, which is below the background concentration of 636 µg/L. All but one total and one dissolved sample result were above the RSL of 43 µg/L. Total and dissolved concentrations were below the RSL in the November 2021 sample from GCL-MW03.

Thallium – Total thallium was detected in 5 of the 10 samples and exceeded the RSL of 0.02 µg/L at GCL-MW03 (0.28 µg/L in May and 1.4 µg/L in November 2021), SRBG-MW01 (0.63 µg/L in November 2021), SRBG-MW02 (0.85 µg/L in December 2021), and SRBG-MW03 (0.22 µg/L in December 2021). The total thallium concentrations did not exceed the MCL of 2 µg/L. Dissolved thallium was only detected in 3 of the 10 samples and exceeded the RSL at GCL-MW01 (3.6 µg/L in May 2021), GCL-MW03 (0.28 µg/L in November 2021) and SRBG-MW02 (0.46 µg/L in December 2021). Only the GCL-MW01 dissolved thallium concentration exceeded the MCL. The detection limits for both total (1 µg/L) and dissolved (1 or 10 µg/L) thallium were above the RSL.

Vanadium – Total vanadium was detected in 5 of the 10 samples. Only two of the results exceeded the RSL of 8.6 µg/L in samples collected at GCL-MW03 (12 µg/L in May and 47 µg/L in November 2021). Dissolved vanadium was only detected in one sample and exceeded the RSL in the November 2021 sample from GCL-MW03 at a concentration of 13 µg/L. The detection limits for dissolved vanadium (50 µg/L) were above the RSL in six of the samples.

6.2 CONCLUSIONS

During the Phase I RI for SRBG, the site was divided into three EUs to allow for refined evaluation of potential chemical contamination and potential exposure. These EUs were the Primary Burn Area, Secondary Burn Area, and Drainage Ditch. In addition, the area identified as the Fire Training Pit had its own focused evaluation. The sampling rationale for each groundwater sampling location was to assess potential impacts to overburden groundwater within or downgradient from the EU source area. Conservative transport modeling in the Phase I RI indicated 13 chemicals may leach from soil and migrate to the groundwater table beneath their respective sources at concentrations exceeding MCLs/RSLs. The 13 chemicals included inorganics (silver), explosives (2,4,6-TNT; 2,4-DNT; 2,6-DNT; 2-amino-4,6-DNT; and 4-amino-2,6-DNT), SVOCs (1,1'-biphenyl, benzaldehyde, caprolactam, hexachloroethane, and naphthalene), and pesticides (alpha- hexachlorocyclohexane and beta- hexachlorocyclohexane). 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 SRBG that may potentially impact groundwater. This qualitative assessment concluded that without available groundwater data, two initial CMCOCs (hexachloroethane and naphthalene) should be assessed during future groundwater studies at the site (Leidos 2018a). Of the 13 chemicals from the transport modeling, only caprolactam was detected in groundwater, but concentrations were below the tap water RSL.

Only seven total inorganics (aluminum, arsenic, cadmium, iron, lead, thallium, and vanadium) exceeded their respective background concentrations and/or the tap water RSL in groundwater at SRBG. Total and filtered aluminum exceedances were limited to GCL-MW03 located in the Secondary Burn Area. Total arsenic only exceeded screening criteria at GCL-MW03 in November 2021. All seven detected dissolved arsenic results exceeded the RSL, but only the June 2021 sample at SRBG-MW02 exceeded the background concentration. The single cadmium (total) exceedance was limited to the November 2021 sample collected at SRBG-MW01 located in the Primary Burn Area. None of the total cobalt concentrations were above background concentrations, and 9 of the 10 dissolved cobalt concentrations exceeded the tap water RSL but were below the corresponding background concentration. Total iron exceeded the screening criteria at four of the five sampling locations: GCL-MW03 (May and November 2021), SRBG-MW01 (June 2021), SRBG-MW02 (December 2021), and SRBG-MW03 (June and December 2021). Four filtered iron results exceeded the tap water RSL at GCL-MW03 (November 2021), SRBG-MW-02 (December 2021), and SRBG-MW03 (December 2021). Total and dissolved lead only exceeded screening criteria at one location (GCL-MW03 location to the west of the Primary Burn Area) in November 2021. Dissolved manganese exceeded the tap water RSL in at least one sample at all sampling locations, but all concentrations were below the corresponding background concentration. Total thallium exceeded screening criteria during both events at GCL-MW03 and only in December 2021 at SRBG-MW01, SRBG-MW02, and SRBG-MW03. Dissolved thallium exceeded screening criteria in May 2021 at GCL-MW01, in November 2021 at GCL-MW03 and in December 2021 at SRBG-MW02 and SRBG-MW03. Vanadium exceedances were limited to one location (GCL-MW03) during both events; both total and dissolved vanadium exceeded screening criteria in November 2021, and only total vanadium exceeded criteria in May 2021. Most metal exceedances were at GCL-MW03, which is located west of the site and cross-gradient of the other wells.

During the data collection program planning phase of the RI, the locations of the three additional monitoring wells were designed to assess potential impacts to the overburden groundwater within and immediately downgradient of the source area from areas where soil COCs were identified for remediation. Three of the four soil remediation areas identified in the FS (Leidos 2018c) are located within the Primary Burn Area and the fourth soil remediation area is located to the east of the Primary Burn Area but with the Secondary Burn Area. No soil remediation areas were identified near GCL-MW03. The groundwater in the overburden is in discontinuous pockets during dry time periods. During wet periods, the general flow direction in the overburden water-bearing zone is radially to the north from SRBG, largely mirroring surface topography (Shaw 2005). Most metal concentration exceedances in groundwater were at GCL-MW03, which is located to the west-southwest of the other wells sampled. None of the metals with concentration exceedances were identified as groundwater COCs in the HHRA (Section 8), In addition, none of the CMCOCs identified in the Phase I RI were detected in the groundwater above screening criteria. It appears the extent of the contaminants in the SRBG groundwater has been adequately characterized.

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	7/10	115	39000	4970	309	Yes	4	2000	n	Yes	2	--	--	--	Exceeds screening level
Metals, Total	Arsenic	7440-38-2	9/10	0.93	9.6	3.97	7.4	Yes	1	0.052	c	Yes	9	10	No	0	Exceeds screening level
Metals, Total	Barium	7440-39-3	10/10	26	120	57	11800	No	0	380	n	No	0	2000	No	0	Below background and RSL
Metals, Total	Beryllium	7440-41-7	3/10	0.33	1.3	0.548	--	--	--	2.5	n	No	0	4	No	0	Below risk screening criteria
Metals, Total	Cadmium	7440-43-9	1/10	0.3	0.3	0.48	--	--	--	0.18	n	Yes	1	5	No	0	Exceeds screening level
Metals, Total	Calcium	7440-70-2	10/10	6200	115000	69100	316000	No	0	--	--	--	0	--	--	--	Essential nutrient
Metals, Total	Chromium	7440-47-3	3/10	2.5	28	5.2	--	--	--	2200	n	No	0	100	No	0	Below risk screening criteria
Metals, Total	Cobalt	7440-48-4	10/10	0.84	9	2.97	12.1	No	0	0.6	n	Yes	10	--	--	--	Below background
Metals, Total	Copper	7440-50-8	6/10	1.9	42	6.66	19.8	Yes	1	80	n	No	0	1300	No	0	Below risk screening criteria
Metals, Total	Iron	7439-89-6	9/10	965	14000	3120	1550	Yes	6	1400	n	Yes	6	--	--	--	Exceeds screening level
Metals, Total	Lead	7439-92-1	4/10	0.6	26	3.73	--	--	--	15	MCL	Yes	1	15	Yes	1	Exceeds screening level
Metals, Total	Magnesium	7439-95-4	10/10	3700	43000	25400	217000	No	0	--	--	--	0	--	--	--	Essential nutrient
Metals, Total	Manganese	7439-96-5	10/10	41	505	237	636	No	0	43	n	Yes	9	--	--	--	Below background
Metals, Total	Mercury	7439-97-6	1/10	0.13	0.13	0.103	--	--	--	0.57	n	No	0	2	No	0	Below risk screening criteria
Metals, Total	Nickel	7440-02-0	10/10	4.2	39	12.1	8.6	Yes	5	39	n	No	0	--	--	--	Below risk screening criteria
Metals, Total	Potassium	7440-09-7	7/10	800	3100	2000	116000	No	0	--	--	--	0	--	--	--	Essential nutrient
Metals, Total	Selenium	7782-49-2	4/10	0.93	3.3	2.28	--	--	--	10	n	No	0	50	No	0	Below risk screening criteria
Metals, Total	Silver	7440-22-4	2/10	0.056	0.06	0.412	--	--	--	9.4	n	No	0	--	--	--	Below risk screening criteria
Metals, Total	Sodium	7440-23-5	10/10	2600	28000	10600	1390000	No	0	--	--	--	0	--	--	--	Essential nutrient
Metals, Total	Thallium	7440-28-0	5/10	0.22	1.4	0.588	--	--	--	0.02	n	Yes	5	2	No	0	Exceeds screening level
Metals, Total	Vanadium	7440-62-2	5/10	1	47	7.86	--	--	--	8.6	n	Yes	2	--	--	--	Exceeds screening level
Metals, Total	Zinc	7440-66-6	2/10	18	68	16.6	507	No	0	600	n	No	0	--	--	--	Below background and RSL
Metals, Dissolved	Aluminum, Dissolved	7429-90-5	2/10	440	10000	1090	--	--	--	2000	n	Yes	1	--	--	--	Exceeds screening level
Metals, Dissolved	Arsenic, Dissolved	7440-38-2	7/10	0.78	7.7	3.95	--	--	--	0.052	c	Yes	7	10	No	0	Exceeds screening level
Metals, Dissolved	Barium, Dissolved	7440-39-3	10/10	8	88	45.4	--	--	--	380	n	No	0	2000	No	0	Below risk screening criteria
Metals, Dissolved	Calcium, Dissolved	7440-70-2	10/10	4700	120000	69700	--	--	--	--	--	--	0	--	--	--	Essential nutrient
Metals, Dissolved	Chromium, Dissolved	7440-47-3	2/10	0.7	7.5	2.82	--	--	--	2200	n	No	0	100	No	0	Below risk screening criteria
Metals, Dissolved	Cobalt, Dissolved	7440-48-4	9/10	0.81	4.4	2.57	--	--	--	0.6	n	Yes	9	--	--	--	Exceeds screening level
Metals, Dissolved	Copper, Dissolved	7440-50-8	3/10	1.9	11	7.94	--	--	--	80	n	No	0	1300	No	0	Below risk screening criteria
Metals, Dissolved	Iron, Dissolved	7439-89-6	9/10	880	3400	1530	--	--	--	1400	n	Yes	4	--	--	--	Exceeds screening level
Metals, Dissolved	Lead, Dissolved	7439-92-1	1/10	6.3	6.3	2.08	--	--	--	15	MCL	No	0	15	No	0	Below risk screening criteria
Metals, Dissolved	Magnesium, Dissolved	7439-95-4	10/10	1900	45000	25700	--	--	--	--	--	--	0	--	--	--	Essential nutrient
Metals, Dissolved	Manganese, Dissolved	7439-96-5	10/10	23	520	235	--	--	--	43	n	Yes	9	--	--	--	Exceeds screening level
Metals, Dissolved	Nickel, Dissolved	7440-02-0	10/10	2.9	15	8.25	--	--	--	39	n	No	0	--	--	--	Below risk screening criteria
Metals, Dissolved	Potassium, Dissolved	7440-09-7	6/10	835	2550	1850	--	--	--	--	--	--	0	--	--	--	Essential nutrient
Metals, Dissolved	Selenium, Dissolved	7782-49-2	2/10	1.4	3.4	4.98	--	--	--	10	n	No	0	50	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	Silver, Dissolved	7440-22-4	1/10	0.62	0.62	1.31	--	--	--	9.4	n	No	0	--	--	--	Below risk screening criteria
Metals, Dissolved	Sodium, Dissolved	7440-23-5	9/10	2600	24000	10100	--	--	--	--	--	--	0	--	--	--	Essential nutrient
Metals, Dissolved	Thallium, Dissolved	7440-28-0	3/10	0.28	3.8	2.6	--	--	--	0.02	n	Yes	3	2	Yes	1	Exceeds screening level
Metals, Dissolved	Vanadium, Dissolved	7440-62-2	1/10	13	13	14.8	--	--	--	8.6	n	Yes	1	--	--	--	Exceeds screening level
Metals, Dissolved	Zinc, Dissolved	7440-66-6	2/10	11	22	17.3	--	--	--	600	n	No	0	--	--	--	Below risk screening criteria
Organics-Semivolatile	Caprolactam	105-60-2	4/9	2.5	3.9	2.84	--	--	--	990	n	No	0	--	--	--	Below risk screening criteria
Organics-Volatile	1,1-Dichloroethane	75-34-3	1/10	0.54	0.54	0.504	--	--	--	2.8	c	No	0	--	--	--	Below risk screening criteria
Organics-Volatile	Chloromethane	74-87-3	1/10	0.2	0.2	0.47	--	--	--	19	n	No	0	--	--	--	Below risk screening criteria
Organics-Volatile	Cyclohexane	110-82-7	3/10	0.54	1	0.568	--	--	--	1300	n	No	0	--	--	--	Below risk screening criteria
Organics-Volatile	M + P Xylene	179601-23-1	1/10	0.17	0.17	0.917	--	--	--	19	n	No	0	--	--	--	Below risk screening criteria
Organics-Volatile	Methylcyclohexane	108-87-2	3/10	0.39	0.63	0.495	--	--	--	--	--	No	0	--	--	--	Detected/no screening criteria
Organics-Volatile	Toluene	108-88-3	1/10	0.22	0.22	0.472	--	--	--	110	n	No	0	1000	No	0	Below risk screening criteria
Organics-Volatile	Xylene, Total	1330-20-7	1/10	0.33	0.33	0.933	--	--	--	19	n	No	0	10000	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 2022).
RSL – USEPA Regional Screening Level for tap water for HQ=0.1 and TR=1E-6 May 2022 update (USEPA 2022).
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
Freq = Frequency
MCL = Maximum Contaminant Level
N = non-carcinogenic
RSL = Regional Screening Level,
USEPA = U.S. Environmental Protection Agency

Analyte	Background	Tapwater RSL
Aluminum	309	2000
Arsenic	7.4	0.052
Cadmium	--	0.18
Chromium	--	2200
Cobalt	12.1	0.6
Iron	1550	1400
Lead	--	15
Manganese	636	43
Thallium	--	0.02
Vanadium	--	8.6

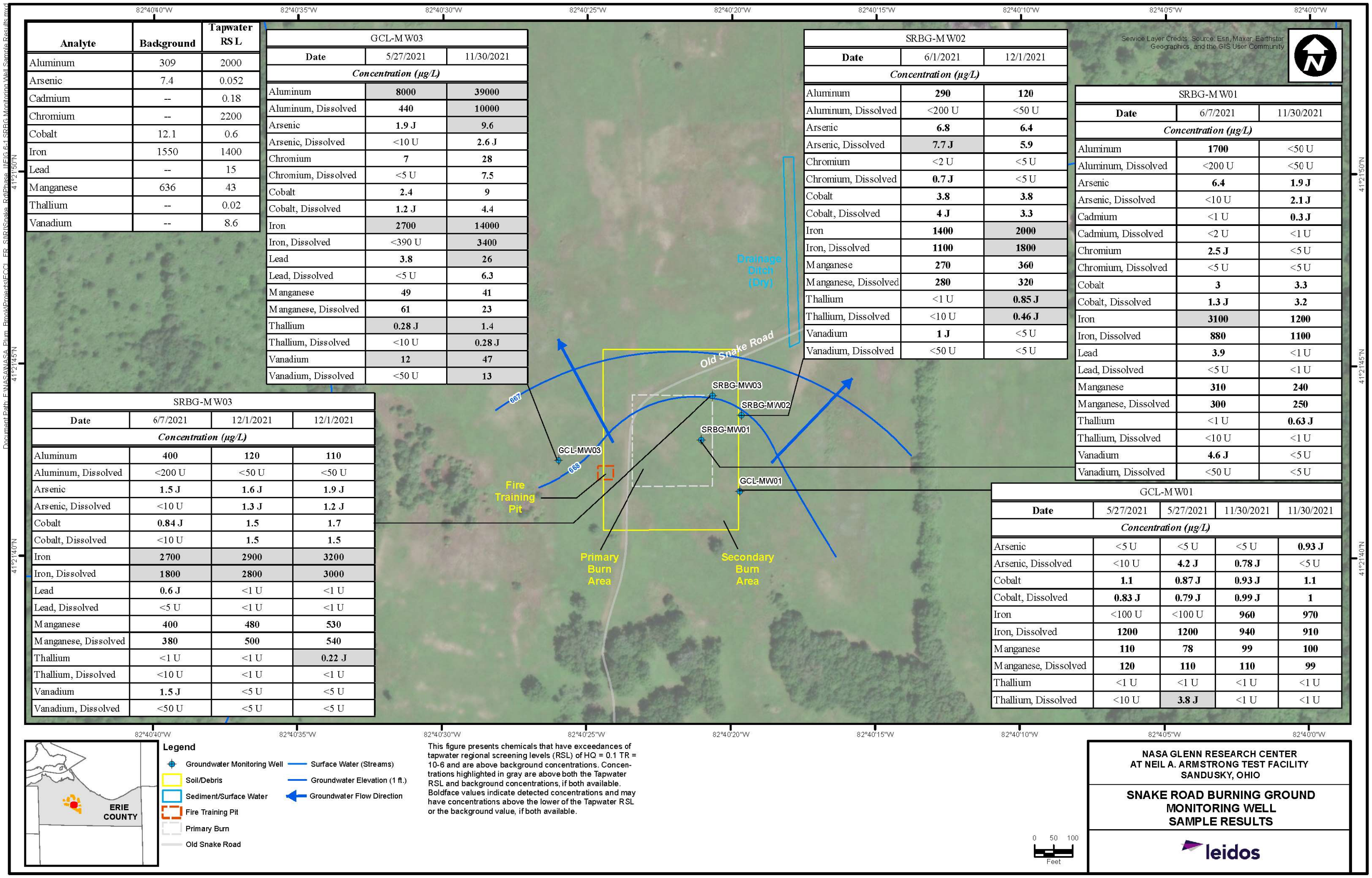
GCL-MW03		
Date	5/27/2021	11/30/2021
	Concentration (µg/L)	
Aluminum	**8000**	**39000**
Aluminum, Dissolved	**440**	**10000**
Arsenic	**1.9 J**	**9.6**
Arsenic, Dissolved	<10 U	**2.6 J**
Chromium	**7**	**28**
Chromium, Dissolved	<5 U	**7.5**
Cobalt	**2.4**	**9**
Cobalt, Dissolved	**1.2 J**	**4.4**
Iron	**2700**	**14000**
Iron, Dissolved	<390 U	**3400**
Lead	**3.8**	**26**
Lead, Dissolved	<5 U	**6.3**
Manganese	**49**	**41**
Manganese, Dissolved	**61**	**23**
Thallium	**0.28 J**	**1.4**
Thallium, Dissolved	<10 U	**0.28 J**
Vanadium	**12**	**47**
Vanadium, Dissolved	<50 U	**13**

SRBG-MW02		
Date	6/1/2021	12/1/2021
	Concentration (µg/L)	
Aluminum	**290**	**120**
Aluminum, Dissolved	<200 U	<50 U
Arsenic	**6.8**	**6.4**
Arsenic, Dissolved	**7.7 J**	**5.9**
Chromium	<2 U	<5 U
Chromium, Dissolved	**0.7 J**	<5 U
Cobalt	**3.8**	**3.8**
Cobalt, Dissolved	**4 J**	**3.3**
Iron	**1400**	**2000**
Iron, Dissolved	**1100**	**1800**
Manganese	**270**	**360**
Manganese, Dissolved	**280**	**320**
Thallium	<1 U	**0.85 J**
Thallium, Dissolved	<10 U	**0.46 J**
Vanadium	**1 J**	<5 U
Vanadium, Dissolved	<50 U	<5 U

SRBG-MW01		
Date	6/7/2021	11/30/2021
	Concentration (µg/L)	
Aluminum	**1700**	<50 U
Aluminum, Dissolved	<200 U	<50 U
Arsenic	**6.4**	**1.9 J**
Arsenic, Dissolved	<10 U	**2.1 J**
Cadmium	<1 U	**0.3 J**
Cadmium, Dissolved	<2 U	<1 U
Chromium	**2.5 J**	<5 U
Chromium, Dissolved	<5 U	<5 U
Cobalt	**3**	**3.3**
Cobalt, Dissolved	**1.3 J**	**3.2**
Iron	**3100**	**1200**
Iron, Dissolved	**880**	**1100**
Lead	**3.9**	<1 U
Lead, Dissolved	<5 U	<1 U
Manganese	**310**	**240**
Manganese, Dissolved	**300**	**250**
Thallium	<1 U	**0.63 J**
Thallium, Dissolved	<10 U	<1 U
Vanadium	**4.6 J**	<5 U
Vanadium, Dissolved	<50 U	<5 U

SRBG-MW03			
Date	6/7/2021	12/1/2021	12/1/2021
	Concentration (µg/L)		
Aluminum	**400**	**120**	**110**
Aluminum, Dissolved	<200 U	<50 U	<50 U
Arsenic	**1.5 J**	**1.6 J**	**1.9 J**
Arsenic, Dissolved	<10 U	**1.3 J**	**1.2 J**
Cobalt	**0.84 J**	**1.5**	**1.7**
Cobalt, Dissolved	<10 U	**1.5**	**1.5**
Iron	**2700**	**2900**	**3200**
Iron, Dissolved	**1800**	**2800**	**3000**
Lead	**0.6 J**	<1 U	<1 U
Lead, Dissolved	<5 U	<1 U	<1 U
Manganese	**400**	**480**	**530**
Manganese, Dissolved	**380**	**500**	**540**
Thallium	<1 U	<1 U	**0.22 J**
Thallium, Dissolved	<10 U	<1 U	<1 U
Vanadium	**1.5 J**	<5 U	<5 U
Vanadium, Dissolved	<50 U	<5 U	<5 U

GCL-MW01				
Date	5/27/2021	5/27/2021	11/30/2021	11/30/2021
	Concentration (µg/L)			
Arsenic	<5 U	<5 U	<5 U	**0.93 J**
Arsenic, Dissolved	<10 U	**4.2 J**	**0.78 J**	<5 U
Cobalt	**1.1**	**0.87 J**	**0.93 J**	**1.1**
Cobalt, Dissolved	**0.83 J**	**0.79 J**	**0.99 J**	**1**
Iron	<100 U	<100 U	**960**	**970**
Iron, Dissolved	**1200**	**1200**	**940**	**910**
Manganese	**110**	**78**	**99**	**100**
Manganese, Dissolved	**120**	**110**	**110**	**99**
Thallium	<1 U	<1 U	<1 U	<1 U
Thallium, Dissolved	<10 U	**3.8 J**	<1 U	<1 U



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 both the Tapwater RSL and background concentrations, if both available. Boldface values indicate detected concentrations and may have concentrations above the lower of the Tapwater RSL or the background value, if both available.

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SNAKE ROAD BURNING GROUND
MONITORING WELL
SAMPLE RESULTS

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 SRBG. Based on groundwater sample results discussed in the previous section, the main SRCs that occur in groundwater at SRBG 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, metals adsorption increases with pH and they 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 at SRBG but not in the groundwater. The nitro groups of TNT are the most prevalent explosives in soils 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. Some types of organic chemicals are very stable, and degradation rates can be very 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 SRBG 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 SRBG 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 SRBG 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 SRBG 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 SRBG 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 SRBG is to the northeast (Figure 4-2). The approximate hydraulic gradient is 0.00457 ft/ft.
- The upper bedrock surface at SRBG is the Devonian Age Ohio Shale. Based on soil boring logs completed at the site for the wells sampled, depth to bedrock is 6.1 to 9.5 feet bgs.
- Based on the 2001 Groundwater RI (USACE 2002), depth to water at SRBG fluctuates throughout the year between approximately 1.5 and 7 feet bgs. During the Phase II RI field investigation, groundwater in the overburden soil was observed at depths ranging from 1.55 to 2.76 feet bgs in May 2021 and 1.69 to 3.72 feet bgs 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 hexachloroethane and naphthalene for future groundwater evaluation to assess the modeling results. Hexachloroethane and naphthalene were not detected in groundwater at SRBG during the Phase II RI. Only inorganic SRCs exist in groundwater at SRBG.

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 SRBG.

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. In addition, the CMCOCs identified in the Phase I RI were not detected in groundwater above screening criteria. The presence of the inorganics above screening levels in groundwater either leached from soil prior to previous investigations or are naturally occurring.

8. HUMAN HEALTH RISK ASSESSMENT

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

The HHRA was performed consistent with previous PBS 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 2022).

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 exposure point concentrations (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 3.8

Section 8.6, Uncertainty Analysis. This section 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. Summary and discussion focused on those results and issues that are most directly relevant to the risk assessment conclusions for SRBG, 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.

SRBG is in the central portion of GRC-ATF (Figure 1-2). The Army used SRBG from 1941 to 1963 for burning explosives during the decommissioning of the PBOW. The volume of explosives destroyed in this area is unknown; however, hazardous substances that the Army destroyed at the burning grounds included materials contaminated with DNT, TNT, pentolite, and asbestos. Waste generated during NASA's D&D efforts that was contaminated or potentially contaminated with explosives or acids was also burned at SRBG. Other hazardous materials that NASA disposed of at SRBG may have included waste oils, solvents, and other chemicals. This area was also used during NASA's tenure for destroying combustible, non-contaminated solid waste (e.g., wood and paper-type debris). The NASA burnable dump was used throughout the 1960s and possibly to the mid-1970s; leftover unburned debris was periodically removed from the site. In the late 1970s, ash was removed from the burn pit and buried near Line Road 16 and North Magazine Road; the burn pit was then backfilled.

The Fire Training Pit, which was located on the west side of Old Snake Road, was constructed in the early 1960s and was used by onsite personnel during fire training exercises. These exercises were performed by partially filling the training pit with water and waste oil and/or diesel fuel. The oil was ignited, and the fire was extinguished with either dry powder or carbon dioxide. The PBS PA indicated foam was also used to suppress the fire. The Fire Training Pit was also used to extinguish materials that were ignited in small metal pans to simulate small scale fires. Solvents were also reportedly in the pit and burned. The volumes and types of solvents and waste oils disposed of in this manner were not documented, and this practice was typically in conjunction with onsite firefighting training conducted in the pit. In addition to fire training, the pit was used on at least two occasions to dispose of solid and explosive waste.

8.2 DATA EVALUATION

8.2.1 Data Sets

Data collected at SRBG from the two rounds of sampling in 2021 (May/June and November/December) were used in this HHRA. All groundwater data were aggregated into a single exposure unit 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, pesticides, 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 begins by identifying all chemicals detected in at least one sample in a given exposure medium (i.e., groundwater). Detected chemicals are eliminated as COPCs based on the criteria below.

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 and depth sampled. If laboratory reanalysis or dilutions were performed, only the appropriate result is used based on data review and validation. QC data, such as sample splits, are not included in the determination of COPCs for this risk assessment. Data qualified during the validation as rejected ("R") were not used in the risk assessment. Field duplicate results were averaged with the primary result if both results were detected or not detected. If only one of the duplicate pair had a detectable concentration, just the detected result was used. 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 2022). To account for the potential effects of multiple chemicals, a target HQ of 0.1 was used for RSLs 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 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 SRBG; 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 2022).
- **M+P Xylene –** The RSLs for m-xylene and p-xylene are the same (i.e., 19 µg/L) so this value was used for the combined isomers in the screening process to select the groundwater COPCs. The same screening level is used for o-xylene and total xylenes.
- **Methylcyclohexane –** No surrogate is available. This chemical was detected at low concentrations in 3 of 10 samples and is discussed in the toxicity assessment (Section 7.4) and the uncertainty section (Section 7.5).

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-one chemicals were detected at least once in groundwater: 22 metals, 1 SVOC, and 8 VOCs (counting xylenes as 3 chemicals). Seven metals (aluminum, arsenic, cadmium, iron, lead, thallium, and vanadium) were selected as COPCs in groundwater. Methylcyclohexane, which does not have an RSL, also was selected as a COPC.

For metals, 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.

8.2.2.3 Vapor Intrusion Screening

A screening assessment was completed to determine if vapor intrusion needed to be evaluated further or risk calculated. The assessment/desktop evaluation determined that since no vapor forming COCs were detected above VISLs in the groundwater sampling events, soil gas or the vapor intrusion pathway did not require additional evaluation.

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 1-4. Steps 3 and 4 are described in Sections 8.3.2 and 8.3.3. 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 1-4 shows the CSEM for SRBG.

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 SRBG may include releases to surface and subsurface soil from the burning of explosives-contaminated debris and residual debris following removal and disposal of contaminated surface and subsurface soil around the buildings and wooden and ceramic waste disposal lines containing TNT. 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

SRBG and GRC-ATF, including their physical setting, historical and current use, topography, and demographics of the area, are described in Sections 1.0 and 3.0.

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.

SRBG is in the central portion of GRC-ATF within a large grassy field with areas of thick shrub/scrub vegetation. Groundwater at GRC-ATF is not 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 SRBG 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. However, the inhalation route was not evaluated because none of the SRBG COPCs are volatile. 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 1-4). 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 SRBG. The RME is an estimate of the highest exposure reasonably expected to occur at the site. The EPC is the single concentration used to represent the RME for each COPC in an environmental medium.

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 using ProUCL Version 5.1.002 (USEPA 2016). ProUCL outputs are provided in Appendix G. The EPC for lead is the calculated average concentration as recommended by USEPA (USEPA 2021b).

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 2022). 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 2021c), 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.

This HHRA evaluates the RME of receptors to contaminants at SRBG. 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 a baseline 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 resulting exposure rate, once the components are multiplied, represents a conservative estimate of actual exposure.

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 SRBG.

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-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. Note that inhalation toxicity values are not included because none of the groundwater COPCs is volatile.

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.

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 equation below:

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

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 methylcyclohexane, and no appropriate surrogates have been identified. This chemical was detected at a low concentration in 3 of 10 samples.

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 2021d). USEPA has developed the IEUBK model (USEPA 2021c), 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 incremental lifetime cancer risk (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:

$$\text{ILCR} = \text{Exposure} \times \text{Toxicity Value}$$

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 $(\text{mg/kg-day})^{-1}$.

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:

$$\text{ILCR}_{total} = \Sigma \text{ILCR}_i$$

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 a hazard index (HI), as shown below:

$$HI = \Sigma HQ_i$$

Where:

HI = hazard index for all toxic effects; and
HQ_i = hazard quotient for the i^{th} 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 2021c). 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 2021b), 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 (9) 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 aluminum)
- The target organ HI of 6 for dermal effects exceeds the target of 1 (due to arsenic [0.9], 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 entirely with arsenic. The geometric mean blood-lead concentration for a child resident of 12 to 72 months is 2.9 µg/dL, and the probability that the blood-lead concentration of a child resident would exceed the target of 10 µg/dL is 0.4 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 impossible 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.

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 maximum detected concentration or not enough samples were detected to calculate a UCL, the maximum detected concentration was used as the EPC. This is generally a conservative estimate of the actual concentration to which receptors are exposed to 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 SRBG 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 2022), 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 was 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 (USEPA 2022). This adds uncertainty to the risk estimate for vanadium because the toxicity value used may not accurately reflect the form of vanadium at SRBG.

Methylcyclohexane was identified as a COPC. However, USEPA reviewed the available toxicity data for methylcyclohexane and concluded there were no acceptable studies for the derivation of an RfD and inadequate information to assess its carcinogenic potential (USEPA 2013). Therefore, no risks were estimated for exposure to methylcyclohexane.

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 SRBG. The HHRA was performed consistent with previous GRC-ATF HHRAs and is based on USEPA and Ohio EPA guidance.

Groundwater data collected at SRBG and used in this HHRA were aggregated into a single exposure unit. GRC-ATF is expected to remain under NASA's control for the foreseeable future. Although SRBG will unlikely 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. SRBG 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 (9) 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 (due to aluminum) and for the HI of 6 for dermal effects (due to arsenic [0.9], thallium [4], 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 entirely with arsenic. The lead model results for the resident child show that less than 5 percent probability exists that children would have a blood lead level greater than the target of 10 µg/dL.

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

- Aluminum was not identified as a COC in groundwater due to the combination of the conservative use of the maximum detected concentration as the EPC, significantly lower concentration detected seasonally in the well with the highest concentration (i.e., 39,000 µg/L in November 2021 versus 8,000 µg/L in May 2021), and significant reduction in the filtered groundwater sample (representing dissolved metals) associated with the maximum detect (i.e., 10,000 µg/L). This dissolved aluminum concentration is approximately four times less than the maximum detected concentration in unfiltered groundwater. Typically, groundwater used as a source of potable water would be filtered, which would result in reduction of the EPC and a corresponding reduction in risk. In addition, uncertainty is associated with the provisional toxicity value used to calculate non-cancer risk.

- Although the maximum detected concentration of arsenic at SRBG (9.6 µg/L) exceeds the background screening value (7.4 µg/L), arsenic concentrations at SRBG are comparable to background levels. The range of SRBG detected concentrations is comparable to the range of background detected concentrations, and the 95 percent UCL concentration (5.68 µg/L) is below the background screening value. In addition, the maximum detected concentration was detected in November 2021 from GCL-MW03. The dissolved arsenic concentration in the same sample was significantly less, at 2.6 µg/L. Note also that the May 2021 arsenic concentration from the same well is 1.9 µg/L, which is well below the background screening value. The detection of 9.6 µg/L is the only result that exceeds the background screening value. For these reasons, arsenic was not identified as a groundwater COC at SRBG.
- 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 (1.4 µg/L) is 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 lower concentration detected seasonally in the well with the highest concentration (i.e., 47 µg/L in November 2021 versus 12 µg/L in May 2021). In addition, the filtered groundwater sample concentration (representing dissolved metals) associated with the maximum detect is 13 µg/L, approximately 3.5 times lower than the unfiltered concentration. Uncertainty also is associated with the use of the toxicity value (which was derived for vanadium pentoxide and altered by factoring out the molecular weight 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 0.4 percent, which is less than the target of 5 percent). Therefore, lead was not identified as a COC in groundwater.

The maximum detected concentrations of chemicals were compared to their respective MCLs (Appendix G). None of the chemicals detected in unfiltered groundwater samples had concentrations that exceeded an MCL. However, the maximum detected concentration of lead (26 µg/L) exceeded the action level (15 µg/L). Note this detection is from GCL-MW03 in November 2021. The concentration of lead in the same well in May 2021 is 3.8 µg/L, well below the action level. The two concentrations were averaged to capture the variability of concentrations over time. The average value is just below the action level.

In summary, no groundwater COCs were identified for hypothetical future residential land use of SRBG.

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

Station	Sample ID	Date Collected
GCL- MW01	SRBGGW1004/SRBGGW9102 (D)	5/27/2021
GCL- MW01	SRBGGW1009/SRBGGW9104 (D)	11/30/2021
GCL- MW03	SRBGGW1005	5/27/2021
GCL- MW03	SRBGGW1010	11/30/2021
SRBG-MW01	SRBGGW1001	6/7/2021
SRBG-MW01	SRBGGW1006	11/30/2021
SRBG-MW02	SRBGGW1002	6/1/2021
SRBG-MW02	SRBGGW1007	12/1/2021

Table 8–1. Groundwater Samples Included in the HHRA for Snake Road Burning Ground (Continued)

Station	Sample ID	Date Collected
SRBG-MW03	SRBGGW1003	6/7/2021
SRBG-MW03	SRBGGW1008	12/1/2021

HHRA = Human Health Risk Assessment
ID = Identifier
D = Duplicate

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

Detected Chemical	COPC
Metals	
Aluminum	X
Arsenic	X
Barium	
Beryllium	
Cadmium	X
Calcium	
Chromium	
Cobalt	
Copper	
Iron	X
Lead	X
Magnesium	
Manganese	
Mercury	
Nickel	
Potassium	
Selenium	
Silver	
Sodium	
Thallium	X
Vanadium	X
Zinc	
SVOCs	
Caprolactam	
VOCs	
Chloromethane	
Cyclohexane	
1,1-Dichloroethane	
Methylcyclohexane	X
Toluene	
Xylene, total	
Xylene, m- + p-	
Xylene, o-	

COPC = Chemical of Potential Concern
SVOC = Semivolatile Organic Compound
VOC = Volatile Organic Compound

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

COPC	CAS Number	Freq of Detect	Minimum Detect	Average Result[a]	Maximum Detect	Dist.	ProUCL Method	95% UCL from ProUCL	EPC	EPC Basis
Aluminum	7429-90-5	7/ 10	115	4970	39000	G	95% KM Bootstrap-t UCL	116000	39000	MDC<UCL
Arsenic	7440-38-2	9/ 10	0.93	3.97	9.6	N	95% KM (t) UCL	5.68	5.68	UCL
Cadmium	7440-43-9	1/ 10	0.3	0.48	0.3	D	Too few detects	--	0.3	MDC
Iron	7439-89-6	9/ 10	965	3120	14000	L	KM H-UCL	14300	14000	MDC<UCL
Lead	7439-92-1	4/ 10	0.6	3.73	26	G	--[b]	--[b]	3.73[b]	Average
Thallium	7440-28-0	5/ 10	0.22	0.588	1.4	N	95% KM (t) UCL	0.881	0.881	UCL
Vanadium	7440-62-2	5/ 10	1	7.86	47	N	95% KM (t) UCL	16.6	16.6	UCL
Methylcyclohexane	108-87-2	3 / 10	0.39	0.495	0.63	N	95% KM (t) UCL	0.619	0.619	UCL

Notes:
All units are micrograms per liter (µg/L)
[a]Average calculated using one-half the detection limit for non-detect results
[b]The EPC for lead is the calculated average concentration in as recommended by USEPA (USEPA 2021b)

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

Dist.:
- D = too few detects to determine a distribution
- G = gamma distribution
- L = lognormal distribution
- N = normal distribution
- < = less than

Table 8–4. Exposure Assumptions for HHRA at Snake 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
Events (EV) (events/day)	1	1
Body weight (BW) (kg)	80	15
Averaging time – non-cancer (ATn)	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	Kp (cm/hr)	Mutagen	GIABS	SFo $(mg/kg\text{-}day)^{-1}$	RfDo* (mg/kg-day)	Critical Effect/System for RfDo
Aluminum	1.00E-03	No	1	--	1.00E+00	Neurological
Arsenic	1.00E-03	No	1	1.50E+00	3.00E-04	Cardiovascular and dermal
Cadmium	1.00E-03	No	5.00E-02	--	1.00E-04	Urinary
Iron	1.00E-03	No	1	--	7.00E-01	Gastrointestinal
Lead	NA					
Thallium	1.00E-03	No	1	--	1.00E-05	Hair follicle atrophy
Vanadium	1.00E-03	No	2.60E-02	--	5.04E-03	Decreased hair cystine
Methylcyclohexane	NA					

Note:
All values are from U.S. Environmental Protection Agency (USEPA) regional screening level (RSL) table dated May 2022 unless otherwise noted
*RfD_o adjusted based on GIABS to derive RfD.

-- = No value available
cm/hour = Centimeters per Hour
COPC = Chemical of Potential Concern
GIABS = Gastrointestinal Absorption Factor
Kp = Permeability Coefficient
mg/kg-day = Milligrams per Kilogram per Day
NA = Not Applicable
RfD = Reference Dose
SF = Cancer Slope Factor

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

COPC	EPC	HQ	ILCR	Was Chemical Identified as a COC	Rationale
Aluminum	39000[a]	2	--	No	Not a COC due to lower concentrations detected seasonally in same well, significant reduction in filtered groundwater samples, and uncertainty associated with toxicity value
Arsenic	5.68	0.9	1E-04	No	Not a COC because detected concentrations are comparable to background
Cadmium	0.3	0.2	--	No	Not a COC due to HQ less than 1
Iron	14000	1	--	No	Not a COC because HQ does not exceed 1 and uncertainty associated with toxicity value
Thallium	0.881	4	--	No	Not a COC due to uncertainty associated with toxicity value and because maximum detected concentration does not exceed MCL
Vanadium	16.6	0.2	--	No	Not a COC due to HQ less than 1, lower concentrations detected seasonally in same well, significant reduction in filtered groundwater samples, and uncertainty associated with toxicity value
Total All Chemicals		9	1E-04	--	--

-- = Not Applicable
COC = Chemical of Concern
COPC = Chemical of Potential Concern
EPC = Exposure Point Concentration
HQ = Hazard Quotient
ILCR = Incremental Lifetime Cancer Risk

9. ECOLOGICAL RISK ASSESSMENT

An ERA was included in the Phase I RI Report. SRBG is approximately 9.9 acres and is vegetated with dry herbaceous field, with four small wetlands scattered in the interior of the site. A plant management area (Central Meadows) and a rare plant species and its habitat also occur within SRBG. Wetlands, rare species and their habitat, and specially designated natural areas are considered important ecological resources, and contamination at SRBG has been documented, 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 cadmium; lead; mercury; PCB-1260; and 2,6-DNT were final COPECs at the Primary Burn Area EU at SRBG. Removal of surface soil in two sample locations in the Primary Burn Area EU, SRBG-SL-001 and SRBG-SL-003, was recommended to protect ecological resources at SRBG (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 SRBG 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

The Army used SRBG from 1941 to 1963 for burning explosives during the decommissioning of PBOW. The volume of explosives destroyed in this area is unknown; however, hazardous substances that the Army destroyed at the burning grounds included materials contaminated with DNT, TNT, pentolite, and asbestos. Waste generated during NASA's D&D efforts that was contaminated or potentially contaminated with explosives or acids was also burned at SRBG. Other hazardous materials that NASA disposed of at SRBG may have included waste oils, solvents, and other chemicals. This area was also used during NASA's tenure for destroying combustible, non-contaminated solid waste (e.g., wood and paper-type debris). The NASA burnable dump was used throughout the 1960s and possibly to the mid-1970s; leftover unburned debris was periodically removed from the site. In the late 1970s, ash was removed from the burn pit and buried near Line Road 16 and North Magazine Road; the burn pit was then backfilled.

The Fire Training Pit, which was located on the western side of Old Snake Road, was constructed in the early 1960s and was used by onsite personnel during fire training exercises. These exercises were performed by partially filling the training pit with water and waste oil and/or diesel fuel. The oil was ignited, and the fire was extinguished with either dry powder or carbon dioxide. The 1991 PA indicated foam was also used to suppress the fire. The Fire Training Pit area was also used to extinguish materials that were ignited in small metal pans to simulate small scale fires. Solvents were also reportedly in the pit and burned. The volumes and types of solvents and waste oils disposed of in this manner were not documented, and this practice was typically in conjunction with onsite firefighting training conducted in the pit. In addition to fire training, the pit was used on at least two occasions to dispose of solid and explosive waste.

SRBG is located west of current Snake Road and north of West Scheid Road. During operational activities, Old Snake Road went through SRBG. As noted in the 1995 Records Review Report (DM 1995), a 1944 historical drawing describes SRBG as being 100 feet wide by 200 feet long oriented in a north-south direction. The drawing indicates the burn ground is accessed by a 10-foot-wide driveway at its northwestern corner extending 50 feet due west to (the unpaved) Old Snake Road, and a 4-foot berm surrounds the burn area with an 8-inch-diameter drainage tile in the northeastern corner.

SRBG is vegetated with dry herbaceous field, with four small wetlands scattered in the interior of the site. A plant management area (Central Meadows) and a rare plant species and its habitat also occur within SRBG. One ephemeral drainage ditch exists at the site, located northeast of the burn area (Figure 1-2). This drainage ditch was dry during the 2015 SI and 2017 Phase I RI and the 2021 Phase II RI field activities.

SRBG currently has no structures. However, debris was identified at the site. Metal debris (shredded steel drum, steel drum lid, and steel posts) and cider blocks were observed, and some ACM was identified as transite, off-white fibrous material, and tan cementitious material.

10.2 SUMMARY OF PREVIOUS INVESTIGATIONS AND DATA USE

The following assessments and evaluations included SRBG:

- 1990 Contamination Evaluation (IT Corporation 1990), which identified SRBG as the Scheid Road Burning Grounds;
- PBS PA (SAIC 1991), which included SRBG as part of the OU4 Burning Grounds evaluation;
- 1992 Phase I Site Characterization (H+GCL 1992), which identified SRBG as "Disposal Area Three";
- 1994 SI (MK 1994), which included SRBG as part of PMU 3 Plum Brook; and
- 1995 Records Review Report (DM 1995), which provided the site history, potential sources, and environmental investigations of SRBG.

The GRC-ATF Multi-Site SI was conducted in August 2015. The SI activities at SRBG included drilling 11 soil borings and collecting 11 surface soil samples, 22 subsurface samples, and 3 sediment samples. Samples were analyzed for VOCs, SVOCs, herbicides, pesticides, PCBs, TAL metals, explosives, and asbestos (0- to 2-foot interval only). In addition, a site walk was performed to identify any painted debris; however, no painted debris was identified. An Asbestos Hazard Evaluation Specialist also performed a site assessment, which included collecting 14 soil samples for analyzing asbestos content and identifying 6 pieces of ACM. Four of the 14 soil samples had detectable concentrations of chrysotile and/or amosite asbestos, all at less than 1 percent. Four of the six pieces of ACM were considered friable and two contained 25 percent chrysotile.

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 impacts soil may have on groundwater; and provides data to update and complete the HHRA and ERA. Five surface soil samples were collected (SR-1 to SR-5). Surface water is not a permanent feature at SRBG. Accordingly, samples collected that were identified as sediment were reclassified as soil in the Phase I RI Report. Subsequently, the two media evaluated in the Phase I RI report were surface soil and subsurface soil. SRBG was divided into three EUs to allow for refined evaluation of potential chemical contamination and potential exposure. These EUs are the Primary Burn Area, Secondary Burn Area, and Drainage Ditch. Data collected at SRBG were aggregated by environmental medium (e.g., surface soil and subsurface soil). In addition, the area identified as the Fire Training Pit has its own focused evaluation using data from soil boring SRBG-SL-008, which was collected from within the Fire Training Pit, as well as soil borings SRBG-SL-006 and SRBG-SL-007, which were collected near the Fire Training Pit.

Based on the Phase I RI results, SRBG was adequately characterized, and further investigation was not warranted to complete the RI for surface and subsurface soil. The HHRA identified the following EUs, sample locations, and COCs that required assessment in an FS:

- Two PCBs (1248 and 1260) and silver were identified as COCs for surface soil in the Primary Burn Area at sample locations SRBG-SL-004 and SRBG-SL-009.
- PCB-1254 (1.4 mg/kg) in SRBG-SL-002 in the Secondary Burn Area is within the range of PCB-1248 and PCB-1260 concentrations in SRBG-SL-004 and SRGB-SL-009. This location within the Secondary Burn Area was recommended for remediation for PCB-1254.

The ERA identified the following sample locations and COPECs that required assessment in an FS:

- Cadmium; lead; mercury; PCB-1260; and 2,6-DNT were final COPECs at the Primary Burn Area EU in surface soil at two sample locations in the Primary Burn Area EU, SRBG-SL-001 and SRBG-SL-003.

Remediation of these locations will address the three sample locations (SRBG-SL-001, SRBG-SL-002, and SRBG-SDSW-004) that had detected asbestos in soil (less than 1 percent). The one piece of ACM (off-white transite at SRBG-DD-001) was considered friable and greater than 1 percent asbestos (chrysotile). However, there was only a small piece of this transite, and it is assumed all identified material was removed for sampling. Consistent with the conclusions of the 2015 SI, additional ACM assessment was not warranted.

In addition, metal fragments, debris, and piping were identified southeast of the Primary Burn Area. 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 (Leidos 2018a).

10.3 SUMMARY OF NATURE AND EXTENT OF GROUNDWATER CONTAMINATION

Thirteen groundwater samples were collected at SRBG, including three field duplicates and five primary samples from each of the two sampling events to adequately characterize SRBG groundwater. Section 6.0 summarizes the nature and extent of contamination.

In groundwater, 22 metals, 1 SVOC, and 8 VOCs were detected. The SVOC and six of the VOCs were detected at concentrations below the risk screening criteria. No risk screening criteria were available for the VOC methylcyclohexane. Seven of the 22 metals (aluminum, arsenic, cadmium, iron, lead, thallium, and vanadium) exceeded their respective background concentrations and/or the tap water RSL at HQ of 0.1, 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 13 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, two initial CMCOCs (hexachloroethane and naphthalene) should be assessed during future groundwater studies at the site (Leidos 2018a). Of the 13 chemicals, only caprolactam was detected in groundwater, but the concentrations were below the tap water RSL.

Seven inorganics (aluminum, arsenic, cadmium, iron, lead, thallium, and vanadium) exceeded their respective background concentrations and tap water RSLs in groundwater at SRBG. Aluminum exceedances were limited to GCL-MW03 located in the Secondary Burn Area. Arsenic exceeded screening criteria in June 2021 at SRBG-MW02, but the duplicate sample's arsenic result at SRBG-MW02 was below the screening criteria. Arsenic also exceeded screening criteria in November 2021 at GCL-MW03. The single cadmium (total) exceedance was limited to the November 2021 sample collected at SRBG-MW01 located in the Primary Burn Area. Iron exceeded the screening criteria at four of the five sampling locations: GCL-MW03 (May and November 2021), SRBG-MW01 (June 2021), SRBG-MW02 (December 2021), and SRBG-MW03 (June and December 2021). Total lead only exceeded screening criteria at one location in November 2021 (GCL-MW03 location to the west of the Primary Burn Area). However, the filtered sample result for lead was below screening criteria. Total thallium exceeded screening criteria during both events at GCL-MW03 and only in December 2021 at SRBG-MW01, SRBG-MW02, and SRBG-MW03. Dissolved thallium exceeded screening criteria in May 2021 at GCL-MW01, in November 2021 at GCL-MW03 and in December 2021 at SRBG-MW02, and SRBG-MW03. Vanadium exceedances were limited to one location (GCL-MW03) in both events; both total and dissolved vanadium exceeded screening criteria in November 2021, and only total vanadium exceeded criteria in May 2021. Most of the metal exceedances were at GCL-MW03, which is located west of the site and cross/upgradient of the other wells.

The groundwater in the overburden is in discontinuous pockets during dry time periods. Since most of the metal concentration exceedances were at GCL-MW03, which is located to the west-southwest of the other wells sampled, it appears the extent of the contaminants in the SRBG groundwater has been adequately characterized. In addition, none of the CMCOCs identified in the Phase I RI were 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: silver; 2,4,6-TNT; 2,4-DNT; 2,6-DNT; 2-amino-4,6-DNT; 4-amino-2,6-DNT; 1,1'-biphenyl; benzaldehyde; caprolactam; hexachloroethane; naphthalene; alpha-hexachlorocyclohexane BHC; and beta-BHC. These chemicals were predicted to exceed the screening criteria in groundwater beneath the source area. The qualitative assessment eliminated silver; 2,4,6-TNT; 2,4-DNT; 2,6-DNT; 2-amino-4,6-DNT; 4-amino-2,6-DNT; 1,1'-biphenyl; benzaldehyde; caprolactam; alpha-BHC; and beta-BHC as final CMCOCs. The other two initial CMCOCs (hexachloroethane and naphthalene) were retained for consideration and groundwater sampling was recommended to fully characterize SRBG (Leidos 2018a).

Hexachloroethane and naphthalene were not detected in groundwater at SRBG during the Phase II RI. Only inorganic SRCs exist in groundwater at SRBG. Based on the information presented in Section 7.0, 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 SRBG.

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 very heterogeneous nature of the unconsolidated glacial material, groundwater flow patterns within unconsolidated soil are difficult to predict. In addition, the CMCOCs identified in the Phase I RI were not detected in groundwater above screening criteria. The presence of the inorganics above screening levels in groundwater either leached from soil prior to previous investigations or are naturally occurring.

10.5 SUMMARY OF HUMAN HEALTH RISK ASSESSMENT

The HHRA documents the potential health risks to humans resulting from exposure to groundwater contamination within SRBG. The HHRA was performed consistent with previous PBS HHRAs and is based on 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 SRBG 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. SRBG is best classified as an inactive area, and plausible receptors include groundskeepers and hunters. No groundwater at PBS is used for drinking water under current or planned future use. At the time of this report, NASA is working to establish the requirements for a land use control prohibiting groundwater use at GRC-ATF.

The groundwater exposure routes evaluated in the HHRA include ingestion and dermal contact. Risks were not calculated for the inhalation pathway because none of the COPCs has sufficient information to develop a toxicity value for inhalation effects. 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 (9) 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 aluminum) and for the HI of 6 for dermal effects (due to arsenic [0.9], thallium [4], 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 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.

No COCs were identified with residential use of groundwater at SRBG. Although arsenic is associated with a cancer risk at the upper bound of the target cancer risk range (i.e., 1E-04) and an HQ close to the target of 1, it was not identified as a COC due to its presence at levels comparable to background. Aluminum and vanadium also were not identified as COCs due to lower concentrations detected seasonally in the same well, significant reduction of concentrations in the filtered samples, uncertainty associated with use of a provisional toxicity value, and/or low HQ (0.2 for vanadium). Thallium was not identified as a COC due to uncertainty associated with the toxicity value and because the maximum detected concentration is below the MCL.

Since no vapor forming COCs were detected in soil and vapor forming chemicals were not detected above VISLs during the first or second round of groundwater sampling, soil gas in not a concern at SRBG.

10.6 SUMMARY OF ECOLOGICAL RISK ASSESSMENT

An ERA was completed in the Phase I RI Report. SRBG is approximately 9.9 acres and is vegetated with dry herbaceous field, with four small wetlands scattered in the interior of the site. A plant management area (Central Meadows) and a rare plant species and its habitat also occur within SRBG. Wetlands, rare species and their habitat, and specially designated natural areas are considered important ecological resources, and there is documentation of contamination at SRBG, so further analysis was conducted in a Level II ERA. It was determined that cadmium; lead; mercury; PCB-1260; and 2,6-DNT were final COPECs at the Primary Burn Area EU at SRBG (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 SRBG, including the contamination sources, exposure pathways, human receptors, and ecological resources. In addition, Figure 1-4, 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 depth range of 3.3 to 6.3 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 the two initial CMCOCs (hexachloroethane and naphthalene) were not detected in groundwater above screening criteria. Seven inorganics (aluminum, arsenic, cadmium, iron, lead, thallium, and vanadium) exceeded their respective background concentrations and tap water RSLs in groundwater at SRBG. 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 SRBG 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 SRBG groundwater is overall well defined using existing data, and no major data gaps remain to be resolved. However, some uncertainties for the CSM for SRBG 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, SRBG 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 SRBG as soil was evaluated in the Phase I RI. Based on the Phase II RI results, SRBG 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 SRBG. Ecological exposures to chemicals in the groundwater is not a concern.

An FS addressing soil contamination at SRBG was prepared in 2018 (Leidos 2018c). The recommended alternative was excavation and offsite disposal. Since no COCs were identified with residential use of groundwater at SRBG, no additional recommendations are warranted for the FS 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 and if the remedial cleanup goals in the FS need to be updated.

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