National Aeronautics and
Space Administration

Lyndon B. Johnson Space Center
White Sands Test Facility
P.O. Box 20
Las Cruces, NM 88004-0020

April 29, 2022

Reply to Attn of: RE-22-053

Mr. Rick Shean, Bureau Chief
New Mexico Environment Department
Hazardous Waste Bureau
2905 Rodeo Park Drive East, Building 1
Santa Fe, NM 87505

Subject: NASA WSTF Groundwater Monitoring Plan Update for 2022

The NASA White Sands Test Facility (WSTF) Hazardous Waste Permit No. NM8800019434, Section VI.B.3 requires the submittal of an updated facility-wide Groundwater Monitoring Plan (GMP) annually beginning in April 2012. The Permit specifies a due date of April 1 beginning in the second year after the anniversary date of the Permit. However, the initial GMP, which was approved by NMED, specifies that annual updates will be submitted on or before April 30 of each year.

Significant revisions to the GMP update for 2022 include:

- NASA reviewed and updated the cleanup levels for hazardous constituents in WSTF groundwater in accordance with the Permit and updated Section 3.1 and Table 3.1 accordingly.

- NASA incorporated the requirements of NMED's November 15, 2021 *Approval with Modifications White Sands Test Facility Groundwater Monitoring Plan* relative to continued sampling for PFAS chemicals.

- NASA evaluated groundwater sampling schedules and updated the affected GMP table to reflect current requirements and monitoring program objectives. Notably, initial PFAS screening is complete.

- NASA updated GMP text and tables to reflect the current status of groundwater monitoring wells and sampling system configurations, accounting for new, decommissioned, reconfigured, or replaced wells since the 2021 Groundwater Monitoring Plan update.

Enclosure 1 provides a paper copy of the updated Groundwater Monitoring Plan for review by NMED. Enclosure 2 provides the complete updated Groundwater Monitoring Plan in PDF format on CD-ROM.

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

If you have any questions or comments, please contact Antonette Doherty of my staff at 575–202–5406.

AMANDA SKARSGARD
Digitally signed by AMANDA SKARSGARD
Date: 2022.04.29 08:27:47 -06'00'

For: Timothy J. Davis
Chief, NASA Environmental Office

2 Enclosures

cc:
New Mexico Environment Department
Attn: Mr. Gabriel Acevedo
Hazardous Waste Bureau
2905 Rodeo Park Drive East, Building 1
Santa Fe, NM 87505

National Aeronautics and Space Administration

White Sands Test Facility

Groundwater Monitoring Plan

April 2022

NM8800019434

NASA Johnson Space Center White Sands Test Facility

Groundwater Monitoring Plan

April 2022

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

AMANDA SKARSGARD
Digitally signed by AMANDA SKARSGARD
Date: 2022.04.29 08:38:59 -06'00'

See Electronic Signature

For: Timothy J. Davis
Chief, Environmental Office

Date

National Aeronautics and Space Administration

Johnson Space Center
White Sands Test Facility
12600 NASA Road
Las Cruces, NM 88012
www.nasa.gov/centers/wstf

www.nasa.gov

Executive Summary

This Groundwater Monitoring Plan (Plan) provides information related to routine groundwater monitoring performed at the National Aeronautics and Space Administration (NASA) White Sands Test Facility (WSTF). Groundwater monitoring is conducted in accordance with NASA WSTF's Hazardous Waste Permit (Permit), issued by the New Mexico Environment Department (NMED) in November 2009 and modified in December 2019. Permit Section VII.B requires that NASA develop a facility-wide Groundwater Monitoring Plan to set forth detailed methods, procedures, and schedules. This plan meets the requirements of the Permit and satisfies the regulatory requirements of 40 CFR 264.90(f) as directed by NMED.

This plan provides specific information related to groundwater monitoring at WSTF, including:

- Background information on the facility, operations performed, hazardous constituents and hazardous wastes managed and released, the nature and extent of groundwater contamination resulting from those operations and releases, potential receptors of contaminated groundwater, pertinent previous investigations related to groundwater, and surface and subsurface conditions.
- Applicable regulatory criteria.
- A detailed description of the existing WSTF groundwater monitoring system.
- Descriptions of the sampling equipment utilized for groundwater monitoring.
- Descriptions of pre-sampling activities such as equipment decontamination, sampling records, determination of groundwater elevations and indicator parameters, and purging of groundwater monitoring wells.
- Discussion of sampling procedures for WSTF groundwater monitoring wells.
- Descriptions of post-sampling activities such as sample management (identification, storage, custody, and shipment), investigation-derived waste (IDW) management, and the determination of groundwater flow direction and rate.
- A summary of the chemical analytical methods utilized by contracted analytical laboratories to analyze for hazardous constituents and other analytes in WSTF groundwater.
- An introduction to the WSTF quality assurance/quality control (QA/QC) program, including a discussion of requirements for contracted analytical laboratories, QC samples, data quality indicators, analytical data quality exceptions, and analytical data management processes.
- The schedules for various activities presented in the Plan.

Table of Contents

History of Revisions

Data of Revision	Summary of Revision
June 2010	Original Groundwater Monitoring Plan
April 2012	Annual revision/update. Significant revisions in the annual update include: an evaluation of hazardous constituents and subsequent revision of text and tables in affected sections; reference to off-site sampling performed in accordance with Permit Section VII.G.2; inclusion of the results of an evaluation of groundwater background concentrations are required by Permit Section 17.5; and the addition of new groundwater monitoring wells to affected sections and tables.
April 2013	Annual revision/update. Significant revisions in the annual update include: removal of text and tables discussing groundwater background sampling and statistical evaluations; addition of new groundwater monitoring wells to the affected sections and tables; update of cleanup levels; and update of sampling frequencies.
April 2014	Annual revision/update. Significant revisions in the annual update include: modification of groundwater monitoring parameters and frequencies; revision of tables and text to reflect well changes since last GMP update; and review/update of cleanup levels.
April 2015	Annual revision/update. Significant revisions in the annual update include: modification of groundwater monitoring parameters and frequencies; revision or addition of tables and text to reflect well changes since the last GMP update; and review and update of cleanup levels.
May 2016	Annual revision/update. Significant revisions in the annual update include: modification of groundwater monitoring parameters and frequencies; revision of tables and text to reflect changes in monitoring wells and sampling equipment since last GMP update; and review and update of groundwater cleanup levels, including a discussion and figure showing historical cleanup levels to support periodic reporting.
April 2017	Annual revision/update. Significant revisions in the annual update include: addition of new groundwater monitoring wells to text and tables; revision of tables and text to reflect changes in monitoring wells and sampling equipment since last GMP update; addition of monitoring well inspection requirements and monitoring wells that require attention in 2017; and review and update of groundwater cleanup levels. Certain sections of the text and tables were also updated to address NMED comments provided in the October 6, 2016 Approval with Modifications Groundwater Monitoring Plan May 2016 (resolved in NASA's December 22, 2016 response to that Approval) and NMED's April 12, 2017 NMED Response to Permittee Comments on the Approval with Modifications of 2016 GMP Update.
April 2018	Annual revision/update. Significant revisions in the annual update include: inclusion of monitoring for 1,4-dioxane as directed by NMED on December 19, 2017; inclusion of analysis of groundwater samples from certain wells by SW-846 Methods 8015 and 8270 as indicated in NASA's IWP for the TDRSS diesel release (SWMU 50), approved by NMED on January 17, 2018; revision of tables and text to reflect changes in monitoring wells and sampling equipment since last GMP update; update on monitoring wells that required attention in

Data of Revision	Summary of Revision
	2017 and additional work for 2018. Certain sections of the text and tables were also updated to address NMED comments provided in the December 19, 2017 Approval with Modifications of the 2017 Groundwater Monitoring Plan.
April 2019	Annual revision/update. Significant revisions in the annual update include: updated text in Section 4.4 to reflect current status of groundwater well evaluation and maintenance activities; revision of tables and text to reflect changes in monitoring wells, sampling equipment, and sampling frequencies since last GMP update; and updates to certain sections of the text and tables to address NMED comments provided in the September 13, 2018 Approval with Modifications Groundwater Monitoring Plan.
May 2020	Annual revision/update. Significant revisions include: updated text in Section 4.4 to reflect current status of groundwater well evaluation and maintenance activities; revised tables and text to reflect changes in monitoring wells, sampling equipment, and sampling frequencies since last GMP update (including plugged and abandoned wells and new wells); and updated certain sections of the text and tables to address NMED comments provided in the December 12, 2019 Approval with Modifications of the 2019 Groundwater Monitoring Plan.
April 2021	Annual revision/update. Revisions include: updated text in Section 4.4 to reflect current status of groundwater well evaluation and maintenance activities; revised tables and text to reflect changes in monitoring wells, sampling equipment, and sampling frequencies since last GMP update; removed PFAS one-time screening from Section 9.7; and updated certain sections of the text and tables to address NMED comments provided in the January 25, 2021 *Approval with Modifications of the 2020 Groundwater Monitoring Plan*.
April 2022	Annual revision/update. Revisions include: updated Section 2.2 to reflect current contaminant extent based on groundwater monitoring; combined geological information from former Figures 2.8 and 2.9 into one new Figure 2.8; updated text in Section 4.1 to provide information on NASA's new monitoring well naming convention; an update on the status of Westbay monitoring well reconfiguration activities in Section 4.2.2; updated text in Section 4.4 to reflect current status of groundwater well evaluation and maintenance activities; an update of Section 9.7 to address NMED comments provided in the November 15, 2021 *Approval with Modifications White Sands Test Facility Groundwater Monitoring Plan* relative to continued sampling for PFAS; update to periodic reporting schedules in Section 11; updated Table 3.1 to include current information on hazardous constituents in WSTF groundwater; updated Table 3.3 to provide current information on monitoring well status and configuration; and, updated Table 11.1 to include current information groundwater sampling frequencies and requirements.

List of Acronyms and Abbreviations

%R	Percent recovery
°C	Degrees Celsius
µg/L	Micrograms per liter
AD	Analyst Duplicates
AFFF	Aqueous Film Forming Foam
bgs	Below ground surface
BLM	Bureau of Land Management
CAS	Chemical Abstract Service
CFR	Code of Federal Regulations
COC	Contaminant of Concern
DMN	N-Nitrodimethylamine
DP	Discharge Permit
DQI	Data quality indicator
DRO	Diesel range organics
EAR	Environmental Activities Report
EPA	U.S. Environmental Protection Agency
FACT	FLUTe Activated Carbon Technique
FBR	Flow-banded rhyolite
ft	Feet
GMP	Groundwater Monitoring Plan
GRO	Gasoline range organics
HWMU	Hazardous waste management unit
IDW	Investigation-derived waste
JDMB	Jornada del Muerto Basin
JER	Jornada Experimental Range (U.S. Department of Agriculture)
JP	Jet Propellant (used in alphanumeric well identification)
K	Hydraulic conductivity
kg	Kilogram
L	Liter
LCS	Laboratory control sample
LCSD	Laboratory control sample duplicate
MB	Method blank
MCL	Maximum Contaminant Level
MDL	Method detection limit
mi	Mile(s)
mL	Milliliters
mm	Millimeter
MPCA	Mid-plume Constriction Area
MPITS	Mid-plume Interception and Treatment System
MS	Matrix spike
MSD	Matrix spike duplicate
MSVM	Multiport Soil Vapor Monitoring
NASA	National Aeronautics and Space Administration
NDMA	N-Nitrosodimethylamine
NELAC	National Environmental Laboratory Accreditation Conference
ng/L	Nanograms per liter
NMAC	New Mexico Administrative Code

NMED	New Mexico Environment Department
NMOSE	New Mexico Office of the State Engineer
PCC	Post-Closure Care
PCE	Tetrachloroethene
PEST	Automated parameter estimation software
PFAS	Per- and polyfluoroalkyl substances
PFOA	Perfluorooctanoic acid
PFOS	Perfluorooctanesulfonic acid
PFTS	Plume Front Treatment System
PL	Private land (used in alphanumeric well identification)
PMR	Periodic Monitoring Report
PPE	Personal protective equipment
PQL	Practical quantitation limit
PVC	Polyvinyl chloride
QA/QC	Quality assurance/quality control
QAR	Quality Assurance Report
RCRA	Resource Conservation and Recovery Act
RFI	RCRA Facility Investigation
RPD	Relative percent difference
RSL	EPA Regional Screening Level
SA	Sample
SAM	San Andres Mountains
SOP	Standard operating procedure
ST	State (used in alphanumeric well identification)
SVOC	Semi-volatile organic compounds
SWMU	Solid waste management unit
T	Transmissivity
TCE	Trichloroethene
TDRSS	Tracking and Data Relay Satellite System
TFM	Thermal Flowmeter
TP	Toxic pollutant
TPH	Total petroleum hydrocarbons
VOC	Volatile organic compounds
WB	Westbay (used in alphanumeric well identification)
WBFZ	Western Boundary Fault Zone
WQCC	NM Water Quality Control Commission
WSTF	White Sands Test Facility

1.0 Introduction

White Sands Test Facility (WSTF) currently operates as a field test installation under the National Aeronautics and Space Administration (NASA) Lyndon B. Johnson Space Center in Houston, Texas. WSTF is a restricted access site, and all activities are industrial in nature. Although the primary purpose of the facility is to provide test services and support to NASA for the United States space program, services are also provided for the Department of Defense, Department of Energy, private industry, and foreign government agencies. WSTF operates several laboratory facilities that conduct simulated use tests for space vehicles and space station materials and compatibility testing.

WSTF is located approximately 18 miles (mi) northeast of Las Cruces, New Mexico. Figure 1.1 provides a vicinity map that shows the general location of WSTF relative to other dominant features and major properties in southern Dona Ana County. Historical operations at WSTF have resulted in a groundwater plume requiring extensive investigation activities and associated corrective actions.

The groundwater assessment program at WSTF was established to determine the nature and extent of groundwater contamination present at WSTF as a result of historical releases of hazardous waste and/or hazardous constituents. Prior to issuance of the current Hazardous Waste Permit (Permit; NMED, 2019a), groundwater sampling was performed as required by NASA's former Hazardous Waste Operating Permit, Post-Closure Care (PCC) Permit, 3008(h) Consent Order (EPA, 1989), the requirements of Resource Conservation Recovery Act (RCRA), and site-specific project plans. Routine groundwater monitoring has enabled NASA to delineate WSTF's groundwater contaminant plume and has provided a thorough understanding of the nature and extent of groundwater contamination. This has allowed NASA to design, construct, and operate state of the art pump and treat systems for corrective actions at the Plume Front and Mid-plume areas. The primary objective of the Plume Front Treatment System (PFTS) is to prevent further migration of the WSTF groundwater contaminant plume. The Mid-plume Interception and Treatment System (MPITS), another voluntary interim measures presumptive remedy, is intended to significantly reduce groundwater contamination through removal and treatment of groundwater in the Mid-plume Constriction Area (MPCA). NASA monitors the effectiveness of the PFTS and MPITS in accordance with the Remediation System Monitoring Plan (NASA, 2020e), approved by New Mexico Environment Department (NMED, 2021a).

1.1 Purpose

This Plan satisfies the requirements of the Permit to develop a comprehensive facility-wide groundwater monitoring plan. It serves as a procedural outline for personnel engaged in routine groundwater sampling and analysis activities at WSTF. It is used in conjunction with site-specific procedural documentation and equipment operations and maintenance manuals. Procedures outlined are consistent with those specified for use at RCRA sites and have been adapted to meet WSTF groundwater monitoring program and Permit requirements. This Plan introduces the methods, procedures, and schedule for conducting routine groundwater monitoring at WSTF. Adherence to the protocols presented in this document assures that samples are collected in a consistent manner, representative of actual groundwater conditions, managed efficiently and effectively, and analyzed by appropriate analytical methods. This Plan outlines the process for reviewing chemical analytical data to ensure that only the highest quality data are generated and available for use in other WSTF projects (corrective action, reporting, etc.).

1.2 Scope

This Plan directs activities related to routine groundwater monitoring throughout WSTF in accordance with Section VI.B of the Permit. It is intended for use as an aid for training technical staff and as an informational guide for trained personnel involved in the collection and processing of WSTF groundwater samples and in the management of chemical analytical data generated from the analyses of those samples. It is also used by NMED to ensure that NASA is performing groundwater monitoring in accordance with applicable federal and state regulations and the Permit. The requirements of this Plan are applicable to all groundwater sampling events performed to accomplish the objectives of this Plan. A WSTF groundwater sampling event consists of specific activities and relevant documentation associated with the collection, management, and analysis of groundwater samples from a distinct groundwater source. A sampling event is performed at a specific groundwater source, typically an individual monitoring well or zone of a multiport well that has been completed in accordance with the Permit and applicable site-specific documentation. Specific requirements and procedures for performing sampling are provided in later sections of this Plan.

1.3 Objectives

The current objective of the groundwater monitoring program is to collect and manage groundwater chemical analytical data to:

- Provide a consistent, accurate representation of actual concentrations of hazardous constituents in the groundwater.
- Monitor the distribution, extent, and movement of hazardous constituents in the groundwater.
- Determine potential threats to human health and the environment from hazardous constituents in the groundwater.
- Monitor the effectiveness of corrective measures used to remediate hazardous constituents released from hazardous and solid waste management units to the groundwater as a result of historical operations.
- Detect the presence of hazardous constituents not previously detected in the groundwater.
- Determine when the corrective measures have reduced the concentrations of hazardous constituents in the groundwater to less than the cleanup levels established according to Permit guidance.

The on-site contractor environmental organization manages and implements groundwater monitoring activities. This organization is staffed with groundwater, hydrogeological, engineering, and environmental compliance personnel. Groundwater personnel are primarily involved in the collection and analysis of groundwater samples for assessment and remediation activities. Hydrogeological personnel are primarily involved in the installation, development, and maintenance of groundwater monitoring and remediation wells and the hydrogeologic interpretation of contaminant distribution and migration. Engineering personnel are responsible for the design, construction, and implementation of corrective actions and successful operation of environmental remediation systems. Compliance personnel are responsible for overseeing the numerous facets of compliance with multiple permits, plans, and other regulatory requirements applicable to WSTF.

2.0 Background

WSTF was established in the early 1960s to support the NASA Apollo Space Program. Primary site activities serve to: develop, qualify, refurbish, and test spacecraft propulsion systems, subsystems, and ground support equipment; investigate flight hardware anomalies; test materials and components; and perform hazard and failure analyses.

Hazardous wastes generated at WSTF during testing and evaluation procedures were historically managed in surface impoundments and underground storage tanks that leaked, subsequently contaminating groundwater. From the early 1960s through the mid-1980s, tanks or waste impoundments in the 200, 300, 400, and 600 industrial areas contributed to groundwater contamination. To minimize further releases of contaminants, these impoundments and tanks were closed under RCRA, and approved by NMED in 1989. The closures were permitted under a PCC Permit in the early 1990s and continue to be monitored in accordance with the Permit and related plans. The locations of these closures, as well as other pertinent WSTF features, are provided in Figure 2.1.

2.1 Wastes Managed and Released

This section provides a description of the primary wastes managed and released at the facility during historical operations and discusses the releases as sources of contamination in the groundwater.

The primary hazardous constituents in groundwater originated from historical waste management operations within the WSTF industrial area (NASA, 1996a). Significant sources within these industrial areas are shown on Figure 2.1. N-Nitrosodimethylamine (NDMA) contamination primarily originated from operations in the 300 and 400 Areas. Most of the halogenated volatile contaminants (trichloroethene [TCE], tetrachloroethene [PCE], trichlorofluoromethane [Freon®[1] 11], and chloroform) originated from the 200 Area with lesser contributions from the 100, 300, 400, and 600 Areas. Four of these hazardous constituents, NDMA, PCE, TCE, and Freon 11, plus non-hazardous constituent Freon 113, are considered the primary contaminants of concern (COC) in WSTF groundwater.

Miscellaneous hazardous constituents, discussed in section 9.6, were also managed and released from activities in the WSTF industrial area. Other constituents that are not hazardous were also managed and released to the groundwater at WSTF. These constituents are routinely sampled for and are discussed in many NASA documents, both current and historical. These chemicals include N-Nitrodimethylamine (DMN), dichlorofluoromethane (Freon 21), and 1,1,2-trichloro-1,2,2-trifluoroethane (Freon 113). Freon 113 had historically been considered a hazardous constituent but was reassessed in 2012 in accordance with the process described in Section 3.1, which resulted in it being removed as a hazardous constituent. However, because it was used in large quantities at WSTF, and is prevalent throughout the groundwater contaminant plume, it is frequently considered a COC within the groundwater assessment program and is included in specific sections of this document.

Little historical data are available describing the exact nature and amounts of chemical wastes that were contained or released at WSTF. COC release estimates were derived from numerical models. Table 2.1 provides a list of potential COC released from individual WSTF areas. Subsequent sections describe sources at the industrial areas at which contaminants were introduced to the surface and subsurface.

2.1.1 Wastes Managed and Released in the 100 Area

The 100 Area Burn Pit is a potential minor source of contamination to the subsurface. This pit in operation from 1969 to 1983 was used for fire-suppression training. Flammable liquid wastes were poured onto the water surface in the pit and ignited. An estimated 1,000 gallons of flammable liquids was burned each year during operation. According to historical records, aqueous film forming foam (AFFF) used during firefighter training at or adjacent to the 100 Area Burn Pit may have contained perfluorooctanoic acid (PFOA) or perfluorooctanesulfonic acid (PFOS), identified as emerging contaminants of concern (NMED, 2019c). This pit was excavated, and residual fluids and soils were

[1] The trade name Freon is a registered trademark of E.I. du Pont de Nemours & Company Corporation (DuPont).

removed in 1984. Five other solid waste management units (SWMUs), the Container Storage Area, Container Storage Unit, wastewater lagoons, Drum Storage Facility, and Temporary Polychlorinated Biphenyl Storage Area, are located in the 100 Area. These SWMU are not considered to be significant sources of COC to groundwater at WSTF.

2.1.2 Wastes Managed and Released in the 200 Area

Several contaminant sources were identified in the 200 Area (Figure 2.1). The two major sources of contamination in the 200 Area, the Chemistry Lab Tank (currently known as the 200 Area East Closure) and the Clean Room Tank (currently known as the 200 Area West Closure), are considered the primary source of TCE in WSTF groundwater. The Chemistry Lab Tank had a storage capacity of 1,500 gallons. This tank was installed in 1964 and received wastes from metallurgical and etching laboratory operations. These wastes were periodically transferred to the 600 Area impoundments. Wastes discharged to the Chemistry Lab Tank included aerospace propellants, organic solvents, oils, spent cutting fluids, spent x-ray developer solutions, cooling water, and other liquids. Closure activity was completed in June 1989.

The Clean Room Tank was a 4,000-gallon tank used from 1964 to 1979 to accumulate wastes generated by precision cleaning of flight hardware. Chemicals disposed to this tank included Freon 113, Freon 11, TCE, chromic acid, isopropyl alcohol, and other solvents. These accumulated wastes were periodically transferred to the 600 Area impoundments. In 1979, the severely corroded tank was removed and was replaced by a new tank installed approximately 50 feet (ft) to the west. The replacement tank was removed from service in 1986 and was found to be extensively corroded upon its removal.

Other potential sources for minor groundwater contamination at the 200 Area included the Clean Room Discharge Pipe, Scape Room Discharge Pipe, Building 203 Discharge Pipe, South Highbay Discharge Pipe, and several other areas of concern identified during historical information research performed prior to the 200 Area investigation (NASA, 2012a). The exact quantities or types of waste discharged to grade at these locations are not known.

2.1.3 Wastes Managed and Released in the 300 Area

The 300 Area surface impoundments (Figure 2.1) are a primary source for release of NDMA to the subsurface. Operation of these impoundments, located in the 300 Propulsion Testing Area of WSTF, began in 1965. The impoundments provided emergency spill containment and fuel treatment systems for discharges of hypergolic rocket fuels, including hydrazine, monomethylhydrazine, unsymmetrical dimethylhydrazine, Aerozine 50, and nitrogen tetroxide. Treatment of rocket fuels consisted of oxidation with calcium hypochlorite followed by discharge to grade to adjacent arroyos. Freon 113 and isopropyl alcohol also were used as referee propellants until 1972. TCE was also used as a cleaning solvent in 1964. Freon 113, isopropyl alcohol, and TCE were discharged to the surface impoundments and, in some instances, to grade.

Additionally, TCE was used to clean pipelines during facility construction of the 300 Propulsion Area during the early 1960s. TCE waste derived from this cleaning activity is suspected to be a source for TCE contamination in groundwater.

2.1.4 Wastes Managed and Released in the 400 Area

The 400 Area Surface Impoundments (Figure 2.1) in the propulsion testing area are a primary source for release of NDMA to the subsurface. These impoundments became operational in 1964. The impoundments provided emergency spill containment and fuel treatment systems for discharges of hypergolic rocket fuels, including hydrazine, monomethylhydrazine, unsymmetrical dimethylhydrazine, Aerozine 50, and nitrogen tetroxide. Treatment of rocket fuels consisted of oxidation with calcium hypochlorite followed by discharge to grade in adjacent arroyos. Freon 113 and isopropyl alcohol also were used as referee propellants until 1972. Freon 11 and Freon 21 were also used as cleaning solvents. Freon 11, Freon 113, and isopropyl alcohol were discharged to the surface impoundments and, in some instances, to grade.

Additionally, TCE was used to clean pipelines during facility construction at the 400 Propulsion Area during the early 1960s. TCE waste from this cleaning activity is suspected to be a source for TCE contamination in groundwater.

2.1.5 Wastes Managed and Released in the 500 Area

The 500 Area Fuel Storage Area (Figure 2.1) is a potential minor source of NDMA in the subsurface. This area consisted of a 20,000-gallon storage tank with secondary containment that was used to store hydrazine fuel, which may have been treated and released to grade at this location. NASA plans additional investigation at this area to determine if there is a source to groundwater (NASA, 2019d).

2.1.6 Wastes Managed and Released in the 600 Area

NASA operated the 600 Area Surface Impoundments (Figure 2.1) from 1968 to 1986. These impoundments were designed to contain saltwater backwash from the facility's water softening plant. They also received an undetermined amount of hazardous waste from the 200 Area Chemistry Lab Tank and Clean Room Tank. The impoundments were lined with an 8-millimeter (mm) polyvinyl chloride (PVC) liner and had a combined capacity of 2 million gallons. NASA closed this unit in 1989, performed an investigation at the 600 Area Closure in 2009 and 2010, and subsequently performed a soil vapor extraction pilot test in 2012. After completing the pilot test, NASA concluded that the vadose zone beneath the Closure is not a source of continuing contamination to the groundwater (NASA, 2012c). Contaminated perched groundwater is being extracted from beneath the 600 Area Closure and transported to and treated by the MPITS (NASA, 2020c).

2.1.7 Wastes Managed and Released in the 700 Area

The 700 Area Landfill (Figure 2.1) is a potential minor source of groundwater contamination. NASA used this 24-acre landfill for the disposal of solid waste between 1964 and 1997. Hazardous wastes may have been disposed to this landfill prior to 1987, when weekly inspections were implemented. Hazardous wastes may have included spent solvents, waste paints, and soft goods contaminated with hydrazine and oxidizer. The landfill was closed in 1998 and is monitored under a PCC Plan (NASA, 1996b) approved by the NMED Solid Waste Bureau. Routine groundwater monitoring is performed in accordance with that plan, and additional investigation is being performed (NASA, 2019a).

2.2 Extent of Contamination

This section briefly describes the spatial distribution of the five primary COC in groundwater at WSTF. The approximate extent of COC plumes is derived primarily from maps constructed using 2021 concentration data, thickness from cross sections constructed in the draft RCRA Facility Investigation (RFI; NASA, 1996a), and concentration data from wells with multiple completion depths. The distribution of other hazardous constituents present in WSTF groundwater does not exceed that of the COC presented in this section. Those hazardous constituents are discussed in more detail in later sections of this Plan.

2.2.1 N-Nitrosodimethylamine

NDMA is believed to have been released to the environment due to its creation during chemical oxidation of 1,1-dimethylhydrazine by calcium hypochlorite. An estimated 34 kilogram (kg) of contaminant mass was released to the environment (NASA, 1996a). Figure 2.2 shows a manual interpretation of the NDMA conceptualized groundwater plume at WSTF utilizing analytical data obtained from groundwater sampling in 2021. The NDMA plume extends westward approximately 20,000 ft from sources at the 300 and 400 Areas; is located entirely within WSTF boundaries; and is as much as 6,100 ft wide in the area upgradient from the MPCA. The highest concentration in this area occurs within well 400-HV-147 installed through the 400 Area Closure at 320,000 nanograms per liter (ng/L). Downgradient of the 400 Area, concentrations reduce and range from 24,000 to 5,000 ng/L within the main mass of NDMA along the plume axis. The width of the NDMA plume narrows to less than 2,800 ft within the MPCA where observed concentrations are between 300 and 9,500 ng/L. A northwest trending plume arm extends approximately 7,000 ft from the MPCA with NDMA concentrations between 2.2 and 200 ng/L. Within the Plume Front area downgradient from the MPCA, the plume widens to approximately 6,300 ft with maximum observed concentrations between 1,100 and 2,200 ng/L. The vertical extent of NDMA, inferred from measured NDMA concentrations in water from wells with multiple-depth sampling points, is estimated to range from less than 325 ft below ground surface (bgs) to approximately 750 ft bgs.

2.2.2 Trichloroethene

An estimated 4,663 kg of TCE contaminant mass was released to the environment (NASA, 1996a). Figure 2.3 shows a manual interpretation of the TCE conceptualized groundwater plume at WSTF utilizing analytical data obtained from groundwater sampling in 2021. The TCE plume extends westward approximately 18,500 ft from primary sources at the 200 Area and is located within WSTF boundaries. The maximum width of the TCE plume is approximately 3,200 ft in the industrial 200 Area. The highest concentration in the industrial 200 Area is 110 µg/L. Downgradient, the width of the TCE plume decreases to approximately 1,600 ft in the vicinity of the MPCA. Observed maximum TCE concentrations in MPCA groundwater are between 48 and 120 micrograms per liter (µg/L). A northwest trending plume arm extends approximately 7,000 ft from the MPCA with TCE concentrations between 3.9 and 25 µg/L. Within the Plume Front, west of the MPCA, the TCE plume is approximately 52,000 ft wide. Concentrations in the Plume Front range from the detection limit to approximately 190 µg/L. Based on multiple-depth sampling data, the inferred vertical extent of TCE in WSTF groundwater likely ranges from less than 325 ft bgs to approximately 750 ft bgs.

2.2.3 Tetrachloroethene

An estimated 80 kg of PCE contaminant mass was released to the environment (NASA, 1996a). Figure 2.4 shows a manual interpretation of the PCE conceptualized groundwater plume at WSTF utilizing analytical data obtained from groundwater sampling in 2021. The PCE plume originating from sources at the 100, 200, and 600 Areas, contains two separate portions, extends westward approximately 20,000 ft from the original release location in the WSTF test areas, and is located entirely within WSTF boundaries. In the MPCA, the PCE plume occurs as a small lobe before pinching out. Observed concentrations range between less than non-detect (<0.21 µg/L) and 6.8 µg/L within the Mid-plume area, although the plume is defined by the PCE cleanup level of 5 µg/L and centered on well BLM-39. Within the Plume Front, a second lobe is centered on the ST-1 well cluster with an observed maximum concentration of 8.1 µg/L. Based on multiple-depth sampling data, the inferred vertical extent of PCE in groundwater likely ranges from less than 325 ft bgs to approximately 750 ft bgs.

2.2.4 Freon 11

An estimated 2,766 kg of Freon 11 contaminant mass was released to the environment (NASA, 1996a). Figure 2.5 shows a manual interpretation of the Freon 11 conceptualized groundwater plume at WSTF utilizing analytical data obtained from groundwater sampling in 2021. The Freon 11 plume extends westward approximately 19,000 ft from sources at the 200, 300, and 400 Areas and is entirely located within WSTF boundaries. The plume is as much as 7,000 ft wide in the WSTF industrial area. The highest concentrations range up to 500 µg/L in the 400 Area, with concentrations typically between 100 and 200 µg/L throughout much of the area upgradient from the MPCA. The width of the Freon 11 plume narrows to approximately 2,000 ft within the MPCA where observed concentrations are between 39 and 150 µg/L. A northwest trending plume arm extends approximately 6,000 ft from the MPCA with maximum Freon 11 concentrations between 17 and 80 µg/L. Within the Plume Front, downgradient from the MPCA, the plume widens to approximately 5,000 ft with maximum observed concentrations between 15 and 180 µg/L. Based on multiple-depth sampling data, the inferred vertical extent of Freon 11 in groundwater likely ranges from less than 325 ft bgs to approximately 750 ft bgs.

2.2.5 Freon 113

Though not designated as a hazardous constituent, Freon 113 remains of interest to NASA for groundwater monitoring purposes. An estimated 4,621 kg of Freon 113 contaminant mass was released to the environment (NASA, 1996a). Figure 2.6 shows a manual interpretation of the Freon 113 conceptualized groundwater plume at WSTF utilizing analytical data obtained from groundwater sampling in 2021. Coalescing Freon 113 plumes originating from sources at the 100, 200, 300, and 400 Areas extend westward approximately 19,000 ft. The coalesced plume is entirely located within WSTF boundaries. The plume is as much as 7,700 ft wide in the area upgradient from the MPCA. The highest concentrations are 440, 360, and 200 µg/L in the 200 Area, MPCA, and Plume Front areas, respectively. The width of the Freon 113 plume narrows to approximately 2,600 ft within the MPCA. A northwest trending plume arm extends approximately 4,000 ft from the MPCA with a maximum Freon 113 concentration of 54 µg/L. Within the Plume Front downgradient from the MPCA, the plume widens to approximately 5,500 ft. A confined secondary plume centered on well 700-D-186 is present near the 700 Area with a Freon113 concentration of 23 µg/L. Based on multiple-depth sampling data, the inferred vertical extent of Freon 113 in groundwater likely ranges from less than 325 ft bgs to approximately 750 ft bgs.

2.3 Potential Receptors

Under current and future conditions, NASA maintains administrative control of lands below which groundwater has been contaminated by historical activities at WSTF. No expansion of water use will occur on lands within NASA's administrative control. Thus, conservatively, the nearest location where a water use well may be installed by an outside entity is at the property boundary directly downgradient of the plume.

Currently, there are no complete exposure pathways or human or ecological receptors of contaminated groundwater. Downgradient public and WSTF water supply wells comprise potential future pathways for exposure to groundwater contamination. Under current conditions, the nearest downgradient water wells are NASA WSTF water supply wells. The distance between the edge of the conceptualized groundwater contaminant plume and the WSTF property boundary to the west is approximately 7,000 ft. The locations of the WSTF water supply wells relative to other pertinent site features are shown in Figure 2.1. Routine sampling of drinking water from the NASA supply wells indicates that the WSTF water supply has not been impacted by WSTF groundwater contaminants. NASA also performed groundwater sampling at six off-site water supply wells in 2010. There was no evidence that these wells had been impacted by NASA's groundwater contaminant plume (NASA, 2010).

2.4 Previous Investigations

NASA has performed numerous environmental investigations at WSTF, including soil sampling, soil gas sampling, air monitoring, and groundwater monitoring. Historical and ongoing groundwater monitoring are most applicable to this Plan. A detailed discussion of the results of routine groundwater monitoring at WSTF is provided in the Periodic Monitoring Reports (PMR) submitted regularly to NMED. PMR include a comprehensive database of historical chemical analytical data from groundwater monitoring.

2.5 Surface Conditions

This section provides a brief description of the surface conditions as they relate to routine groundwater monitoring. Specific information on site conditions was provided in the WSTF RFI (NASA, 1996a).

2.5.1 Climate

The climate at WSTF is characterized by abundant sunshine, wide diurnal variation in temperature, low relative humidity, and variable precipitation. WSTF typically receives an average of 10 inches of rain per year, with the majority of rainfall events occurring in intense, brief, and localized thunderstorms during the late summer.

2.5.2 Surface Water Bodies

The major perennial surface water body in the region is the Rio Grande River, located approximately 15 mi west of WSTF within the Mesilla Valley. There are no natural surface water bodies at WSTF. The natural surface water body closest to the facility is Isaacks Lake, an ephemeral playa lake located approximately 8 mi southwest of the site at the lowest elevation in the Jornada del Muerto Basin (JDMB), a hydrologically closed basin (Figure 2.7) that is separated from the Mesilla Valley to the west by an uplifted horst block represented by the Doña Ana Mountains. Water is typically present in the playa only in years with above-average precipitation.

In certain areas, man-made channels or structures have been constructed to facilitate drainage and prevent erosion during high flow events. The only permanent surface water bodies at WSTF are the Test Stand 302 Cooling Water Discharge Pond and the 400 Area discharge ponds.

2.5.3 Surface Drainage

WSTF is characterized by high evaporation and infiltration rates, which are typical of a desert climate. Precipitation from the brief intense thunderstorms that falls upon the mountain range and alluvial fans cannot evaporate or infiltrate immediately and is transported downstream via arroyos. Arroyo surface flow generally terminates within minutes to hours after the end of a precipitation event. Topographic maps of the area indicate that numerous well-developed arroyos from WSTF terminate northeast of Isaacks Lake, and sheet flow drainage patterns characterize the western half of WSTF.

2.6 Subsurface Conditions

This section provides a brief description of the surface conditions as they relate to routine groundwater monitoring. Specific information on site conditions was provided in the WSTF RFI (NASA, 1996a).

2.6.1 Site-Wide Stratigraphy

Outcrops of Pennsylvanian limestone, sandstone, and siltstone bedrock that dip at approximately 22 degrees to the west occur adjacent and east of the WSTF 200 and 300 Areas. Exposed bedrock, or shallow bedrock covered by a thin (0 ft to 100 ft) veneer of alluvial sediments characterizes the fractured bedrock aquifer in the source areas. Bedrock west of the source areas is comprised of more gently westward dipping Tertiary volcanics overlain by a thicker alluvial sequence. Pennsylvanian and Tertiary bedrock lithologies are juxtaposed in the subsurface along the regional northwest-trending Hardscrabble Hill Fault that is exposed 2 mi south of WSTF on Hardscrabble Hill. West of the WSTF source areas, the alluvium thickness increases from approximately 100 ft to 350 ft within the MPCA. Immediately west of the MPCA, a structural feature known as the Western Boundary Fault Zone (WBFZ) displaces bedrock and the thickness of the alluvial unit increases significantly to over 2,500 ft within the JDMB. Alluvium consists of unconsolidated Quaternary alluvial fan deposits of the Santa Fe Group derived from the San Andres Mountains (SAM), located to the east of WSTF. Figure 2.8 shows the basic geologic features of WSTF, including an inset that highlights the MPCA where the predominant WSTF geological features coexist. A detailed description of site geology is available in the Draft RFI Report, Volume Two, Chapter Four (NASA, 1996a).

2.6.2 Site-Wide Structural Geology

Two types of geologic deformation of the alluvium/bedrock stratigraphic section are recognized near WSTF. The oldest and least prevalent deformation consists of west-northwest trending folds and faults associated with the Late Cretaceous to Early Tertiary Laramide Orogeny (Seager, 1981). This deformation is identified within outcrops of the western SAM within Bear Canyon, located 1 mi northeast of the eastern limit of the groundwater plume in the 300 Area. The Laramide faulting is defined by the Bear Peak Fold and Thrust Zone, which strikes to west-northwest of WSTF into the JDMB.

Younger and more widespread post-Laramide deformation at WSTF is attributable to regional Late Tertiary Basin and Range normal faulting and directly affects the stratigraphy within the contaminated portion of the aquifer. East-west extensional forces across the southwestern United States resulted in the formation of northwest-trending structural depressions and adjacent fault-bound mountains. WSTF is located partially on the pediment slope of the SAM (bounding the JDMB on the east) and partially within the downfaulted JDMB. Approximately 6 mi west of the WSTF boundary, the JDMB is bounded on the west side by the Doña Ana Mountains. Numerous northwest-trending subsurface half-graben normal faults within the western pediment slope of the SAM below WSTF have been identified from shallow seismic reflection and well log data. Regional structural features displaying the predominant northwest trend include the WBFZ and the Tertiary Hardscrabble Hill fault. The Hardscrabble Hill fault is located east of the Mid-plume and strikes below the WSTF 100 Area. This fault has an inferred displacement of several thousand feet (Seager, 1981), and juxtaposes Paleozoic limestone on the east against Tertiary volcanic rocks on the west. The bedrock surface has been beveled, and no offset of the bedrock surface is apparent. The WBFZ is a northwest-trending, regional-scale series of normal half-graben faults that offset the top of the bedrock from a depth of 400 ft on the bedrock pediment slope to a depth greater than 2,500 ft within the JDMB to the west. The WBFZ has a width of approximately 2,000 ft and is defined based on borehole lithologies and geophysical survey data.

2.6.3 Groundwater Hydrostratigraphy

Groundwater below the WSTF industrial areas is hosted within a fractured bedrock aquifer comprised of Pennsylvanian sedimentary rocks and Tertiary volcanic rocks at depths between approximately 100 ft and 200 ft bgs. The water table is relatively coincident with, and just below the contact between bedrock and the overlying alluvium. In the MPCA, groundwater occurs at a depth of approximately 300 to 450 ft bgs in an unconfined to semi-confined fractured bedrock aquifer. In the Plume Front area west of the WBFZ, groundwater occurs in an alluvial aquifer as a result of bedrock being displaced to inferred depths of up to 2,500 ft bgs toward the center of the JDMB. This aquifer yields relatively large quantities of potable water. At the Plume Front, the elevation of the water table within the upper aquifer of the JDMB ranges from 390 to 475 ft bgs and has been relatively consistent (within 3 to 6 ft) over a historical monitoring period of 40 years. Aquifer conditions in the vicinity of the Plume Front vary from unconfined to leaky confined due to the presence of discontinuous confining layers of clay or cemented alluvial horizons. Leaky confined conditions are generally prevalent within and to the west of the WBFZ. Figure 2.9 shows a cross-sectional view of WSTF's geology. The location of the cross-section is shown in Figure 2.1.

2.6.4 Groundwater Flow System

Groundwater beneath WSTF generally originates as mountain front recharge through precipitation in the southern SAM immediately east of the facility. As shown in Figure 2.9, groundwater flows generally to the west through fractured bedrock and along the base of the overlying alluvial section down the pediment slope on the western flank of the SAM, and merges with the groundwater flow system of the JDMB alluvial aquifer west of the WBFZ.

Groundwater recharge to the local aquifers occurs primarily through precipitation infiltrating into exposed bedding planes, fractures, and faults along the mountain front, or through infiltration of the permeable alluvial deposits into the underlying subsurface bedrock. Annual mountain-front recharge is estimated to be 50 to 200 acre-ft per mi of mountain front (Wilson et al., 1981; NASA, 1996a, 1999). Recharge from the southern SAM catchment areas (Bear Canyon to the north and Loman Canyon to the south) infiltrates the aquifer within the source areas and moves across the MPCA into the Plume Front area. West of the WSTF site boundary in the vicinity of the axis of the JDMB, recharge through precipitation is more limited. This is a result of reduced rainfall, higher evaporation rates, an increased depth to groundwater, and the presence of shallow and relatively thick lacustrine clay deposits within the alluvial section.

Minor artificial recharge areas are present on the pediment slope adjacent to the 300 and 400 Areas where WSTF has historically discharged excess test water relatively continuously over the last 30 years. Spent test water, discharged to grade, infiltrates the adjacent 300/400 Area arroyo and recharges the groundwater system. Annually, approximately 90 acre-ft are estimated to recharge the aquifer over a distance of 7,000 ft downgradient of the 300 Area in the 300/400 Area arroyo (NASA, 1996a, 1999, 2013a). Water used in testing activities at WSTF is supplied by production wells completed in the JDMB aquifer in the western portion of WSTF. Hence, this artificial recharge simply recycles groundwater from one part of the flow system to another and does not represent a net increase in aquifer recharge.

Groundwater flow from east to west in the fractured bedrock aquifer below WSTF is a result of a hydraulic gradient between the higher topographic elevations in the SAM-front recharge area and the lower elevations of the WSTF Plume Front in the JDMB. Horizontal hydraulic gradients at WSTF are steep in the source area and MPCA bedrock pediment aquifer (0.05 ft/ft or 250 ft/mi), where small-scale, interconnected fractures promote localized irregular downgradient groundwater movement. The rates of movement through the fractured bedrock are highly variable but are inferred to reach velocities of up to 750 ft per year. West of the WBFZ, horizontal hydraulic gradients are significantly lower within the alluvial aquifer of the JDMB (0.0002 ft/ft or 1 ft/mi).

Figure 2.10 provides a groundwater elevation map of WSTF.

2.6.5 Hydraulic Properties

Hydraulic conductivity (K) and transmissivity (T) values are typically several orders of magnitude greater in the alluvial aquifer than in the fractured bedrock aquifer. Recent groundwater flow modeling was accomplished by adjusting hydraulic conductivity to best match observed hydraulic heads. Figure 2.11 presents the calibrated horizontal hydraulic conductivity values used in the model, which match the range of hydraulic conductivities measured during aquifer pumping and slug tests.

Hydraulic conductivity zones were delineated across the WSTF model domain based on distribution of geologic units. Those units included fractured rocks (limestone, rhyolite, and andesite) and alluvial fan deposits. Figure 2.11 shows the distribution of these zones. Table 2.2 identifies these zones, geologic units they represent, distribution, K values derived from model calibration, and the range and geometric mean values for K derived from aquifer tests. The large number of significant digits indicated for hydraulic conductivities in Figure 2.11 and Table 2.2 were calculated by automated parameter estimation software (PEST). While measuring hydraulic conductivity to this level of accuracy is impossible, the software resolves hydraulic conductivity within the range of acceptable values specified by the user so that model calibration errors are minimized. These hydraulic conductivities are not field measured; however, they lie within the range of conductivities observed during field testing and result in a best fit match to observed hydraulic heads when paired with the other model hydraulic parameters.

The low permeability rhyolite and andesite unit, representing areas of dry holes and extremely small well yields, was assigned a very low K to represent these low permeability rocks. No test data are available to verify the calibrated value.

With one exception, calibrated horizontal K of zones representing other fractured rock units fell within the range of measured K derived from aquifer pumping and slug tests. These tests represented point values in an extremely heterogeneous system and the range was correspondingly large. Calibrated K of the representing fractured rhyolite east of the flow-banded rhyolite was lower than the observed range. That range was obtained from only three slug tests and may not be representative of the bulk hydraulic properties of this fractured rhyolite. In the case of several of the fractured rock units, the calibrated vertical K exceeds the horizontal K. This is a reasonable result given that fracture permeability dominates, and near-vertical normal faults are known to exist in the fractured bedrock units.

The K of the alluvium was calibrated to observed distance-drawdown relationships observed during pumping tests at Well J (for the distal basin-fill deposits) and NASA-PT (renamed PFE-3 [alluvium in zone]). The actual rates of groundwater flow at the Plume Front and similar areas of the JDMB alluvium are inferred to vary between 17 and 50 ft per year.

3.0 Regulatory Criteria

3.1 Hazardous Constituents and Cleanup Levels

The Permit requires that NASA establish cleanup levels for all hazardous waste and hazardous waste constituents in Permit Attachment 15, as well as perchlorate, methyl tert-butyl ether, and munitions constituents identified in the Permit Section I.J. In accordance with the definition provided in Permit Section I.J, NASA established cleanup levels for those hazardous constituents specified in 40 CFR Part 261 Appendix VIII and 40 CFR Part 264 Appendix IX which have been consistently detected at the facility and "are reasonably expected to be in or derived from waste contained in a regulated unit" as indicated in 40 CFR 264.93. Cleanup levels were assigned to groundwater contaminants listed in Appendix VIII in 40 CFR Part 261 and/or Appendix IX in 40 CFR Part 264. NASA follows a stepwise process to develop groundwater cleanup levels:

1. Each hazardous constituent was evaluated individually to determine if a United States Environmental Protection Agency (EPA) Drinking Water Maximum Contaminant Level (MCL; 40 CFR Part 141) exists.
2. Each hazardous constituent was evaluated to determine if a New Mexico Water Quality Control Commission (WQCC) numeric standard existed in Paragraphs (1-33) of Subsection A; Paragraphs (1-10) of Subsection B; and Paragraphs (1-5) of Subsection C 20.6.2.3103 New Mexico Administrative Code (NMAC).
3. Each hazardous constituent was evaluated to determine if it is listed as a toxic pollutant (TP) in 20.6.2.7.T(2) NMAC.
4. If the hazardous constituent is NOT listed as a TP and has:
    a. Either an MCL or a WQCC standard, that value was assigned.
    b. Both an MCL and a WQCC standard, the lower of the two values was assigned.
    c. Neither an MCL nor a WQCC standard, a Regional Screening Level (RSL) was determined in accordance with Permit Attachment 15.1.1.c (Step 7) and assigned as the cleanup level.
5. If the contaminant is listed as a TP in 20.6.2.7.T(2) NMAC, the RSL was determined according to Step 7.
6. Then, for each hazardous constituent listed as a TP, the lowest value of the existing drinking water MCL, the WQCC numeric standard, or the EPA RSL was assigned as the cleanup level.
7. For each hazardous constituent falling into the category of Step 4c or Step 5, above, the EPA RSL for tap water was determined as follows:
    a. For carcinogenic hazardous constituents, the RSL corresponding to a cancer risk level of 1.0E-05 was assigned. Note that the EPA RSLs for carcinogens are equivalent to a 1.0E-06 excess cancer risk. Therefore, for carcinogens, the RSL must be increased by an order of magnitude to meet Permit Attachment 15 requirements (NMED, 2019a).
    b. For each non-carcinogenic hazardous constituent, the RSL for tap water corresponding to a hazard index of 1.0 was determined (EPA, 2020).

Hazardous constituents are classified into the following categories to facilitate their analysis: volatile organic compounds (VOC); nitrosamines; metals; inorganics; semi-volatile organic compounds (SVOC); and miscellaneous hazardous constituents. Table 3.1 provides the current cleanup levels for hazardous wastes and hazardous constituents detected in groundwater at WSTF. In each PMR submitted to NMED, NASA compares the results of groundwater monitoring to the current established cleanup levels. Groundwater cleanup levels tend to fluctuate over time as the understanding of health risk evolves. To illustrate this variability, Figure 3.1 summarizes the cleanup levels for the four primary hazardous constituents in WSTF groundwater (NDMA, TCE, PCE, and Freon 11) between November 2009, when the current RCRA permit was issued by NMED, and the present. Table 3.2 identifies several other constituents that have been detected in WSTF groundwater that are of interest to NASA. These analytes are not hazardous constituents and thus do not have cleanup levels. However, NASA believes these analytes may be associated with historical or other activities at WSTF and has determined that they should be included in routine groundwater monitoring at WSTF.

3.2 Background Concentrations

NASA performed groundwater sampling at four upgradient monitoring wells and provided a statistical evaluation of background concentrations in Appendix A of the 2012 Groundwater Monitoring Plan (GMP) Update (NASA, 2012b). However, the data set was not sufficient to perform all required statistical evaluations (NMED, 2012), so additional sampling was required. NASA evaluated additional groundwater samples collected from background/upgradient wells since the 2012 GMP update and determined that the data set is now adequate for statistical evaluation. NASA submitted a *Background Groundwater Study Investigation Work Plan* to NMED in February 2021 (NASA, 2021b).

3.3 Detection Monitoring

Detection monitoring will be performed at WSTF as required by Permit Section VI.D.2, which requires NASA to report new detections and refers to the requirements of this Plan and incorporates the requirements of 40 CFR 264.101. This section discusses these requirements and provides procedures for conducting detection monitoring at WSTF.

3.3.1 Detection Monitoring at Hazardous Waste Management Units (HWMUs)

40 CFR 264.101 does not specifically address requirements related to detection monitoring at hazardous waste management units (HWMU). In order to determine potential requirements for detection monitoring, NASA consulted 40 CFR 264.98, which requires the collection of samples for analyses of Appendix IX constituents at the compliance point. Because NASA has entered corrective action and is not specifically subject to these requirements, specific compliance points have not been identified for the facility or closed HWMU. However, in order to ensure that additional hazardous constituents are not released to the groundwater from the closed HWMU or current activities in the operational areas of the facility, groundwater samples from five wells, 200-B-240; 200-SG-1; 300-A-120; 400-C-143; and BLM-3-182, will be analyzed for Appendix IX constituents.

Appendix IX constituents that have been detected at WSTF are included in Table 3.2. Wells that are utilized for detection monitoring near HWMUs are identified in Table 3.3. Detections of new Appendix IX constituents are managed as indicated in Section 3.3.3.

3.3.2 Facility-wide Detection Monitoring

As indicated in the Permit, a "new detection is any incidence of a constituent being detected in a groundwater sample collected from a monitoring well that has never been detected in prior samples obtained from that monitoring well." NASA samples groundwater monitoring wells at WSTF for a variety of hazardous constituents in accordance with this Plan. Chemical analytical data are reviewed to determine if new hazardous constituents have been detected. New detections are managed as indicated in the following section.

3.3.3 Management and Reporting of New Detections

NASA manages and reports previously undetected hazardous constituents identified during detection monitoring using an iterative process. First, NASA project chemists evaluate chemical analytical data and related laboratory reports in accordance with the quality requirements specified in Section 10.0 to determine if the detection is reliable. If the detection is not validated, or is an estimated value, no further action is required. If the detection is validated, NASA will resample the location at which the constituent was detected during the next scheduled sampling event at that monitoring well or zone. NASA will report the detection and scheduled confirmatory resampling in the subsequent PMR. If the constituent is not detected in the resample, NASA will report the resampling results to NMED in the subsequent PMR. No additional further action is required. If the detection is confirmed in the resample, NASA will report the detection to NMED in the subsequent PMR and propose a course of action related to the detection.

New or reconfigured groundwater monitoring wells will not be subject to facility-wide detection monitoring and related reporting until they have been sampled for at least one year as specified in Section 11.3.

4.0 Groundwater Monitoring System

This section describes the groundwater monitoring system in use at WSTF. It provides general information related to the groundwater monitoring wells in use, including: a list of the monitoring wells and their designations; a discussion of well drilling activities and basic procedures; a summary of well construction information; a description of well security practices; a summary of well maintenance activities; and a brief description of the procedures for well abandonment.

4.1 Groundwater Monitoring Well Identification and Designation

WSTF groundwater monitoring well identifications are stenciled on the protective outer casing or on one of the well's protective barrier posts. Groundwater monitoring wells that were installed as part of the original RCRA groundwater detection program are designated as NASA 3 through NASA 10.

Groundwater monitoring wells installed between March 1987 and December 2021 are identified by a three-part alphanumeric code. Well designations are determined by location of the well site or other unique descriptor, an alphanumeric identification digit, and the depth (in ft bgs) to the top of the screened interval or to the discreet location of a multiport monitoring well. An example of well numbering is BLM-1-435. In this example, "BLM" indicates that the well was installed on land controlled by the Bureau of Land Management at the time of installation, the "1" indicates it was the first well completed on BLM land, and the "435" indicates that the top of the screened interval is located at 435 ft bgs. Multiport wells, in their entirety, are designated only by the location of the well site or other unique descriptor and the alphanumeric identification digit. The designation of a specific sampling zone in a multiport well incorporates the depth to that zone for three-part well zone designation and unique identification. As example of multiport well numbers is PL-7-480, in which the "PL" indicates the was installed on private land (at the time of completion), the "7" indicates that this was the seventh well to be completed on private land, and the "480" indicates that the sampling port is located 480 ft bgs.

Beginning in January 2022, groundwater monitoring wells are identified by a four-part alphanumeric code. Well designations are determined by the location of the well site relative to established WSTF areas (100 through 800), a unique well number (sequentially numbered for that WSTF area), a well purpose designation, and a number representing the sampling port or zone number within the well. Multiport wells, in their entirety, are designated by the location of the well site, the well number, and the well purpose. An example of this well numbering scheme is 600A-002-GW-1. In this example, "600A" indicates that the well was installed in the portion of the WSTF 600 Area located within the industrial area (the eastern portion of WSTF), "002" indicates the well was the second to be installed within this area, "GW" indicates that the well will be used to monitor groundwater, and "1" identifies the first and shallowest sampling zone within the well.

Groundwater monitoring wells at WSTF have been installed to monitor various areas of the groundwater plume or to serve specific functions in the groundwater monitoring program. The functional groups into which WSTF groundwater monitoring wells have been assigned are described below. A summary of

WSTF's active groundwater monitoring wells is provided in Table 3.3. The locations of groundwater monitoring wells are provided in Figure 2.1.

4.1.1 Background/Upgradient Wells

Background monitoring wells are installed in the aquifer upgradient of the facility and HWMU at which hazardous waste was released to the groundwater. These wells are reasonably expected to be free of contamination resulting from activities at WSTF. In general, groundwater samples collected from these wells can be considered representative of the background conditions at eastern WSTF. Due to the size and geological complexity of the facility, upgradient wells may not be fully representative of background conditions at some locations to the west of the WSTF industrial area.

4.1.2 Source/Industrial Area Wells

Numerous groundwater monitoring wells have been installed in the vicinity of or adjacent to closed HWMUs at WSTF and in nearby sections of the industrial area. These wells were originally intended to monitor groundwater downgradient of the closures, determine if the HWMUs were continuing sources of contamination to the groundwater, and/or determine the nature and extent of groundwater contamination in the industrial area. Several of these wells or zones were previously designated as PCC monitoring wells (Points of Compliance or Supplemental) and were subject to semi-annual replicate sampling for a variety of hazardous constituents (NASA, 1996a). Historical and current chemical analytical data indicate that groundwater in these areas remains contaminated but show no evidence of additional releases of hazardous constituents to the groundwater (NASA, 2022a). Typical PCC monitoring is not required by the Permit. Source/industrial area groundwater monitoring wells are now primarily used on a less frequent basis to continue monitoring groundwater contaminant behavior in the vicinity of the HWMUs in order to support characterization of the contaminant plume, assist with source are investigations, and if required, provide data for the development, implementation, and monitoring of corrective actions in these areas. Source/industrial area monitoring wells are installed in the thin veneer of alluvial sediments or the fractured bedrock underlying the thin alluvium in the WSTF industrial area.

Source/industrial area wells are divided into three subcategories: 100/600 Area wells; 200 Area wells; and 300/400 Area wells.

4.1.3 Northern Boundary Wells

Groundwater monitoring wells installed to the north and west of the WSTF industrial area serve primarily to bound the conceptualized groundwater contaminant plume in that region. Chemical analytical data collected from these wells provide information related to the migration of hazardous constituents along the northern limit of the plume. Included in this group of monitoring wells are those designated for groundwater monitoring in the vicinity of the closed 700 Area Landfill. Sampling of these monitoring wells is performed in accordance with a Closure and Post-closure Care Plan (NASA, 1996b) approved by the NMED Solid Waste Bureau.

4.1.4 Southern Boundary Wells

Groundwater monitoring wells installed to the south and west of the WSTF industrial area are also utilized to bound the conceptualized groundwater contaminant plume in that region. Chemical analytical data collected from these wells provide information related to the migration of hazardous constituents along the southern limit of the plume. Historical analytical data indicate very little plume activity in this area, thus monitoring of wells to the south of the industrial boundary is typically performed less frequently than at other more critical locations in and around the plume.

4.1.5 Mid-plume Constriction Area Wells

The MPCA is of great interest to NASA because of the potential for intercepting significant concentrations of groundwater contaminants in the area. As a result, numerous groundwater monitoring wells have been installed within, as well as upgradient and downgradient of, the MPCA to characterize groundwater and contaminant movement in that region of the plume. These wells are installed at varying depths in both alluvium and fractured bedrock.

4.1.6 Plume Front Wells

Groundwater monitoring wells installed in the Plume Front area are used to characterize the conceptualized groundwater contaminant plume, identify and monitor the leading edge of the plume, and monitor the effects of the PFTS, NASA's voluntary interim measures to prevent further westward migration of the plume. These wells are installed at varying depths in the alluvium west of the WBFZ and provide horizontal and vertical delineation of the plume.

Plume Front groundwater monitoring wells are further divided into two subcategories: wells within the main portion of the contaminant plume that are used to determine the impacts of the PFTS on groundwater contamination and those installed near the leading edge of the plume that are used to effectively monitor the horizontal and vertical extent of the contaminant plume and ensure the overall effectiveness of the PFTS.

4.1.7 Sentinel Wells

Sentinel wells are those groundwater monitoring wells installed beyond the leading edge of the conceptualized contaminant plume that have not been impacted by historical or current operations at WSTF. Sentinel wells provide monitoring points at depths within the aquifer where contaminant migration is a concern. Evidence of WSTF COC at these wells or zones indicate uncontrolled migration of contaminants beyond a defined spatial limit (such as a capture zone) and may initiate changes in remediation system operation or other actions to prevent further contaminant migration. These wells are in the alluvium west of the WBFZ and serve to bound the plume both horizontally and vertically.

4.2 Groundwater Monitoring Well Construction

Groundwater monitoring well construction varies at WSTF based on the specific geological conditions and groundwater monitoring requirements at each well location. Groundwater monitoring wells are described as conventional or multiport. Currently, active multiport wells utilize Westbay®[2] or Water FLUTe™ sampling systems (see Sections 5.2 and 5.3). NASA may consider the use of other multiport monitoring systems. The details of these designs are discussed below. Additional information related to the construction of WSTF groundwater monitoring wells is provided in Table 3.3.

4.2.1 Conventional Monitoring Wells

Conventional monitoring wells are designed to monitor specific, discrete intervals within the aquifer. Conventional monitoring wells consist of a single borehole in which the well casing is installed. The targeted zone or zones are monitored using a segment of slotted, or screened, casing which accesses the formation surrounding this screened interval. Screened intervals are typically 10 to 20 ft in length and are isolated from the remainder of the boreholes during installation of the casing to ensure only the targeted

[2] Westbay is a registered trademark of Nova Metrix Ground Monitoring (Canada) Ltd.

zones are sampled. Conventional wells are used to measure groundwater elevations and to collect groundwater samples that are representative of the groundwater in the vicinity of the screened interval.

Conventional well casing size and material varies based on the geological conditions and groundwater monitoring requirements at each well location. WSTF conventional groundwater monitoring wells vary in size from 1.5 to 5 inches in diameter and are constructed of PVC, stainless-steel, or a combination of PVC and stainless-steel.

4.2.2 Westbay Monitoring Wells

Westbay multilevel groundwater monitoring systems are designed to monitor multiple water-bearing zones within a single borehole. The systems are currently in use at WSTF to collect groundwater samples, obtain groundwater formation pressures to determine piezometric elevations, and perform hydraulic conductivity determinations. Data obtained from these wells are used to formulate a three-dimensional conceptualization of the groundwater contamination plume.

The Westbay system is a multiple-level groundwater monitoring system which employs a single, closed access, PVC casing with valved ports to perform well monitoring activities. The valved ports are used to provide controlled access to a multiple number of monitoring zones within a single borehole. The Westbay system is installed directly in a stable borehole or in a multi-screened conventionally installed monitoring well casing. Inflatable packers are integrated into the Westbay casing design and are individually inflated against the walls of the borehole or outer casing to isolate specific monitoring zones and secure the Westbay casing within the borehole or outer casing. Westbay wells are designed to provide direct access to formation water. This allows the collection of in situ groundwater samples and hydrogeological data. As a result of this design, the requirement to excessively purge each monitoring zone prior to sample collection is eliminated. Specialized downhole instruments are used to access the valved ports within the well.

Based on direction from NMED, NASA developed a plan to reduce the use of Westbay wells at WSTF and perform monitoring at some present Westbay locations with sampling systems that allow for some purging of groundwater (NMED, 2011). In 2013, NASA removed the Westbay casing from monitoring wells JP-3 and WW-2 and replaced the Westbay sampling systems with two dedicated low-flow sampling systems (NASA, 2013b). In November 2014, NASA removed the Westbay casing from monitoring wells BLM-28 and BLM-32. NASA installed a Water FLUTe sampling system in the open borehole at BLM-32 in August 2015 (NASA, 2016). Groundwater sampling of the well was initiated in the fourth quarter of 2015. NASA reconfigured Westbay wells WW-4 and WW-5 to purgeable sampling systems in 2015 in accordance with the NMED approved schedule. The Westbay sampling systems were removed from both wells and redevelopment of the sampling zones began in September 2015. NASA installed four-zone Water FLUTe systems in these wells in November 2015 (NASA, 2016) and performed initial groundwater sampling in December 2015 and January 2016, respectively. In 2016 and early 2017, NASA removed the Westbay sampling systems from monitoring wells JER-1, JER-2, ST-6, and ST-7. Following redevelopment of the conventional casings in each well, multi-zone Water FLUTe systems were installed in each well as reported in the *Westbay Reconfiguration Report (Wells JER-1, JER-2, ST-6, and ST-7)* (NASA, 2017a). Westbay monitoring well BLM-37 was also scheduled for reconfiguration in 2016. However, the Westbay casing became lodged in the outer stainless-steel casing and broke. Numerous attempts to retrieve the casing failed. NASA plugged and abandoned the well in June 2019 (NASA, 2019b) and replaced it with new groundwater monitoring well BLM-42. NASA also plugged and abandoned Westbay well PL-5 (NASA, 2019b) and replaced it with new groundwater monitoring well PL-12. NASA proposed the reconfiguration of Westbay wells PL-7, PL-8, PL-10, ST-5, and WW-3 in the *NASA WSTF Westbay Well Reconfiguration Work Plan for Wells PL-7, PL-8, PL-10,* *ST-5, and WW-3*, provided for NMED review on April 29, 2021 (NASA, 2021e). NASA also proposed the plugging and abandonment of Westbay well PL-6 and replacement with new groundwater monitoring well 600C-002-GW (NASA, 2022b). NASA has reconfigured nine Westbay wells, two with dual-zone dedicated bladder pump systems and seven with Water FLUTe systems. NASA plugged and abandoned two Westbay wells and replaced them with dual-zone conventional wells. One Westbay well has been removed and awaits replacement. NASA continues to sample 21 Westbay wells at WSTF, some of which may be reconfigured in the future.

4.2.3 Water FLUTe Monitoring Wells

Water FLUTe monitoring well systems are designed to monitor multiple water-bearing zones within a single borehole or conventional well. The systems are currently used at WSTF to collect groundwater samples and obtain groundwater elevation data. Data obtained from these wells are used in combination with data obtained from Westbay monitoring wells to continually refine the three-dimensional conceptualization of the groundwater contamination plume.

Similar to the Westbay monitoring system, the Water FLUTe system may be installed directly in a stable borehole or within a multi-screened conventional monitoring well casing. The Water FLUTe consists of a flexible polyurethane coated nylon fabric liner that contains several monitoring ports. Sealing pressure created by excess water inside the waterproof flexible liner above the static water level in the formation ensures that there is no communication between monitoring zones in the borehole or well. Tubing extends from multiple sample ports in the flexible liner to the top of the borehole or well casing. This allows for the collection of representative groundwater samples from discrete depths. Pressurized gas (typically nitrogen) is used to drive water from the pump tube in the system to the sampling tube and up to the surface during purging and groundwater sampling activities. Purging is required before sampling to ensure representative groundwater samples are being collected. No downhole instruments are required to operate the Water FLUTe monitoring system. The system is operated from ground surface with pressurized gas during purging and sample collection activities.

4.3 Groundwater Monitoring Well Security

WSTF is a secure facility that is regularly patrolled by trained security forces tasked with restricting access to the facility to authorized personnel only. In addition to this institutional security, monitoring wells are equipped with locking caps that are secured at all times, except during monitoring activities conducted in accordance with this Plan or other site-specific project documents. Keys are issued only to personnel directly involved in the collection of groundwater samples, well maintenance, or well inspection activities.

4.4 Groundwater Monitoring Well Evaluation and Maintenance

Groundwater monitoring well sites are inspected during each sampling event and during periodic inspections to ensure safe and secure sampling locations are maintained at all times.

NASA performs qualitative evaluations of monitoring well performance on an ongoing basis to determine if monitoring wells require additional development, maintenance, reconfiguration, or replacement. Groundwater monitoring wells may also be inspected with a downhole camera system to ensure well and sample integrity is maintained. The downhole camera system is utilized on an as-needed basis to perform inspections at the discretion of qualified groundwater monitoring personnel. NASA has identified several wells that may require attention.

4.4.1 Well 200-LV-150

Groundwater monitoring well 200-LV-150 (Figure 2.1) was installed in June 2014 as part of the 200 Area investigation. In 2017 and early 2018, NASA completed development of this monitoring well, installed a dedicated low-flow bladder pump in the well, and collected the required groundwater samples from the well in February 2018. NASA sampled the well again in November 2018, but during the next scheduled sampling event in November 2019 it failed to recharge adequately to collect representative groundwater samples. NASA informed NMED of the well performance issue in the Monthly Environmental Activity Report (EAR) and proposed no-purge sampling in the 2020 GMP update (NASA, 2020d). NMED disapproved this technique in the *Approval with Modifications NASA WSTF Periodic Monitoring Report First Quarter 2020* (NMED, 2021c) and the *Approval with Modifications Groundwater Monitoring Plan* (NMED, 2021b).

In the Approval with Modifications of the NASA Groundwater Monitoring Plan 2020 Update, NMED directed NASA to attempt an alternative purging and sampling method, such as a non-dedicated purge pump and bailer. NASA assessed the viability of sampling well 200-LV-150 with a dedicated low-flow bladder pump during the summer of 2021 and determined that a replacement sampling system was required. NASA replaced the sampling system in September 2021 and successfully sampled the well in October 2021. Well 200-LV-150 is included in the Plan for scheduled groundwater sampling.

4.4.2 200-SG Wells

On September 13, 2018, NMED approved NASA's April 24, 2018 GMP update for 2018 (NMED, 2018; NASA, 2018) with modifications, one of which required NASA to provide additional information on wells 200-SG-2 and 200-SG-3 (Figure 2.1) and provide the rationale for not including them in the sampling schedule. NASA's December 3, 2018 response provided the required information and indicated that NASA would evaluate wells 200-SG-2 and 200-SG-3 for potential future sampling (NASA, 2018). In April 2019, NASA evaluated the performance of the two wells, and determined that the groundwater levels in each are inadequate to allow for the collection of representative samples. NASA also determined that the relatively low concentrations of WSTF COC in these wells are not representative of groundwater within the Gardner Spring Arroyo in which monitoring well 200-D-109 (Section 4.4.1) is installed.

In their January 25, 2021 *Approval with Modifications of the NASA Groundwater Monitoring Plan 2020 Update*, NMED directed NASA to prepare and submit a work plan for abandonment of monitoring wells 200-SG-2 and 200-SG-3 and installation of replacement wells, to be submitted for review no later than November 30, 2021 (NMED, 2021c). NASA submitted the *Well Plugging Plan of Operations for Multiport Soil Vapor Groundwater Monitoring Wells 200-SG-2 and 200-SG-3* for NMED review on November 30, 2021 (NASA, 2021j). NMED approved the work plan on January 10, 2022 (NMED, 2022b). NASA does not intend to replace these wells and they are not included in this Plan.

4.4.3 Wells 300-C-128, 400-C-118, 400-C-143, BLM-1-435, and PL-3-453

In the February 21, 2022 *Approval with Modifications Periodic Monitoring Report Second Quarter 2021*, NMED expressed concern about declining water levels at WSTF groundwater monitoring wells 300-C-128, 400-C-118, 400-C-143, BLM-1-435, and PL-3-453 (NMED, 2022d). NMED indicated that NASA could continue to evaluate these wells and directed NASA to provide recommendations for their disposition in this Plan.

Although the groundwater elevation at well 300-C-128 (Figure 2.1) was inadequate for sampling in 2020, NASA successfully sampled the well in October 2021. NASA plans to continuing monitoring the water level in this well and sampling the well in accordance with this Plan. No further action is planned at this time.

NASA evaluated monitoring wells 400-C-118 and 400-C-143 (Figure 2.1) in September 2021 and determined the groundwater elevation in well 400-C-118 is inadequate for the collection of representative groundwater samples. Based on routine measurements of water levels at WSTF, NASA concludes that groundwater levels at this location are unlikely to recover. NASA believes the well should be plugged and abandoned. The water level in well 400-C-143 remains adequate for groundwater sampling, and the well's proximity to well 400-C-118 ensures that groundwater monitoring at this important location is sufficient for contaminant plume characterization. NASA does not intend to install another groundwater monitoring well near this location to replace well 400-C-118. Well 400-C-118 has been removed from this Plan and well 400-C-143 will replace it for detection monitoring in accordance with Section 3.3 of this Plan.

NASA attempted to sample well BLM-1-435 (Figure 2.1) twice in 2021, but the water level in the well was not sufficient to allow for sampling during either planned event. NASA sampled well PL-3-453 in October 2020 but was unable to sample the well in 2021 because of the ongoing decline in the groundwater elevation at this location. Based on the generally declining water table observed at WSTF, NASA concludes that water levels in these wells are unlikely to recover adequately to provide representative groundwater samples in the future. These wells have been removed from this Plan. NASA expects to plug and abandon these wells in 2022 and evaluate the groundwater monitoring well network to determine if replacement wells are necessary. The results of the evaluation with be provided in the GMP update for 2023.

4.4.4 Wells 400-KV-142 and 400-LV-125

Multiport soil vapor and groundwater monitoring wells 400-KV-142 and 400-LV-125 (Figure 2.1) were installed during the 400 Area Closure investigation in January 2017 at NMED's request (NASA, 2021f; pages 30-31). Subsequent attempts to sample the groundwater components of these wells were largely unsuccessful due to inadequate groundwater recharge (in 400-KV-142) or to the complete lack of groundwater (in 400-LV-125). NASA evaluated these wells in July 2020 and concluded that there is inadequate groundwater within the wells to support the collection of representative groundwater samples. NASA plans to plug and abandon the groundwater components of these wells while retaining the soil vapor sampling ports. NASA does not plan to replace these wells and they are not included in this Plan.

4.4.5 Well BLM-2-482

Groundwater monitoring well BLM-2-482 (Figure 2.1) was last sampled on May 17, 2012 before the static water level in the casing dropped to a depth that prevents the collection of representative groundwater samples. In July 2021, NASA evaluated this well and co-located well BLM-2-630 and concluded that the water level at this location is unlikely to recover sufficiently to allow for the collection of groundwater samples from well BLM-2-482. NASA also determined that groundwater contaminant concentrations in existing well BLM-2-630 are consistent with historical concentrations in well BLM-2-482 and, as a result, that well BLM-2-630 provides adequate groundwater monitoring at this location in the contaminant plume. NASA plans to plug and abandon well BLM-2-482 and does not plan to replace the well. The well has been removed from other sections of this Plan.

4.4.6 Well BLM-28-515

Based on direction from NMED, NASA developed a plan to reduce the use of Westbay wells at WSTF and perform monitoring at some present Westbay locations with sampling systems that allow for some purging of groundwater (NMED, 2011). In November 2014, NASA removed the Westbay casing from monitoring well BLM-28 (Figure 2.1).

In April 2019, NASA installed a sampling system in the borehole, which became lodged in the borehole. NASA attempted to recover the dedicated sampling system from well BLM-28 in November 2019; however only the steel support cable, dedicated bladder pump, and tubing were removed from the borehole. There is borehole wall collapse zone at approximately 400 ft bgs that resulted in several feet of fill on top of the inflatable packer that remains in the borehole at approximately 500 ft bgs. NASA evaluated the BLM-28 borehole and determined that future reuse for groundwater monitoring is not feasible. NASA submitted the *Well Reconfiguration Report for Well BLM-28 and Notice of Intent to Plug and Abandon* on May 4, 2020 (NASA, 2020b). On November 19, 2020, NMED provided requirements for abandonment and replacement of the well (NMED, 2020b). A work plan for abandonment of BLM-28 was to be submitted to NMED no later than April 30, 2021. Following complete evaluation of all available data and information, NASA was to either submit a work plan for a replacement monitoring well or formally notify NMED that BLM-28 will not be replaced, no later than January 31, 2022. NASA submitted the *Well Abandonment Work Plan for Well BLM-28* on April 29, 2021 (NASA, 2021d, which NMED approved on January 10, 2022 (NMED, 2022a. NASA submitted the *Work Plan for Drilling and Installation of Monitoring Well 600B-001-GW* on August 31, 2021 (NASA, 2021h). NASA plans to replace well BLM-28 with proposed well 600B-001-GW following NMED approval of the work plan. Well BLM-28 is not included in this Plan.

4.4.7 Well BLM-30

On March 29, 2016, NMED approved NASA's January 27, 2016 *NASA WSTF Periodic Monitoring Report – Fourth Quarter 2015* with a comment expressing uncertainty about the source of detections of NDMA in well BLM-30 (Figure 2.1) during 2015 (NMED, 2016a). NMED directed NASA to submit a work plan for the conversion of these Westbay wells to purgeable systems. NASA developed and submitted the *Detections of NDMA and TCE in WSTF Groundwater Monitoring Wells BLM-30, PL-5, PL-6, PL-7, PL-8, PL-10, ST-5, and WW-3* (NASA, 2017b) on March 30, 2017, which included the *Westbay Well Reconfiguration Work Plan for Well BLM-30*. NASA received NMED's October 4, 2017 Approval with Modifications (NMED, 2017a) that required NASA to revise the BLM-30 reconfiguration work plan. NASA evaluated NMED's comments and submitted the revised *Well Reconfiguration Work Plan for Well BLM-30* on December 28, 2017 (NASA, 2017d). Between December 2018 and July 2019, NASA attempted to remove the Westbay casing from the BLM-30 borehole to allow for borehole evaluation and well reconfiguration. Although most of the casing was removed, approximately 90 ft of Westbay casing was not recoverable. After careful consideration, NASA determined that reconfiguration of this borehole was not feasible. On August 29, 2019, NASA submitted the *NASA WSTF Drilling Work Plan for Abandonment of Well BLM-30 and Drilling of New Groundwater Monitoring Well BLM-43* (NASA, 2019c). NMED approved the plan with modifications on November 5, 2020 (NMED, 2020a) and directed NASA to submit a well complete report for replacement well BLM-43 no later than November 20, 2021. To accommodate delays resulting from COVID-19 work restrictions, NASA requested an extension of time for submittal of the well completion report on September 28, 2021 (NASA, 2021i). NMED approved the request on October 27, 2021, extending the due date for the well completion report to November 30, 2022 (NMED, 2021). Well BLM-30 has been removed from other sections of this Plan.

4.4.8 Well BLM-31

The Westbay sampling system in groundwater monitoring well BLM-31(Figure 2.1) became inaccessible to downhole sampling equipment in 2002. NASA discontinued sampling of the well at that time because it was located beyond the conceptualized groundwater contaminant plume. NASA is planning an evaluation of well BLM-31 to determine if it can be reused or reconfigured, or if it will be plugged and abandoned. For either reconfiguration or plugging, NASA will prepare and submit the appropriate work plan to NMED. Pending its reconfiguration or replacement, well BLM-31 has been removed from other sections of this Plan.

4.4.9 Well BW-4

Westbay monitoring well BW-4 (Figure 2.1) was utilized as a monitoring location for the 200/600 Areas and Mid-plume Constriction Area groundwater tracer test (NASA, 2012d). While attempting to remove groundwater dye tracer sampling equipment deployed in the Westbay casing, the equipment became lodged in the casing and could not be retrieved. In February 2018, NASA's subcontracted drilling company removed approximately 185 ft (of 475 ft total) of Westbay casing. The remainder of the Westbay casing was drilled out of the borehole. In 2019 and early 2020, NASA used a variety of techniques to evaluate the BW-4 borehole for potential reuse in the groundwater monitoring program. First, NASA conducted downhole logging which included resistivity, temperature, spontaneous potential, 3-arm caliper, acoustic and optical imaging and heat-pulse thermal flowmeter (TFM) logs. NASA worked with FLUTe to perform FLUTe Activated Carbon Technique (FACT) and borehole transmissivity profiles. Finally, NASA performed a second Heat-Pulse TFM log to positively identify open fractures in the well capable of transmitting groundwater. NASA used the results of testing to evaluate the borehole at BW-4 and concluded that the fracture zone at a depth of 330 ft below top of casing is most conducive to future groundwater sampling. On June 29, 2021, NASA submitted the *Well Reconfiguration Work Plan for Well BW-4*, which detailed NASA's intent to grout the borehole below 330 ft bgs and install a single-zone sample system at or above 330 ft (NASA, 2021e). NMED approved the work plan on January 18, 2022 with modifications and direction to submit a well reconfiguration report no later than March 30, 2023 (NMED, 2022c).

4.4.10 Well NASA 8

Sampling at monitoring well NASA 8 (Figure 2.1) was discontinued in 2015 when the water level in the well became inadequate for the collection of representative groundwater samples. NASA plans to plug and abandon this well and has determined that a replacement well is not required because existing and recently installed monitoring wells adjacent to the 600 Area Closure continue to provide adequate groundwater monitoring coverage. NASA is not included in this Plan.

4.4.11 Well NASA 9

Monitoring well NASA 9 (Figure 2.1) was scheduled for sampling in October 2020. NASA was unable to sample the well because access to the screened interval was prevented by the intrusion of roots into the well casing and screen. In the November 15, 2021 *Approval with Modifications White Sands Test Facility Groundwater Monitoring Plan*, NMED directed NASA to submit a work plan for the abandonment and replacement of well NASA 9 no later than April 29, 2022 (NMED, 2021e). NASA submitted the *Work Plan for Abandonment and Replacement of NASA 9* in April 2022 (NASA, 2022c). Well NASA 9 has been removed from other sections of this Plan.

4.4.12 Well WW-4

The Water FLUTe sampling system was removed from well WW-4 (Figure 2.1) to support the collection of groundwater samples in accordance with the *Response to Approval with Modifications for Groundwater Data Representativeness Phase 1: Water FLUTe Well Evaluation Abbreviated Investigation Report* (NASA, 2019b). NASA completed the evaluation and submitted the *Modifications for Groundwater Data Representativeness Phase 1: Water FLUTe Well Evaluation Abbreviated Investigation Report* to NMED on August 17, 2021 (NASA, 2021g). NASA replaced the Water FLUTe system in this well in late February 2022 and plans to resume routine groundwater sampling required by the GMP in April 2022.

4.5 Groundwater Monitoring Well Abandonment

When groundwater monitoring wells are no longer required to meet the objectives of the groundwater assessment program, or have reached the end of their useful lives, they are abandoned. The goal of well abandonment is to seal the borehole so that it cannot serve as a conduit for the migration of contaminants. Well abandonment at WSTF is performed in accordance with procedures established in the Permit and 19.27.4 NMAC. Typically, the well casing is filled from the bottom upwards with an appropriate sealing material (bentonite, cement slurry, etc.) approved by the New Mexico Office of the State Engineer (NMOSE). NASA will submit a well abandonment plan to the NMOSE in accordance with 19.27.4 NMAC. If the well to be plugged and abandoned is an active sampling location in this Plan, the Permit requires that NASA submit a copy of the certification required by 19.27.4 NMAC to NMED no less than fifteen days prior to the well's removal from service. Because the cited NMAC does not include a requirement for certification, NASA will provide a copy of the plugging plan that must be submitted to the NMOSE prior to well abandonment fieldwork. 19.27.4 NMAC also requires that the driller contractor that plugs a well submit a plugging record to the NMOSE within 30 days of well abandonment. NASA receives copies of the plugging records and will provide these records to NMED within 60 days of well abandonment.

5.0 Sample Equipment

Equipment used for the collection of groundwater samples is designed to minimize the impact on sample integrity during the sample collection process. Equipment requirements for WSTF groundwater monitoring wells vary depending upon the type of monitoring well installed at the monitoring location. As previously indicated in this Plan, WSTF utilizes both conventionally installed monitoring wells and multiport monitoring wells for groundwater assessment purposes. This section describes the groundwater sampling equipment utilized in each type of monitoring well currently installed at WSTF. Sampling equipment is also summarized in Table 3.3.

5.1 Conventional Monitoring Wells

Several types of dedicated and non-dedicated well sampling systems are used at WSTF due to the variability of sampling conditions encountered. Factors that influence the type of system selected for each conventional monitoring well include the depth to water, volume of water to be purged, water recovery rate, frequency of sampling, overall integrity of the well casing, and the cost of system installation.

5.1.1 Dedicated Bladder Pump Systems

Numerous conventional wells are equipped with dedicated positive displacement bladder pump systems. In this design, the wells are purged and sampled using the dedicated bladder pump. The pumps are constructed of PVC, stainless-steel, Teflon®[3], and/or polyethylene depending on the monitoring objectives at that location. Samples are collected directly from Teflon-lined polyethylene, Teflon, or polyethylene discharge tubing. These materials are used to minimize the sorptive effects of pump or tubing material on sample quality. The pressure necessary to operate the bladder pumps is supplied by compressed nitrogen cylinders or liquid nitrogen dewars.

[3] Teflon is a registered trademark of The Chemours Company.

5.1.1.1 Bladder Pump Systems for Low-Flow Sampling

Many of the wells with very low yield are equipped with dedicated bladder pumps are designated for low-flow sampling. Wells equipped with low-flow systems are slowly purged until groundwater indicator parameters stabilize, in lieu of three casing volumes. When these parameters are stable, sample collection is initiated as described in later sections of this Plan.

5.1.1.2 Bladder Pump Systems for Higher Volume Purging and Sampling

Certain conventional monitoring wells that are capable of sustained flow are equipped with dedicated bladder pumps that are used to purge at least three casing volumes of groundwater prior to sampling with the bladder pump. Dedicated bladder pump systems are used in wells with relatively short groundwater columns so that three casing volumes can be attained in a short period of time and with a small purge volume.

5.1.2 Dedicated Bladder Pump/Inflatable Packer Systems

Several wells are equipped with dedicated inflatable packer/bladder pump systems. In this type of system, an inflatable packer is used to isolate monitoring zones, effectively shortening the water column in order to reduce purging time and volume. Water is purged and sampled from the monitoring zone(s) using a dedicated bladder pump. Samples are collected directly from the discharge tubing to ensure sample quality.

5.1.2.1 Single Zone Packer Systems

Many conventional monitoring wells have a single screened interval near the bottom of the well. In these wells, an inflatable packer may be used to isolate a sampling zone in the well extending from just above the screened interval or targeted monitoring zone to the bottom of the well. This type of sampling system is used in monitoring wells where a relatively large amount of purging would be required if the packer was not used or where an irregularity in the casing prevents the collection of representative samples using other sampling techniques.

5.1.2.2 Multiple Zone Packer Systems

Conventional monitoring wells may also be equipped with multiple screened intervals within a single casing to allow for the collection of groundwater samples from multiple depths within the aquifer. The screened intervals are separated by inflatable packer(s) to prevent vertical mixing between monitoring zones. This type of sampling system is used to provide for the collection of groundwater samples from multiple screened intervals in one conventional well casing in which other multiport sampling systems are not ideally suited or have proven to be suboptimal.

5.1.3 Non-Dedicated Purge Pumps and Bailers

Although dedicated equipment is preferred for sample collection at WSTF, there are occasions when dedicated equipment is impractical or is incapable of sample collection because of equipment failure or current well and/or hydrogeologic conditions. Under specific circumstances, such as dedicated equipment failure, non-dedicated equipment is used to purge groundwater monitoring wells and to collect groundwater samples. New groundwater monitoring wells may also be sampled using non-dedicated purge pumps and bailers until their purge characteristics can be determined and the appropriate dedicated equipment selected, acquired, and installed.

For these conditions, non-dedicated bailers constructed of material appropriate for the sampling objectives are used to collect samples after purging with a non-dedicated pump. A non-dedicated pneumatically driven purge pump is used to evacuate the specified volume of water, then a bailer is lowered into the well for sample collection using a non-dedicated stainless-steel cable. The pump, if desired, can also be used to collect samples for inorganic analytes. Due to possible effects on sample integrity, this pump is not typically used to collect samples with volatilization potential.

To eliminate cross-contamination between wells, the pneumatic pump and bailer are decontaminated prior to each use. To ensure that the decontamination procedures are effective and to determine the potential occurrence of field contamination, equipment blanks are collected at regular intervals as indicated in later sections of this Plan. Decontamination procedures are briefly described in Section 6.0.

5.1.4 Other Equipment and Supplies

In addition to the specific sampling equipment listed in the previous sections, a variety of general equipment is required for sampling conventional monitoring wells. For instance, certified clean sample containers are used to ensure the collection of quality groundwater samples. Sample containers are provided by the contracted analytical laboratory or a qualified third-party vendor and meet strict industry standard cleanliness requirements. NASA requires that sample containers be certified clean by an independent laboratory. Additional required equipment includes, but is not limited to: source of compressed nitrogen (or other suitable compressed gas to operate pneumatic equipment); pneumatic controllers and related hardware; replacement tubing; portable purge/decontamination water collection container(s); portable electric generator; water level indicator (depth probe); portable water quality instruments; calibration/check standards for instruments; personal protective equipment (PPE); polyethylene baggies; ice chests and ice; and decontamination equipment and supplies (steam cleaner/pressure washer, detergent, brushes, etc.).

5.2 Westbay Monitoring Wells

Westbay sampling systems are designed to monitor multiple water-bearing zones within a single borehole using a single dedicated casing string. The systems are currently in use at WSTF to collect groundwater samples, obtain groundwater formation pressures to estimate piezometric elevations, and perform hydraulic conductivity determinations. NASA uses data obtained from these wells to formulate a three-dimensional conceptualization of the groundwater contamination plume.

5.2.1 MOSDAX Sampler Probe

The MOSDAX®[4] sampler probe is a non-dedicated electronic tool used to measure downhole fluid pressures and obtain in situ groundwater samples from Westbay wells. The system is operated by a handheld controller. The controller displays pressure readings and controls the downhole fluid measurement and sample collection functions of the probe. The probe contains an electronic strain-gauge pressure transducer for measuring fluid pressures within the Westbay standpipe and through the measurement port couplings located in each monitoring zone. The probe is equipped with an electronically controlled sample apparatus that, when appropriately activated, accesses a one-way valve in the Westbay well casing and collects a groundwater sample directly from the aquifer.

---

[4] MOSDAX® is a registered trademark of Nova Metrix Ground Monitoring (Canada) Ltd. Corporation.

5.2.2 Stainless-steel Sample Bottles

Groundwater samples are collected from Westbay wells using the MOSDAX sampler probe and retrieved in a series of stainless-steel sample bottles that are attached to the probe. These non-dedicated sample bottles are decontaminated prior to sample collection at each well, and equipment blanks are collected for analysis by the specific volatile analytical method(s) required at each well. Decontamination procedures are briefly described in Section 6.0.

5.2.3 Other Equipment and Supplies

In addition to the specific sampling equipment listed in the previous sections, a variety of general equipment is required for sampling Westbay monitoring wells. For instance, certified clean sample containers are used to ensure the collection of quality groundwater samples. Additional equipment includes, but is not limited to: portable purge/decontamination water collection container(s); portable electric generator; vacuum pump; water level indicator (depth probe); portable water quality instruments; calibration/check standards for instruments; PPE; polyethylene baggies; ice chests and ice; and decontamination equipment and supplies (steam cleaner/pressure washer, detergent, brushes, etc.).

5.3 Water FLUTe Monitoring Wells

The Water FLUTe is a purgeable groundwater sampling and water level measurement system designed to monitor multiple zones within a single borehole. The system consists of waterproof polyurethane coated nylon fabric liner with integrated spacers that create sampling intervals for each discrete sampling port. Groundwater flows from the formation into the spacer and through a sealed sample port in the liner. Polyvinylidene fluoride and/or nylon tubing extends from the sample port to the top of the well casing to permit groundwater purging and sample collection from discrete monitoring zones.

5.3.1 Water FLUTe Flexible Liner

The Water FLUTe flexible liner is constructed of polyurethane coated nylon. The waterproof liner seals the entire borehole by maintaining excess water inside the liner above the static groundwater level in the formation. Spacers are sewn into the liner, which pull the liner away from the borehole wall to create discrete monitoring intervals.

5.3.2 Water FLUTe Sample Port and Internal Tubing

Sample ports are located in the Water FLUTe liner at the top of each monitoring zone to facilitate purging and sample collection. Polyvinylidene fluoride and/or nylon tubing extends from each sample port to the top of the well casing. Two tubes are present at the top of the well casing for each monitoring zone. Pressurized gas such as nitrogen is applied to the larger pump tube within the system during purging and sampling activities to drive water down to the bottom of the liner and up the second smaller sample tube of the system. A check valve is located at the bottom of the pump tube in order to isolate the sample port and formation from the pump tube during purging and sampling activities. A second check valve is located near the bottom of the sample tube and prevents the backflow of water from the sample tube to the pump tube and formation once the gas pressure is released.

5.3.3 Other Equipment and Supplies

In addition to the specific sampling equipment listed in the previous sections, a variety of general equipment is required for sampling Water FLUTe monitoring wells. For instance, certified clean sample containers are used to ensure the collection of quality groundwater samples. Additional equipment includes, but is not limited to: source of compressed nitrogen (or other suitable compressed gas to operate the Water FLUTe system); pneumatic controllers and related hardware; portable purge/decontamination water collection container(s); water level indicator (depth probe); transducer interface module; portable water quality instruments; calibration/check standards for instruments; PPE; polyethylene baggies; and ice chests and ice.

6.0 Pre-Sampling Activities

A variety of tasks are performed at groundwater sampling events prior to the collection of groundwater samples. These pre-sampling activities include: initiation of the field sampling record (logbook); decontamination of non-dedicated sampling equipment; well site inspection; measurement of the groundwater elevation; well purging (if required); and the measurement of groundwater indicator parameters. As previously indicated, WSTF currently utilizes both conventional and multiport monitoring well configurations for the collection of groundwater samples. Monitoring well sampling systems can be further categorized depending on the purge and sample methods utilized at each monitoring well. In general, purging and sampling of conventional monitoring wells is performed either by utilizing low-flow techniques (i.e., a minimal volume of water is purged prior to sampling), or by purging a set volume of groundwater prior to sample collection. Some pre-sampling activities and equipment requirements differ based upon the specific sampling system and techniques in use at each monitoring well. The following sections briefly describe the basic pre-sampling tasks that are performed at each groundwater sampling event.

6.1 Decontamination of Non-Dedicated Equipment

Non-dedicated sampling equipment is thoroughly decontaminated between uses to prevent cross-contamination. Previous demonstrations have shown that WSTF contaminants are efficiently removed through the use of heated water, environmentally safe detergent, and/or triple rinsing with purified water. Equipment is first transferred to the steam cleaning pad or decontamination sink. Equipment is disassembled if possible, and each piece is pressure washed on the steam pad or washed with heated water and detergent in the decontamination sink. Equipment is then rinsed with purified water before being covered or wrapped with polyethylene sheets or placed in plastic baggies to prevent contamination before use. If the equipment cannot be hot pressure washed or exposed to detergent, it is triple rinsed with purified water and stored in polyethylene wrap or plastic baggies. All fluids used or produced during the decontamination activities are managed as investigation-derived waste (IDW) as described later in this Plan.

6.2 Field Sampling Record (Logbook)

The field sampling record, typically a bound, hard copy logbook, is used to record all activities, observations, and measurements that take place in the field during sampling events. Records of the field activities should be sufficient to allow an experienced individual, not associated with the sampling event, to recreate the events by reading the logbook. Following each sampling event, the field sampling record for the event is reviewed and approved by a knowledgeable contractor environmental staff member to ensure completeness and accuracy. The sampling record is maintained on site as a permanent record of the sampling event.

Information that is included in the field sampling record each time sampling is conducted includes:

- Monitoring well identification/designation.
- Date of the sampling event.

- Site-specific procedural documentation to be used.
- Identification of the members of the sampling party.
- Climatic/weather conditions.
- Initial static water level.
- Calculated purge volume (if required – dependent on sampling equipment).
- Purge rate, purge duration, purge time, and volume of water purged (if required).
- Well evacuation method and equipment.
- Sample collection method and equipment.
- Decontamination procedures for non-dedicated equipment in use.
- Indicator parameter measurements, equipment used, calibration or check standards, standard lot number(s), and most recent calibration date(s).
- Identification of field quality control samples and source of blank water.
- Groundwater sample collection sequence.
- Unique sample identification number for each sample.
- Type of sample container used for each sample.
- Method(s) of preservation used for each sample.
- Chemical analysis or analytical method to be performed on each sample.
- Laboratory (or laboratories) performing the analyses.
- Problems encountered during field activities and any corrective actions implemented.
- Any other relevant field observations.
- Signatures of preparer and reviewer.

Individual field sampling records vary depending on the type of well sampled, sampling equipment used, specific samples and quality control samples collected, and other project-specific requirements. Site-specific procedural documents used for groundwater sampling provide the specific requirements of the field sampling record for each type of groundwater sampling operation.

6.3 Equipment Calibration/Verification

Prior to use, field instrumentation and/or equipment used for the measurement of groundwater indicator parameters and/or the collection of other data is calibrated or verified as instructed in site-specific procedural documentation. Field instruments are calibrated as recommended by the manufacturer using certified traceable calibration standards. Records of calibration and/or field verification of calibration and operation are included in the field sampling record.

6.4 Well Site Inspection

Upon arrival at the well location, and prior to implementation of sampling activities, field personnel inspect the well location to ensure that it is safe and easily accessible for the planned work activities. They also inspect the condition of the wellhead, locking well cap, cement pad, and protective bollards.

Any anomalies are noted in the field logbook and reported to the appropriate contractor environmental organization personnel for corrective action.

6.5 Groundwater Elevation

6.5.1 Static Water Level in Conventional Monitoring Wells

The static water level, or groundwater elevation, is manually measured in each conventional monitoring well prior to collecting samples at each sampling event. The static water level is also measured in many wells on an established schedule to provide consistent groundwater elevation data for use in groundwater modeling and the development of groundwater elevation maps for reporting. The frequency for determining the groundwater elevation in conventional wells is presented in Section 11.1.

To measure the static water level in a conventional monitoring well, a water level probe is slowly lowered down the well casing until it contacts the water surface as indicated by audible/visual alarms on the probe. The probe is then raised and lowered very slowly until the depth to water is determined to the nearest 0.01 ft. The depth measurement, reference point (top of casing or ground surface), and the corresponding date and time of measurement are recorded in the appropriate field logbook, which is provided to the responsible environmental contractor personnel for review.

On infrequent occasions when a water level cannot be measured due to unforeseen circumstances, such as a depressed water level or equipment failure, the field sampling record will be updated with the pertinent information.

6.5.2 Static Water Level in Westbay Monitoring Wells

In order to determine the groundwater elevation in Westbay wells, the hydraulic pressure at the desired measurement port is measured using the MOSDAX sampler probe. This pressure is used to calculate the piezometric level of the measurement port, which is converted to the groundwater elevation at that location. Prior to sampling a zone in a Westbay well, the hydraulic pressure at the measurement port is measured and recorded in the field logbook. Groundwater elevations are also determined at select Westbay wells on an established schedule to facilitate groundwater modeling and aid in the development of groundwater elevation maps for reporting. The frequency for determining the groundwater elevation in Westbay wells is presented in Section 11.1.

The depth to water inside the Westbay casing is first measured as indicated in the preceding section. A series of surface checks are performed on the MOSDAX sampler probe to ensure it is functioning correctly prior to measurement and sampling activities. To measure the hydraulic pressure, the MOSDAX sampler probe is lowered into the Westbay casing and located in the desired measurement port within the casing. The probe is allowed to equilibrate, after which the hydraulic pressure of the formation is measured using the electronic transducer in the MOSDAX sampler probe. If required, the hydraulic pressure is measured at each measurement port in the Westbay well to complete the pressure profile. These pressure measurements and their corresponding date and time of measurement are recorded in the field sampling record, which is provided to the responsible contractor environmental personnel for review. A relatively simple mathematical equation is applied later to convert field measurements to the piezometric elevation for the desired location.

6.5.3 Static Water Level in Water FLUTe Monitoring Wells

Deep water table depths and small diameter tubing used within the Water FLUTe monitoring well systems prevent direct measurement of the static water level in most Water FLUTe monitoring wells at

WSTF. In lieu of direct measurement, dedicated vented pressure transducers are used to determine the static water level at individual Water FLUTe monitoring zones before collecting samples during each sampling event. If there is there is no pressure transducer present at a specific monitoring zone, or the transducer fails to function as designed, the static water level may be determined by the measuring the volume of water expelled during a full purge cycle. The frequency for determining the groundwater elevation in Water FLUTe wells is presented in Section 11.1.

To determine the static water level at a Water FLUTe well, the indicated feet of water above the transducer is recorded and subtracted from the initial transducer reading that was obtained immediately following installation of the Water FLUTe system. The difference between these values is then subtracted from the recorded static water level that was measured before installation of the Water FLUTe system. Groundwater elevation is determined by subtracting the calculated static water level value from the measuring reference point elevation, which is the top of the well casing. The transducer reading and the corresponding date and time of the measurement are recorded in the appropriate field logbook and provided to the responsible environmental contractor personnel for review.

In cases where a Water FLUTe monitoring zone does not contain a dedicated pressure transducer, or the transducer fails to provide a reliable reading, the static water level is calculated from the volume of water expelled from the zone during a full purge cycle. The measured purge volume and system tubing diameter measurement is used with the general cylinder volume equation to determine the height of water above the bottom of the Water FLUTe system. The calculated water height measurement is added to known depth of the system to determine the static water level. Groundwater elevation is determined by subtracting the calculated static water level value from the measuring reference point elevation, which is the top of the well casing. The purge volume and the corresponding date and time of the measurement are recorded in the appropriate field logbook and provided to the responsible environmental contractor personnel for review after the completion of field sampling activities. Groundwater elevations calculated from purge volumes are not used to develop graphical representations of the groundwater surface at WSTF.

6.6 Well Purging/Preparation

This section provides basic purging procedures for the well systems described in previous sections of this Plan.

6.6.1 Bladder Pump Systems for Low-flow Sampling

Most conventional groundwater monitoring wells are purged and sampled using dedicated low-flow sampling equipment (Table 3.3). Groundwater is purged from these wells slowly to avoid vertical mixing of the water within the casing. Some non-dedicated low-flow sampling equipment is assembled prior to purging a monitoring well. Using a properly rated pressure regulator and flex hose, a pressure source (typically compressed nitrogen gas) is connected to a pneumatic controller box, which is then attached to the wellhead with a second flex hose. A dedicated discharge tube constructed of material appropriate for the sampling objectives is attached to the appropriate port on the wellhead and routed to the flow-through cell (flow cell). A section of non-dedicated tubing is routed from the flow cell to the purge water collection container.

The pressure source and pneumatic controller are set at the starting pressure based on the depth of the bladder pump. The purge cycle is then optimized using the available settings (refill, discharge, and throttle) on the pneumatic controller. The static water level is monitored during purging to ensure minimal drawdown. If the water level begins to drop, the purge rate of the well is reduced such that the water level can be maintained within 25 percent of the distance between the top of the screened interval and the pump intake. If the drawdown exceeds this limit, an additional volume of water equal to that of the excess drawdown is purged prior to sample collection.

Some wells at WSTF are installed in very low yield formations. If the water level in the well continues to drop with each purge cycle when the refill is set to the maximum time, the well is considered low yield. For these wells, modified purging techniques are used to ensure that stagnant casing water is not sampled. Purging is continued at the low rate until the water level has dropped to three times the maximum allowable drawdown. Purging is discontinued at this point and the water level is allowed to recover to a level adequate to collect groundwater samples without exceeding three times the allowable drawdown. When the water level has recovered sufficiently, the bladder pump is cycled several times to clear stagnant water from the discharge tubing before sample collection.

During purging operations, groundwater indicator parameters are monitored at regular intervals as discussed in Section 6.7.1.

6.6.2 Dedicated Bladder Pump Systems for Higher Volume Purging and Sampling

In wells with dedicated bladder pump systems (Table 3.3), the depth to water in the well casing is utilized in conjunction with the total well depth to calculate the required volume of groundwater to be purged. Typically, three well volumes are purged prior to sampling. Using a properly rated pressure regulator and flex hose, a pressure source (typically compressed nitrogen gas) is connected to a pneumatic controller box, which is then attached to the wellhead with a second flex hose. If the well is not already equipped with dedicated discharge tubing, a dedicated or disposable discharge tube is attached to the appropriate port on the wellhead and routed to the purge water collection container.

The pressure source and pneumatic controller are set at the starting pressure based on the depth of the bladder pump. The purge cycle is then optimized using the available settings (refill, discharge, and throttle) on the pneumatic controller. Using a container of known volume, the purge rate is determined by monitoring the time required to fill the container. At established intervals during purging, primary and secondary indicator parameters are measured as indicated in Section 6.7.2. When three well casing volumes have been removed, purging is complete, and sampling can be initiated.

Low yield wells (those that do not recover sufficiently to produce three well casing volumes) are pumped dry. If the recovery rate is greater than 10 ft per hour, the well is allowed to recover for one hour then purged dry again. The well can be sampled when the water rises to a level that permits the pump to function. In cases where the recovery rate is less than 10 ft per hour, the water level is allowed to rise to a level that permits the pump to function, then sampling is performed. All pertinent information related to purge volumes and times is recorded in the field logbook.

6.6.3 Dedicated Bladder Pump/Inflatable Packer Systems

Several conventional monitoring wells are equipped with dedicated inflatable packers (Table 3.3) that are positioned to isolate the monitoring zone(s) in the well. Inflation of the packer shortens the water column and effectively reduces the required purge volume. The well casing volume used for purging is equal to that between the bottom of the packer and the bottom of the well sump or the volume required to achieve stable indicator parameters during low-flow sampling. Following packer inflation using compressed nitrogen, purging is performed using a dedicated bladder pump as described in the preceding section.

6.6.4 Non-Dedicated Purge Pumps and Bailers

Recently installed groundwater monitoring wells, those that have not been fully characterized, or wells in which dedicated equipment is not ideal, are purged using the non-dedicated pump (Table 3.3). Also, in the event that dedicated equipment fails or otherwise becomes unserviceable, it can be removed and non-dedicated equipment can be used to purge and sample a monitoring well. The total required purge volume is calculated based on the monitoring well design. The decontaminated non-dedicated purge pump is lowered into the well and activated using a pressure source. The pumping rate is measured to determine the time required to complete purging. The well is then purged as described in previous sections. When the required volume of groundwater has been purged and groundwater indicator parameters have been measured, the non-dedicated purge pump is removed from the well and sampling can be performed as indicated later in this Plan.

6.6.5 Westbay Monitoring Wells

Westbay wells are designed to allow the collection of groundwater samples directly from the formation with minimal active purging. The Westbay sampling apparatus must be assembled prior to sample collection. Previously decontaminated stainless-steel sampling bottles are triple rinsed with purified water and attached to the bottom of the Westbay probe for use in sample collection. WSTF procedures for sampling Westbay wells require that these stainless-steel sample bottles be rinsed once with formation water prior to sample collection. The sampling apparatus is lowered into the monitoring well and located in the sampling port at the least contaminated monitoring zone. The sampler probe, which is controlled from the surface, is used to access the formation outside the Westbay casing through a one-way valve in the casing and a corresponding valve in the probe. When the probe is located in the sampling port, it is sealed against the one-way valve in the casing to open it. The valve in the probe is then opened and a small volume of groundwater is drawn through the probe and into the stainless-steel sample bottles attached to it. This volume, typically between one and two liters, is purged from the formation and used for the measurement of groundwater indicator parameters prior to sample collection.

6.6.6 Water FLUTe Monitoring Wells

Water FLUTe monitoring systems allow for the purging and sampling of multiple groundwater monitoring zones within a single conventional well or borehole. Monitoring wells or open boreholes equipped with Water FLUTe sampling systems (Table 3.3) are configured to isolate the monitoring zone(s) in the well or borehole. The pressure provided by excess water inside the FLUTe liner above the formation static water level seals the liner to the borehole or casing wall. This process isolates the monitoring zone and significantly reduces the volume of groundwater that must be purged to obtain representative samples.

The Water FLUTe monitoring system uses pressurized gas (typically nitrogen) to drive water from the system’s larger pump tube to the smaller sample tube during purging activities. The gas pressure applied during purging activities is sufficient to expel all water from the system. Once all water is expelled, the gas pressure is released, and a check valve opens to allow the system to refill with formation water through the sample port. This process is repeated until a sufficient volume of water is discharged from the system to ensure representative groundwater samples are collected. Two to four gallons are typically purged from each monitoring zone prior to sample collection.

6.7 Groundwater Indicator Parameters

This section describes the field measurements, or groundwater indicator parameters, that are collected during the purging and sampling of groundwater monitoring wells. Generally, the first and last samples of groundwater collected at each sampling event are reserved for the measurement of indicator parameters. The collection of groundwater for the measurement of indicator parameters is an integral part of the groundwater sampling process. As a result, the process of collecting indicator parameters varies slightly depending on the specific monitoring well system in use. The following is a brief discussion of indicator parameters and the equipment and supplies used for the different monitoring well configurations present at WSTF.

6.7.1 Bladder Pump Systems for Low-Flow Sampling

The majority of conventional monitoring wells at WSTF are sampled using dedicated low-flow bladder pumps (Table 3.3). Indicator parameters are measured during low-flow purging operations in accordance with acceptable low-flow practices and recorded in "sets." Indicator parameters are monitored using an in-line flow-through cell, which is equipped with multiple probes and/or sensors that measure temperature, pH, conductivity, oxidation/reduction potential, and dissolved oxygen. Turbidity is frequently measured separately using water collected upstream of the flow cell. The depth to water is also closely monitored to ensure minimal drawdown during low-flow sampling. Indicator parameters are monitored throughout purging operations. When three sets of indicator parameters have stabilized to within 10 percent, purging is considered complete and sampling is initiated.

6.7.2 Dedicated Bladder Pump Systems

A number of conventional monitoring wells at WSTF are equipped with dedicated bladder pumps (Table 3.3). Some of these monitoring wells also utilize dedicated inflatable packers to isolate the screened intervals and reduce the volume of purge water generated during purging. Indicator parameters are collected from non-low-flow dedicated bladder pumps in a similar manner. Groundwater is collected directly from the dedicated bladder pump discharge tubing and is dispensed into a small clean container for parameter measurement using field instruments. A small volume of groundwater is dispensed directly into the turbidity vial for use in the field turbidity meter. Each set of indicator parameters typically consists of temperature, pH, conductivity, and turbidity. Generally, sampling personnel collect three sets of indicator parameters when sampling a well equipped with a dedicated bladder pump: the initial parameters are collected when approximately two casing volumes of water have been removed from the well; the secondary parameters are collected immediately prior to sampling after three casing volumes of water have been purged; and the third and final set is collected after all the necessary groundwater samples have been collected.

6.7.3 Non-Dedicated Purge Pumps and Bailers

When dedicated sampling systems are not practical or fail to provide the overall groundwater sample quality required at WSTF, non-dedicated purge pumps and bailers are used (Table 3.3). When sampling with this equipment, indicator parameters are measured in a manner similar to that employed when sampling with dedicated bladder pumps, in which three sets of indicator parameters are collected. The initial and secondary parameters are measured using groundwater collected directly from the discharge tubing of the non-dedicated purge pump and dispensed into a small clean container or turbidity vial. The final set of indicator parameters is dispensed from the bailer into the appropriate vessel after the required groundwater samples have been collected.

6.7.4 Westbay Monitoring Wells

The collection of indicator parameters at Westbay monitoring wells (Table 3.3) utilizes much of the same equipment as other sampling methods. Groundwater obtained from the initial sample collection "run" is used for the measurement of indicator parameters. When the Westbay probe and sampling apparatus is brought to the surface, groundwater is dispensed directly from the lowermost sample bottle into a small clean container and turbidity vial for measurement of indicator parameters with field instruments. Excess groundwater is discarded into the purge water collection container and managed appropriately in accordance with specific instructions provided in later sections of this Plan. Two sets of indicator parameters are measured – initial and final. Each set consists of temperature, pH, conductivity, and turbidity. Initial parameters are obtained using water collected before the groundwater samples, while the final parameters are those measured using the water that remains in the stainless-steel Westbay sampling bottles after groundwater samples have been collected.

6.7.5 Water FLUTe Monitoring Wells

Indicator parameters are measured at Water FLUTe wells (Table 3.3) using groundwater collected during the first sample "stroke" of the system. After purging is complete, the gas pressure is lowered to the required sampling pressure defined for the particular system. The sampling pressure for each Water FLUTe is carefully calculated to ensure that a buffer of water remains in the pump tube during sample collection. This ensures that the water being collected during sampling is not aerated by the pressurized gas used to expel water from the system. During the initial sample stroke, an initial volume of water is collected to ensure any residual air is removed from the system prior to sampling. This water is used for the measurement of indicator parameters to help monitor system performance. Any excess groundwater remaining after these indicator parameters are collected is discarded into the purge water collection container and managed appropriately in accordance with specific instructions provided in later sections of this Plan. Two sets of indicator parameters are measured as part of sampling – initial and final. Each set consists of temperature, pH, conductivity, and turbidity. Initial parameters are obtained using water collected before the groundwater samples, while the final parameters are those measured using groundwater that is discharged in the final sample stroke after groundwater samples have been collected.

7.0 Sampling Procedures

This section summarizes the procedures for sampling groundwater monitoring wells at WSTF.

7.1 Conventional Monitoring Wells

7.1.1 Dedicated Bladder Pump Systems

After the monitoring well has been purged as described in Section 6.6, the pumping rate is adjusted to approximately 100 milliliter (mL) per minute to facilitate the collection of samples for analysis of volatiles. A VOC sample vial is positioned under the discharge tube at an angle that allows the water to flow down the inside of the container with a minimum of turbulence. As the vial fills, it is rotated to an upright position and filled until a reverse meniscus is visible. The vial is capped, inverted to check for air bubbles, and placed on ice. When the vials have been filled, they are assigned a sample number as indicated in this Plan and appropriately labeled and sealed. The remaining groundwater samples are collected in descending order of sensitivity to volatilization. Each sample is assigned a sample number and appropriately labeled and sealed. Samples that must be cooled are placed on ice. Pertinent sampling information (sample numbers, relevant activities/conditions, etc.) are recorded in the field logbook.

7.1.2 Non-Dedicated Purge Pumps and Bailers

Following removal of the non-dedicated purge pump from the groundwater monitoring well after purging, the well is sampled using a non-dedicated Teflon bailer. The bailer is first decontaminated as previously described, and then transported to the well site wrapped in polyethylene sheeting to ensure cleanliness. It is attached to a stainless-steel wire rope and lowered into the monitoring well. As it approaches the groundwater surface, the rate of descent is slowed, and personnel listen for the sound of the bailer entering the water. It is slowly lowered into the water until it fills and is then raised to the surface. A decontaminated delivery stopcock is placed into the bottom of the bailer and a small amount of groundwater is flowed through the stopcock to serve as a final rinse. Groundwater is also collected at this time to measure the final turbidity. Samples sensitive to volatilization are collected from the stopcock in a manner similar to that previously described. VOC vials are filled, checked for headspace, labeled, sealed, and placed on ice. The bailer is lowered, filled, and retrieved as necessary to fill the remaining sample containers. Groundwater is collected from the last bailer run to measure final indicator parameters other than turbidity. All pertinent information related to sample collection is recorded in the field logbook.

7.2 Westbay Monitoring Wells

Previous sections of this Plan described the processes for measuring the hydraulic pressure in Westbay monitoring zones, assembling the sampling apparatus, and removing a small volume of groundwater from the formation at the sampling location to measure indicator parameters and rinse the sample collection bottles. To collect groundwater samples, the Westbay sampling apparatus is lowered into the well casing and located in the sampling port at the least contaminated monitoring zone, ensuring that equipment is not cross-contaminated between zones if decontamination is ineffective. It is sealed against the one-way valve in the casing and the valve in the probe is opened. Groundwater is collected from the sampling port using the MOSDAX sampler probe and stainless-steel sample bottles. When the bottles have been filled with groundwater, the valves are closed and the sampling apparatus is brought to the surface. Groundwater is then dispensed from the lowermost stainless-steel sampling bottle directly into the appropriate sample container. Samples are collected in descending order of sensitivity to volatilization as described in previous sections of the Plan. The process is repeated at each required monitoring zone. All pertinent information related to sample collection is recorded in the field logbook.

7.3 Water FLUTe Monitoring Wells

Previous sections of this Plan described the processes for determining the water level in Water FLUTe sampling systems and purging a sufficient volume of groundwater from the formation at the sampling location to measure indicator parameters and ensure the collection of representative groundwater. To collect groundwater samples, the gas pressure is lowered to the predefined sampling pressure for the system. The sampling pressure varies between each well because of different static water levels and tubing lengths within the Water FLUTe systems. The defined sampling pressure for each system maintains a buffer of water in the system's pump tube while samples are being collected. This ensures that the water being collected is not aerated by the pressurized gas. A sample "stroke" is initiated at a zone by opening the control valve for the pressurized gas, which pushes water down the pump tube to the sampling tube within the system. This process is identical to the purging procedure, but the gas is applied at a lower pressure to maintain the buffer of water with the system, as described previously. An initial volume of water is collected to ensure there is no remaining air within the system, which is also used to measure initial indicator parameters.

After confirming no air remains within the system, groundwater samples are collected directly from the Water FLUTe sample tube at the top of the well casing. The discharge from the sample tube slows and eventually stops as water is expelled from the system. When this occurs, the gas pressure is released, which allows the check valve at the bottom of the pump tube to open. This allows groundwater from within the liner spacer to flow through the sample port and refill the pump tube. A second check valve at the bottom of the sample tube also closes to prevent the backflow of water from the sample tube to the pump tube while the system is in a relaxed state. Subsequent sample strokes are used to produce a sufficient volume of water for the required samples. Samples are collected in descending order of sensitivity to volatilization as described in previous sections of the Plan. Following final sample collection and measurement of final indicator parameters, the gas pressure is increased back to the purge pressure to expel all water from the system's sample tube. This water is discarded into the purge water collection container and managed appropriately in accordance with specific instructions provided in later sections of this Plan. All pertinent information related to sample collection is recorded in the field logbook.

8.0 Post-sampling Activities

Following groundwater sampling, a variety of tasks must be performed to complete the sampling event. Post-sampling activities are summarized in this section.

8.1 Sample Management

Environmental samples collected at WSTF are strictly controlled. This section briefly describes the manner in which samples are identified, labeled and sealed, stored, documented, and shipped to off-site laboratories to ensure proper custody is maintained.

8.1.1 Sample Identification

A unique sample number is assigned to each sample at the time of collection that identifies the general sample collection location and sample date (year [YY], month [MM], day [DD], and time [TTTT; military]. An example of a sample number is: 2205251035. In this example, 20 refers to the year (2022), 0525 refers to the date of collection (May 25), and 1035 refers to the time of collection (1035 hours, or 10:35 AM). In some instances, the sample number may be followed by a letter that identifies a specific field sampling crew or project. Additionally, when collecting samples for certain projects, the sample number may be preceded by an additional letter that identifies the sample collection location (e.g., Plume Front extraction well). This sample identification format is used for all groundwater samples and quality control samples.

8.1.2 Sample Labels and Custody Seals

Sample labels are required to avoid sample misidentification, either in the field, during packaging, or at the analytical laboratory. Sample labels are affixed to each sample container by sampling personnel immediately after sample collection and preservation (if required). Sample labels include, at a minimum, the following information:

- The unique sample number as previously defined.
- Identification of the well/zone being sampled.
- Identification of the sampling personnel.
- The analysis required for the sample.
- The preservation method utilized for the sample.

Sample custody seals are required to ensure that samples are not tampered with prior to laboratory preparation or analysis. Custody seals are completed and affixed to each sample container by sampling personnel immediately after the sample label is affixed to the container. Custody seals are placed over or around the cap of each sample container in a manner that ensures the seal must be broken to access the groundwater in the container. This ensures that access to the sample is controlled and limited to the receiving laboratory. Seals are inspected upon arrival of the sample at the analytical laboratory. Sample seals include, at a minimum, the following information:

- The unique sample number.
- Identification of the well/zone being sampled.
- Identification of the sampling personnel.

Additional custody seals are placed on sample shipping containers to demonstrate that the container is not tampered with during shipment to the analytical laboratory. Ice chest custody seals are affixed to the ice chest in a manner that ensures the seal must be broken to access the samples in the shipping container. Seals are inspected upon arrival of the shipping container at the analytical laboratory. Seals include, at a minimum, the following information:

- The date the container was packaged.
- The initials or signature of the individual responsible for packaging the sample shipping container.

8.1.3 Sample Storage

Most groundwater samples collected at WSTF must be cooled to 4 ± 2 °C following collection. To prevent alteration of these samples during collection, sample containers are cooled on ice prior to sample collection. Immediately following collection, preservation, and labeling, groundwater samples are placed on ice until they are transferred to refrigerated storage. Until shipment or transfer to the analytical laboratory, groundwater samples that require refrigeration are stored in a secure dedicated refrigerator that maintains a constant temperature of 4 ± 2 °C. Additionally, all samples that potentially contain contaminants that are sensitive to volatilization are stored (and later shipped) with the container septa facing down. This procedure minimizes possible volatilization of the target compounds through the septum.

8.1.4 Sample Custody

NASA maintains strict custody of groundwater samples at all times. As part of each sampling event, field chain of custody forms are updated with pertinent sample information, including: the date of the sampling event; location of sampling event; unique sample number(s); number of sample containers for each sample; sample matrix; required analysis for each sample; signature of the individual relinquishing custody; signature of the individual accepting custody; and the date of each. Throughout the sampling event, sampling personnel retain physical custody of groundwater samples. Upon completion of the sampling event, or as dictated by operational requirements, sampling personnel deliver groundwater samples to a secure dedicated refrigerator for storage prior to their shipment to a contracted laboratory. These personnel sign and date the internal chain of custody form(s) and indicate that sample custody was relinquished to secure storage. Access to the sample storage refrigerator is restricted to sampling and sample management personnel.

The designated sample management personnel accept custody of the samples as part of the packaging and shipment process described in the following section, and sign and date the custody form(s) accordingly. Separate lab- or contract-specific external chain of custody forms are prepared by the designated sample management personnel as part of the sample shipping process. The external chain of custody form includes pertinent information, including: date of shipment; laboratory name and purchase order number; return address for analytical results; project personnel contact information; unique sample number(s); number of sample containers for each sample; sample matrix; required analysis for each sample; applicable notes/comments; signature of the individual relinquishing custody; signature of the individual accepting custody; and the date of each. Completed chain of custody forms are retained as part of the sampling event record.

8.1.5 Sample Packaging and Shipment

Groundwater samples are securely packaged prior to shipment to off-site contracted analytical laboratories. Sample management personnel inspect sample containers to confirm sample identity and the accuracy and consistency of labels and related documentation. Sample containers are then wrapped or packaged in appropriately sized packaging material such as bubble wrap or foam inserts in a manner that will prevent breakage during shipment. Samples are then securely packed into an appropriately sized ice chest with sealed drain hole for shipment to the contracted analytical laboratory. The signed and dated external chain of custody form is placed in the ice chest, which is then sealed with a custody seal as previously indicated. The ice chest is further sealed to prevent any potential leakage should a sample container break during shipment.

After being securely packaged, groundwater samples collected at WSTF are typically shipped by commercial carrier (UPS, FedEx, etc.) to an off-site contracted analytical laboratory. Sealed ice chests are provided to the designated representative of the commercial carrier and shipped via next-day delivery service to the analytical laboratory. Sample shipping containers are managed by the commercial carrier as standard parcels to ensure delivery to the analytical laboratory in the specified time. Sealed ice chests are not accessed by shipping company personnel during shipment. Samples are scheduled for delivery to the analytical laboratory within their method-specified holding times with adequate time for the laboratory to initiate sample preparation and analysis. Upon arrival at the analytical laboratory, the shipping container is inspected by laboratory sample management personnel. Laboratory personnel then break the ice chest custody seal, review the chain of custody form, inspect sample containers, determine the temperature of samples using their laboratory-approved method, and accept custody of the samples by signing and dating the custody form. Complete chain of custody forms are included in the final report submitted by the analytical laboratory to NASA and are maintained at WSTF as part of the final analytical report.

8.2 IDW Management

WSTF groundwater contains halogenated and non-halogenated solvents such as TCE and Freon 11 that were used historically for degreasing and other laboratory processes. Due to the presence of these types of contaminants, special management requirements apply to purged groundwater and related media.

Under the Contained-In Policy, the EPA requires environmental media to be managed as if they were hazardous waste if they contain listed hazardous waste or exhibit a hazardous characteristic. By application of the Contained-In Policy, groundwater removed from the contaminated portion of the WSTF plume has been characterized as F001 and F002 listed waste. Furthermore, several F001 and F002 regulated hazardous constituents are present at many monitoring locations in WSTF groundwater at concentrations that exceed groundwater cleanup levels.

Environmental media is considered to meet the definition of a RCRA solid waste at the time it becomes actively managed. The term “Active Management” is defined by EPA as “physically disturbing the accumulated wastes within a management unit…” (57 FR 37298). Therefore, contaminated groundwater is considered to be a solid waste and is therefore subject to the RCRA hazardous waste identification and management requirements at the time that it is removed from a groundwater monitoring well. Because groundwater removed from the WSTF plume meets one or more of the listed waste definitions, any other material that comes into contact with contaminated groundwater is similarly regulated as “contact waste.” Contact waste includes spent PPE, contaminated sampling supplies, plastic, and other material that has come into contact with contaminated media. More specifically, this material is debris contaminated with environmental media containing hazardous waste.

During groundwater monitoring activities, several types of IDW are generated, including, but not limited to: contaminated groundwater collected during monitoring well purging and sampling operations; fluids generated during decontamination of non-dedicated sampling equipment; and potentially contaminated debris. The management strategy for this IDW is provided in the following sections.

8.2.1 IDW Water

Water generated during purging and/or development of monitoring wells or during decontamination of equipment that has come into contact with contaminated groundwater is collected in containers of various sizes (carboys, drums, trailer-mounted tanks, etc.). Containers are managed on site in accordance with requirements of 40 CFR 262.17 and 20.4.1.300 NMAC, including markings, accumulation time limits, and container requirements.

Within the permissible accumulation time limits, IDW water is transferred to the MPITS for storage, treatment, and discharge. The MPITS was designed and operates with provisions for the storage and treatment of IDW water as described in the MPITS Interim Measure Work Plan (NASA, 2008) and Discharge Permit (DP) Renewal and Modification, DP-1255 (NMED, 2017b).

8.2.2 IDW Contact Waste

IDW contact waste, or potentially contaminated debris, that has come into contact with contaminated water includes, but is not limited to: non-dedicated sampling equipment (tubing, bailers, etc.) that cannot be decontaminated for recycling or reuse; disposable PPE such as gloves; and disposable equipment used for decontamination of equipment. This waste is collected at the end of each working shift and transferred into an appropriate container that is managed on site in accordance with the requirements of 40 CFR 262.17, including markings, accumulation time limits, and container requirements. Within the permissible accumulation time limits, IDW contact waste is shipped off-site for treatment and disposal at an approved facility, as appropriate.

8.3 Determination of Groundwater Flow Direction and Rate

Groundwater flow directions are estimated using hand-contoured potentiometric surface maps. Groundwater flow direction is assumed to occur perpendicular to equipotential lines, except where contaminant distribution or other data indicate significant anisotropy. Currently, the spatial distribution of groundwater contaminants is consistent with groundwater flow directions approximately perpendicular to equipotential lines; however, this may change as more data are collected.

The groundwater flow rate is calculated for several facility zones based on groundwater flow directions inferred from potentiometric surface maps and physical properties of aquifer materials. For example, the facility is typically subdivided into zones such as "source areas, Mid-plume, and Plume Front" or "bedrock and alluvium." The average gradient and flow direction for all shallow monitoring intervals inside each of the zones are determined using groundwater gradient calculations. The rate of groundwater flow is calculated using Darcy's Law according to the equation:

$$\text{Groundwater velocity} = [K(dh/dl)]/n_e$$

In the above equation, "K" is the average horizontal hydraulic conductivity of the aquifer zone, "dh/dl" is the average hydraulic gradient, and "ne" is the average effective porosity of the zone. The negative sign indicates that the direction of groundwater flow is down the hydraulic gradient. Average hydraulic conductivity is calculated using available aquifer test and numerical modeling results. Average effective porosity is estimated based on available lithologic data and numerical modeling results. Groundwater flow direction at WSTF is represented in Figure 2.11.

9.0 Chemical Analytical Methods

Samples are collected from WSTF groundwater monitoring wells and analyzed by a variety of chemical analytical methods. Chemical analytical methods used to analyze for the hazardous constituents and other analytes discussed in Section 3.1 are specified in this section. For many hazardous constituents or other analytes, NASA requests a chemical analytical method that is best suited for quantitation of that analyte based on past experience with WSTF groundwater. In other cases, NASA expects the analytical laboratory to propose an analytical method for the most effective and efficient analysis of the compound. In all cases, the analytical laboratory will utilize the most recent EPA and/or industry-accepted chemical analytical methods available for the hazardous constituent specified. For each hazardous constituent, preferred method detection limits (MDL), which are equal to 20 percent of the applicable cleanup level in accordance with Permit Section 17.3, are presented. Preferred MDL and accompanying practical quantitation limits (PQL) are incorporated into the competitive bid process for securing contracted analytical services in order to obtain the most sensitive analyses possible. Laboratories are required to achieve the lowest practicable MDL for hazardous constituents as indicated in Permit Section 17.3.3.c. More specific information related to the quality assurance and quality control (QA/QC) practices and procedures associated with the WSTF groundwater monitoring program are provided in Section 10.0.

9.1 Volatile Organic Compounds

Samples for the analysis of VOC are collected at each groundwater monitoring well or zone at each scheduled sampling event. To best quantitate the levels of VOC in WSTF groundwater, NASA's contracted laboratories use standard operating procedures based on current SW-846 methods (EPA, 2017-2021). Table 9.1 provides the preferred MDL and PQL for the analysis of volatile organic hazardous constituents and other analytes in WSTF groundwater.

9.2 NDMA

Samples for the analysis of NDMA are collected at each groundwater monitoring well or zone outside of the 100/600 Area at most scheduled sampling events. To most effectively quantitate the levels of NDMA in WSTF groundwater, NASA uses two analytical methods: Modified EPA Method 607 (for groundwater with higher levels of NDMA) and a more sensitive low-level analytical method (for groundwater with lower levels of NDMA). NASA selects the appropriate analytical method for the analysis of NDMA based on well location and expected concentrations. Table 9.1 provides the preferred MDL and PQL for the low-level analytical method for the analysis of NDMA in WSTF groundwater.

EPA Method 607 Section 13.2 requires analytical results to be reported in µg/L without correction for recovery data, and per the method, the laboratory cannot adjust analytical data for observed extraction efficiencies. The method further states that all QC data obtained should be reported with the sample results. To meet this requirement, NDMA extraction efficiency of the laboratory control sample is provided in data reported from EPA Method 607 in Appendix A.2 in each NASA PMR.

For graphical representations of reported NDMA data in each PMR, it is not possible to include quality control data results or qualifiers. Therefore, the data are corrected for extraction efficiency to better represent NDMA concentrations among sample points on a comparable basis. The calculation is:

Corrected Result = Reported Result / (Extraction Efficiency % [i.e., whole number / 100])

9.3 Metals

Samples for the analysis of metals are collected at each groundwater monitoring well or zone, usually on a less frequent basis than for VOC and nitrosamines. Several different methods are used to analyze for metals in groundwater samples. The contracted analytical laboratory specifies the most appropriate analytical method to best achieve the preferred MDL and PQL. Table 9.1 provides the preferred MDL and PQL for the analysis of metals in WSTF groundwater.

9.4 Inorganic Compounds

Samples for the analysis of inorganic compounds are collected at most groundwater monitoring wells and zones on a less frequent basis than for VOC and nitrosamines. Inorganic compounds are analyzed for in groundwater samples using several different methods. The recommended methods and associated preferred MDL and PQL are provided in Table 9.2. The contracted analytical laboratory may recommend analytical methods other than those requested by NASA to more effectively and efficiently achieve the preferred MDL and PQL. NASA expects to accept these laboratory recommendations if the proposed alternate analytical methods meet or exceed the analytical criteria of the analytical methods specified in Table 9.2. Specific information related to the analytical method utilized is included in the PMR.

9.5 Semi-Volatile Organic Compounds

Samples for the analysis of SVOC are collected at most groundwater monitoring wells and zones on a less frequent basis than for VOC and nitrosamines because only a limited number of SVOC have been detected in WSTF groundwater. To quantitate concentrations of SVOC in WSTF groundwater, NASA uses the most current version of SW-846 Method 8270. The recommended methods and associated target MDL and PQL for the analysis of SVOC are provided in Table 9.2. The contracted analytical laboratory may recommend analytical methods other than those requested by NASA to more effectively and efficiently achieve the preferred MDL and PQL. NASA expects to accept these laboratory recommendations if the proposed alternate analytical methods meet or exceed the analytical criteria of the analytical methods specified in Table 9.2. Specific information related to the analytical method utilized is included in the PMR.

On December 19, 2017, NMED provided the *Approval with Modifications Groundwater Monitoring Plan* (for the 2017 GMP update), in which they directed NASA to utilize SW-846 Method 8270 with Selective Ion Monitoring for the analysis of 1,4-dioxane at specific groundwater monitoring wells at WSTF (NMED, 2017c). Table 9.2 also provides the target MDL and PQL for the analysis of 1,4-dioxane.

9.6 Miscellaneous Hazardous Constituents

Samples for the analysis of miscellaneous hazardous constituents are collected only at selected groundwater monitoring wells and zones. Samples are collected on a relatively infrequent basis because only a limited number of these hazardous constituents have been detected in WSTF groundwater. The recommended methods and associated preferred MDL and PQL for the analysis of miscellaneous hazardous constituents are provided in Table 9.2. The contracted analytical laboratory may recommend analytical methods other than those requested by NASA to more effectively and efficiently achieve the preferred MDL and PQL. NASA expects to accept these laboratory recommendations if the proposed alternate analytical methods meet or exceed the analytical criteria of the analytical methods specified in Table 9.2. Specific information related to the analytical method utilized is included in the PMR.

NASA submitted the *Response to Disapproval of First Tracking and Data Relay Satellite System (TDRSS) Diesel Release (SMWU 50) Investigation Work Plan* on July 27, 2017 (NASA, 2017d). In the revised work plan, NASA recommended the collection of groundwater samples for the analysis of total petroleum hydrocarbons (TPH) (gasoline range organics [GRO] and diesel range organics [DRO]) by SW-846 Method 8015 from groundwater monitoring wells that may have been impacted by the release of diesel fuel at SWMU 50 (EPA, 1986). Though GRO and DRO are not considered hazardous constituents, preferred MDL and PQL for this ongoing sampling effort are provided in Table 9.2.

9.7 Per- and Polyfluoroalkyl Substances

On December 12, 2019, NMED directed NASA to perform initial groundwater screening for AFFF chemicals of concern at WSTF and provide the results of the screening in the comprehensive fourth quarter 2020 PMR (NMED, 2019b). NASA collected groundwater samples for the analysis of per- and polyfluoroalkyl substances (PFAS) in 2020 for initial screening at select groundwater monitoring wells proximal to areas that were historically associated with the use of AFFF in the 100 and 200 Areas. The wells were listed in the 2020 GMP update (NASA, 2020d) and results were presented in the fourth quarter 2020 PMR (NASA, 2021a).

In the November 15, 2021 *Approval with Modifications White Sands Test Facility Groundwater Monitoring Plan*, NMED directed NASA to propose additional PFAS sampling at WSTF in this Plan (NMED, 2021e). NMED instructed NASA to collect groundwater samples for the analysis of PFAS using PFAS-free sampling equipment and industry-accepted best practices to ensure the collection of representative and defensible PFAS samples. NMED also directed NASA to collect samples for the analysis of the 24 chemicals of concern and four replacement chemicals specified in NMED's 2019 Risk Assessment Guidance for Site Investigations and Remediation (RA Guidance; NMED, 2019a) and analyze for these chemicals using SW-846 Methods 3512 and 8327.

NASA replaced the dedicated sampling system and equipment with non-fluoropolymer-based materials (e.g., Teflon) in wells 100-D-176, 200-B-240, and BLM-14-327 and plans to resample these wells. NASA will also resample well 600-G-138, which requires non-dedicated sampling equipment that will not contain fluoropolymer-based materials. In addition to these four wells, NASA plans to sample several other wells using existing equipment as identified in this Plan. The selection criteria for these wells are based on their proximity to the potential source areas (100 and 200 Areas) and the concentrations of PFAS detections results as reported in revised fourth quarter 2020 PMR (NASA, 2021a). Groundwater monitoring wells identified for 2022 follow-on PFAS sampling (Table 11.1) were selected to support an ongoing initiative related to PFAS in groundwater sponsored by the NASA Headquarters Environmental Management Division. NASA is performing a preliminary assessment of potential PFAS contamination in groundwater at numerous NASA centers, including WSTF. As a result of this self-imposed requirement, the wells selected for 2022 PFAS sampling differ slightly from those identified in NASA's December 21, 2021 *Response to Approval with Modifications of NASA WSTF Periodic Monitoring Report – Fourth Quarter 2020* (NASA, 2021k). To accommodate schedule constraints placed on WSTF by NASA Headquarters, NASA expects to collect groundwater samples for the analysis of PFAS in mid-2022 and plans to summarize the results of the assessment in a report to be published later in 2022. NASA will provide a copy of the report to NMED for reference purposes when it becomes available for use at WSTF.

10.0 Quality Assurance/Quality Control Program

This section outlines QA/QC requirements to ensure that WSTF groundwater monitoring data are valid and of known quality. Collecting and maintaining valid data of known quality supports the groundwater monitoring program goal of providing consistent and accurate representation of actual groundwater contaminant concentrations and movement over time. To achieve this goal, this Plan as a whole provides a consistent framework for the generation of valid physical and chemical analytical data. This section addresses the following specific data quality elements:

- Field and laboratory quality control procedures and measurement evaluation criteria to ensure that collection and analytical systems generate data of sufficient quality to meet the program goals.
- Laboratory reporting requirements sufficient to support the program goals.
- Quality assurance review procedures designed to indicate the extent to which groundwater monitoring data generated is appropriate for its intended use.
- Early detection of deficiencies and prompt corrective action to minimize effects on data quality.

All data generating steps, including sample collection, shipment, analysis, custody control, document control, data review, and data storage are performed using established procedures to ensure data quality. This Plan, coupled with adherence to procedures outlined in site-specific procedural documents, equipment operation and maintenance manuals, analytical statements of work, laboratory standard operating procedures (SOP), and laboratory quality manuals ensures that data meet the objectives of the WSTF groundwater monitoring program.

This section provides specific information related to the following QA/QC issues associated with the groundwater monitoring program at WSTF:

- Contracted chemical analytical laboratories.
- Quality control samples and related procedures.
- Data quality indicators.
- Analytical data quality exceptions and qualified data.
- Analytical data management, including verification and validation.
- Internal reporting.

10.1 Contracted Analytical Laboratories

The contractor environmental organization contracts accredited analytical laboratories to analyze groundwater samples in support of the WSTF groundwater monitoring program. Prior to awarding any analytical support contracts, each analytical laboratory must respond to all requirements in the Statement of Work prepared by qualified contractor environmental organization personnel, submit proof of accreditation by an industry-recognized accreditation body, and submit the laboratory quality manual and applicable SOP to the contractor environmental organization for review and approval. These documents ensure that laboratories meet the performance criteria for WSTF groundwater monitoring activities.

Contracted analytical laboratories will perform all analyses using procedures detailed in the submitted laboratory SOP that are based on the most recent EPA and industry-accepted preparation and analytical methods for an aqueous matrix (groundwater) as discussed in the previous section.

10.1.1 Laboratory Quality Manual

Documentation of the analytical effort is outlined in the Quality Manuals submitted by the analytical laboratories as part of the competitive bid process. The contractor environmental organization reviews and approves the laboratory Quality Manual prior to a contracted laboratory commencing analyses. The laboratory's Quality Manual must include, at a minimum, the following:

- Personnel qualifications and training plans.
- Documentation and records management procedures.
- Quality control procedures.
- Work processes, operating procedures and methods.
- Quality assessment, standardization and response action plans.

10.1.2 Laboratory Deliverables

The laboratory analytical data package shall be prepared with sufficient information to meet the requirements of the WSTF groundwater monitoring program. The data packages shall be delivered to responsible contractor environmental organization personnel for review and incorporation into the data management module. At a minimum, the laboratory analytical data packages will include the following information:

- Laboratory company name.
- Client provided project number or client company name.
- Laboratory work order, report number or sample delivery group identifier.
- Laboratory report date.
- Client provided sample number.
- Laboratory assigned sample identification.
- Sample matrix.
- Sample type identifier, i.e., sample (SA), method blank (MB), laboratory control samples (LCS), laboratory control sample duplicates (LCSD), matrix spikes (MS), or matrix spike duplicates (MSD).
- Date sample received in laboratory.
- Instrument calibration.
- Calibration range for all analytes.
- Preparation method identifier.
- Date of sample preparation and/or extraction.
- Analytical method identifier.
- Date sample analyzed.
- Time sample analyzed.
- Extraction batch number (if applicable).
- Quality control lot number.
- Dilution factor.
- Quantitation limits.
- Method detection limits.

- Instrument-specific detection limits.
- Instrument number or identification.
- Sample preparation logs.
- Analyst name.
- Analyst bench notes.
- Chemical Abstract Service (CAS) numbers.
- Analyte names.
- Analytical results.
- Result units.
- Extraction efficiency (if appropriate).
- Surrogate recovery information (if appropriate), including percent recovery (%R), control limits, and spiking levels.
- Quality control sample results including, but not limited to, LCS and LCSD, MB, MS and MSD, and analyst duplicates (AD).
- Spiking levels, calculations, and control limits for %R and relative percent difference (RPD) of LCS/LCSD and MS/MSD pairs as well as RPD for analyst duplicates.
- Quality control data qualifiers and associated narratives including corrective action narratives and narratives that indicate no quality issues were encountered for each method (as applicable).
- Definitions for all laboratory data qualifiers used.
- Relevant comments concerning sample or analytical conditions.
- Confirmation of conformance with required analytical protocol(s).
- Pertinent sample receipt information and documentation including holding times and condition of sample upon receipt.
- Final signed copy of the chain(s) of custody for samples in the report.
- Laboratory approval signatures.

10.1.3 Retention of Documents

The analytical laboratory is required to maintain demonstrations of capability, raw data, chromatograms, logbooks, and all other relevant analytical information for at least five years after sample analysis and must make this information available to the responsible contractor environmental organization personnel upon request. This information is required to ensure the validity of reported data and to rectify any discrepancies that may arise.

10.2 Quality Control Samples

The WSTF groundwater monitoring program utilizes both field and laboratory QC samples to ensure that program quality objectives are met.

10.2.1 Field Quality Control Samples

Field QC samples include equipment blanks, field blanks, trip blanks, and field duplicate samples. The descriptions and purposes of field QC samples are provided in Table 10.1. Field QC samples are collected at the frequencies specified in Table 10.2. The evaluation criteria and potential corrective actions for issues related to field QC samples are described in Table 10.3.

10.2.2 Laboratory Quality Control Samples

Laboratory QC samples include method blanks, laboratory control samples, matrix spikes, matrix spike duplicates, and surrogate spikes. The descriptions and purposes of laboratory QC samples are provided in Table 10.4. Laboratory QC sample analysis is performed at the frequencies specified in Table 10.5. The evaluation criteria and potential corrective actions for issues related to laboratory QC samples are described in Table 10.6.

10.3 Data Quality Indicators (DQI)

This section describes the DQIs that are applicable to the WSTF groundwater monitoring program.

10.3.1 Precision

Precision is the degree to which a set of measurements of the same property, obtained under similar conditions conform to themselves. Precision is expressed as RPD between field duplicate samples, duplicate matrix spikes, duplicate laboratory control samples or analyst duplicate samples. RPD is calculated as follows:

$$RPD = [\,|x_1 - x_2| \;/\; ((x_1 + x_2) / 2)]\,(100)$$

In the above equation, x_1 and x_2 are the reported concentrations for each duplicate sample.

For values approaching the limit of quantitation (less than three times the PQL), a qualitative evaluation of precision may be applied.

10.3.2 Bias

Bias is the systematic or persistent distortion of a measurement process, which causes errors in one direction (i.e., the expected sample measurement is different from the sample’s true value). Bias is expressed as percent recovery. Percent recovery (%R) is calculated as follows:

$$\%R = (R / S)\,(100)$$

In the above equation, R is the reported concentration and S is the spiked concentration.

10.3.3 Representativeness

Representativeness is a measure of the degree to which data accurately and precisely represent a population characteristic. Representativeness is a qualitative term that should be evaluated to determine whether measurements are made and physical samples collected in such a manner that the resulting data appropriately reflect the media and phenomenon measured or studied. The representativeness criteria is satisfied by ensuring that samples are collected and analyzed using standardized procedures throughout the sampling and analytical process. These standardized procedures include: this Plan; all applicable

WSTF site-specific procedural documentation associated with groundwater sample collection, sample management, and data review and management; standardized laboratory accreditation requirements for quality systems; and current laboratory-specific SOP for all chemical analytical methods.

10.3.4 Comparability

Comparability is a qualitative parameter expressing the confidence with which one data set can be compared with another. Sample data should be comparable with other measurement data for similar samples and sampling conditions. This goal is achieved using standard collection and analytical techniques and reporting analytical data in appropriate units.

10.3.5 Sensitivity

Sensitivity refers to the capability of a method or instrument to discriminate between measurement responses representing different levels (e.g., concentrations) of a variable of interest. The sensitivity indicator of primary interest is the limit of detection. In determining the detection limit, the focus is on the concentration that can be distinguished from the noise of the method. The preferred limits of detection are a maximum of 20 percent of the cleanup levels. These preferred limits will be incorporated into the analytical statements of work for the groundwater monitoring program. Detection limits that exceed the cleanup levels for analytical results reported as “not detected” are considered data quality exceptions and an explanation for the exceedance and its acceptability for use shall be provided.

10.4 Analytical Data Quality Exceptions (Qualifications)

The analytical laboratory is required to assign data qualifiers (flags) to analytical results that are outside the laboratory acceptance criteria and constitute data quality exceptions. Designated contractor environmental organization personnel review laboratory deliverables and convert laboratory-assigned data qualifiers to the equivalent WSTF-designated qualifiers provided in Table 10.7. Laboratory-assigned qualifiers are converted in order to maintain data comparability and integrity and to ensure consistency of data qualification across the WSTF groundwater monitoring program regardless of contracted analytical laboratories.

A significant data quality exception is the result of an anomaly in the analytical process that will negatively impact the usability of the chemical analytical data. During groundwater monitoring activities, significant data quality exceptions may infrequently arise at the laboratory that negatively impact the implementation of this Plan or interfere with the ability to meet the objectives of the groundwater monitoring program. In the event of a significant data quality exception at a contracted analytical laboratory, the laboratory must notify the responsible WSTF contractor environmental organization personnel within one business day of the discovery in order to allow for the consideration and implementation of corrective actions. If corrective actions that meet the objectives of this Plan cannot be implemented, the responsible contractor environmental organization personnel will relate the issue to the facility project manager or designee, who will contact NMED within one business day of receipt of laboratory notification of the exception. The facility project manager or designee will discuss the implications of the data quality exception with the NMED project leader and determine whether the data will still be considered acceptable or if sample re-analysis or resampling is necessary. The facility project manager or designee will summarize the results of the discussion with the NMED project leader in a memorandum, which will be submitted to NMED by email within three business days of the verbal discussion.

10.5 Analytical Data Management

The amount of chemical analytical data produced by WSTF groundwater monitoring activities requires that standard procedures are used to manage, store, and process all groundwater chemical analytical data. This section discusses the procedures used to ensure that groundwater chemical analytical data are effectively processed.

The environmental database used by the site contractor environmental organization is a modular database system. Modules included in this system are the data management module and the environmental database module. The contractor environmental organization also retains all documentation related to chemical analytical data in the database modules. All documentation is managed pursuant to federal records management protocol, Permit-required records retention criteria, and site-specific record management procedures.

10.5.1 Data Management Module

The data management module is utilized to gather and organize analytical data for the various evaluation and reporting requirements associated with WSTF groundwater monitoring activities. Responsible contractor environmental organization personnel perform verification and validation procedures, organize the laboratory data and the corresponding QA discussion, set data qualifiers, and prepare the data for final reporting. The evaluation criteria in Table 10.3 and Table 10.6 as well as all associated documentation mentioned in this groundwater monitoring plan provide the basis for the data quality review. The data are reviewed, qualified, and approved by the responsible contractor environmental organization personnel.

10.5.2 Environmental Database Module

The WSTF environmental database module is managed by the contractor environmental organization as directed by NASA. Groundwater chemical analytical data are verified and validated by the contractor environmental organization prior to incorporation into the archival environmental database module. This module is the final repository for all verified and validated analytical data and allows data end-users the ability to use stored data for generating reports, tables, graphs, and other visual presentations.

10.5.2.1 Database Management

Management of the environmental database is performed pursuant to specific procedures outlined in site-specific procedural documentation applicable to groundwater database operations and quality assurance. The site contractor environmental organization is the only organization which can input or edit data in the environmental database module. All other individuals are granted "read only" access. This precludes data modification by personnel other than specific qualified personnel within the contractor environmental organization.

10.5.2.2 Analytical Data End-Users

The primary end-users of groundwater chemical analytical data are the contractor environmental organization, NASA Environmental Office personnel, and NMED. The contractor environmental organization uses the chemical analytical data, in conjunction with collected geophysical data, to interpret and present technical assessments of the hydrogeological system. In addition, the contractor environmental organization uses the data to prepare regulatory and technical reports. NASA Environmental Office personnel and NMED use data presentations as guidance for making decisions concerning the groundwater monitoring program.

10.6 Internal Reporting

In order to facilitate the transfer of information within the contractor environmental organization and to other interested on-site stakeholders, various internal assessment and reporting mechanisms have been developed. These include: internal quality systems evaluation and related report; internal quality assurance report; and consideration and evaluation of corrective actions applicable to organizational operations. These tools are described in more detail below.

10.6.1 Technical Systems Evaluation

Technical system evaluations are an essential element in the overall management of groundwater chemical analytical data. These evaluations are designed to verify compliance with this Plan and other applicable documentation and to assess the overall quality of the data collection and generation system. Evaluated systems include sample collection, sample analysis procedures, and data management and reporting techniques.

A technical systems evaluation is a qualitative evaluation of the entire data collection and generation system used in the WSTF groundwater monitoring program. This evaluation examines all phases of the sampling and analysis system: collection of samples; preservation and handling of samples; transport of samples; documentation of field and analytical steps; quality control procedures; data reporting; and data processing and management.

This evaluation is performed on at least an annual basis by an independent individual with the training and expertise to perform the evaluation. The evaluator submits an evaluation report to the responsible contractor environmental organization management personnel. The report presents the results of the evaluation and provides recommendations for corrective actions.

10.6.2 Internal Quality Assurance Report

Responsible contractor environmental organization data management personnel develop internal Quality Assurance Reports (QAR) periodically during the year to facilitate the review and evaluation of overall groundwater analytical data quality by stakeholders in the groundwater monitoring program. At a minimum, QAR include the quantity and type of field QC samples analyzed, the quantity and type of individual field data qualifiers applied, the quantity and type of individual laboratory data qualifiers applied, a list of all QA narratives associated with the included sampling events, a summary by analytical method of notable data quality issues, a summary of all notable anomalies associated with the report, and a follow-up, if necessary, on previous notable anomalies. QAR are prepared periodically during the PMR reporting period (see Section 11.4) using chemical analytical data for the reporting period. They are compiled on a quarterly basis for inclusion in the PMRs for submittal to NMED.

10.6.3 Internal Corrective Actions

Responsible contractor environmental organization personnel initiate corrective actions when data evaluation, preparation of environmental reports, or technical systems evaluations indicate discrepancies. The corrective actions can include procedural changes, resampling, collection of additional quality control samples, additional field evaluations, review of analytical laboratory procedures, addition of data qualifiers and narratives to analytical data, or any other procedure that will mitigate issues or identify further discrepancies. Discrepancies deemed to meet the definition of a data quality exception will be reported as described in Section 10.4. Corrective actions, recommendations, and specific steps taken to resolve data quality discrepancies are reported to the responsible contractor environmental organization management representative for further action.

11.0 Schedule

This section provides the schedules for activities specified in this Plan.

11.1 Groundwater Elevations

Groundwater elevations are determined as described in Section 6.5. At a minimum, groundwater elevations are measured each time a groundwater monitoring well is sampled, assuming the water level is adequate and groundwater sampling equipment allows access. The groundwater elevation may be determined more frequently at some groundwater monitoring wells to provide consistent groundwater elevation data for use in groundwater modeling and the development of groundwater elevation maps for reporting.

11.2 Groundwater Monitoring Schedule

Each groundwater monitoring location is sampled for specific hazardous constituents and other analytes based on its location in the conceptualized contaminant plume as illustrated in Section 4.1. Groundwater sampling is performed at these monitoring wells and/or zones as described in Section 7.0 for some or all of the chemical analyses discussed in Section 9.0. Table 11.1 provides the monitoring requirements and sampling frequencies for each active groundwater monitoring well or zone in the WSTF groundwater monitoring network.

Table 11.1 includes several frequencies for sampling groundwater monitoring wells. Monitoring wells/zones scheduled for quarterly sampling will be sampled for the specified analyses four times per calendar year, with sampling events approximately three months apart. Monitoring wells/zones scheduled for semi-annual sampling will be sampled for the specified analysis twice per calendar year, with sampling events approximately six months apart. Monitoring wells/zones scheduled for annual sampling will be sampled for the specified analysis once per calendar year, with sampling events occurring approximately twelve months apart. Monitoring wells/zones scheduled for biennial sampling will be sampled for the specified analysis every two calendar years, with sampling events occurring approximately 24 months apart. Monitoring wells/zones scheduled for triennial sampling will be sampled for the specified analysis every three calendar years, with sampling events occurring approximately the 36 months apart. The completion of individual scheduled sampling events may vary by several weeks as a result of well site accessibility, personnel/equipment availability, and other project-specific limitations.

Groundwater sampling schedules are developed on a monthly basis and used to schedule sampling activities for the coming month. Monthly schedules can also be approximated for subsequent months upon NMED request. NASA's ability to complete groundwater sampling as scheduled may be impacted by lack of access to well locations, equipment malfunction, or other unforeseen events. If a groundwater monitoring well/zone cannot be sampled within 30 days of its scheduled sampling date for reasonably foreseen reasons, NASA will request a variance from the established sampling schedule 30 days prior to the scheduled sampling event. Reasonably foreseen reasons for not completing sampling within 30 days of a scheduled sampling event include, but are not limited to planned access limitations for security reasons, chronic equipment restrictions that affect multiple sampling events over the longer term, and site infrastructure limitations that prevent access. If a monitoring well/zone is not sampled within 30 days of its scheduled sampling event because of unforeseen reasons, NASA will notify NMED of the delay in the subsequent Monthly EAR and indicate when sampling is expected to be completed. Unforeseen reasons for not completing planned sampling include such problems as failure of sampling equipment or short-term unplanned resource limitations with lingering impact.

11.3 Schedule for Sampling New Monitoring Wells

Following installation, groundwater monitoring wells are developed in accordance with industry accepted practices and established site-specific procedures. Hydrogeological personnel oversee drilling, installation, and development activities. When development is complete, groundwater monitoring wells are allowed to equilibrate for up to 30 days prior to initial sampling, which is typically performed between ten and 30 days after completion of development. New or reconfigured groundwater monitoring wells and zones are sampled quarterly for at least one year for VOC, nitrosamines, metals, SVOC, and inorganic compounds. After at least one year of sampling, the monitoring well will be assigned to the appropriate well group as described in Section 4.1 and the results of the initial sampling will be utilized to determine the most appropriate sampling requirements and schedule. Results of initial sampling will be reported in the PMR with other chemical analytical data. The sampling schedule assigned to the monitoring well will be included in the first annual revision of this Plan following establishment of the schedule and sampling requirements.

11.4 Schedule for Periodic Reporting

The environmental program at WSTF is diverse and comprehensive, requiring the submittal of several routine reports to keep NMED updated on environmental activities, including groundwater monitoring. Three periodic reports are applicable to groundwater monitoring:

- Monthly EAR, which includes a brief description of compliance, monitoring, and corrective action activities during the month. The EAR is submitted to NMED no later than the 15th of each month for activities in the preceding calendar month.
- Standard PMR, which includes chemical analytical data that were processed through the WSTF data management system from January through June of each year. This PMR also includes brief discussions of groundwater monitoring and remediation activities and summarizes the results of groundwater and remediation system monitoring performed between January and June. To allow sufficient time to receive and process chemical analytical results for the six-month reporting period, this PMR is submitted to NMED no later than September 30 for the reporting period January through June.
- Comprehensive PMR, which presents chemical analytical data that were processed through the WSTF data management system from July through December of each year, as well as a more comprehensive evaluation of corrective measures. This PMR includes a complete evaluation of contaminant plume capture and detailed results of remediation system monitoring. To allow sufficient time to receive and process chemical analytical results for the six-month reporting period, this PMR is submitted to NMED no later than March 31 of each year and includes information applicable to the preceding year (January through December).

11.5 Schedule for Review and Revision of Plan

In accordance with Section VI.B.3 of the Permit, this Plan will be reviewed and revised on an annual basis to include such changes as: the addition of new monitoring wells/zones; deletion of abandoned monitoring wells/zones; deletion of or reduction in sampling requirements at monitoring wells/zones whose production of groundwater has been significantly reduced; sampling of wells beyond the Outer Boundary; or to change monitoring parameters or frequencies. The Permit requires that a revised Plan be submitted no later than April 1 of the second and each subsequent year after the effective date of the Permit. However, communication with NMED subsequent to issuance of the Permit indicated that April 30 would be a more acceptable date. Therefore, annual revisions of the Plan are scheduled for submittal to

NMED on or before April 30 of each year. Submittal of the revised Plan does not constitute a Permit modification.

12.0 References

EPA. (1986, September). *Method 8015, Third Edition of the Test Methods for Evaluating Solid Waste, Physical/Chemical Methods*, EPA publication SW-846. Washington, D.C.

EPA. (1989, December 18). *U.S. EPA Docket No. VI-002(h)-88-H.* Dallas, TX.

EPA. (1993-2015). *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods*, EPA publication SW-846, Third Edition, Final Updates I (1993), II (1995), IIA (1994), IIB (1995), III (1997), IIIA (1999), IIIB (2005), IV (2008), and V (2015). Washington, D.C.

EPA. (2017-2021). *The SW-846 Compendium.* Retrieved from https://www.epa.gov/hw-sw846/sw-846-compendium

EPA. (2018, June). *Method 8260D, Phase II, Update VI to the Third Edition of the Test Methods for Evaluating Solid Waste, Physical/Chemical Methods*, EPA publication SW-846. Washington, D.C.

EPA. (2020, November). *Regional Screening Level Tables; Residential Tapwaters*. Retrieved from https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables

Ground and Surface Water Protection, Water Quality Control Commission, 20.6.2 NMAC (12-21-18).

Hazardous Waste Management, Environmental Improvement Board, 20.4.1 NMAC, (12-1-18).

NASA Johnson Space Center White Sands Test Facility. (1996a, March 1). *Submittal of Draft RCRA Facility Investigation (RFI) and Corrective Measures Study (CMS) Reports*. Las Cruces, NM.

NASA Johnson Space Center White Sands Test Facility. (1996b, July 3). *NASA White Sands Test Facility (WSTF) Solid Waste Management Facility – Closure and Post-Closure Care Plan*. Las Cruces, NM.

NASA Johnson Space Center White Sands Test Facility. (1999, September) *Phase II Mid-plume Constriction Area (MPCA) Investigation Report*. Las Cruces, NM.

NASA Johnson Space Center White Sands Test Facility. (2008, July 15). *Mid-plume Interception and Treatment System Interim Measures Work Plan*. Las Cruces, NM.

NASA Johnson Space Center White Sands Test Facility. (2010, December 21). *Investigation Report for NASA WSTF Required Interim Measures Work Plan for Sampling Off-site Water Supply Wells*. Las Cruces, NM.

NASA Johnson Space Center White Sands Test Facility. (2012a, June 20). *Response to NMED Disapproval – NASA White Sands Test Facility (WSTF) 200 Area Investigation Work Plan and 200 Area Historical Information Summary*. Las Cruces, NM.

NASA Johnson Space Center White Sands Test Facility. (2012b, May 17). *NASA WSTF Groundwater Monitoring Plan Update for 2012*. Las Cruces, NM.

NASA Johnson Space Center White Sands Test Facility. (2012c, September 13,). *Response to NMED Disapproval – NASA White Sands Test Facility (WSTF) 600 Area Soil Vapor Extraction Pilot Test Investigation Report*. Las Cruces, NM.

NASA Johnson Space Center White Sands Test Facility, (2012d, May 10). *Work Plan for Tracer Testing in the 200/600 Areas and Mid-Plume Constriction Area*. Las Cruces, NM.

NASA Johnson Space Center White Sands Test Facility. (2013a, May 15). *Update of the NASA-JSC White Sands Test Facility Groundwater Flow and Contaminant Transport Model*. Las Cruces, NM.

NASA Johnson Space Center White Sands Test Facility. (2013b, December 16). *Well Completion Reports for the Conversion of Westbay Wells WW-2 and JP-3*. Las Cruces, NM.

NASA Johnson Space Center White Sands Test Facility. (2016, March 30). *Well Configuration Reports for Wells BLM-32, WW-4 and WW-5*. Las Cruces, NM.

NASA Johnson Space Center White Sands Test Facility. (2017a, March 22). *Westbay Reconfiguration Report (Wells JER-1, JER-2, ST-6, and ST-7)*. Las Cruces, NM.

NASA Johnson Space Center White Sands Test Facility. (2017b, March 30). *Detections of NDMA and TCE in WSTF Groundwater Monitoring Wells BLM-30, PL-5, PL-6, PL-7, PL-8, PL-10, ST-5, and WW-3*. Las Cruces, NM.

NASA Johnson Space Center White Sands Test Facility. (2017c, July 27). *Response to Disapproval of First Tracking Data Relay Satellite System (TDRSS) Diesel Release (SWMU 50) Investigation Work Plan.* Las Cruces, NM.

NASA Johnson Space Center White Sands Test Facility. (2017d, December 28). *Well Reconfiguration Work Plan for Well BLM-30*. Las Cruces, NM.

NASA Johnson Space Center White Sands Test Facility. (2018, April 24). *NASA WSTF Groundwater Monitoring Plan Update for 2018. Las Cruces, NM.*

NASA Johnson Space Center White Sands Test Facility. (2018, December 3). *Response to NMED Approval with Modifications WSTF 2018 Groundwater Monitoring Plan Correction*. Las Cruces, NM.

NASA Johnson Space Center White Sands Test Facility. (2019a, August 8). *Response to NMED Approval with Modifications SWMU 49 (700 Area Landfill) Phase I Investigation Work Plan and Historical Information Summary*. Las Cruces, NM.

NASA Johnson Space Center White Sands Test Facility. (2019b, August 28). *Well Plugging Records for NASA Wells BLM-37 (LRG-16097 POD 1), PL-5 (LRG-17595 POD 1), and 200-D-109 (LRG-17703 POD 1)*. Las Cruces, NM.

NASA Johnson Space Center White Sands Test Facility. (2019c, August 29). *NASA WSTF Drilling Work Plan for Abandonment of Well BLM-30 and Drilling of New Groundwater Monitoring Well BLM-43*. Las Cruces, NM.

NASA Johnson Space Center White Sands Test Facility. (2019d, November 21). *Response to Disapproval of 500 Area Fuel Storage (SWMU 47) Investigation Work Plan*. Las Cruces, NM.

NASA Johnson Space Center White Sands Test Facility. (2020a, February 27). *Groundwater Data Representativeness Phase 1: Water FLUTe Well Evaluation Abbreviated Investigation Report*. Las Cruces, NM.

NASA Johnson Space Center White Sands Test Facility. (2020a, May 4). *Well Plugging Plan of Operations for NASA Well BLM-28*. Las Cruces, NM.

NASA Johnson Space Center White Sands Test Facility. (2020b, May 4). *Well Reconfiguration Report for Well BLM-28 and Notice of Intent to Plug and Abandon*. Las Cruces, NM.

NASA Johnson Space Center White Sands Test Facility. (2020c, May 26). *600 Area Perched Groundwater Extraction Pilot Test Interim Status Report – Project Year 7*. Las Cruces, NM.

NASA Johnson Space Center White Sands Test Facility. (2020d, May 26). *NASA WSTF Groundwater Monitoring Plan Update for 2020*. Las Cruces, NM.

NASA Johnson Space Center White Sands Test Facility. (2020e, August 3). *NASA WSTF Remediation System Monitoring Plan Annual Update for 2020*. Las Cruces, NM.

NASA Johnson Space Center White Sands Test Facility. (2021a, February 3). *NASA WSTF Periodic Monitoring Report – Fourth Quarter 2020. Las Cruces, NM.*

NASA Johnson Space Center White Sands Test Facility. (2021b, February 18). *NASA White Sands Test Facility (WSTF) Background Groundwater Study Investigation Work Plan*. Las Cruces, NM.

NASA Johnson Space Center White Sands Test Facility. (2021c, April 29*). NASA WSTF Westbay Well Reconfiguration Work Plan for Wells PL-7, PL-8, PL-10, ST-5, and WW-3*. Las Cruces, NM

NASA Johnson Space Center White Sands Test Facility. (2021d, April 29). *Well Abandonment Work Plan for Well BLM-28*. Las Cruces, NM.

NASA Johnson Space Center White Sands Test Facility. (2021e, June 29*). NASA WSTF Well Reconfiguration Work Plan for Well BW-4*. Las Cruces, NM.

NASA Johnson Space Center White Sands Test Facility. (2021f, July 27). *NASA WSTF 400 Area Closure Investigation Report – NMED Third Disapproval Response. Las Cruces, NM.*

NASA Johnson Space Center White Sands Test Facility. (2021g, August 17). *Response to Approval with Modifications for Groundwater Data Representativeness Phase 1: Water FLUTe Well Evaluation Abbreviated Investigation Report. Las Cruces, NM.*

NASA Johnson Space Center White Sands Test Facility. (2021h, August 31). *NASA WSTF Work Plan for Drilling and Installation of Monitoring Well 600B-001-GW. Las Cruces, NM.*

NASA Johnson Space Center White Sands Test Facility. (2021i, September 28). *Request for Extension of Time for Submittal of the Completion Report for Monitoring Well BLM-30 Abandonment and Installation of Replacement Monitoring Well BLM-43. Las Cruces, NM.*

NASA Johnson Space Center White Sands Test Facility. (2021j, November 30). *Well Plugging Plan of Operations for Multiport Soil Vapor Groundwater Monitoring Wells 200-SG-2 and 200-SG-3. Las Cruces, NM.*

NASA Johnson Space Center White Sands Test Facility. (2021k, December 21). *Response to Approval with Modifications of NASA WSTF Periodic Monitoring Report – Fourth Quarter 2020*. Las Cruces, NM.

NASA Johnson Space Center White Sands Test Facility. (2022a, February 1). *NASA WSTF Periodic Monitoring Report – Fourth Quarter 2021*. Las Cruces, NM.

NASA Johnson Space Center White Sands Test Facility. (2022b, February 1*). NASA WSTF Work Plan for Drilling and Installation of Monitoring Well 600C-002-GW and Abandonment of PL-6.* Las Cruces, NM.3

NASA Johnson Space Center White Sands Test Facility. (2022c, April xx). *Work Plan for Abandonment and Replacement of NASA 9.* Las Cruces, NM.

NMED Ground Water Quality Bureau. (2017, July 14). *Discharge Permit Renewal and Modification, DP-1255, NASA White Sands Testing Facility*. Santa Fe, NM.

NMED. Hazardous Waste Bureau. (2009, November). *Hazardous Waste Permit. NM8800019434, to United States National Aeronautics and Space Administration for the White Sands Test Facility Located in Doña Ana County, New Mexico*. Santa Fe, NM.

NMED. Hazardous Waste Bureau. (2011, December 16). *Notice of Approval with Modifications Investigation Report for Evaluating the Representativeness of Groundwater Samples Collected from Westbay Wells*. Santa Fe, NM.

NMED. Hazardous Waste Bureau. (2012, August 8). *Approval 2012 Update Groundwater Monitoring Plan*. Santa Fe, NM.

NMED Hazardous Waste Bureau. (2016, March 29). *Approval NASA WSTF Periodic Monitoring Report Fourth Quarter 2015*. Santa Fe, NM.

NMED Hazardous Waste Bureau. (2017a, October 4). *Approval with Modifications Detections of NDMA (N-Nitrosodimethylamine) and TCE (Trichloroethylene) In WSTF Groundwater Monitoring Wells BLM-30, PL-5, PL-6, PL-7, PL-8, PL-10, ST-5, and WW-3*. Santa Fe, NM.

NMED Hazardous Waste Bureau. (2017b, December 19). *Approval with Modifications Groundwater Monitoring Plan*. Santa Fe, NM.

NMED Hazardous Waste Bureau. (2018, September 13). *Approval with Modifications White Sands Test Facility Groundwater Monitoring Plan*. Santa Fe, NM.

NMED Hazardous Waste Bureau. (2019a, June 19) *Risk Assessment Guidance for Site Investigations and Remediation. Volume 1. Soil Screening Guidance for Human Health Risk Assessments. Revision 2.* Santa Fe, NM.

NMED Hazardous Waste Bureau. (2019b, December 12). *Approval with Modifications Groundwater Monitoring Plan*. Santa Fe, NM.

NMED Hazardous Waste Bureau. (2020a, November 5). *Approval With Modifications Work Plan for Abandonment of NASA WSTF Well BLM-30 and Replacement With Monitoring Well BLM-43*. Santa Fe, NM.

NMED Hazardous Waste Bureau. (2020b, November 19). *Well Reconfiguration Report for Well BLM-28 and Notice of Intent to Plug and Abandon*. Santa Fe, NM.

NMED Hazardous Waste Bureau. (2021a, January 25). *Approval Remediation System Monitoring Plan*. Santa Fe, NM.

NMED Hazardous Waste Bureau. (2021b, January 25). *Approval with Modifications Groundwater Monitoring Plan*. Santa Fe, NM.

NMED Hazardous Waste Bureau. (2021c, January 25). *Approval with Modifications NASA WSTF Periodic Monitoring Report First Quarter 2020*. Santa Fe, NM.

NMED Hazardous Waste Bureau. (2021d, October 27). *Approval Request for Extension of Time for Submittal of the Completion Report for Monitoring Well BLM-30 Abandonment and Installation of Replacement Monitoring Well BLM-43.* Santa Fe, NM

NMED Hazardous Waste Bureau. (2021e, November 15). *Approval with Modifications White Sands Test Facility Groundwater Monitoring Plan*. Santa Fe, NM.

NMED Hazardous Waste Bureau. (2022a, January 10). *Approval Well Abandonment Work Plan for Well BLM-28. Santa Fe, NM.*

NMED Hazardous Waste Bureau. (2022b, January 10). *Approval Well Plugging Plan of Operations for Multiport Soil Vapor Groundwater Monitoring Wells 200-SG-2 and 200-SG-3. Santa Fe, NM*.

NMED Hazardous Waste Bureau. (2022c, January 18). *Approval with Modifications Well Reconfiguration Work Plan for BW-4. Santa Fe, NM*.

NMED Hazardous Waste Bureau. (2022d, February 21). 3-8-2022 *Approval with Modifications Periodic Monitoring Report Second Quarter 2021. Santa Fe, NM.*

Seager, W. (1981, May). *Geology of Organ Mountains and Southern San Andres Mountains, New Mexico*. Memoir 36, New Mexico Bureau of Mines and Mineral Resources, Socorro, New Mexico.

Solid Waste Facility Ground Water Monitoring System Plan and Ground Water Monitoring Plan; Corrective Action, New Mexico Environmental Improvement Board, 20.9.9 NMAC (8-2-07).

Standards for Ground Water of 10,000 mg/l TDS Concentration or Less, Water Quality Control Commission, 20.6.2.3103 NMAC (12-21-18).

Wilson, C., White, R., Orr, B., & Roybal, R. (1981). *Water Resources of the Rincon and Mesilla Valleys and Adjacent Areas, New Mexico. New Mexico State Engineer's Technical Report*, Santa Fe, New Mexico.

Well Driller Licensing; Construction, Repair and Plugging of Wells, Office of the State Engineer, 19.27.4 NMAC (6-30-17).

Figures

Figure 1.1 **WSTF and Surrounding Areas**

(SEE NEXT PAGE)

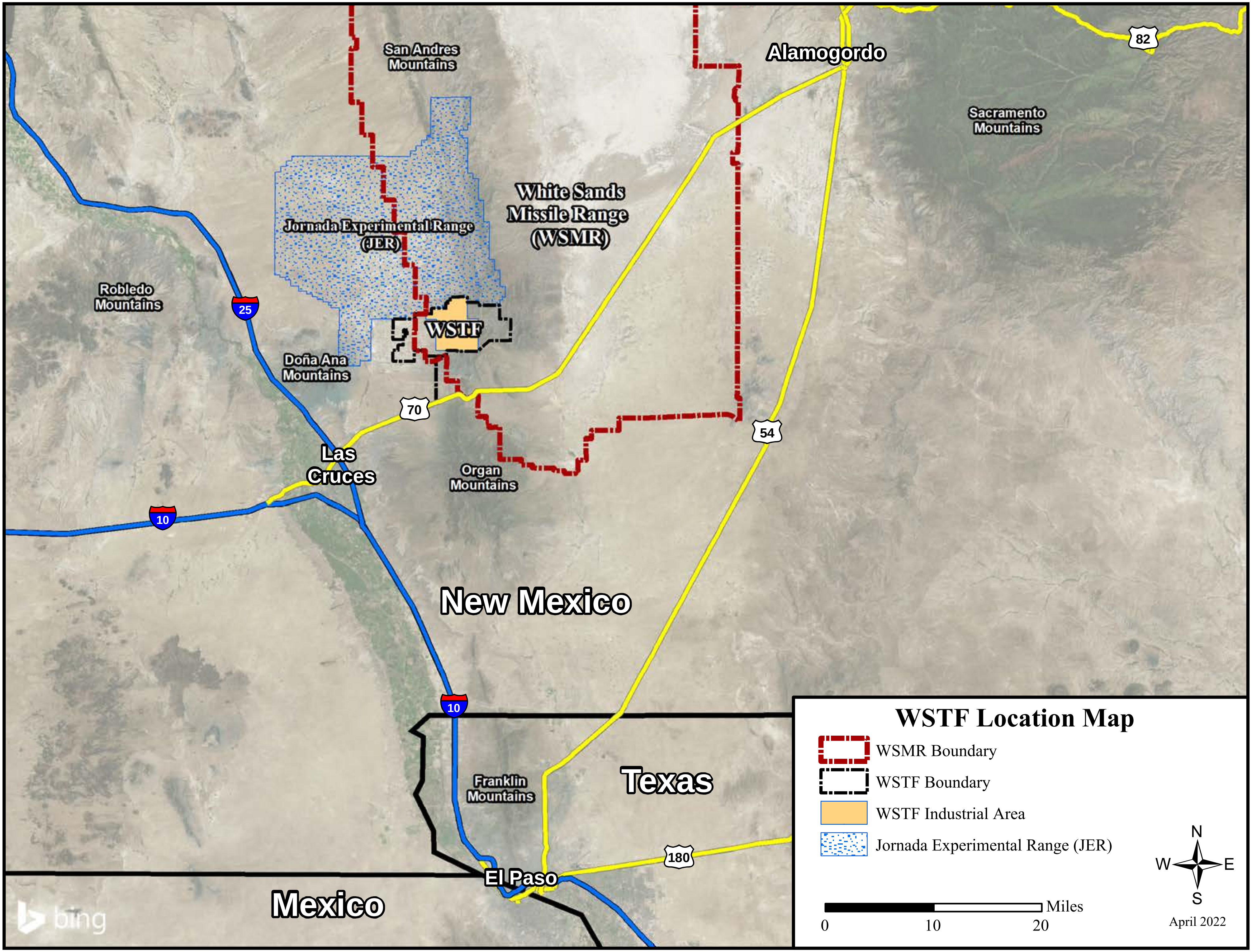

San Andres Mountains
Alamogordo
82
Sacramento Mountains
White Sands Missile Range (WSMR)
Jornada Experimental Range (JER)
Robledo Mountains
25
WSTF
Doña Ana Mountains
70
54
Las Cruces
Organ Mountains
10
New Mexico
10
Franklin Mountains
Texas
180
El Paso
Mexico
WSTF Location Map
WSMR Boundary
WSTF Boundary
WSTF Industrial Area
Jornada Experimental Range (JER)
N
W
E
S
Miles
0
10
20
April 2022

Figure 2.1 **Pertinent WSTF Site Features**

(SEE NEXT PAGE)

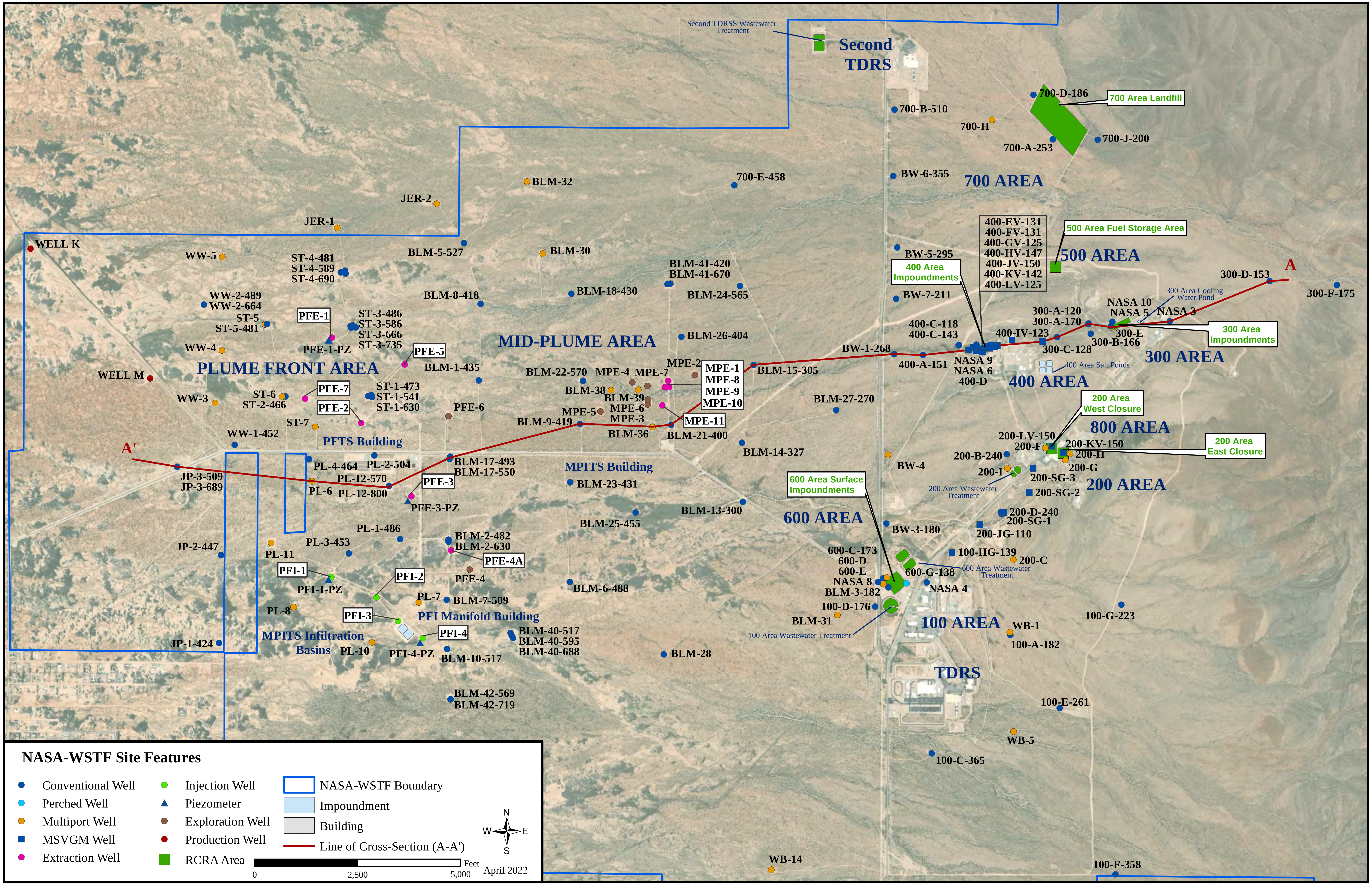
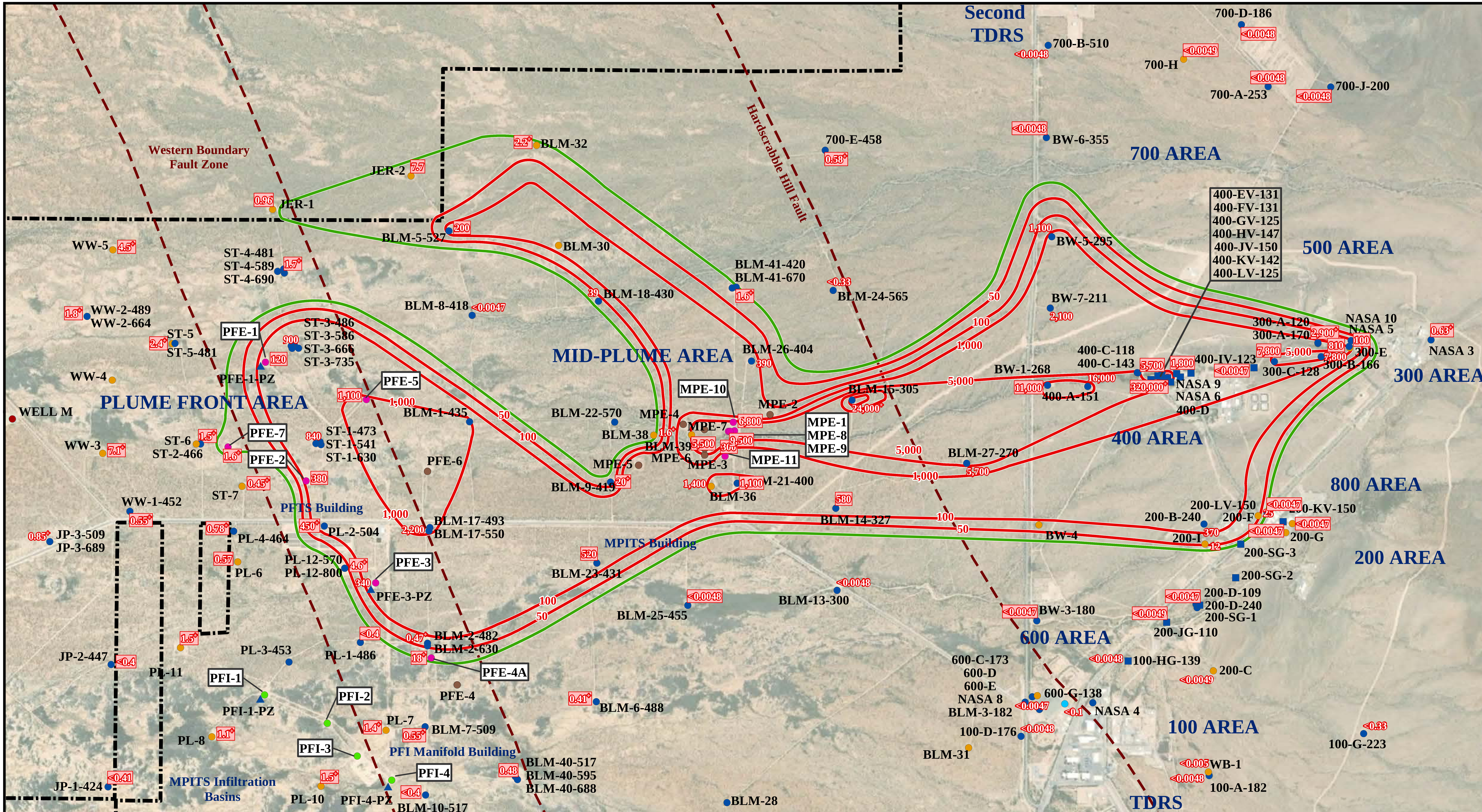

Second TDRSS Wastewater Treatment
Second TDRS
700-D-186
700 Area Landfill
700-B-510
700-H
700-A-253
700-J-200
700 AREA
BLM-32
700-E-458
BW-6-355
JER-2
JER-1
WELL K
BLM-5-527
BLM-30
WW-5
ST-4-481
ST-4-589
ST-4-690
BLM-41-420
BLM-41-670
BLM-18-430
BLM-24-565
BW-5-295
400 Area Impoundments
400-EV-131
400-FV-131
400-GV-125
400-HV-147
400-JV-150
400-KV-142
400-LV-125
500 Area Fuel Storage Area
500 AREA
300-D-153
A
300-F-175
300 Area Cooling Water Pond
WW-2-489
WW-2-664
BLM-8-418
BW-7-211
ST-5
ST-5-481
PFE-1
ST-3-486
ST-3-586
ST-3-666
ST-3-735
WW-4
PFE-1-PZ
PFE-5
MID-PLUME AREA
BLM-26-404
400-C-118
400-C-143
400-IV-123
300-A-120
300-A-170
NASA 10
NASA 5
NASA 3
300-E
300 Area Impoundments
300-B-166
300-C-128
BW-1-268
NASA 9
NASA 6
400-D
400-A-151
300 AREA
WELL M
PLUME FRONT AREA
BLM-1-435
BLM-22-570
MPE-4
MPE-7
MPE-2
MPE-1
MPE-8
MPE-9
MPE-10
BLM-15-305
400 Area Salt Ponds
400 AREA
WW-3
ST-6
ST-2-466
PFE-7
ST-1-473
ST-1-541
ST-1-630
PFE-2
PFE-6
BLM-38
BLM-39
MPE-6
MPE-3
MPE-5
BLM-9-419
BLM-27-270
200 Area West Closure
ST-7
WW-1-452
PFTS Building
BLM-36
MPE-11
BLM-21-400
800 AREA
A'
200-LV-150
200-F
200-KV-150
200-H
200 Area East Closure
PL-4-464
PL-2-504
BLM-17-493
BLM-17-550
MPITS Building
BLM-14-327
BW-4
200-B-240
200-I
200-G
200-SG-3
JP-3-509
JP-3-689
PL-12-570
PL-6
PL-12-800
PFE-3
BLM-23-431
600 Area Surface Impoundments
200 Area Wastewater Treatment
200-SG-2
200 AREA
PFE-3-PZ
BLM-13-300
600 AREA
200-D-240
200-SG-1
BLM-25-455
PL-1-486
BW-3-180
200-JG-110
BLM-2-482
BLM-2-630
JP-2-447
PL-3-453
PL-11
600-C-173
600-D
600-E
100-HG-139
200-C
PFE-4A
PFI-1
PFE-4
600-G-138
600 Area Wastewater Treatment
PFI-2
PFI-1-PZ
BLM-6-488
NASA 8
BLM-3-182
NASA 4
PL-7
BLM-7-509
PL-8
100-D-176
100-G-223
PFI-3
PFI Manifold Building
BLM-31
100 AREA
WB-1
MPITS Infiltration Basins
PFI-4
BLM-40-517
BLM-40-595
BLM-40-688
100 Area Wastewater Treatment
100-A-182
JP-1-424
PL-10
PFI-4-PZ
BLM-10-517
BLM-28
TDRS
BLM-42-569
BLM-42-719
100-E-261
WB-5
100-C-365
NASA-WSTF Site Features
Conventional Well
Perched Well
Multiport Well
MSVGM Well
Extraction Well
Injection Well
Piezometer
Exploration Well
Production Well
RCRA Area
NASA-WSTF Boundary
Impoundment
Building
Line of Cross-Section (A-A')
N
W
E
S
0
2,500
5,000
Feet
April 2022
WB-14
100-F-358

Figure 2.2 **Distribution of NDMA in WSTF Groundwater**

(SEE NEXT PAGE)



NDMA Maximum Concentrations in Groundwater for Fourth Quarter 2021

- 50 — Equiconcentration Line (ng/L)
- NDMA Cleanup Level (1.1 ng/L)
- Multiport Well
- Conventional Well
- Perched Well
- MSVGM Well
- Extraction Well
- Injection Well
- Piezometer
- Exploration Well
- Production Well
- Fault
- WSTF Boundary

0 — 4,000 — 8,000 Feet

N, W, E, S

Note:
Method 607 NDMA results corrected for extraction efficiency.
* - The analytical batch LCS_01MAR21 laboratory control sample recoveries of NDMA (1.4%) were outside laboratory control limits; corrected detections were excluded for 3Q2021.
\+ - Data value has a QA flag. See Appendix A.2 for specific flags.
50 - Sample event result was within the quarterly date range. No outline indicates an earlier sample event.
- Non-detect values displayed "<Detection Limit"
- No value indicates the well has not been sampled in the last year.

April 2022

Figure 2.3 **Distribution of TCE in WSTF Groundwater**

(SEE NEXT PAGE)

TCE Maximum Concentrations in Groundwater for Fourth Quarter 2021

Red line	Equiconcentration Line (ug/L)
Green line	TCE Cleanup Level (4.9 ug/L)
Orange dot	Multiport Well
Dark blue dot	Conventional Well
Light blue dot	Perched Well
Blue square	MSVGM Well
Magenta dot	Extraction Well
Green dot	Injection Well
Blue triangle	Piezometer
Brown dot	Exploration Well
Dark red dot	Production Well
Dashed line	Fault
Dash-dot line	WSTF Boundary

Scale: 0 — 4,000 — 8,000 Feet

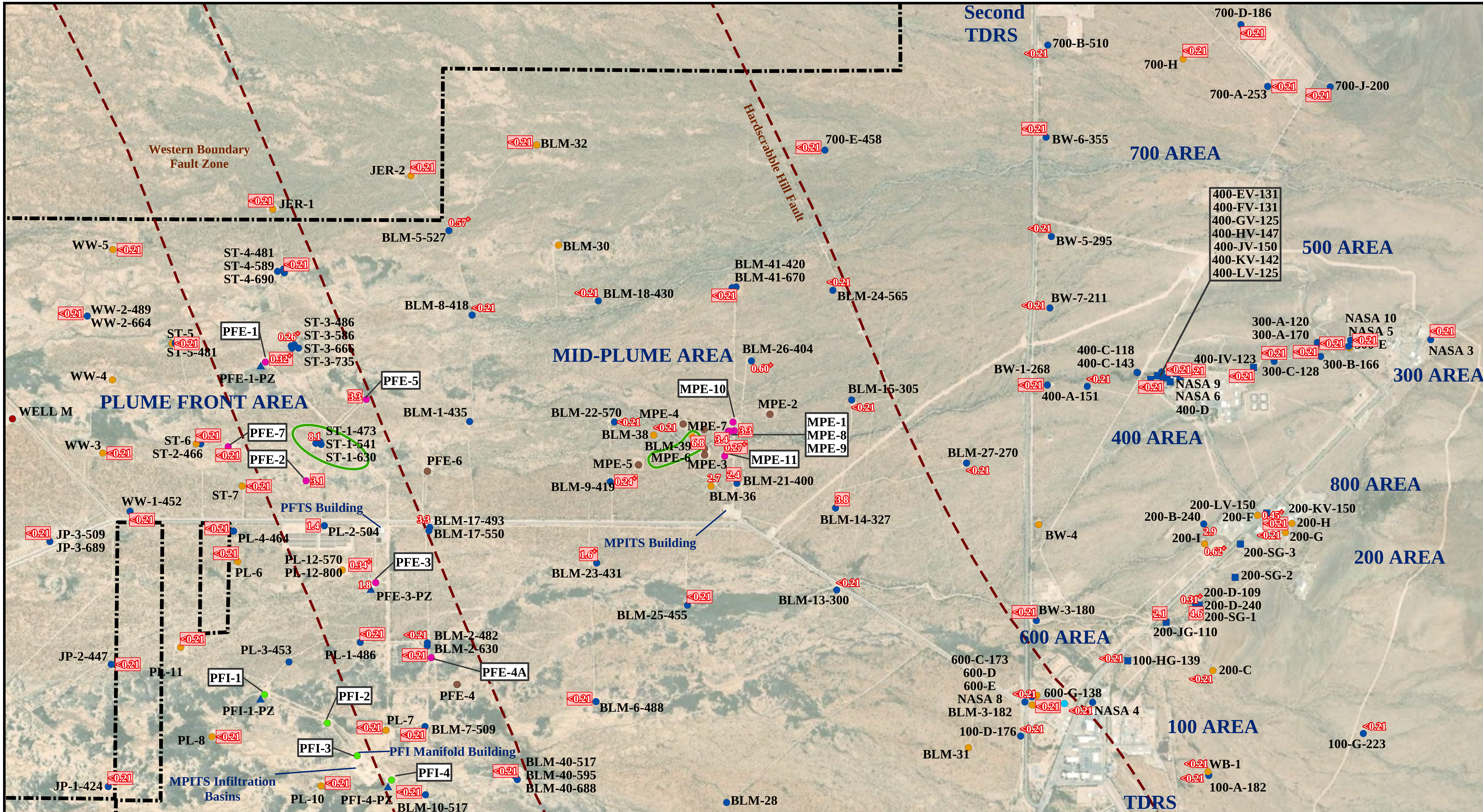
N / S / E / W

Note:
+ - Data value has a QA flag. See Appendix A.2 for specific flags.
50 - Sample event result was within the quarterly date range. No outline indicates an earlier sample event.
- Non-detect values displayed "<Detection Limit"
- No value indicates the well has not been sampled in the last year.

April 2022

Figure 2.4 **Distribution of PCE in WSTF Groundwater**

(SEE NEXT PAGE)



PCE Maximum Concentrations in Groundwater for Fourth Quarter 2021

PCE Cleanup Level (5 ug/L)
Multiport Well
Conventional Well
Perched Well
MSVGM Well
Extraction Well
Injection Well
Piezometer
Exploration Well
Production Well
Fault
WSTF Boundary

0 4,000 8,000 Feet

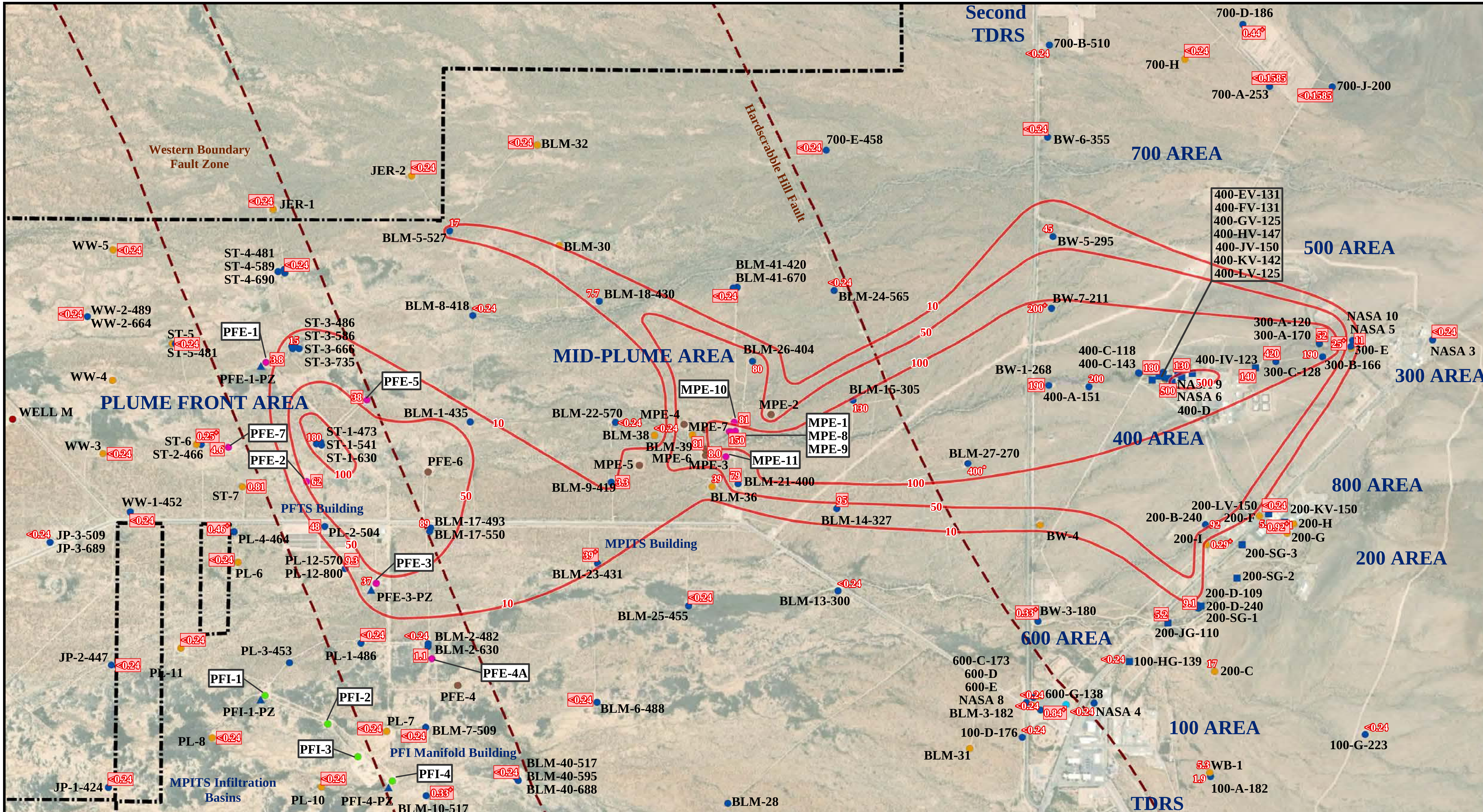
Note:
\+ - Data value has a QA flag. See Appendix A.2 for specific flags.
ND - Non-detect values <0.21 ug/L
- Sample event result was within the quarterly date range. No outline indicates an earlier sample event.
- No value indicates the well has not been sampled in the last year.

N W E S

April 2022

Figure 2.5 Distribution of Freon 11 in WSTF Groundwater

(SEE NEXT PAGE)



Freon 11 Maximum Concentrations in Groundwater for Fourth Quarter 2021

Multiport Well
Conventional Well
Perched Well
MSVGM Well
Extraction Well
Injection Well
Piezometer
Exploration Well
Production Well
Fault
WSTF Boundary
Equiconcentration Line (ug/L)

0 4,000 8,000 Feet

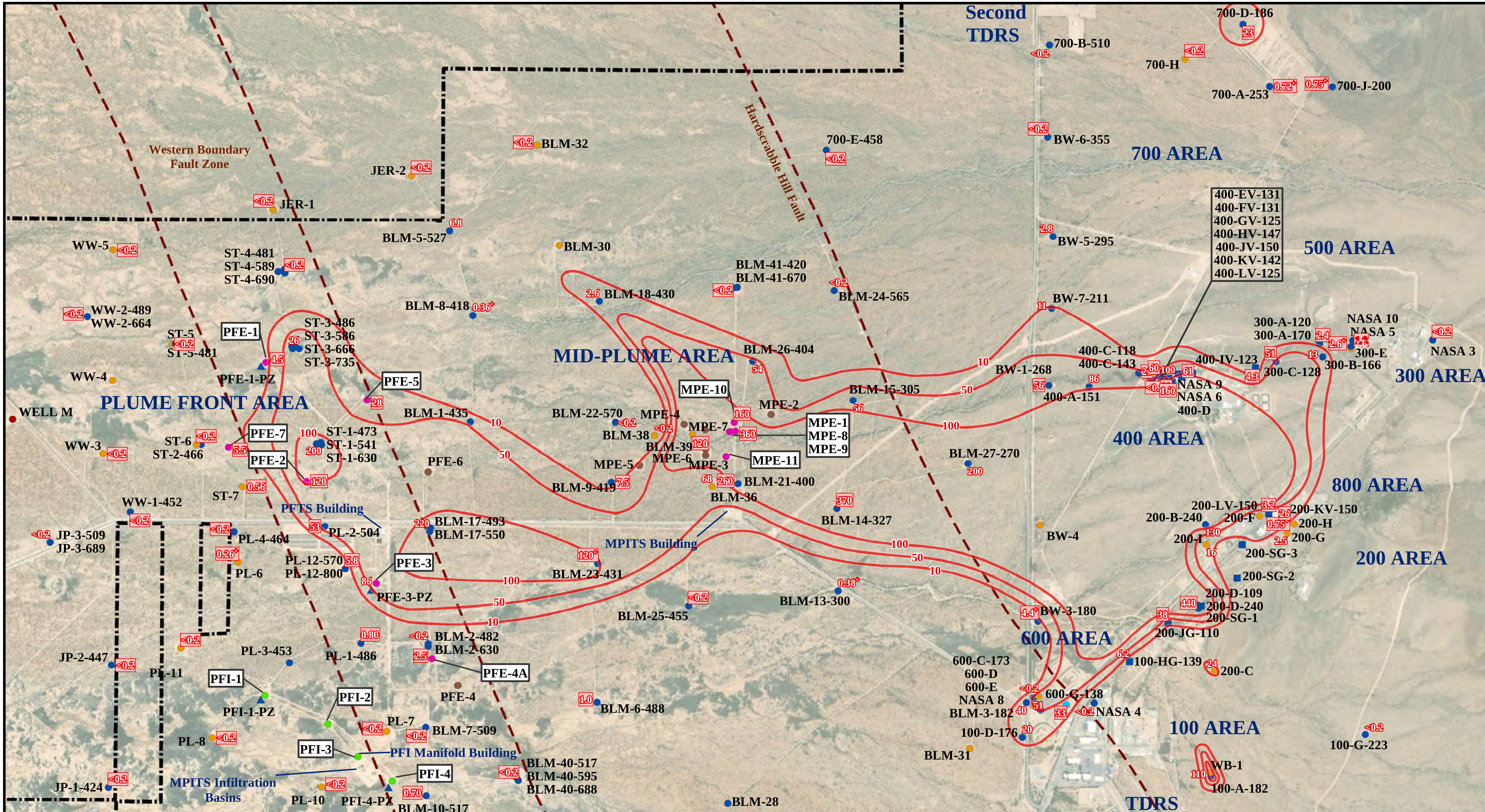
N W E S

Note:
Freon 11 concentations are below the EPA RSL (5,200 ug/L).
\+ - Data value has a QA flag. See Appendix A.2 for specific flags.
ND - Non-detect values <0.24 ug/L
- Sample event result was within the quarterly date range. No outline indicates an earlier sample event.
- No value indicates the well has not been sampled in the last year.

April 2022

Figure 2.6 Distribution of Freon 113 in WSTF Groundwater

(SEE NEXT PAGE)



Freon 113 Maximum Concentrations in Groundwater for Fourth Quarter 2021

- Multiport
- Conventional Well
- Perched Well
- MSVGM Well
- Extraction Well
- Injection Well
- Piezometer
- Exploration Well
- Production Well
- Fault
- WSTF Boundary
- Equiconcentration Line (ug/L)

0 4,000 8,000 Feet

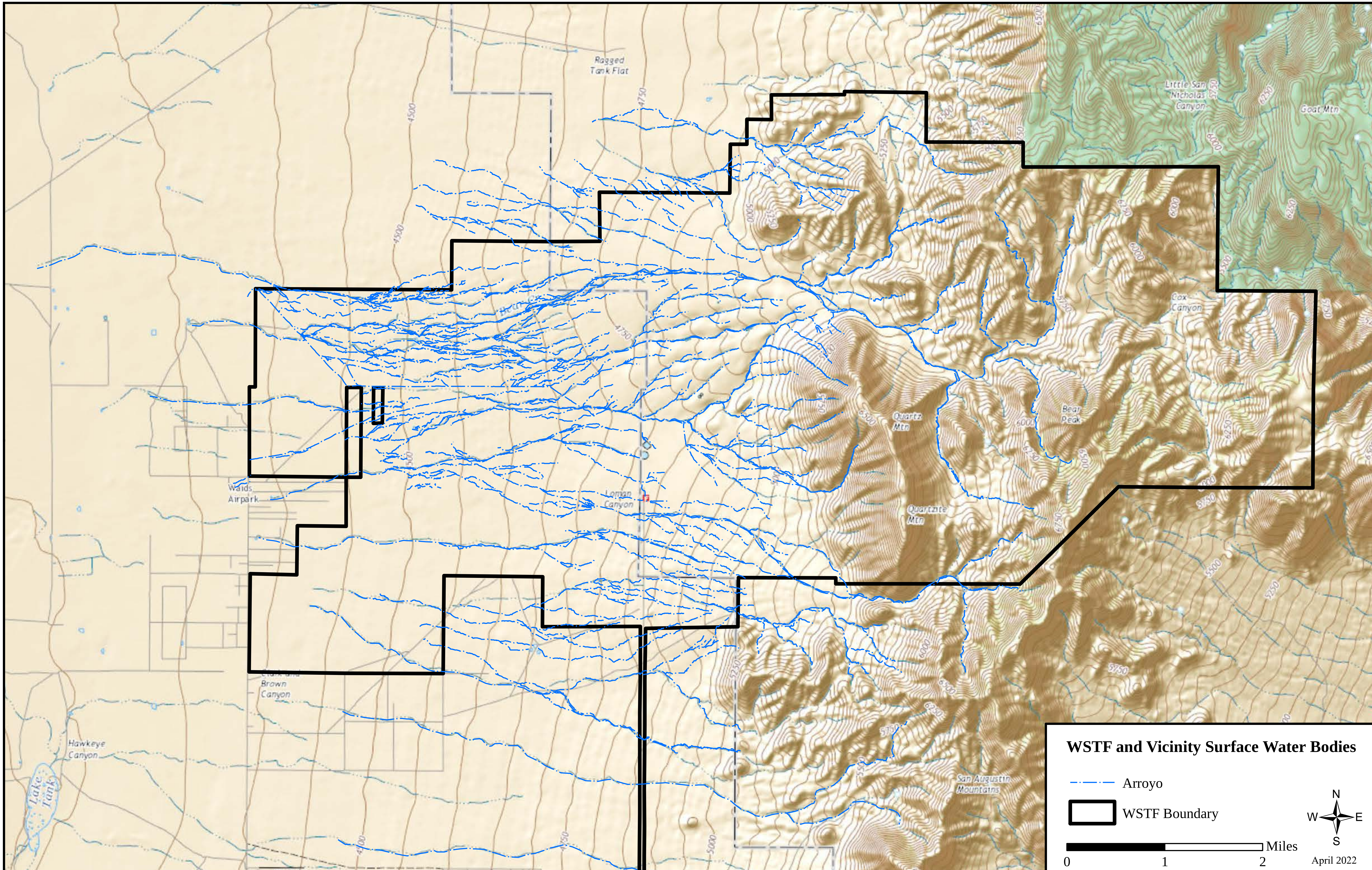
N W E S

Note:
Freon 113 concentations are below the EPA RSL (10,000 ug/L).
\+ Data value has a QA flag. See Appendix A.2 for specific flags.
ND Non-detect values <0.20 ug/L
80 - Sample event result was within the quarterly date range. No outline indicates an earlier sample event.
\- No value indicates the well has not been sampled in the last year.

April 2022

Figure 2.7 WSTF and Vicinity Surface Water Bodies

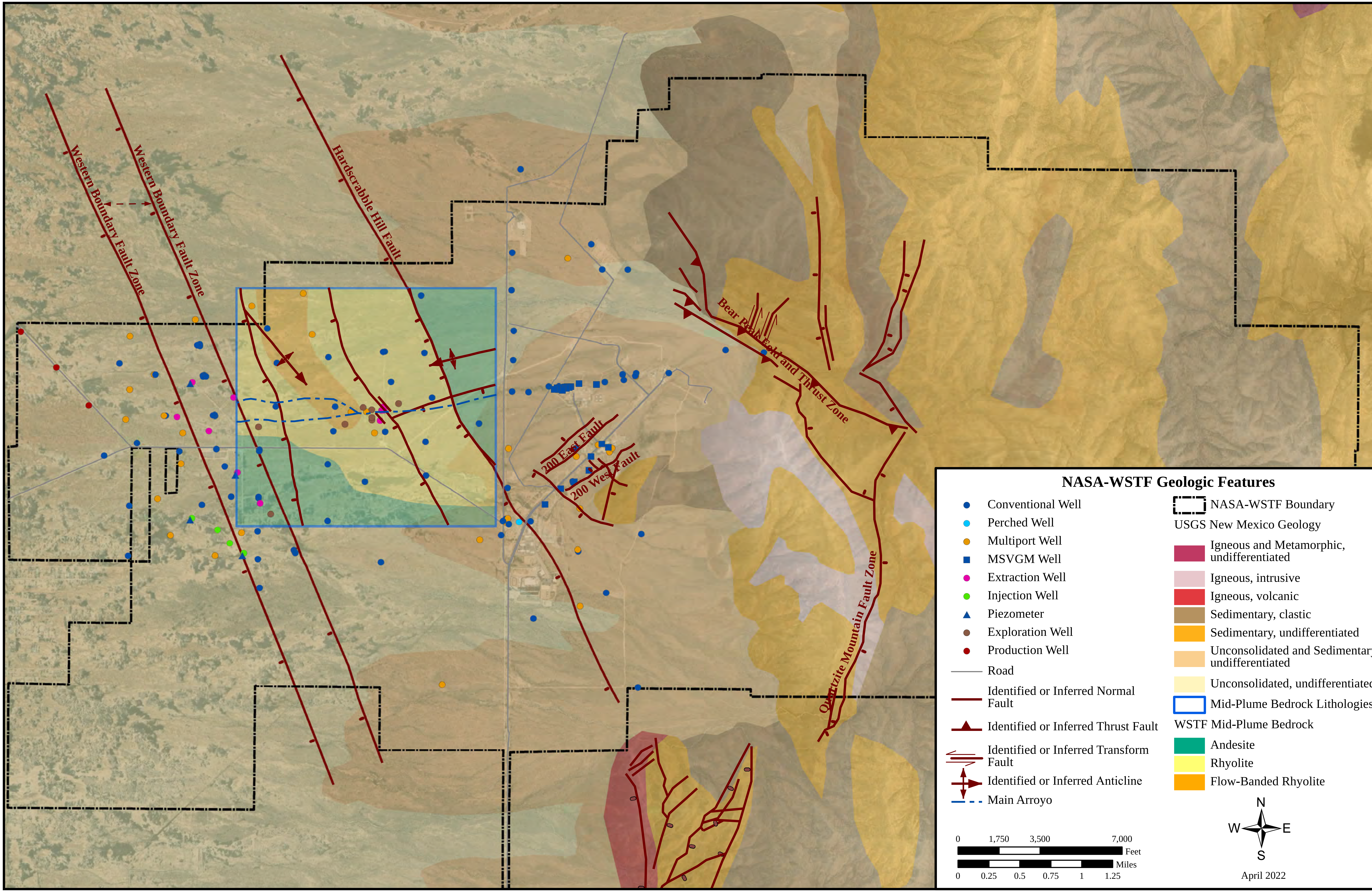
(SEE NEXT PAGE)



WSTF and Vicinity Surface Water Bodies
Arroyo
WSTF Boundary
0
1
2
Miles
N
S
E
W
April 2022
Ragged Tank Flat
Little San Nicholas Canyon
Goat Mtn
Cox Canyon
Quartz Mtn
Bear Peak
Quartzite Mtn
Lohman Canyon
Wards Airpark
Brown Canyon
Hawkeye Canyon
Lake Tank
San Augustin Mountains
Shoestring

Figure 2.8 **WSTF Geological Features**

(SEE NEXT PAGE)



Western Boundary Fault Zone
Western Boundary Fault Zone
Hardscrabble Hill Fault
Bear Peak Fold and Thrust Zone
200 East Fault
200 West Fault
Quartzite Mountain Fault Zone
NASA-WSTF Geologic Features
Conventional Well
Perched Well
Multiport Well
MSVGM Well
Extraction Well
Injection Well
Piezometer
Exploration Well
Production Well
Road
Identified or Inferred Normal Fault
Identified or Inferred Thrust Fault
Identified or Inferred Transform Fault
Identified or Inferred Anticline
Main Arroyo
NASA-WSTF Boundary
USGS New Mexico Geology
Igneous and Metamorphic, undifferentiated
Igneous, intrusive
Igneous, volcanic
Sedimentary, clastic
Sedimentary, undifferentiated
Unconsolidated and Sedimentary, undifferentiated
Unconsolidated, undifferentiated
Mid-Plume Bedrock Lithologies
WSTF Mid-Plume Bedrock
Andesite
Rhyolite
Flow-Banded Rhyolite
0 1,750 3,500 7,000
Feet
Miles
0 0.25 0.5 0.75 1 1.25
N
W
E
S
April 2022

Figure 2.9 WSTF Hydrostratigraphy (Geologic Cross-section)

(SEE NEXT PAGE)

SITE-WIDE CROSS-SECTION A'-A

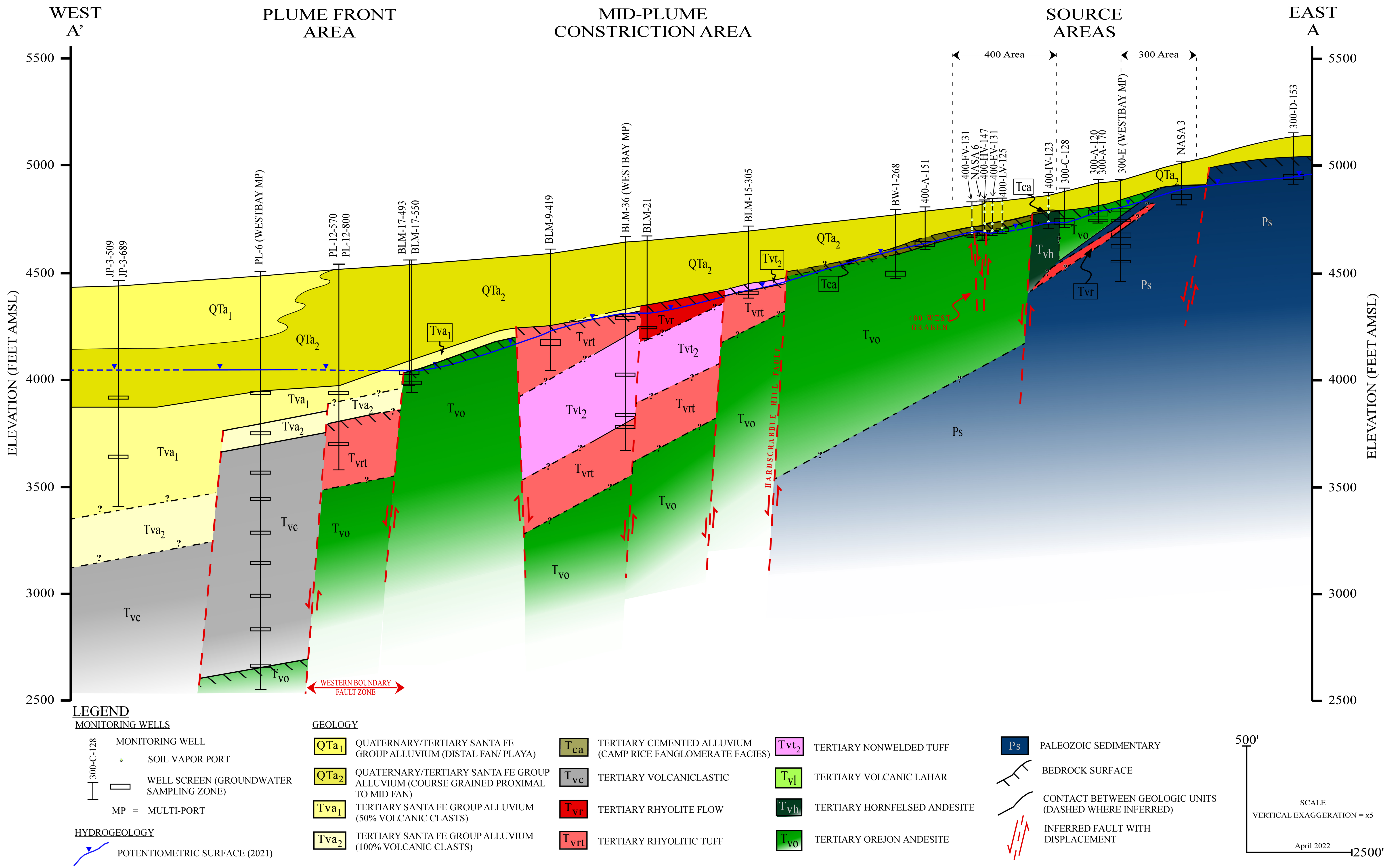
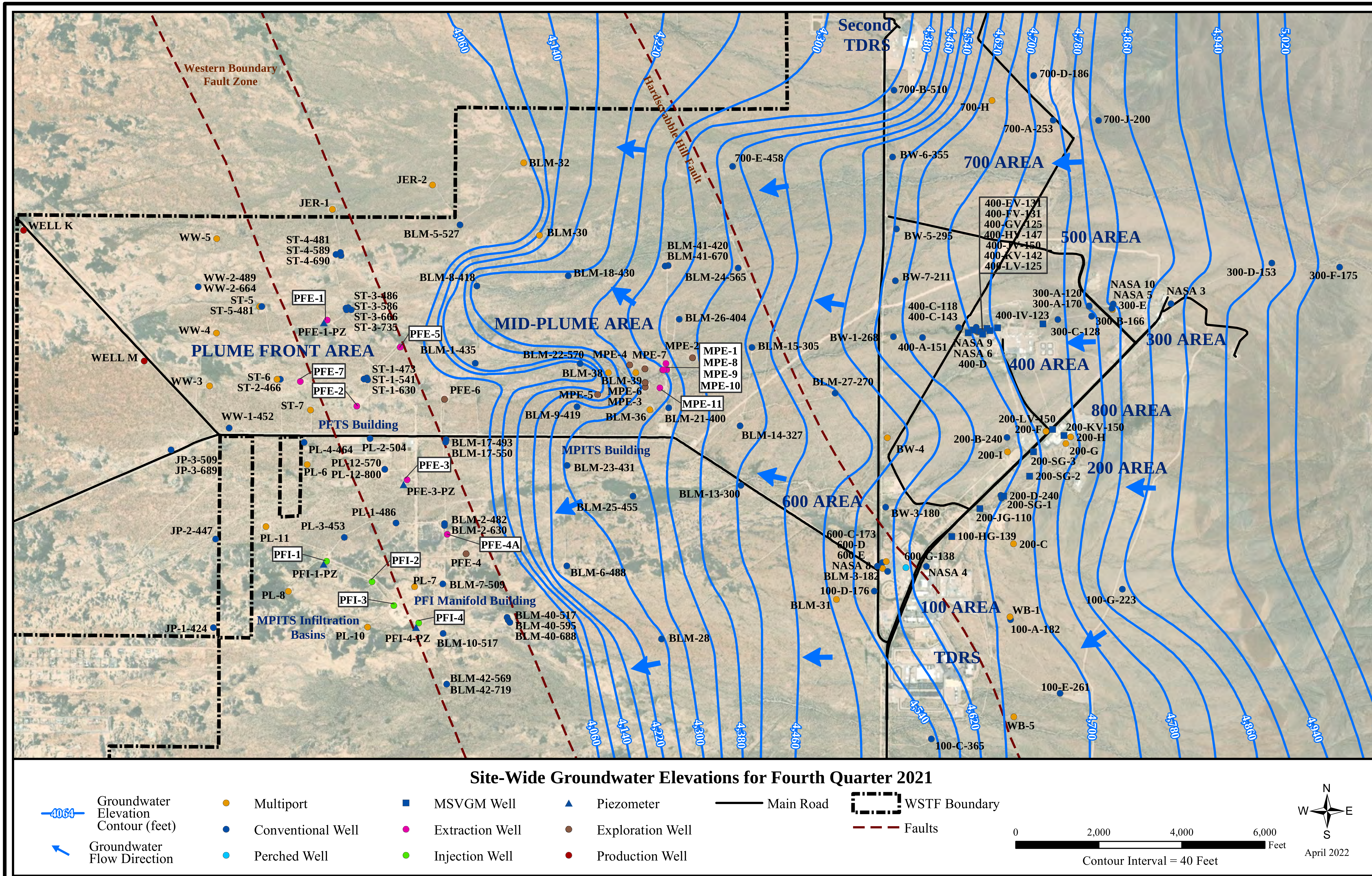


Figure 2.10 **WSTF Groundwater Elevation Map**

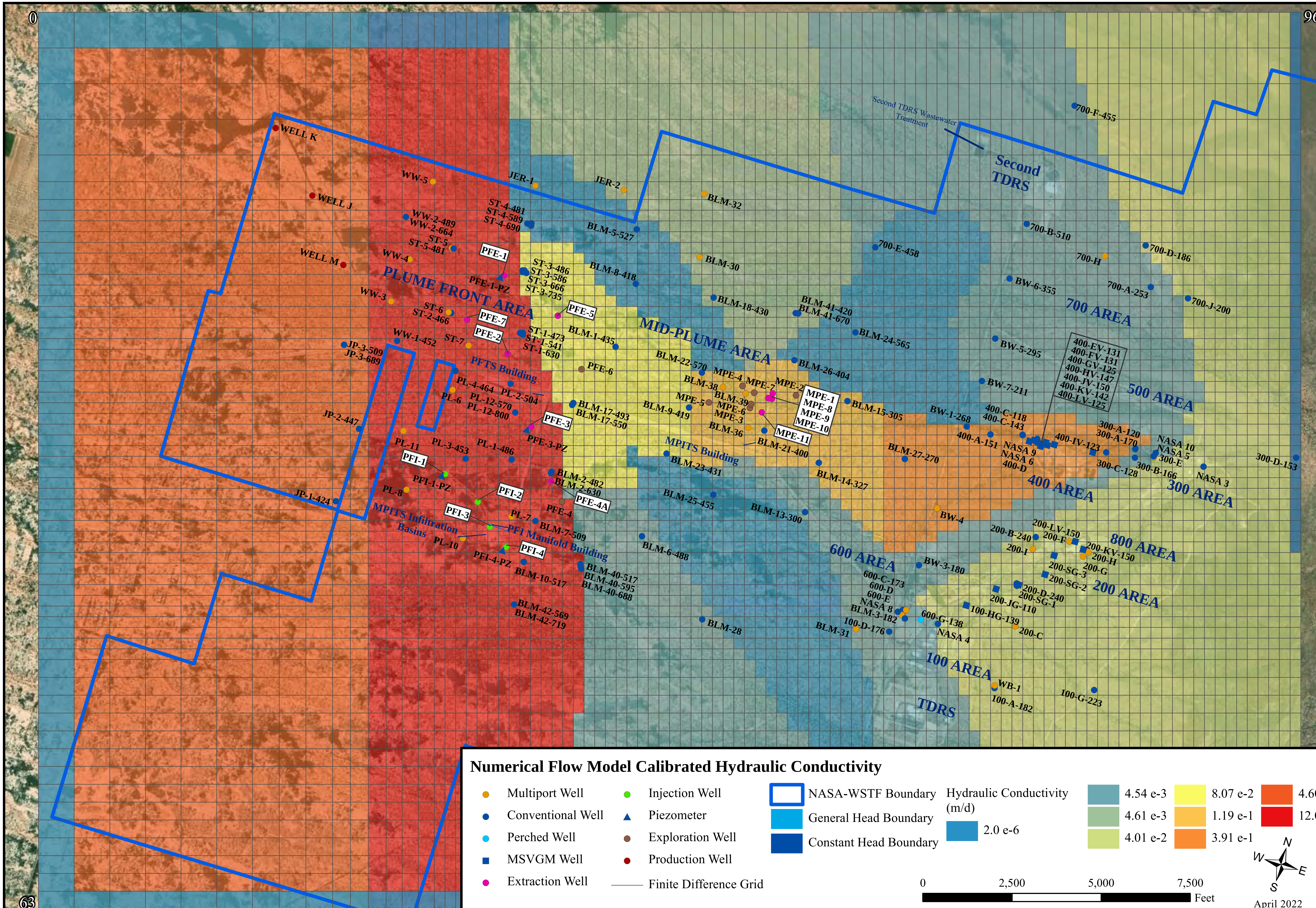
(SEE NEXT PAGE)



Site-Wide Groundwater Elevations for Fourth Quarter 2021

Figure 2.11 Numerical Flow Model Calibrated K, Estimated Using PEST

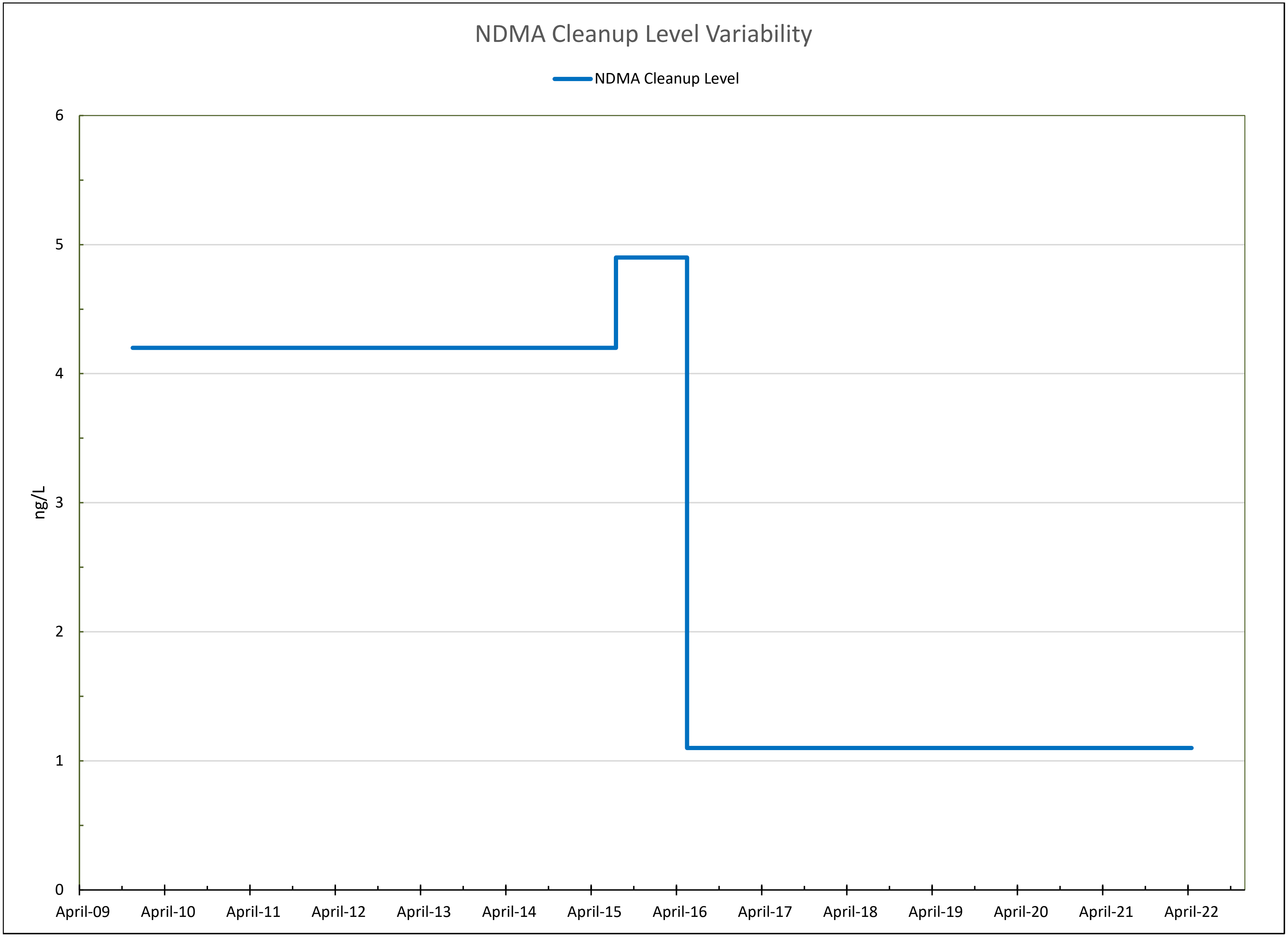
(SEE NEXT PAGE)



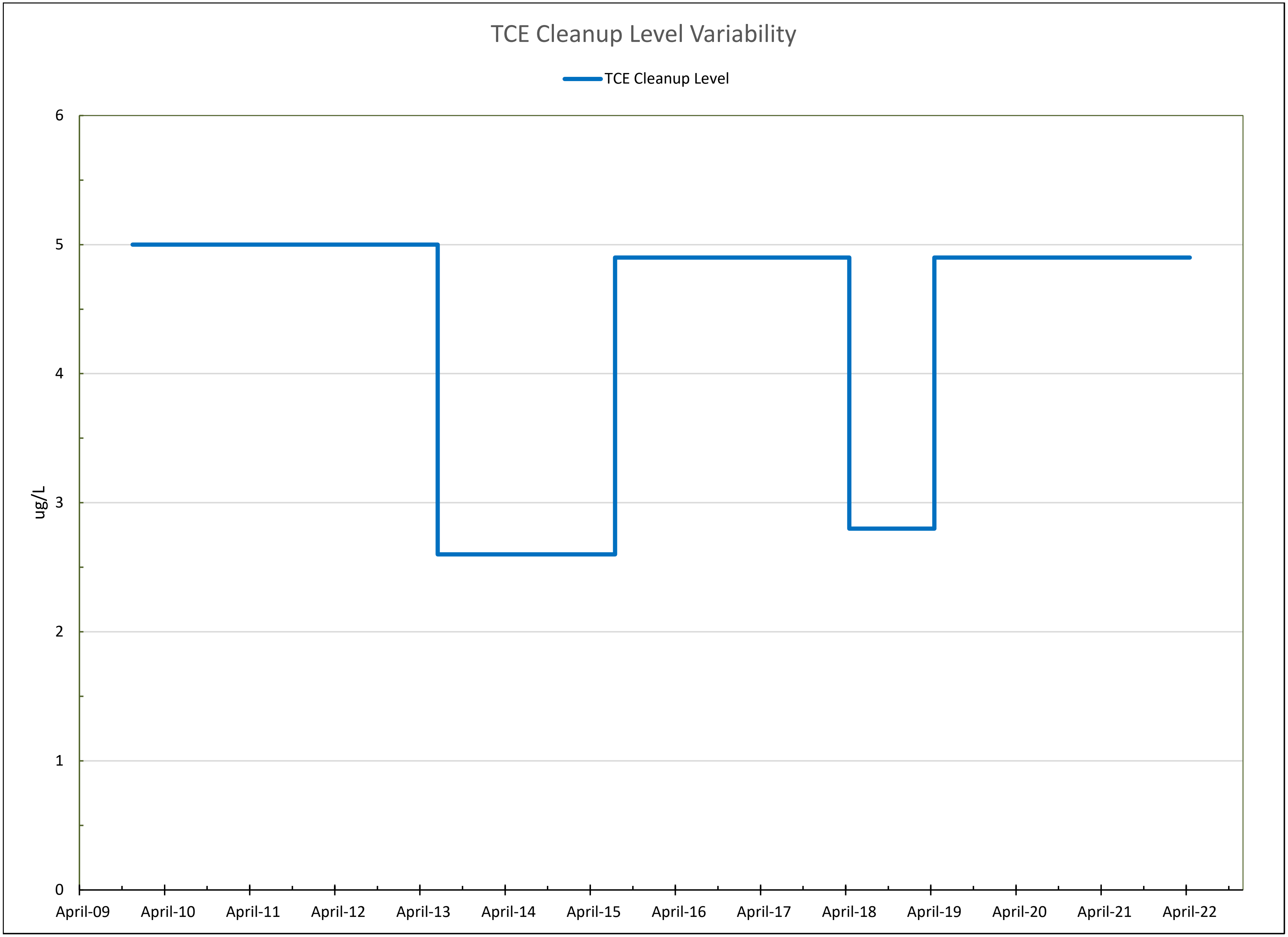
Numerical Flow Model Calibrated Hydraulic Conductivity
Multiport Well
Conventional Well
Perched Well
MSVGM Well
Extraction Well
Injection Well
Piezometer
Exploration Well
Production Well
Finite Difference Grid
NASA-WSTF Boundary
General Head Boundary
Constant Head Boundary
Hydraulic Conductivity (m/d)
2.0 e-6
4.54 e-3
4.61 e-3
4.01 e-2
8.07 e-2
1.19 e-1
3.91 e-1
4.60
12.0
0
2,500
5,000
7,500
Feet
N
E
S
W
April 2022
0
96
63
PLUME FRONT AREA
MID-PLUME AREA
700 AREA
500 AREA
400 AREA
300 AREA
800 AREA
200 AREA
600 AREA
100 AREA
TDRS
Second TDRS
Second TDRS Wastewater Treatment
PFTS Building
MPITS Building
MPITS Infiltration Basins
PFI Manifold Building
WELL K
WELL J
WELL M
PFE-1
PFE-2
PFE-3
PFE-4A
PFE-5
PFE-7
PFI-1
PFI-2
PFI-3
PFI-4
MPE-1
MPE-8
MPE-9
MPE-10
MPE-11

Figure 3.1 **Groundwater Cleanup Level Variability**

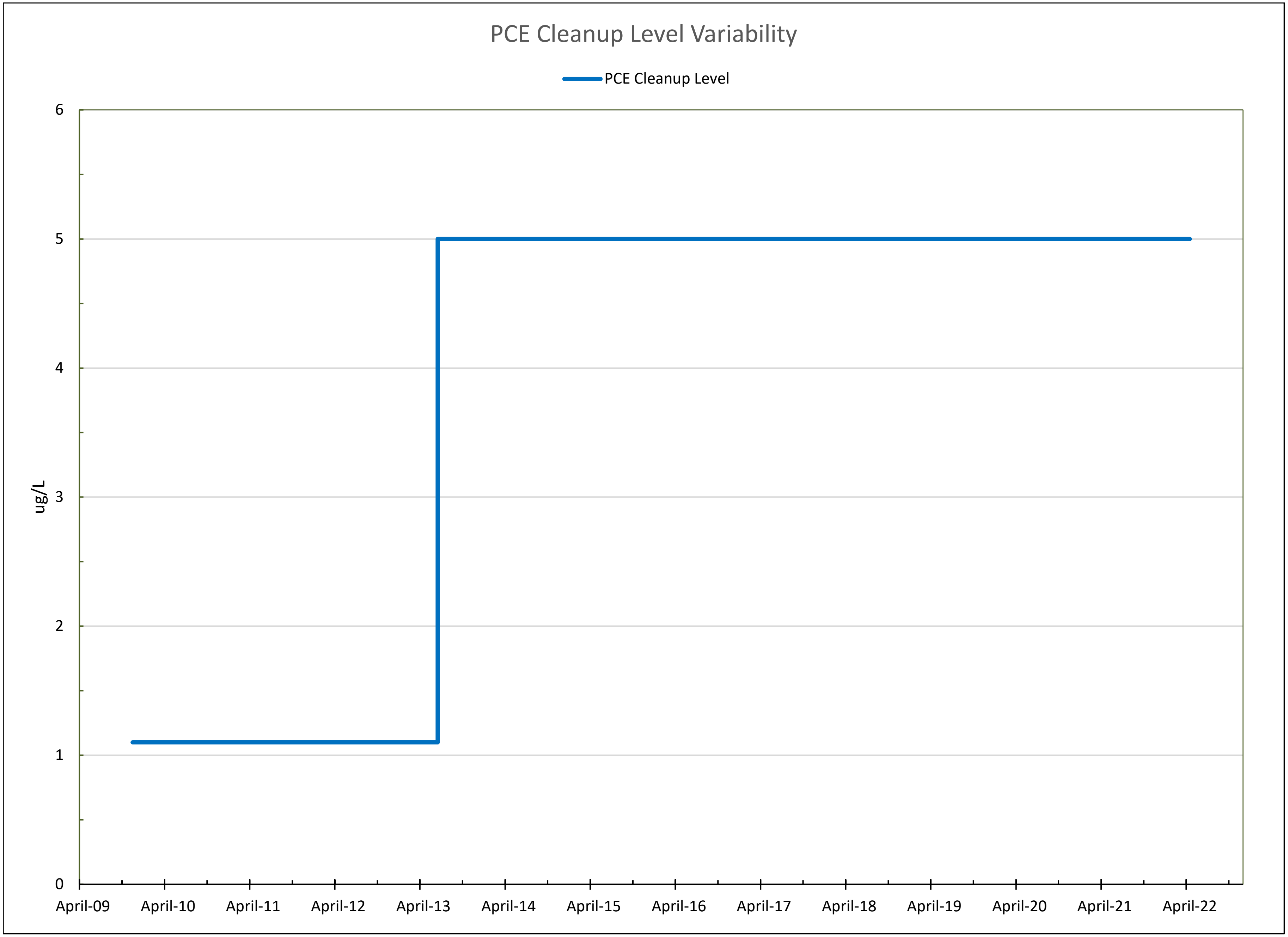
(SEE NEXT PAGE)



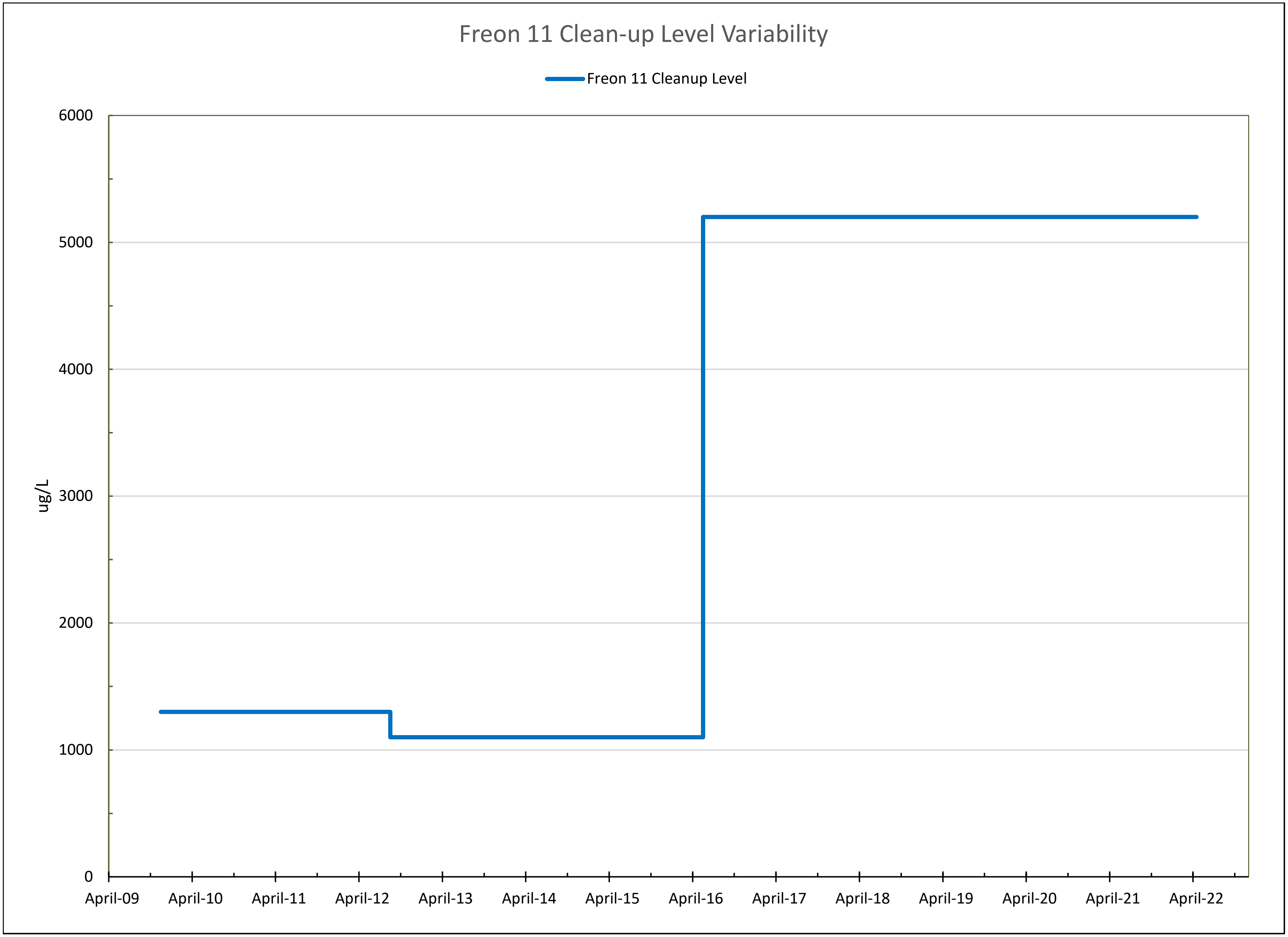
NDMA Cleanup Level Variability
NDMA Cleanup Level
ng/L
0
1
2
3
4
5
6
April-09
April-10
April-11
April-12
April-13
April-14
April-15
April-16
April-17
April-18
April-19
April-20
April-21
April-22



TCE Cleanup Level Variability
TCE Cleanup Level
ug/L
6
5
4
3
2
1
0
April-09
April-10
April-11
April-12
April-13
April-14
April-15
April-16
April-17
April-18
April-19
April-20
April-21
April-22



PCE Cleanup Level Variability
PCE Cleanup Level
ug/L
0
1
2
3
4
5
6
April-09
April-10
April-11
April-12
April-13
April-14
April-15
April-16
April-17
April-18
April-19
April-20
April-21
April-22


Freon 11 Clean-up Level Variability
Freon 11 Cleanup Level
ug/L
6000
5000
4000
3000
2000
1000
0
April-09
April-10
April-11
April-12
April-13
April-14
April-15
April-16
April-17
April-18
April-19
April-20
April-21
April-22

Tables

Table 2.1 Summary of COC/Waste Utilization and Potential Sources at WSTF

COC	100 Area	200 Area	300 Area	400 Area	500 Area	600 Area	700 Area
NDMA		201	X	X	*		
TCE		X	X			X	*
PCE	X	X					
Freon 11		X	X	X		X	*
Freon 113		X	X	X		X	*

X – Indicates that the COC was utilized in this area or that there is a known source/release of the COC.
* – Indicates a potential source/release of the COC in this area.

Table 2.2 Zones of Hydraulic Conductivity (K) at WSTF

Geologic Unit	Distribution	Calculated Horizontal K (m/day)	Calculated Vertical K (m/day)	Geometric Mean Horizontal K (min/max) (m/day)
Low permeability rhyolite and andesite	Areas defined by dry holes and low well yields north and south of contaminant plume (includes flow-banded rhyolite [FBR])	2.0E-006	6.33E-009	N/A[1] (dry/29)
Fractured rhyolite	Mid-plume area	0.119	0.199	0.06 (1.7e-003/0.27)
Fractured andesite	Zone extending south to north across the east central model domain	0.00454	0.00016	0.012 (1.2e-004/1.92)
Limestone	Zone along eastern boundary of the model domain	0.04009	0.00058	1.39 (3.4e-003/224)
Basin-fill sediments	PFTS area	12[2]	1.2	1.62 (2.6e-003/116)
Basin-fill sediments	PFTS area, layers 1-14 and as a sediment veneer overlying most of the fractured rock zones	12[2]	1.2	1.62 (2.6e-003/116)
Distal basin-fill sediments	Western portion of the model domain in the JDMB	4.6[2]	0.1	1.62 (2.6e-003/116)
Fractured rhyolite	South of flow-banded rhyolite	0.081	0.2	0.198 (1.2e-003/3.42)
Fractured andesite	Zone encompassing the 300 and 400 Areas	0.391	0.0047	0.51 (4.1e-003/20.8)
Fractured rhyolite	Zone east of the FBR	0.0046	0.0199	0.69[3] (0.14/2.82)

1 – Not applicable – hydraulic conductivity of dry and low yield wells not estimated.

2 – Alluvium horizontal hydraulic conductivity was calibrated to distance-drawdown observations during pumping tests of Well J and PFE-3.

3 – Only three slug test measured hydraulic conductivity measurements available. Reasonable hydraulic conductivity range assumed equal to Zone 2.

Table 3.1 Hazardous Constituents in WSTF Groundwater

CAS Number	Analyte Name	Toxic Pollutant	MCL	WQCC	RSL	Cleanup Level	Unit	Source
				Volatile Organics				
100-41-4	Ethylbenzene	Yes	700	700	15	**15**	µg/L	EPA RSL
100-42-5	Styrene	Yes	100	100	1,200	**100**	µg/L	20.6.2.3103 NMAC
107-06-2	1,2-Dichloroethane (EDC)	Yes	5	5	1.7	**1.7**	µg/L	EPA RSL
107-12-0	Propionitrile (Ethyl Cyanide)[1]	No	NA	NA	NA	**NA**	NA	NA
107-13-1	Acrylonitrile	Yes	NA	NA	0.52	**0.52**	µg/L	EPA RSL
108-88-3	Toluene	Yes	1,000	1,000	1,100	**1,000**	µg/L	20.6.2.3103 NMAC
108-90-7	Chlorobenzene	Yes	100	NA	78	**78**	µg/L	EPA RSL
127-18-4	Tetrachloroethene (PCE)[2]	Yes	5	5	110	**5**	µg/L	20.6.2.3103 NMAC
1330-20-7	m,p-Xylenes	Yes	10,000	620	190	**190**	µg/L	EPA RSL
156-60-5	trans-1,2-Dichloroethene	Yes	100	100	68	**68**	µg/L	EPA RSL
56-23-5	Carbon tetrachloride	Yes	5	5	4.6	**4.6**	µg/L	EPA RSL
67-64-1	Acetone	No	NA	NA	18,000	**18,000**	µg/L	EPA RSL
67-66-3	Chloroform[2]	Yes	80[3]	100	2.2	**2.2**	µg/L	EPA RSL
71-43-2	Benzene	Yes	5	5	4.6	**4.6**	µg/L	EPA RSL
71-55-6	1,1,1-Trichloroethane (TCA)	Yes	200	200	8,000	**200**	µg/L	20.6.2.3103 NMAC
74-83-9	Bromomethane	Yes	NA	NA	7.5	**7.5**	µg/L	EPA RSL
74-87-3	Chloromethane	Yes	NA	NA	190	**190**	µg/L	EPA RSL
75-00-3	Chloroethane (Ethyl Chloride)	No	NA	NA	8,300	**8,300**	µg/L	EPA RSL
75-01-4	Vinyl chloride	Yes	2	2	0.19	**0.19**	µg/L	EPA RSL
75-09-2	Methylene chloride (dichloromethane)	Yes	5	5	110	**5**	µg/L	20.6.2.3103 NMAC
75-15-0	Carbon disulfide	No	NA	NA	810	**810**	µg/L	EPA RSL
75-25-2	Bromoform	Yes	80[3]	NA	33	**33**	µg/L	EPA RSL

Table 3.1 Hazardous Constituents in WSTF Groundwater

CAS Number	Analyte Name	Toxic Pollutant	MCL	WQCC	RSL	Cleanup Level	Unit	Source
75-27-4	Bromodichloromethane	Yes	80[3]	NA	1.3	**1.3**	µg/L	EPA RSL
75-34-3	1,1-Dichloroethane	Yes	NA	25	28	**25**	µg/L	20.6.2.3103 NMAC
75-35-4	1,1-Dichloroethene	Yes	7	7	280	**7**	µg/L	20.6.2.3103 NMAC
75-69-4	Trichlorofluoromethane (CFC 11)	Yes	NA	NA	5,200	**5,200**	µg/L	EPA RSL
75-71-8	Dichlorodifluoromethane (CFC 12)	Yes	NA	NA	200	**200**	µg/L	EPA RSL
78-87-5	1,2-Dichloropropane (DCPA)	Yes	5	5	8.5	**5**	µg/L	20.6.2.3103 NMAC
78-93-3	2-Butanone (MEK)	No	NA	NA	5,600	**5,600**	µg/L	EPA RSL
79-00-5	1,1,2-Trichloroethane	Yes	5	5	2.8	**2.8**	µg/L	EPA RSL
79-01-6	Trichloroethene (TCE)[2]	Yes	5	5	4.9	**4.9**	µg/L	EPA RSL
				Nitrosamines				
62-75-9	N-Nitrosodimethylamine[2]	Yes	NA	NA	0.0011	**0.0011**	µg/L	EPA RSL
				Metals				
7439-92-1	Lead	No	0.015[4]	0.015	0.015	**0.015**	mg/L	20.6.2.3103 NMAC
7439-97-6	Mercury (elemental)	No	0.002	0.002	0.00063	**0.002**	mg/L	40 CFR Part 141
7440-02-0	Nickel (soluble salts)	No	NA	0.2	0.39	**0.2**	mg/L	20.6.2.3103 NMAC
7440-22-4	Silver	No	NA	0.05	0.094	**0.05**	mg/L	20.6.2.3103 NMAC
7440-28-0	Thallium (soluble salts)	No	0.002	0.002	0.002	**0.002**	mg/L	20.6.2.3103 NMAC
7440-31-5	Tin	No	NA	NA	12	**12**	mg/L	EPA RSL
7440-36-0	Antimony (metallic)	No	0.006	0.006	0.0078	**0.006**	mg/L	20.6.2.3103 NMAC
7440-38-2	Arsenic	No	0.01	0.01	0.00052	**0.01**	mg/L	20.6.2.3103 NMAC
7440-39-3	Barium	No	2	2	3.8	**2**	mg/L	20.6.2.3103 NMAC
7440-41-7	Beryllium	No	0.004	0.004	0.025	**0.004**	mg/L	20.6.2.3103 NMAC
7440-43-9	Cadmium	No	0.005	0.005	0.0018	**0.005**	mg/L	20.6.2.3103 NMAC

Table 3.1 Hazardous Constituents in WSTF Groundwater

CAS Number	Analyte Name	Toxic Pollutant	MCL	WQCC	RSL	Cleanup Level	Unit	Source
7440-47-3	Chromium (Total)	No	0.1	0.05	NA	**0.05**	mg/L	20.6.2.3103 NMAC
7440-48-4	Cobalt	No	NA	0.05	0.006	**0.05**	mg/L	20.6.3.3103 NMAC
7440-50-8	Copper	No	1.3[3]	1.0	0.8	**1.0**	mg/L	20.6.2.3103 NMAC
7440-62-2	Vanadium	No	NA	NA	0.086	**0.086**	mg/L	EPA RSL
7440-66-6	Zinc	No	NA	10.0	6.0	**10.0**	mg/L	20.6.2.3103 NMAC
7782-49-2	Selenium	No	0.05	0.05	0.1	**0.05**	mg/L	20.6.2.3103 NMAC
				Inorganics				
14797-73-0	Perchlorate[5]	Yes	15[6]	NA	14	**15**	µg/L	40 CFR Part 141
				Semi-volatile Organics				
84-74-2	Di-n-butylphthalate (Dibutyl Phthalate)	Yes	NA	NA	900	**900**	µg/L	EPA RSL
108-39-4	m-Cresol	No	NA	NA	930	**930**	µg/L	EPA RSL
117-81-7	Bis(2-Ethylhexyl)phthalate	Yes	6	NA	56	**6**	µg/L	40 CFR Part 141
				Miscellaneous Hazardous Constituents				
108-95-2	Phenol	Yes	NA	5	5,800	**5**	µg/L	20.6.2.3103 NMAC
3268-87-9	Octachlorodibenzo-p-dioxin (OCDD)[5]	No	NA	NA	NA	**NA**	NA	NA
39001-02-0	Octachlorodibenzofuran (OCDF)[5]	No	NA	NA	NA	**NA**	NA	NA
57-12-5	Cyanide	No	0.2	0.2	0.0015	**0.2**	mg/L	20.6.2.3103 NMAC
93-72-1	2,4,5-Trichlorophenoxypropionic (TP) acid (Silvex)	No	50	NA	110	**50**	µg/L	40 CFR Part 141
18496-25-8	Sulfide[1]	No	NA	NA	NA	**NA**	NA	NA

MCL – Maximum Contaminant Level

WQCC – New Mexico Water Quality Control Commission Numerical Standard

RSL – EPA Regional Screening Level for Residential Tapwaters; equivalent to H=1 or modified to = 1.0E-05 risk.

NA – Not Available/Applicable

Table 3.1 Hazardous Constituents in WSTF Groundwater

CAS Number	Analyte Name	Toxic Pollutant	MCL	WQCC	RSL	Cleanup Level	Unit	Source

[1] The constituent is listed in 40 CFR 264, Appendix IX. No further information is available.

[2] NMED Discharge Permit (DP)-1255 Treatment Standard for this contaminant may be lower than the Cleanup Level derived through the process established in the Permit.

[3] The MCL was listed in the November 2021 EPA RSL update with a note to see the RSLs User's Guide. The RSL User's Guide Section 5.25 states that even though individual trihalomethanes (bromoform, dibromochloromethane, chloroform) have a MCL listed as 80 µg/L in the RSL table, the 80 µg/L is the MCL for total trihalomethanes.

[4] Drinking water action level. Lead and copper are regulated by a treatment technique that requires systems to control the corrosiveness of their water. If this concentration is detected in more than 10% of customer taps sampled, the drinking water utility must take action to reduce the concentration at customer taps.

[5] Perchlorate is not listed in 40 CFR 261, Appendix VIII or 40 CFR 264, Appendix IX. However, it is listed as a toxic pollutant in 20.6.2.7.T(2) NMAC.

[6] The MCL was listed in the November 2021 EPA RSL update with a note to see the RSLs User's Guide. The RSL User's Guide Section 5.26 states that the Office of Solid Waste and Emergency Response (OSWER) issued an Interim Drinking Water Health Advisory for exposure to perchlorate of 15 µg/L in water. OSWER recommended using 15 µg/L where no federal or state applicable or relevant and appropriate requirements exist under federal or state laws for clean-up decisions.

[7] The constituent is listed in 40 CFR 261, Appendix VIII. No further information is available.

Table 3.2 Other Analytes of Interest in WSTF Groundwater

CAS Number	Analyte Name	Analysis Type	CAS Number	Analyte Name	Analysis Type
109-99-9	Tetrahydrofuran (THF)	VOC	14808-79-8	Sulfate	Inorganics
306-83-2	2,2-Dichloro-1,1,1-trifluoroethane (CFC 123)	VOC	16887-00-6	Chloride	Inorganics
354-23-4	1,2-Dichloro-1,1,2-trifluoroethane (CFC 123a)	VOC	16984-48-8	Fluoride	Inorganics
67-63-0	2-Propanol	VOC	14797-55-8	Nitrate/Nitrite as N	Inorganics
75-43-4	Dichlorofluoromethane (CFC 21)	VOC	NA	Alkalinity	Inorganics
76-13-1	1,1,2-Trichloro-1,2,2-trifluoroethane (CFC 113)	VOC	NA	Total Dissolved Solids (TDS)	Inorganics
4164-28-7	N-Nitrodimethylamine	Nitrosamines	314-40-9	Bromacil	SVOC
7440-70-2	Calcium	Metals	123-91-1	1,4-dioxane[1]	SVOC SIM
7440-23-5	Sodium	Metals	30402-15-4	Total Penta CDF	Miscellaneous
7440-24-6	Strontium	Metals	41903-57-5	Total Tetra CDD	Miscellaneous
7440-42-8	Boron	Metals	55684-94-1	Hexachlorodibenzofurans (HxCDF), Total	Miscellaneous
8006-61-9	GRO	TPH			
68334-30-5	DRO	TPH			

[1] – Indicates that the constituent is on the 40 CFR §264 Appendix IX groundwater monitoring list.

Table 3.3 WSTF Groundwater Monitoring Wells

Well Name	Well Construction	Monitoring Zone(s) (ft bgs)	Sampling System
		Upgradient Monitoring Wells	
100-F-358	Conventional PVC	358-368	Dedicated low-flow bladder pump
100-G-223	Conventional PVC	223-233	Dedicated low-flow bladder pump
300-F-175	Conventional PVC	175-185	Dedicated low-flow bladder pump
NASA 3	Conventional PVC/SS	119-139	Dedicated bladder pump
		100/600 Area Monitoring Wells	
100-A-182	Conventional PVC/SS	182-192	Dedicated low-flow bladder pump
100-D-176	Conventional PVC/SS	176-196	Dedicated low-flow bladder pump
100-HG-139	Conventional PVC w/MSVM	139-159	Dedicated low-flow bladder pump
600-C-173	Conventional PVC/SS	173-193	Dedicated low-flow bladder pump
600-E	Open borehole	280	Westbay MP-38
600-G-138	Conventional PVC	138-148	Non-dedicated purge pump and bailer
BLM-3-182[1]	Conventional PVC/SS	182-203	Dedicated bladder pump
BW-3-180	Conventional PVC/SS	179-200	Dedicated low-flow bladder pump
NASA 4	Conventional PVC/SS	146-166	Dedicated bladder pump
WB-1	Open borehole	200, 225, 330	Westbay MP-38
		200 Area Monitoring Wells	
200-B-240[1]	Conventional PVC/SS	240-250	Dedicated low-flow bladder pump
200-C	Open borehole	170, 225, 270	Westbay MP-38
200-D-240	Conventional PVC/SS	240-250	Dedicated low-flow bladder pump
200-F	Open borehole	225, 370, 420	Westbay MP-38
200-G	Open borehole	175, 220, 340, 420, 495	Westbay MP-38
200-H	Open borehole	225, 331, 433	Westbay MP-38
200-I	Open borehole	185, 300, 375, 490, 675, 795	Westbay MP-38
200-JG-110	Conventional PVC w/MSVM	110-130	Dedicated low-flow bladder pump

Table 3.3 WSTF Groundwater Monitoring Wells

Well Name	Well Construction	Monitoring Zone(s) (ft bgs)	Sampling System
200-SG-1[1]	Conventional PVC w/MSVM	123-138	Dedicated bladder pump
200-KV-150	Conventional PVC w/MSVM	150-170	Dedicated low-flow bladder pump
200-LV-150	Conventional PVC w/MSVM	150-170	Dedicated low-flow bladder pump
BW-4	Open borehole	330	Dedicated low-flow bladder pump[2]
300/400 Area Monitoring Wells			
300-A-120[1]	Conventional PVC/SS	121-146	Dedicated low-flow bladder pump
300-A-170	Conventional PVC/SS	170-175	Dedicated low-flow bladder pump
300-B-166	Conventional PVC/SS	166-176	Dedicated low-flow bladder pump
300-C-128	Conventional PVC/SS	128-154	Dedicated low-flow bladder pump
300-D-153	Conventional PVC/SS	153-174	Dedicated bladder pump
300-E	Open borehole	138, 183	Westbay MP-38
400-A-151	Conventional SS	151-176	Dedicated low-flow bladder pump
400-C-143[1]	Conventional SS	143-153	Dedicated low-flow bladder pump
400-D	Open borehole	195, 275, 355	Westbay MP-38
400-EV-131	Conventional SS w/MSVM	131-146	Dedicated low-flow bladder pump
400-FV-131	Conventional SS w/MSVM	131-146	Dedicated low-flow bladder pump
400-GV-125	Conventional SS w/MSVM	125-140	Dedicated low-flow bladder pump
400-HV-147	Conventional SS w/MSVM	147-162	Dedicated low-flow bladder pump
400-IV-123	Conventional SS w/MSVM	123-138	Dedicated low-flow bladder pump
400-JV-150	Conventional PVC w/MSVM	150-165	Dedicated low-flow bladder pump
BW-1-268	Conventional PVC/SS	268-289	Dedicated low-flow bladder pump
BW-5-295	Conventional PVC/SS	295-305	Dedicated low-flow bladder pump
BW-7-211	Conventional PVC/SS	211-222	Dedicated low-flow bladder pump
NASA 5	Conventional PVC/SS	110-130	Dedicated bladder pump
NASA 6	Conventional PVC/SS	128-148	Dedicated bladder pump

Table 3.3 WSTF Groundwater Monitoring Wells

Well Name	Well Construction	Monitoring Zone(s) (ft bgs)	Sampling System
NASA 10	Conventional PVC/SS	110-130	Dedicated bladder pump
Northern Boundary Monitoring Wells			
700-A-253	Conventional SS	253-263	Dedicated low-flow bladder pump
700-B-510	Conventional SS	510-530	Dedicated low-flow bladder pump
700-D-186	Conventional PVC/SS	186-196	Dedicated low-flow bladder pump
700-E-458	Conventional SS	458-479	Dedicated low-flow bladder pump
700-F-455[3]	Conventional SS	455-475	None
700-H	Open borehole	350, 535, 670	Westbay MP-38
700-J-200	Conventional SS	200-220	Dedicated low-flow bladder pump
BLM-24-565	Conventional SS	565-585	Dedicated low-flow bladder pump
BLM-32	Open borehole	543-563, 571-591, 632-647	Water FLUTe
BLM-41-420	Conventional PVC	420-430	Dedicated low-flow bladder pump
BLM-41-670	Conventional PVC	670-680	Dedicated low-flow bladder pump
BW-6-355	Conventional SS	355-375	Dedicated low-flow bladder pump
JER-1	Conventional PVC	483-493, 563-573, 683-693	Water FLUTe
JER-2	Conventional PVC	504-514, 584-894, 683-693	Water FLUTe
Southern Boundary Monitoring Wells			
100-C-365	Conventional SS	365-386	Dedicated low-flow bladder pump
100-E-261	Conventional PVC/SS	261-271	Dedicated low-flow bladder pump
BLM-6-488	Conventional SS	488-498	Dedicated low-flow bladder pump
BLM-13-300	Conventional PVC/SS	300-310	Dedicated low-flow bladder pump
BLM-25-455	Conventional SS	455-465	Dedicated low-flow bladder pump
BLM-28	Open borehole	NA	To be plugged and abandoned
BLM-31[4]	Open borehole	350, 485, 770	Westbay MP-38
BLM-40-517	Conventional PVC	517-527	Dedicated low-flow bladder pump

Table 3.3 WSTF Groundwater Monitoring Wells

Well Name	Well Construction	Monitoring Zone(s) (ft bgs)	Sampling System
BLM-40-595	Conventional PVC	595-605	Dedicated low-flow bladder pump
BLM-40-688	Conventional PVC	688-698	Dedicated low-flow bladder pump
WB-5	Open borehole	250, 280, 345	Westbay MP-38
WB-14	Open borehole	520	Westbay MP-38
MPCA Monitoring Wells			
BLM-5-527	Conventional SS	527-537	Dedicated low-flow bladder pump
BLM-8-418	Conventional SS	418-428	Dedicated low-flow bladder pump
BLM-9-419	Conventional SS	419-440	Dedicated low-flow bladder pump
BLM-14-327	Conventional SS	327-337	Dedicated low-flow bladder pump
BLM-15-305	Conventional PVC/SS	305-315	Dedicated low-flow bladder pump
BLM-18-430	Conventional SS	430-451	Dedicated low-flow bladder pump
BLM-21-400	Conventional SS	400-410	Dedicated low-flow bladder pump
BLM-22-570	Conventional SS	570-592	Dedicated low-flow bladder pump
BLM-23-431	Conventional SS	431-441	Dedicated low-flow bladder pump
BLM-26-404	Conventional SS	404-414	Dedicated low-flow bladder pump
BLM-27-270	Conventional SS	270-280	Dedicated low-flow bladder pump
BLM-36	Conventional SS	350, 610, 800, 860	Westbay MP-38
BLM-38	Conventional SS	480, 620	Westbay MP-38
BLM-39	Conventional SS	385, 560	Westbay MP-38
Main Plume Monitoring Wells			
BLM-1-435	Conventional SS	435-446	Dedicated inflatable packer and bladder pump
BLM-2-630	Conventional SS	630-640	Dedicated low-flow bladder pump
BLM-17-493	Conventional SS	493-513	Dedicated low-flow bladder pump
BLM-17-550	Conventional SS	550-561	Dedicated low-flow bladder pump
PL-1-486	Conventional SS	486-496	Dedicated low-flow bladder pump

Table 3.3 WSTF Groundwater Monitoring Wells

Well Name	Well Construction	Monitoring Zone(s) (ft bgs)	Sampling System
PL-2-504	Conventional SS	405-514	Dedicated low-flow bladder pump
PL-12	Conventional PVC	570-580, 800-810	Dedicated low-flow bladder pumps separated by dedicated inflatable packer
ST-1-473	Conventional SS	473-483	Dedicated low-flow bladder pump
ST-1-541	Conventional SS	541-551	Dedicated low-flow bladder pump
ST-1-630	Conventional SS	630-640	Dedicated low-flow bladder pump
ST-3-486	Conventional SS	486-496	Dedicated low-flow bladder pump
ST-3-586	Conventional SS	586-596	Dedicated low-flow bladder pump
ST-3-666	Conventional SS	666-676	Dedicated low-flow bladder pump
ST-3-735	Conventional SS	735-755	Dedicated low-flow bladder pump
Plume Front Monitoring Wells			
BLM-7-509	Conventional SS	509-520	Dedicated low-flow bladder pump
BLM-10-517	Conventional SS	517-527	Dedicated low-flow bladder pump
PL-3-453	Conventional SS	453-646	Dedicated low-flow bladder pump
PL-4-464	Conventional SS	464-474	Dedicated low-flow bladder pump
PL-6	Conventional SS	545, 725, 915, 1195, 1335	Westbay MP-38
PL-7	Conventional SS	480, 560, 630	Westbay MP-38
ST-2-466	Conventional SS	466-476	Dedicated low-flow bladder pump
ST-4-481	Conventional SS	481-491	Dedicated low-flow bladder pump
ST-4-589	Conventional SS	589-599	Dedicated low-flow bladder pump
ST-4-690	Conventional SS	690-710	Dedicated low-flow bladder pump
ST-5-481	Conventional SS	481-491	Dedicated low-flow bladder pump
ST-5	Conventional SS	485, 655, 815, 985, 1175	Westbay MP-38
ST-6	Conventional SS	528-538, 568-578, 678-688, 824-834, 970-980	Water FLUTe

Table 3.3 WSTF Groundwater Monitoring Wells

Well Name	Well Construction	Monitoring Zone(s) (ft bgs)	Sampling System
ST-7	Conventional SS	453-463, 543-553, 779-789, 970-980	Water FLUTe
WW-1-452	Conventional SS	452-462	Dedicated low-flow bladder pump
		Sentinel Monitoring Wells	
BLM-42	Conventional PVC	569-579, 709-719	Dedicated low-flow bladder pumps separated by dedicated inflatable packer
JP-1-424	Conventional SS	424-434	Dedicated low-flow bladder pump
JP-2-447	Conventional SS	447-457	Dedicated low-flow bladder pump
JP-3	Conventional SS	509-519, 689-699	Dedicated low-flow bladder pumps separated by dedicated inflatable packer
PL-8	Conventional SS	455, 605, 780, 965	Westbay MP-38
PL-10	Conventional SS	592, 484, 813, 962	Westbay MP-55
PL-11	Conventional PVC	470-480, 530-540, 710-720, 820-830, 980-990	Water FLUTe
WW-2	Conventional SS	489-499, 664-674	Dedicated low-flow bladder pumps separated by dedicated inflatable packer
WW-3	Conventional PVC	469, 569, 710, 978	Westbay MP-55
WW-4	Conventional PVC	419-429, 589-599, 848-858, 948-958	Water FLUTe
WW-5	Conventional PVC	459-469, 579-589, 809-819, 909-919	Water FLUTe

[1] – Indicates that the well has been designated for detection monitoring in accordance with Section 3.3.1.

[2] – Indicates that the Westbay sampling system was removed from this well. The current open borehole cannot be sampled. NASA evaluated the borehole and determined that a dedicated low-flow bladder pump will be installed in the open borehole in 2022.

[3] – Indicates that the well is located on the USDA Jornada Experimental Range and no longer accessible to NASA for sampling. NASA is consulting with USDA personnel to determine the well's final disposition.

[4] – Indicates that a deflection in the Westbay casing prevents access to the Westbay sampling zones. The well cannot be sampled. NASA is evaluating the well to determine if reuse, reconfiguration, or replacement is necessary.

NA – Not available/applicable.

MP-38 – Westbay multiport casing with 38 mm (1.5 inch) Inner Diameter

MP-55 – Westbay multiport casing with 55 mm (2.25 inch) Inner Diameter

Table 3.3 WSTF Groundwater Monitoring Wells

Well Name	Well Construction	Monitoring Zone(s) (ft bgs)	Sampling System

MSVM – Multiport soil vapor monitoring
PVC – Polyvinyl chloride
SS – Stainless-steel

Table 9.1 Preferred Analytical Requirements for VOCs, Nitrosamines, and Metals in WSTF Groundwater

CAS Number	Analyte	Preferred MDL – 20% of Cleanup Level[1]	Preferred PQL[1]	Unit
	VOCs by SW-846 Method 8260 (current version)			
100-41-4	Ethylbenzene	3.0	15	µg/L
100-42-5	Styrene	20	100	µg/L
107-06-2	1,2-Dichloroethane (EDC)	0.34	1.7	µg/L
107-12-0	Propionitrile	NA[2]	NA[2]	µg/L
107-13-1	Acrylonitrile	0.104	0.52	µg/L
108-88-3	Toluene	150	750	µg/L
108-90-7	Chlorobenzene	15.6	78	µg/L
109-99-9	Tetrahydrofuran (THF)	NA[2]	NA[2]	µg/L
127-18-4	Tetrachloroethene (PCE)	1.0	5.0	µg/L
1330-20-7	m,p-Xylenes	38	190	µg/L
156-60-5	trans-1,2-Dichloroethene	13.6	68	µg/L
306-83-2	2,2-Dichloro-1,1,1-trifluoroethane (Freon123)	NA[2]	NA[2]	µg/L
354-23-4	1,2-Dichloro-1,1,2-trifluoroethane (Freon123a)	NA[2]	NA[2]	µg/L
56-23-5	Carbon tetrachloride	0.92	4.6	µg/L
67-63-0	2-Propanol	NA[2]	NA[2]	µg/L
67-64-1	Acetone	2,800	14,000	µg/L
67-66-3	Chloroform	0.44	2.2	µg/L
71-43-2	Benzene	0.92	4.6	µg/L
71-55-6	1,1,1-Trichloroethane (TCA)	12	60	µg/L
74-83-9	Bromomethane	1.5	7.5	µg/L
74-87-3	Chloromethane	38	190	µg/L
75-00-3	Chloroethane	4,200	21,000	µg/L
75-01-4	Vinyl chloride	0.038	0.19	µg/L
75-09-2	Methylene chloride	1.0	5.0	µg/L
75-15-0	Carbon disulfide	162	810	µg/L
75-25-2	Bromoform	6.6	33	µg/L
75-27-4	Bromodichloromethane	0.26	1.3	µg/L
75-34-3	1,1-Dichloroethane	5.0	25	µg/L
75-35-4	1,1-Dichloroethene	1.0	5.0	µg/L
75-43-4	Dichlorofluoromethane (Freon 21)	NA[2]	NA[2]	µg/L
75-69-4	Trichlorofluoromethane (Freon11)	1,040	5,200	µg/L
75-71-8	Dichlorodifluoromethane (Freon12)	40	200	µg/L
76-13-1	1,1,2-Trichloro-1,2,2-trifluoroethane (Freon 113)	NA[2]	NA[2]	µg/L
78-87-5	1,2-Dichloropropane (DCPA)	1	5	µg/L

Table 9.1 Preferred Analytical Requirements for VOCs, Nitrosamines, and Metals in WSTF Groundwater

CAS Number	Analyte	Preferred MDL – 20% of Cleanup Level[1]	Preferred PQL[1]	Unit
78-93-3	2-Butanone (MEK)	1,120	5,600	µg/L
79-00-5	1,1,2-Trichloroethane	0.56	2.8	µg/L
79-01-6	Trichloroethene (TCE)	0.98	4.9	µg/L
Nitrosamines by Low-Level Analytical Method				
4164-28-7	N-Nitrodimethylamine	NA[2]	NA[2]	µg/L
62-75-9	N-Nitrosodimethylamine	0.00022	0.0011	µg/L
Metals by Laboratory-Specified Best Method				
7439-92-1	Lead	0.003	0.015	mg/L
7439-97-6	Mercury	0.0004	0.002	mg/L
7440-02-0	Nickel	0.04	0.20	mg/L
7440-22-4	Silver	0.01	0.050	mg/L
7440-23-5	Sodium	NA[2]	NA[2]	mg/L
7440-24-6	Strontium	1.86	9.3	mg/L
7440-28-0	Thallium	0.00004	0.0002	mg/L
7440-31-5	Tin	2.4	12	mg/L
7440-36-0	Antimony	0.0012	0.0060	mg/L
7440-38-2	Arsenic	0.002	0.01	mg/L
7440-39-3	Barium	0.2	1.0	mg/L
7440-41-7	Beryllium	0.0008	0.004	mg/L
7440-42-8	Boron	0.15	0.75	mg/L
7440-43-9	Cadmium	0.001	0.005	mg/L
7440-70-2	Calcium	NA[2]	NA[2]	mg/L
7440-47-3	Chromium	0.01	0.05	mg/L
7440-48-4	Cobalt	0.0012	0.006	mg/L
7440-50-8	Copper	0.20	1.0	mg/L
7440-62-2	Vanadium	0.0172	0.086	mg/L
7440-66-6	Zinc	2	10	mg/L
7782-49-2	Selenium	0.01	0.05	mg/L

NA – Not Available/Applicable

[1] – These are the maximum preferred analytical requirements allowed by Permit Section 17.3.

[2] – Indicates that the analytical laboratory will be required to provide the best achievable level for review prior to performing analytical work related to the WSTF groundwater monitoring program.

Table 9.2 Preferred Analytical Requirements for Inorganics, SVOCs, and Miscellaneous COCs in WSTF Groundwater

CAS Number	Analyte	Recommended Analytical Method	Preferred MDL[1] – 20% of Cleanup Level	Preferred PQL[1]
Inorganic Compounds by Various Methods				
14797-55-8	Nitrate/Nitrite as N	300.0	2.0 mg/L	10 mg/L
14797-73-0	Perchlorate	331.0	2.2 µg/L	11 µg/L
14808-79-8	Sulfate	300.0	NA[2]	NA[2]
16887-00-6	Chloride	300.0	NA[2]	NA[2]
16984-48-8	Fluoride	300.0	NA[2]	NA[2]
NA	Alkalinity	SM2320	NA[2]	NA[2]
NA	Total Dissolved Solids (TDS)	SM2540	100 mg/L	500 mg/L
SVOCs by Various Methods				
84-74-2	Di-n-butylphthalate	SW-846 Method 8270	180 µg/L	900 µg/L
108-39-4	m-Cresol	SW-846 Method 8270	186 µg/L	930 µg/L
117-81-7	Bis(2-Ethylhexyl)phthalate	SW-846 Method 8270	1.2 µg/L	6.0 µg/L
314-40-9	Bromacil	Modified EPA Method 607	NA[2]	NA[2]
123-91-1	1,4-Dioxane	SW-846 Method 8270 SIM	0.92 µg/L	4.59 µg/L
Miscellaneous Constituents by Various Methods				
108-95-2	Phenol	SW-846 Method 9066	1.0 µg/L	5.0 µg/L
30402-15-4	Total Penta CDF	SW-846 Method 8290	NA[2]	NA[2]
3268-87-9	Octachlorodibenzo-p-dioxin (OCDD)	SW-846 Method 8290	NA[2]	NA[2]
39001-02-0	Octachlorodibenzofuran (OCDF)	SW-846 Method 8290	NA[2]	NA[2]
41903-57-5	Total Tetra CDD	SW-846 Method 8290	NA[2]	NA[2]
55684-94-1	Hexachlorodibenzofurans (HxCDF), Total	SW-846 Method 8290	NA[2]	NA[2]
57-12-5	Total Cyanide	SW-846 Method 9012	0.04 mg/L	0.2 mg/L

Table 9.2 Preferred Analytical Requirements for Inorganics, SVOCs, and Miscellaneous COCs in WSTF Groundwater

CAS Number	Analyte	Recommended Analytical Method	Preferred MDL[1] – 20% of Cleanup Level	Preferred PQL[1]
93-72-1	2,4,5-TP (Silvex)	SW-846 Method 8151	10 μg/L	50 μg/L
8006-61-9	GRO	SW-846 Method 8015	50 μg/L[3]	100 μg/L[3]
68334-30-5	DRO	SW-846 Method 8015	50 μg/L[3]	100 μg/L[3]
NA	Sulfide	SW-846 Method 9030	NA[2]	NA[2]

NA – Not Available/Applicable

[1] – These are the maximum preferred analytical requirements allowed by Permit Section 17.3.

[2] – Indicates that the analytical laboratory will be required to provide the best achievable level for review prior to performing analytical work related to the WSTF groundwater monitoring program.

[3] – Indicates that the constituent is not a hazardous constituent with a WSTF groundwater cleanup level and that the MDL and PQL are recommended to meet project objectives in the SMWU 50 Investigation Work Plan (NASA, 2017c).

Table 10.1 Field Quality Control Samples

QC Sample	QC Sample Description and Purpose
Equipment Blank	A sample of analyte-free purified water which has been used to rinse common sampling equipment to check effectiveness of decontamination procedures. This type of blank also indicates contamination in the field and during handling, transport, shipping, laboratory, and analytical processes which may affect analytical results.
Field Blank	A blank prepared in the field by filling a clean sample container with analyte-free purified water and appropriate preservative, if any, for the specific sampling activity being undertaken. This type of sample provides a check for contamination derived in the field and during handling, transport, shipping, laboratory, and analytical processes.
Trip Blank	A sample of analyte-free purified water prepared in a contaminant free environment that is carried to the sampling site and transported to the laboratory for analysis without having been exposed to sampling procedures. This type of sample serves as a check on sample contamination originating from sample handling, transport, shipping, site conditions, laboratory, and analytical processes.
Field Duplicate Sample	A second sample is taken immediately after an original sample at the same sampling location. This sample provides an estimate of the overall system precision.

Table 10.2 Frequencies for the Collection of Field Quality Control Samples

QC Sample	Frequency for VOCs	Frequency for High Level Nitrosamines Method	Frequency for Low Level Nitrosamines Method	Frequency for Metals
Equipment Blank	100% of all VOC sampling events where non-dedicated sampling equipment is used. Not applicable if dedicated sampling equipment is used.	2% of all high-level nitrosamines sampling events where non-dedicated sampling equipment is used. Not applicable if dedicated sampling equipment is used.	100% of all low-level nitrosamines sampling events where non-dedicated sampling equipment is used. Not applicable if dedicated sampling equipment is used.	5% of all metals sampling events where non-dedicated sampling equipment is used. Not applicable if dedicated sampling equipment is used.
Field Blank	100% of all VOC sampling events where dedicated sampling equipment is used. Not required if non-dedicated sampling equipment is used and a VOC equipment blank is collected in the field.	Not required if a high-level equipment blank is collected in the field, otherwise 2% of all high-level nitrosamines sampling events.	100% of all low-level nitrosamines sampling events where dedicated sampling equipment is used. Not required if non-dedicated sampling equipment is used and a low-level nitrosamines equipment blank is collected in the field.	Not required if a metals equipment blank is collected in the field, otherwise 5% of all metals sampling events.
Trip Blank	Collected for VOC sampling event at a frequency sufficient to fulfill minimum requirement of one trip blank per VOC sample shipment.	Not required.	Collected for low-level nitrosamines sampling event at a frequency sufficient to fulfill minimum requirement of one trip blank per low level nitrosamines sample shipment.	Not required.
Field Duplicate Sample	10% of all VOC sampling events.	10% of all high-level nitrosamines sampling events.	10% of all low-level nitrosamines sampling events.	10% of all metals sampling events

Table 10.3 Evaluation Criteria and Corrective Action for Field QC Samples

QC Sample	Evaluation Criteria and Corrective Action
Equipment Blank	In the event of equipment blank contamination, analytical data shall be qualified if the concentration of an analyte in the blank is greater than 1/10 of the amount measured in the sample. The primary reason to collect an equipment blank is to check effectiveness of equipment decontamination procedures. However, an equipment blank is also subject to the same field, handling, transport, shipping, laboratory, and analytical conditions as the sample. To determine whether equipment blank contamination results from ineffective equipment decontamination procedures, all blank and sample contamination must be evaluated. When significant and consistent equipment blank contamination is present, the cause must be investigated and corrective action taken to minimize or eliminate the problem.
Field Blank	In the event of field blank contamination, analytical data shall be qualified if the concentration of an analyte in the blank is greater than 1/10 of the amount measured in the sample. The primary reason to collect a field blank is to check for contamination derived in the field. However, a field blank is also subject to the same handling, transport, shipping, laboratory, and analytical conditions as the sample. To determine whether field blank contamination results from field conditions, all blank and sample contamination must be evaluated. When significant and consistent field blank contamination is present, the cause must be investigated and corrective action taken to minimize or eliminate the problem.
Trip Blank	In the event of trip blank contamination, analytical data shall be qualified if the concentration of an analyte in the blank is greater than 1/10 of the amount measured in the sample. The primary reason to collect a trip blank is to check for contamination derived from sample handling, transport, shipping, and site conditions. However, a trip blank is also subject to the same laboratory and analytical conditions as the sample. To determine whether trip blank contamination results from sample handling, transport, shipping, or site conditions, all blank and sample contamination must be evaluated. When significant and consistent trip blank contamination is present, the cause must be investigated and corrective action taken to minimize or eliminate the problem.
Field Duplicate Sample	The results from field duplicate samples are primarily designed to estimate overall system precision. Precision is expressed as RPD (relative percent difference). Results are compared to the evaluation criteria for field duplicate samples in the test method. Where there are no established criteria for field duplicate samples, the WSTF contractor environmental organization shall determine internal criteria, such as adopting analyst duplicate or laboratory control sample duplicate criteria, and document the method used to establish the limits. For field duplicate results outside established criteria, the data shall be reported with appropriate data qualifying codes. When field duplicate precision is significantly and consistently outside evaluation criteria, corrective action shall be taken to minimize or eliminate the problem.

Table 10.4 Descriptions of Laboratory Quality Control Samples

QC Sample	QC Sample Description
Method Blank	Analyte-free deionized water processed simultaneously with and under the same conditions as samples through all steps of the analytical procedures, and in which no analytes or interferences are present at concentrations that impact the analytical results for sample analyses. The method blank is used to assess the preparation or analytical batch for possible contamination during the preparation and processing steps.
Laboratory Control Sample	Analyte-free deionized water spiked with verified known amounts of analytes or a material containing known and verified amounts of analytes. The laboratory control sample is used to evaluate the performance of the total analytical system (i.e., for systematic error or bias) including all preparation and analysis steps.
Matrix Spike	A sample prepared by adding a known mass of analyte to a specified amount of matrix sample for which an independent estimate of analyte concentration is available. Matrix spike samples are used to indicate the effect of the sample matrix on the accuracy of the results generated using the selected method. The information from these controls is sample/matrix specific and would not normally be used to determine the validity of the entire batch.
Matrix Spike Duplicate	A second replicate matrix spike prepared in the laboratory and analyzed to obtain a measure of the precision of the recovery for each analyte.
Surrogate Spike	Introduction of a compound into the samples, blanks, and laboratory control samples similar to the analytes of interest, but not normally found in environmental samples, blanks and laboratory control samples. The surrogate spike provides a continuous monitor of the performance of the analytical system and the effectiveness of the method in dealing with sample matrices.

Table 10.5 Frequency of Analysis for Laboratory Quality Control Samples

QC Sample	Frequency for VOCs	Frequency for High Level Nitrosamines Method	Frequency for Low Level Nitrosamines Method	Frequency for Metals
Method Blank	One for each preparation or analytical batch of 20 groundwater samples or less.	One for each preparation batch of 20 groundwater samples or less.	One for each preparation batch of 20 groundwater samples or less.	One for each preparation batch of 20 groundwater samples or less.
Laboratory Control Sample	One for each preparation or analytical batch of 20 groundwater samples or less.	One for each preparation batch of 20 groundwater samples or less.	One for each preparation batch of 20 groundwater samples or less.	One for each preparation batch of 20 groundwater samples or less.
Matrix Spike/Matrix Spike Duplicate[1]	2% of groundwater samples analyzed.	2% of groundwater samples analyzed.	2% of groundwater samples analyzed.	2% of groundwater samples analyzed.
Surrogate Spike	100% of all blanks, groundwater samples and standards.	100% of all blanks, groundwater samples and standards.	100% of all blanks, groundwater samples and standards.	Not applicable.

[1] – WSTF matrix spike samples are collected in the field specifically as matrix spikes and delivered to the analytical laboratory to be appropriately spiked and analyzed. The analytical laboratory is required to spike these samples as specified in the method regardless of the requirements for other project samples in the same analytical batch. In this way, matrix specific recovery for WSTF groundwater is monitored without placing onerous requirements on the analytical laboratory. Historically, matrix effects on volatiles, semi-volatiles, and metals analysis of WSTF groundwater are not significant. Therefore, the frequencies of these samples have been decreased from historical levels to levels sufficient to monitor potential changes in the matrix.

Table 10.6 Evaluation Criteria and Corrective Action for Laboratory QC Samples

QC Sample	Evaluation Criteria and Corrective Action
Method Blank	While the goal is to have no detectable contaminants, each method blank must be critically evaluated as to the nature of the interference and the effect on the analysis of each sample with the batch. The source of contamination shall be investigated and measures taken to minimize or eliminate the problem and affected samples reprocessed or data shall be appropriately qualified if: 1. The concentration of an analyte in the blank is at or above the quantitation limit, and is greater than 1/10 of the amount measured in any sample, or; 2. The blank contamination otherwise affects the sample results as per the method requirements. When a blank is determined to be contaminated, the cause must be investigated and measures taken to minimize or eliminate the problem. Samples associated with a contaminated blank shall be evaluated as to the best corrective action for the samples (e.g. reprocessing or data qualifying codes). In all cases the corrective action must be documented by the laboratory.
Laboratory Control Sample	The results of the individual batch laboratory control sample are calculated in percent recovery (bias) allowing comparison to method or laboratory established evaluation criteria. The individual laboratory control sample is compared to the evaluation criteria as published in the test method. Where there are no established criteria, the laboratory shall determine internal criteria and document the method used to establish the limits. A laboratory control sample that is determined to be within the criteria effectively establishes that the analytical system is in control and validates system performance for the samples in the associated batch. Samples analyzed along with a laboratory control sample determined to be "out of control" shall be considered suspect and the samples reprocessed and re-analyzed or the data reported with appropriate data qualifying codes. If a large number of analytes are in the laboratory control sample, it becomes statistically likely that a few will be outside control limits. Contracted laboratories shall refer to the NELAC accreditation standards for handling marginal laboratory control sample exceedances for laboratory control samples with a large number of analytes.
Matrix Spike/Matrix Spike Duplicate	The results from the matrix spike/matrix spike duplicate are primarily designed to assess the accuracy of analytical results in a given matrix and are expressed as bias, or percent recovery, and precision, or relative percent difference. The laboratory shall document the calculation for percent recovery and relative percent difference. The results are compared to the evaluation criteria as published in the test method. Where there are no established criteria, the laboratory shall determine internal criteria and document the method used to establish the limits. For matrix spike results outside established criteria, corrective action shall be documented or the data reported with appropriate data qualifying codes.
Surrogate Spike	Surrogate spike results are compared to the evaluation criteria as published in the test method. Where there are no established criteria, the laboratory

Table 10.6 Evaluation Criteria and Corrective Action for Laboratory QC Samples

QC Sample	Evaluation Criteria and Corrective Action
	shall determine internal criteria and document the method used to establish the limits. Surrogates outside the evaluation criteria must be evaluated for the effect on individual sample results. Results reported from analyses with "out of control" surrogate recoveries should include appropriate data qualifiers.

Table 10.7 Description of WSTF Data Qualifiers

Data Qualifier	Description
*	User defined qualifier. See specific quality assurance narrative.
A	The result of an analyte for a laboratory control sample (LCS), initial calibration verification (ICV) or continuing calibration verification (CCV) was outside standard limits.
AD	Relative percent difference for analyst (laboratory) duplicates was outside standard limits.
D	The reported result is from a dilution.
EB	The analyte was detected in the equipment blank.
FB	The analyte was detected in the field blank.
G	The result is an estimated value greater than the upper calibration limit.
i	The result, quantitation limit, and/or detection limit may have been affected by matrix interference.
J	The result is an estimated value less than the quantitation limit, but greater than or equal to the detection limit.
NA	The value/result was either not analyzed for or not applicable.
ND	The analyte was not detected above the detection limit.
Q	The result for a blind control sample was outside standard limits.
QD	The relative percent difference for a field duplicate was outside standard limits.
R	The result is rejected due to serious deficiencies in the ability to analyze the sample and meet quality control criteria. The presence or absence of the analyte cannot be verified.
RB	The analyte was detected in the method blank.
S	The result was determined by the method of standard addition.
SP	The matrix spike recovery and/or the relative percent difference for matrix spike duplicates was outside standard limits.
T	The sample was analyzed outside the specified holding time or temperature.
TB	The analyte was detected in the trip blank.
TIC	The analyte was tentatively identified by a GC/MS library search and the amount reported is an estimated value.

Table 11.1 Sampling Frequencies of WSTF Groundwater Monitoring Wells/Zones

Well/Zone	VOC	NDMA[1]	Metals	Inorganics	SVOC	Misc.	Comments
Upgradient Monitoring Wells/Zones							
100-F-358	SA	SA	A	A	A	SA[2]	Annual Appendix IX, 1,4-Dioxane
100-G-223	SA	SA	A	A	A	SA[2], A[3], Once[4]	Annual Appendix IX, Annual SWMU 50, 1,4-Dioxane, 2022 PFAS
300-F-175	SA	SA	A	A	A	SA[2]	Annual Appendix IX, 1,4-Dioxane
NASA 3	SA	SA	A	A	A	A	Annual Appendix IX
100/600 Area Monitoring Wells/Zones							
100-A-182	A		A	TA	A[5]	A[3], Once[4]	Annual SWMU 50, 2022 PFAS
100-D-176	A		A	TA	A[5]	A[3], Once[4]	Annual SWMU 50, 2022 PFAS
100-HG-139	A		A	TA	A[5]		
600-C-173	A		A	TA	A[5]	Once[4]	2022 PFAS
600-E-280	A		A	TA	A[5]	Once[4]	2022 PFAS
600-G-138	A		A	TA	A[5]	Once[4]	2022 PFAS
BLM-3-182[6]	A		A	TA	A[5]	Once[4]	Annual Appendix IX, 2022 PFAS
BW-3-180	SA		SA	BA	SA[5]		
NASA 4	A		A	TA	A[5]		
WB-1-200	A		A	TA	A[5]		
WB-1-255	A		A	TA	A[5]		
WB-1-330	A		A	TA	A[5]	Once[4]	2022 PFAS
200 Area Monitoring Wells/Zones							
200-B-240[5]	A	A	A	TA	A[5]	Once[4]	Annual Appendix IX, 2022 PFAS
200-C-170	A	A	A	TA	A[5]		
200-C-225	A	A	A	TA	A[5]		
200-C-270	A	A	A	TA	A[5]		
200-D-240	A	A	A	TA	A[5]		

Table 11.1 Sampling Frequencies of WSTF Groundwater Monitoring Wells/Zones

Well/Zone	VOC	NDMA[1]	Metals	Inorganics	SVOC	Misc.	Comments
200-F-225	A	A	A	TA	A[5]		
200-F-370	A	A	A	TA	A[5]		
200-F-420	A	A	A	TA	A[5]		
200-G-175	A	A	A	TA	A[5]		
200-G-220	A	A	A	TA	A[5]		
200-G-340	A	A	A	TA	A[5]		
200-G-420	A	A	A	TA	A[5]		
200-G-495	A	A	A	TA	A[5]		
200-H-225	A	A	A	TA	A[5]		
200-H-331	A	A	A	TA	A[5]		
200-H-433	A	A	A	TA	A[5]		
200-I-185	A	A	A	TA	A[5]		
200-I-300	A	A	A	TA	A[5]		
200-I-375	A	A	A	TA	A		
200-I-490	A	A	A	TA	A[5]		
200-I-675	A	A	A	TA	A[5]		
200-I-795	A	A	A	TA	A[5]		
200-JG-110	A	A	A	TA	A[5]		
200-SG-1[5]	A	A	A	TA	A[5]	A	Annual Appendix IX
200-KV-150	A	A	A	TA	A[5]		
200-LV-150	A	A	A	TA	A[5]		
300/400 Area Monitoring Wells/Zones							
300-A-120[5]	A	A	A	TA	A[5]	A	Annual Appendix IX
300-A-170	A	A	A	TA	A[5]		
300-B-166	A	A	A	TA	A[5]		
300-C-128	A	A	A	TA	A[5]		

Table 11.1 Sampling Frequencies of WSTF Groundwater Monitoring Wells/Zones

Well/Zone	VOC	NDMA[1]	Metals	Inorganics	SVOC	Misc.	Comments
300-D-153	A	A	A	TA	A[5]		
300-E-138	A	A	A	TA	A[5]		
300-E-183	A	A	A	TA	A[5]		
400-A-151	A	A	A	TA	A[5]		
400-C-143[5]	A	A	A	TA	A[5]	A	Annual Appendix IX
400-D-195	A	A	A	TA	A[5]		
400-D-275	A	A	A	TA	A[5]		
400-D-355	A	A	A	TA	A[5]		
400-EV-131	SA	A	A	TA	A[5]		
400-FV-131	SA	A	A	TA	A[5]		
400-GV-125	SA	A	A	TA	A[5]		
400-HV-147	SA	A	A	TA	A[5]		
400-IV-123	A	A	A	TA	A[5]		
400-JV-150	SA	A	A	TA	A[5]		
BW-1-268	SA	SA	SA	BA	SA[5]		
BW-5-295	SA	SA	SA	BA	SA[5]		
BW-7-211	SA	SA	SA	BA	SA[5]		
NASA 5	A	A	A	TA	A[5]		
NASA 6	A	A	A	TA	A[5]		
NASA 10	A	A	A	TA	A[5]		
Northern Boundary Monitoring Wells/Zones							
700-A-253	SA	SA	A	BA	A[5]	Once[4]	SA Landfill, 2022 PFAS
700-B-510	A	A	A	BA	A[5]		
700-D-186	SA	SA	A	BA	A[5]	Once[4]	SA Landfill, 2022 PFAS
700-E-458	A	A	A	BA	A[5]		
700-F-455[7]							

Table 11.1 Sampling Frequencies of WSTF Groundwater Monitoring Wells/Zones

Well/Zone	VOC	NDMA[1]	Metals	Inorganics	SVOC	Misc.	Comments
700-H-350	SA	SA	A	BA	A[5]	Once[4]	SA Landfill, 2022 PFAS
700-H-535	SA	SA	A	BA	A[5]		SA Landfill
700-H-670	SA	SA	A	BA	A[5]		SA Landfill
700-J-200	SA	SA	A	BA	A[5]	Once[4]	SA Landfill, 2022 PFAS
BLM-24-565	SA	SA	A	BA	A[5]		
BLM-32-543	Q	Q	A	BA	A		
BLM-32-571	Q	Q	A	BA	A		
BLM-32-632	Q	Q	A	BA	A		
BLM-41-420	SA	SA	A	BA	A[5]		
BLM-41-670	SA	SA	A	BA	A[5]		
BW-6-355	SA	SA	A	BA	A[5]		
JER-1-483	Q	Q	A	BA	A, Q[2]		1,4-Dioxane
JER-1-563	Q	Q	A	BA	A, Q[2]		1,4-Dioxane
JER-1-683	Q	Q	A	BA	A, Q[2]		1,4-Dioxane
JER-2-504	Q	Q	A	BA	A, Q[2]		1,4-Dioxane
JER-2-584	Q	Q	A	BA	A, Q[2]		1,4-Dioxane
JER-2-684	Q	Q	A	BA	A, Q[2]		1,4-Dioxane
Southern Boundary Monitoring Wells/Zones							
100-C-365	A		A	BA	A[5]	A[3], Once[4]	Annual SWMU 50, 2022 PFAS
100-E-261	A		A	BA	A[5]	A[3]	Annual SWMU 50
BLM-6-488	Q	Q	A	BA	A[5]	A[3], Once[4]	Annual SWMU 50, 2022 PFAS
BLM-13-300	A	A	A	BA	A[5]	A[3], Once[4]	Annual SWMU 50, 2022 PFAS
BLM-25-455	A	A	A	BA	A[5]	A[3]	Annual SWMU 50
BLM-40-517	SA	SA	A	BA	A[5]	A[3]	Annual SWMU 50
BLM-40-595	SA	SA	A	BA	A[5]		

Table 11.1 Sampling Frequencies of WSTF Groundwater Monitoring Wells/Zones

Well/Zone	VOC	NDMA[1]	Metals	Inorganics	SVOC	Misc.	Comments
BLM-40-688	SA	SA	A	BA	A[5]		
WB-5-250	A		A	BA	A[5]		
WB-5-280	A		A	BA	A[5]		
WB-5-345	A		A	BA	A[5]		
WB-14-520	A		A	BA	A[5]		
MPCA Monitoring Wells/Zones							
BLM-5-527	SA	SA	A	BA	A[5]		
BLM-8-418	SA	SA	A	BA	A[5]		
BLM-9-419	SA	SA	A	BA	A[5]	Once[4]	2022 PFAS
BLM-14-327	SA	SA	A	BA	A[5]	Once[4]	2022 PFAS
BLM-15-305	SA	SA	A	BA	A[5]		
BLM-18-430	SA	SA	A	BA	A[5]		
BLM-21-400	SA	SA	A	BA	A[5]		
BLM-22-570	SA	SA	A	BA	A[5]		
BLM-23-431	SA	SA	A	BA	A[5]		
BLM-26-404	SA	SA	A	BA	A[5]		
BLM-27-270	SA	SA	A	BA	A[5]		
BLM-36-350	SA	SA	A	BA	A[5]		
BLM-36-610	SA	SA	A	BA	A[5]		
BLM-36-800	SA	SA	A	BA	A[5]		
BLM-36-860	SA	SA	A	BA	A[5]		
BLM-38-480	SA	SA	A	BA	A[5]		
BLM-38-620	SA	SA	A	BA	A[5]		
BLM-39-385	SA	SA	A	BA	A[5]		
BLM-39-560	SA	SA	A	BA	A[5]		

Table 11.1 Sampling Frequencies of WSTF Groundwater Monitoring Wells/Zones

Well/Zone	VOC	NDMA[1]	Metals	Inorganics	SVOC	Misc.	Comments
Main Plume Monitoring Wells/Zones							
BLM-1-435	SA	SA	A	BA	A[5]		
BLM-2-630	SA	SA	A	BA	A[5]		
BLM-17-493	SA	SA	A	BA	A[5]		
BLM-17-550	SA	SA	A	BA	A[5]		
PL-1-486	Q	Q	A	BA	A[5]		
PL-2-504	Q	Q	A	BA	A[5]	Once[4]	2022 PFAS
PL-12-570	Q	Q	A	BA	A[5]		
PL-12-800	Q	Q	A	BA	A[5]		
ST-1-473	SA	SA	A	BA	A[5]		
ST-1-541	SA	SA	A	BA	A[5]	Once[4]	2022 PFAS
ST-1-630	SA	SA	A	BA	A[5]		
ST-3-486	SA	SA	A	BA	A[5]		
ST-3-586	SA	SA	A	BA	A[5]		
ST-3-666	SA	SA	A	BA	A[5]		
ST-3-735	SA	SA	A	BA	A[5]		
Plume Front Monitoring Wells/Zones							
BLM-7-509	Q	Q	A	BA	A[5]		
BLM-10-517	Q	Q	A	BA	A[5]		
PL-3-453	Q	Q	A	BA	A[5]		
PL-4-464	Q	Q	A	BA	A[5]		
PL-6-545	Q	Q	A	BA	A[5]		
PL-6-725	Q	Q	A	BA	A[5]		
PL-6-915	A	A	A	BA	A[5]		
PL-6-1195	A	A	A	BA	A[5]		

Table 11.1 Sampling Frequencies of WSTF Groundwater Monitoring Wells/Zones

Well/Zone	VOC	NDMA[1]	Metals	Inorganics	SVOC	Misc.	Comments
PL-6-1335	A	A	A	BA	A[5]		
PL-7-480	Q	Q	A	BA	A[5]		
PL-7-560	Q	Q	A	BA	A[5]		
PL-7-630	A	A	A	BA	A[5]		
ST-2-466	A	A	A	BA	A[5]		
ST-4-481	Q	Q	A	BA	A[5]		
ST-4-589	Q	Q	A	BA	A[5]		
ST-4-690	Q	Q	A	BA	A[5]		
ST-5-481	A	A	A	BA	A[5]		
ST-5-485	Q	Q	A	BA	A[5]	Once[4]	2022 PFAS
ST-5-655	Q	Q	A	BA	A[5]		
ST-5-815	A	A	A	BA	A[5]		
ST-5-985	A	A	A	BA	A[5]		
ST-5-1175	A	A	A	BA	A[5]		
ST-6-528	Q	Q	A	BA	A	Q[2]	1,4-Dioxane
ST-6-568	Q	Q	A	BA	A	Q[2], Once[4]	1,4-Dioxane, 2022 PFAS
ST-6-678	Q	Q	A	BA	A	Q[2]	1,4-Dioxane
ST-6-824	Q	Q	A	BA	A		
ST-6-970	Q	Q	A	BA	A		
ST-7-453	Q	Q	A	BA	A		
ST-7-544	Q	Q	A	BA	A		
ST-7-779	Q	Q	A	BA	A		
ST-7-970	Q	Q	A	BA	A		
WW-1-452	Q	Q	A	BA	A[5]	Once[4]	2022 PFAS
Sentinel Monitoring Wells/Zones							
BLM-42-569	Q	Q	A	BA	BA[5]		

Table 11.1 Sampling Frequencies of WSTF Groundwater Monitoring Wells/Zones

Well/Zone	VOC	NDMA[1]	Metals	Inorganics	SVOC	Misc.	Comments
BLM-42-689	Q	Q	A	BA	BA[5]		
JP-1-424	Q	Q	A	BA	BA[5]		
JP-2-447	Q	Q	A	BA	BA[5]		
JP-3-509	Q	Q	A	BA	BA[5]		
JP-3-689	Q	Q	A	BA	BA[5]		
PL-8-455	Q	Q	A	BA	BA[5]	Q[2]	1,4-Dioxane
PL-8-605	Q	Q	A	BA	BA[5]	Q[2]	1,4-Dioxane
PL-8-780	A	A	A	BA	BA[5]		
PL-8-965	A	A	A	BA	BA[5]		
PL-10-484	Q	Q	A	BA	BA[5]	Q[2]	1,4-Dioxane
PL-10-592	Q	Q	A	BA	BA[5]	Q[2]	1,4-Dioxane
PL-10-813	A	A	A	BA	BA[5]		
PL-10-962	A	A	A	BA	BA[5]		
PL-11-470	Q	Q	A	BA	A	Q[2]	1,4-Dioxane
PL-11-530	Q	Q	A	BA	A	Q[2]	1,4-Dioxane
PL-11-710	Q	Q	A	BA	A	Q[2]	1,4-Dioxane
PL-11-820	Q	Q	A	BA	A		
PL-11-980	Q	Q	A	BA	A		
WW-2-489	Q	Q	A	BA	BA[5]		
WW-2-664	Q	Q	A	BA	BA[5]		
WW-3-469	Q	Q	A	BA	BA[5]		
WW-3-569	Q	Q	A	BA	BA[5]	Once[4]	2022 PFAS
WW-3-710	A	A	A	BA	BA[5]		
WW-3-978	A	A	A	BA	BA[5]		
WW-4-419	Q	Q	A	BA	Q		
WW-4-589	Q	Q	A	BA	Q	Once[4]	2022 PFAS

Table 11.1 Sampling Frequencies of WSTF Groundwater Monitoring Wells/Zones

Well/Zone	VOC	NDMA[1]	Metals	Inorganics	SVOC	Misc.	Comments
WW-4-848	Q	Q	A	BA	Q		
WW-4-948	Q	Q	A	BA	Q		
WW-5-459	Q	Q	A	BA	A	Once[4]	2022 PFAS
WW-5-579	Q	Q	A	BA	A		
WW-5-809	Q	Q	A	BA	A		
WW-5-909	Q	Q	A	BA	A		

[1] – The selection of the appropriate analytical method for the analysis of NDMA (Modified EPA Method 607 or the approved low-level method) is based on location and expected concentration at the designated well/zone.

[2] – Indicates that the well has been designated for sampling of 1,4-dioxane in accordance with NMED direction provided in NMED's December 19, 2017 *Approval with Modifications Groundwater Monitoring Plan* (NMED, 2017b).

[3] – Indicates that the well is sampled annually for PAH and TPH (DRO and GRO) in accordance with the NMED-approved *First Tracking Data Relay Satellite System (TDRSS) Diesel Release (SWMU 50) Investigation Work Plan* (NASA, 2017c), submitted to NMED on July 27, 2017.

[4] – Indicates that the well will be sampled for additional PFAS screening in accordance with NMED direction provided on November 15, 2021 in the *Approval with Modifications White Sands Test Facility Groundwater Monitoring Plan* (NMED, 2021e).

[5] – Indicates that the well/zone will be sampled for bromacil only.

[6] – Indicates that the well/zone has been designated for detection monitoring in accordance with Section 3.3.1.

[7] – Indicates that the well is located on the USDA Jornada Experimental Range and no longer accessible to NASA for sampling. NASA is consulting with USDA personnel to determine the well's final disposition.

A – Indicates that sampling is performed for this analysis annually.

BA – Indicates that sampling is performed for this analysis biennially.

Q – Indicates that sampling is performed for this analysis quarterly.

SA – Indicates that sampling is performed for this analysis semi-annually.

SA Landfill – Indicates that the well is sampled semi-annually in accordance with 20.9.9 NMAC and the *Solid Waste Management Facility - Landfill Closure and Post-Closure Care Plan* (NASA, 1996b).

TA – Indicates that sampling is performed for this analysis triennially.

TBD – To be determined.