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Groundwater Investigation Report

for

Per-and Polyfluoroalkyl Substances (PFAS)

at

National Aeronautics and Space Administration (NASA)
Jet Propulsion Laboratory (JPL)
Pasadena, California

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US Army Corps of Engineers,
Los Angeles District
915 Wilshire Boulevard, Suite 930
Los Angeles, California 90017-3401

National Aeronautics and Space Administration
NASA Management Office
Jet Propulsion Laboratory
4800 Oak Grove Drive (Building 180)

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ABBREVIATIONS

%	percent
°F	degrees Fahrenheit
µg/L	micrograms per liter
AFFF	aqueous film-forming foam
AHA	Activity Hazard Analysis
amsl	above mean sea level
AOPC	Areas of Potential Concern
APPL	Agriculture & Priority Pollutants Laboratories
APP/SSHP	Accident Prevention Plan/Site Safety and Health Plan
bgs	below ground surface
Caltech	California Institute of Technology
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CoC	Chain of custody
COC	Contaminants of concern
COPC	Contaminant of Potential Concern
CSM	Conceptual Site Model
DI	deionized
DoD	Department of Defense
DOT	Department of Transportation
DQCR	Daily Quality Control Report
DQO	Data quality objective
DTSC	Department of Toxic Substances Control
CDWR	California Department of Water Resources
Ebasco	Ebasco Services, Inc.
ELAP	Environmental Laboratory Accreditation Program
Feet per day	ft/day
FFA	Federal Facilities Agreement
FFRDC	federally funded research and development center
FID	flame ionization detector
ft	feet/foot
FWEC	Foster Wheeler Environmental Corporation
G2S	G2S LLC
GALCIT	Graduate Aerospace Laboratories of the California Institute of Technology
GAMA	Groundwater Ambient Monitoring and Assessment
gpm	gallons per minute
GPS	Global Positioning System
HA	Health Advisory
HDPE	High-Density Polyethylene
IDW	investigation derived waste
IX	ion exchange

JPL	Jet Propulsion Laboratory
LACoFD	Los Angeles County Fire Department
LARWQCB	Los Angeles Regional Water Quality Control Board
LAWC	Lincoln Avenue Water Company
LC-MS/MS	liquid chromatography-tandem mass spectrometry
LDC	Laboratory Data Consultants
LGAC	Liquid-Phase Granular Activated Carbon
Ma	million years old
MHTS	Monk Hill Treatment System
MWD	Metropolitan Water District
NASA	National Aeronautics and Space Administration
ND	Non-detect
NGWA	National Groundwater Association
NPL	National Priorities List
NTC	National Training Center
NTU	nephelometric turbidity unit
OEHHA	Office of Environmental Health and Hazard Assessment
OU	operable unit
ORP	Oxidation-reduction potential
PA	Preliminary Assessment
PFAS	per- and polyfluoroalkyl substances
PFBA	perfluorobutanoic acid
PFBS	perfluorobutanesulfonic acid
PFDoA	perfluorododecanoic acid
PFHpA	perfluoroheptanoic acid
PFHxA	perfluorohexanoic acid
PFHxS	perfluorohexane sulfonate
PFNA	perfluorononanoic acid
PFOA	perfluorooctanoic acid
PFOS	perfluorooctane sulfonate
PFOSA	perfluorooctanesulfonamide
PFTeDA	perfluorotetradecanoic acid
PFUDA	perfluoroundecanoic acid
PHG	Public Health Goal
PID	photoionization detector
POC	point of contact
PPE	Personal protection equipment
ppm	parts per million
ppt	parts per trillion
psi	pounds per square inch
PWP	Pasadena Water and Power
PWS	Performance Work Statement
QA/QC	Quality Assurance/Quality Control

QAPP	Quality Assurance Project Plan
QSM	Quality Systems Manual
RCRA	Resource Conservation and Recovery Act
RI	Remedial Investigation
ROD	Record of Decision
RML	Removal Management Levels
RSL	Regional Screening Level
RTC	response to comment
RWQCB	Regional Water Quality Control Board
SDWIS	Safe Drinking Water Information System
SI	Site Inspection
SOP	Standard Operating Procedure
SSHO	Site Safety and Health Officer
SWRCB	State Water Resources Control Board
THQ	Target Hazard Quotient
TR	Target Cancer Risk
UFP-QAPP	Uniform Federal Policy for Quality Assurance Project Plans
USACE	United States Army Corps of Engineers
USC	United States Code
USCS	Unified Soil Classification System
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
VOA	volatile organic analysis
VOC	volatile organic compound

EXECUTIVE SUMMARY

This report presents the findings of groundwater sampling of per- and polyfluoroalkyl substances (PFAS) conducted at the National Aeronautics and Space Administration's (NASA's) Jet Propulsion Laboratory (JPL) in Pasadena, California. PFAS are a class of synthetic organofluorine compounds with unique properties that make them useful in various consumer and industrial products. Their potential impact to human health and the environment have resulted in evolving guidance and regulations regarding safe levels.

The PFAS SI Report was finalized in February 2024 and documented the results of groundwater and soil sampling at five Areas of Potential Concern (AOPC) at JPL (NASA, 2024). Based on the results of the SI at JPL, NASA recommended performing more comprehensive PFAS sampling of monitoring wells within and near the JPL Facility to determine if PFAS analysis of samples collected from select wells should be added to the JPL groundwater monitoring program and to determine if additional soil sampling is warranted.

NASA performed the more comprehensive sampling of monitoring wells in March 2024. This report presents the results of the comprehensive sampling event. Based on these results, NASA recommends inclusion of PFAS analysis into future groundwater monitoring events beginning in May 2025. Additional soil sampling is not recommended at this time.

1 INTRODUCTION

1.1 Purpose of Report

This groundwater investigation report was prepared by G2S LLC (G2S), under Contract No. W912PL22C0003 to document the results of SI activities conducted at five Areas of Potential Concern (AOPCs) located at the National Aeronautics and Space Administration's (NASA's) Jet Propulsion Laboratory (JPL) in Pasadena, California. The purpose of the groundwater investigation was to determine through groundwater sampling the extent of per- and polyfluoroalkyl substances (PFAS) near JPL and the need for additional soil sampling.

The data presented in this report were collected and evaluated in accordance with the Final SI Work Plan for PFAS at NASA JPL (NASA, 2022a).

1.2 Per- and Polyfluoroalkyl Substances Overview

PFAS are a class of synthetic organofluorine compounds that possess a chemical structure that gives them unique properties, including thermal stability and the ability to repel both water and oil. These chemical properties make them useful components in a wide variety of consumer and industrial products, including non-stick cookware, food packaging, waterproof clothing, fabric stain protectors, lubricants, paints, and firefighting foams. Guidance and regulations around safe levels of PFAS in the environment are evolving, and NASA considered the latest published federal and State of California levels when evaluating PFAS concentrations detected at the JPL Site.

In April 2024, EPA finalized a National Primary Drinking Water Regulation (NPDWR) establishing Maximum Contaminant Levels (MCLs) for six PFAS in drinking water, including perfluorooctanoic acid (PFOA), perfluorooctane sulfonic acid (PFOS), perfluorononanoic acid (PFNA), hexafluoropropylene oxide dimer acid (HFPO-DA, commonly known as GenX Chemicals), perfluorohexane sulfonic acid (PFHxS), and perfluorobutane sulfonic acid (PFBS) (USEPA, 2024a). This rule includes individual MCLs for PFOA, PFOS, PFHxS, PFNA, and HFPO-DA, and a Hazard Index (HI) MCL for PFAS mixtures containing at least two or more of PFHxS, PFNA, HFPO-DA, and PFBS. The rule requires public water systems to monitor for these PFAS and notify the public of the levels of these PFAS by 2027. Public water systems have until 2029 to implement solutions that reduce these PFAS if monitoring shows that drinking water levels exceed these MCLs (USEPA, 2024a).

As of November 2024, the USEPA has established Regional Screening Levels (RSLs) for 31 PFAS compounds (USEPA, 2024b). Eleven of these 31 PFAS compounds are reported when samples are analyzed using USEPA Method 1633. These PFAS compounds include PFOS, PFOA, PFNA, HFPO-DA, PFBS, PFHxS, perfluorobutanoic acid (PFBA), perfluorohexanoic acid (PFHxA), perfluorododecanoic acid (PFDoA), perfluoroundecanoic acid (PFUDA), and perfluorotetradecanoic acid (PFTeDA). RSLs are used to identify contaminated media (i.e., air, tap water, and soil) at a site that may need further investigation. In general, if a contaminant concentration is below the screening level, no further action or investigation is needed. If the concentration is above the screening level, further investigation may be needed to determine if action is required. The USEPA publishes updates to the RSL tables in May and November each year.

The California State Water Resources Control Board (SWRCB) has not promulgated standards for any PFAS to date but has issued Notification Levels (NLs) and Response Levels (RLs). NLs represent the concentration level of a contaminant in drinking water that does not pose a significant health risk but warrants notification according to the Division of Drinking Water (DDW). A RL is set higher than a NL and represents a recommended chemical concentration at which water systems consider taking a water

source out of service or provide treatment. NLs and RLs have been established for PFOA, PFOS, PFBS, and PFHxS (SWRCB, 2023).

On April 5, 2024, the California Office of Environmental Health and Hazard Assessment (OEHHA) adopted Public Health Goals (PHGs) for PFOA and PFOS based on carcinogenic effects (OEHHA, 2024). PHGs are not regulatory standards. However, state law requires SWRCB to set drinking water standards for chemical contaminants as close to the corresponding PHG as is economically and technologically feasible.

For the purposes of NASA's PFAS investigation, groundwater analytical results are compared to the USEPA MCLs. If an MCL is not established, the lower of the Tap Water RSL (Target Cancer Risk [TR] of 1E-06 and Target Hazard Quotient [THQ] of 0.1) or the SWRCB NL will be used for comparison. Analytical results for soils are compared to the USEPA RSL table for residential soil (TR=1E-06, THQ=0.1). Table 1-1 below presents the screening values.

Table 1-1. Summary of Current Groundwater and Soil Screening Criteria for PFAS

Parameter	Chemical Abstract Number	USEPA Regional Screening Level Table[a] (November 2024)		USEPA MCL[b] (April 2024) (ng/L)	SWRCB DDW NL[c] (ng/L)	OEHHA PHGs[d] (ng/L)
		Residential Soil (µg/kg)	Tap Water (ng/L)			
PFOA	335-67-1	0.019	0.0027	4	5.1	0.007
PFOS	1763-23-1	0.63	0.2	4	6.5	1
PFHxS	355-46-4	130	39	10	3	NE
PFNA	375-95-1	19	5.9	10	NE	NE
HFPO-DA (GenX Chemicals)	13252-13-6	23	1.5	10	NE	NE
PFBS	375-73-5	1900	600	NE	500	NE
Mixtures Containing Two or More of PFHxS, PFNA, HFPO-DA, and PFBS	See Above			1.0 (unitless) Hazard Index	See Above	See Above
PFBA	375-22-4	7800	1800	NE	NE	NE
PFHxA	307-24-4	3200	990	NE	NE	NE
PFDoA	307-55-1	320	100	NE	NE	NE
PFTeDA	376-06-7	6300	2000	NE	NE	NE
PFUDA	2058-94-8	1900	600	NE	NE	NE

Notes:

[a] USEPA Regional Screening Levels (November 2024): https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables (TR=1E-06, THQ=0.1)

[b] USEPA MCLs for PFAS: https://www.epa.gov/sdwa/and-polyfluoroalkyl-substances-pfas. The combined hazard index (HI) for PFBS, HFPO-DA, PFNA, and PFHxS is determined as follows:

- Step 1. Divide the measured concentration of HFPO-DA (Gen X) by the health-based value of 10 ng/L.
- Step 2. Divide the measured concentration of PFBS by the health- based value of 2000 ng/L.
- Step 3. Divide the measured concentration of PFNA by the health-based value of 10 ng/L.
- Step 4. Divide the measured concentration of PFHxS by the health-based value of 9 ng/L.
- Step 5. Add the ratios from steps 1, 2, 3 and 4 together.
- If the running annual average HI greater than 1.0, it is a violation of the proposed HI MCL.

[c] SWRCB DDW Notification Levels: https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/pfas.html.

[d] OEHHA PHGs: https://oehha.ca.gov/public-health-goals-phgs?page=3

ng/L = nanogram per liter

µg/kg = microgram per kilogram

NE = not established

1.3 Objectives

The objective for the PFAS groundwater investigation at NASA JPL was to supplement data collected during the PFAS SI (NASA, 2024). The SI was completed in compliance with the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), 42 United States Code (USC) § 9601 et seq. and State of California environmental regulations. This report also integrates information contained in other remedial investigation reports as part of the JPL CERCLA program.

1.4 Investigation Scope

The scope of this investigation was to identify the nature and extent of PFAS in groundwater at JPL. The groundwater investigation included the collection of groundwater samples, sample analyses, third-party data validation, and report preparation. As a part of this task, groundwater samples were collected from existing monitoring wells within and downgradient of JPL to assess presence or absence of PFAS in groundwater. The goal of the investigation was to determine whether data are sufficient to serve as part of a Remedial Investigation/ Feasibility Study (RI/FS). It should be noted that USEPA considers all PA/SI documentation associated with PFAS at Federal Facilities on the National Priorities List (NPL) to be part of the RI/FS (USEPA, 2023c).

1.5 Regulatory Framework

In October 1992, the JPL site was placed on the NPL and, therefore, is subject to the provisions of CERCLA to regulate investigation and cleanup. The parties to the Federal Facilities Agreement (FFA) include NASA, the USEPA, the California Department of Toxic Substances Control (DTSC), and the Regional Water Quality Control Board (RWQCB). NASA is the lead federal agency, and USEPA, DTSC, and RWQCB provide guidance and oversight to the JPL CERCLA Program.

Prior to more recent USEPA guidance on PFAS, NASA Headquarters conducted PFAS PAs at 10 NASA Centers/Facilities (JPL being one of the ten facilities) to identify whether past or present activities may have resulted in a release of PFAS into the environment and to qualitatively evaluate potential exposure to PFAS in environmental media for receptors at and within a 1-mile radius of each NASA Center/Facility. The PFAS PA for JPL was finalized in February 2021 and the PFAS SI was finalized in February 2024.

The PFAS PA and PFAS SI were conducted voluntarily by NASA following the CERCLA process. In April 2024, USEPA finalized a rule to designate PFOA and PFOS as hazardous substances under CERCLA, resulting in PFAS now being officially investigated following the CERCLA process.

1.6 Report Organization

This PFAS Groundwater Investigation Report is organized as follows:

- Section 1, Introduction – Describes the investigation objectives, regulatory framework, and content of the PFAS SI Work Plan.
- Section 2, Site Background – Provides background information including site location and description, site history, summary of previous investigations, and regulatory history.
- Section 3, Environmental Setting – Summarizes physical characteristics of the Site including climate, topography, geology, hydrogeology, surface water features, and land use.
- Section 4, Field Activities and Analytical Protocols – Provides an overview of the groundwater sampling field activities, analytical methods, and analytical results.

- Section 5, Quality Assurance/Quality Control – Overview of the Uniform Federal Policy-Quality Assurance Project Plan (UFP-QAPP) requirements, documentation that the QAPP requirements have been met, and a data review and usability evaluation.

- Section 6, Migration and Exposure Pathways and Targets – Provides a summary of the groundwater migration pathway and potential exposure pathways and receptors for PFAS based on the results of the investigation.

- Section 7, Summary and Conclusions.

The following are appended to this document:

- APPENDIX A: Tabulated Results and Figures
- APPENDIX B: Laboratory Analytical Data Package
- APPENDIX C: Third-Party Data Validation Package
- APPENDIX D: Field Documentation – Pre-Sampling Water Levels, Sampling Logs, Calibration Logs, and Daily Tailgate Safety Meeting Forms

2 SITE BACKGROUND

2.1 Site Location and Description

JPL is a federally funded research and development center (FFRDC) in Pasadena, California, currently operated under contract with the California Institute of Technology (Caltech) for NASA. JPL's primary activities include the exploration of the earth and solar system by automated spacecraft and the design and operation of the Global Deep Space Tracking Network.

Located in Los Angeles County, the JPL site is situated between the incorporated cities of La Cañada Flintridge and Pasadena and is bordered on the east by the unincorporated community of Altadena. JPL encompasses approximately 176 acres of land and more than 150 buildings and other structures. Of the JPL Facility's 176 acres, approximately 156 acres are federally owned. The remaining land is leased for parking from the City of Pasadena and the Flintridge Riding Club. Development at JPL is primarily located in two regions, an early-developed northeastern area and a later-developed southwestern area. Figure 2-1 is a location map showing the JPL Facility and surrounding areas.

Under the CERCLA program, JPL has been divided into three operable units (OUs). OU1 addresses on-facility groundwater at JPL; OU2 addresses on-facility vadose zone soil at JPL; and OU3 addresses off-facility groundwater adjacent to the JPL property. Cleanup of OU2 is complete, as documented in the Remedial Action Report for Operable Unit 2 (NASA, 2007). A Final Record of Decision (ROD) is currently in place for both OU1 and OU3 (NASA, 2018). The Third Five-Year Review was completed for OU1 and OU3 in 2022 (NASA, 2022), showing the continued effectiveness of the remedies at JPL.

The remedies for OU1 and OU3 include three treatment systems: the Source Area Treatment System (OU1) and two systems in OU3, the Monk Hill Treatment System (MHTS) and the Lincoln Avenue Water Company (LAWC) Treatment System. These systems utilize liquid-phase granular activated carbon (LGAC) to remove volatile organic compounds (VOCs) and ion exchange (IX) to remove perchlorate. For the source area treatment system, the treated water is reinjected into the aquifer utilizing three injection wells located approximately 350 feet up gradient from the extraction wells. Treated water from the MHTS and LAWC Treatment System is used as drinking water.

The PA Report recommended four AOPCs (the Site) for further assessment and one AOPC was added during the SI. The description of each AOPC location is provided below. Figure 2-2 presents a Site map showing the locations of the AOPCs.

2.1.1 AOPC 1: Emergency Landing Facility

The Emergency Landing Facility is an approximately 1.25-acre area located in the northern portion of JPL off Mesa Road near Building 243. The facility is located on the mesa north of and at a higher elevation than the main campus of JPL (north of the JPL Thrust Fault) and has a heliport that is used to support Los Angeles County Fire Department (LACoFD) helicopters in the event of a forest fire (Tetra Tech, 2021).

2.1.2 AOPC 2 and 3: Waste Disposal Areas (Seepage Pits and Waste Pits)

40 seepage pits (collectively AOPC 2) and four waste pits (collectively AOPC 3) are being considered as a single potential source based on proximity to each other. The seepage pits were used from approximately 1945 to 1960 to dispose of a variety of liquid wastes associated with laboratory operations, including sanitary wastes, solvents, paints, wastewater from parts cleaning, and other chemicals. Seepage pits were located primarily in the eastern/northeastern portion the JPL Facility.

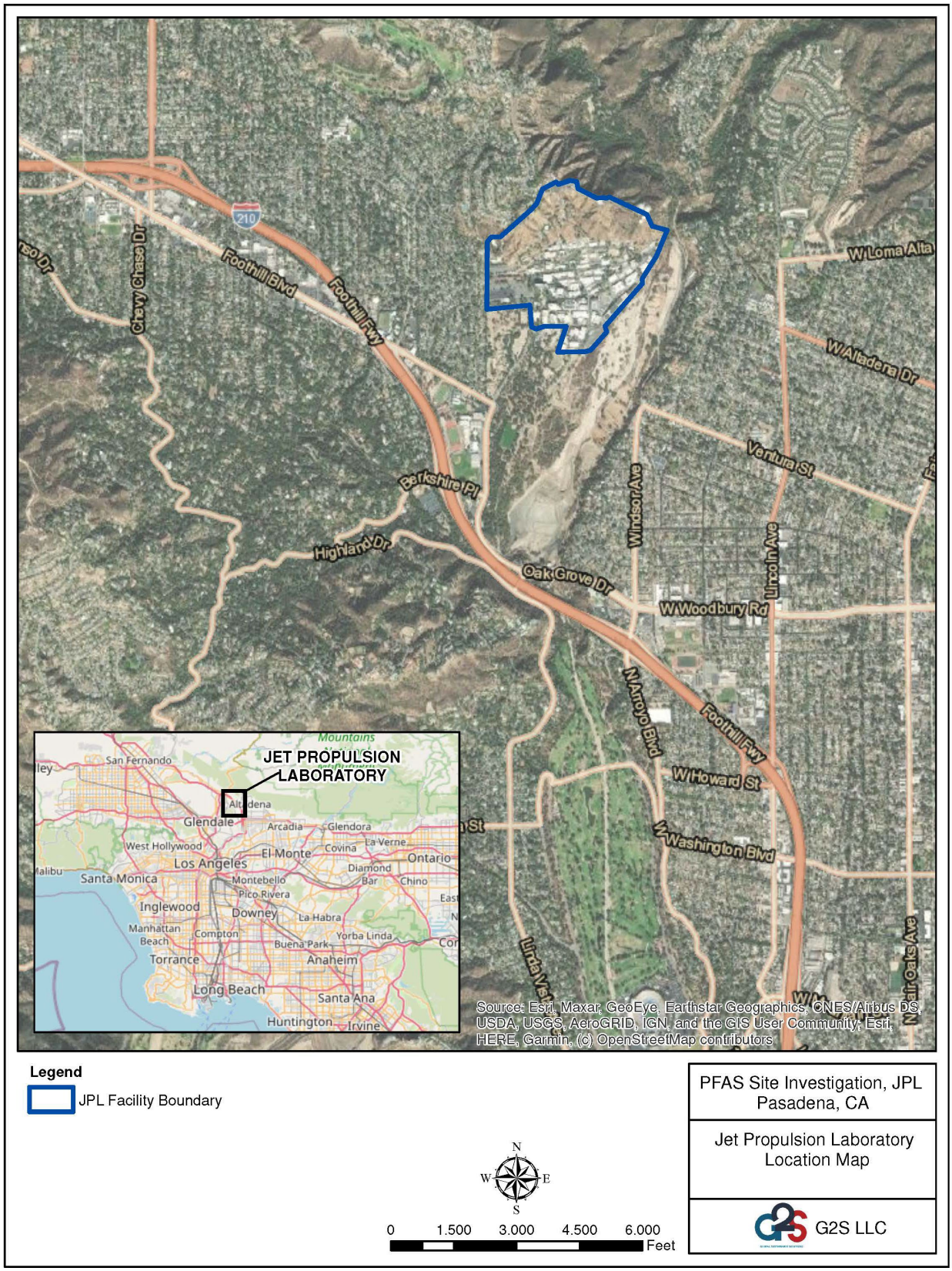

Figure 2-1. Site Location Map

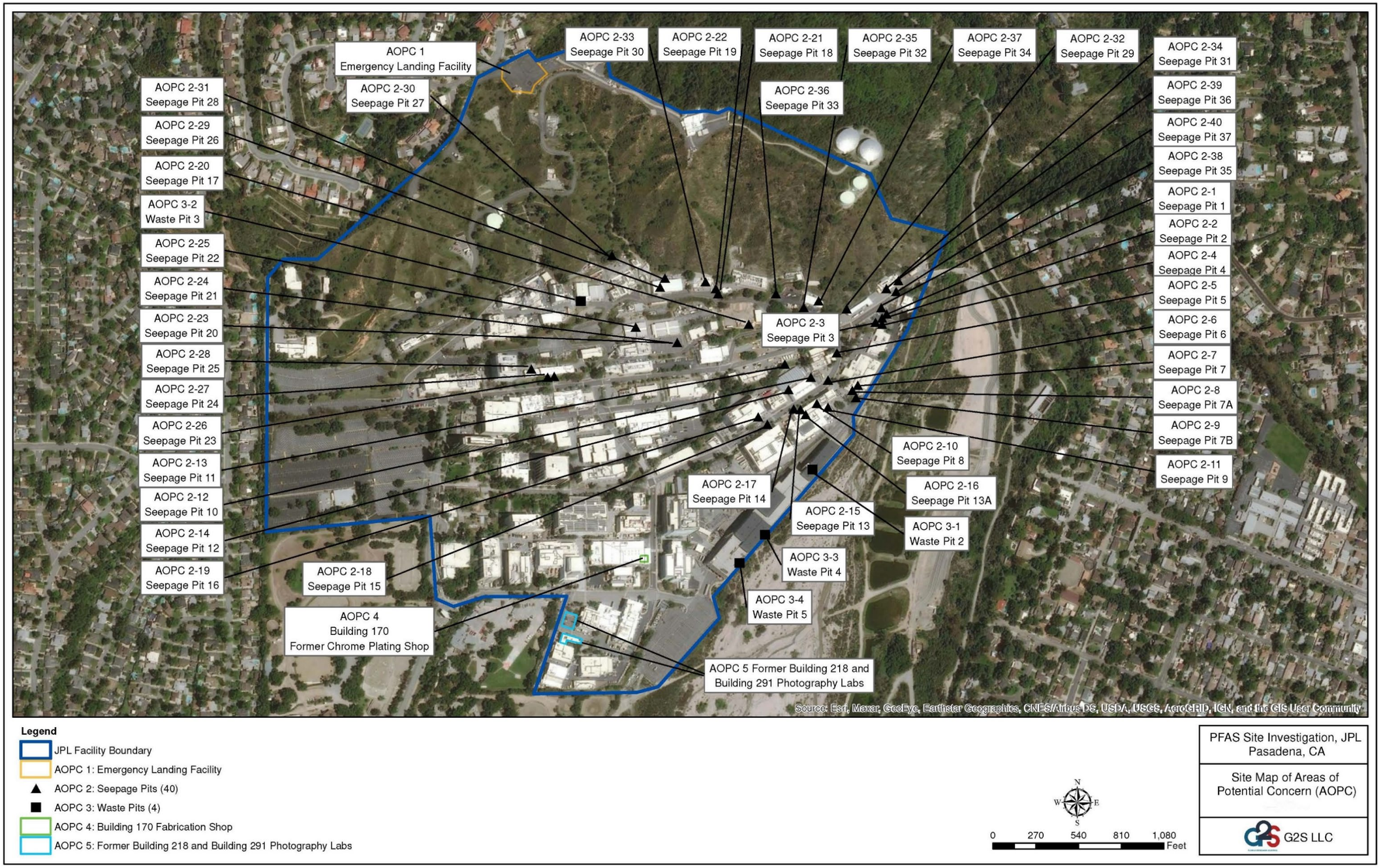

Figure 2-2. Site Map of AOPCs

The waste pit disposal areas were located along what was the boundary between JPL and the Arroyo Seco at the time, but they currently fall within the JPL boundary. One additional waste disposal area was documented to the south of Former Building 45. Waste pits were used from 1945 to 1960 to dispose of materials such as wood, glass, metal parts and shavings, drums of chemical wastes, and other hazardous and municipal wastes and were designed as open, bermed areas that were later backfilled.

2.1.3 AOPC 4: Building 170 Fabrication Shop

Building 170 houses the Fabrication Shop and is in the southern portion of JPL between Mariner Road and Forestry Camp Road that includes the Former Chrome Plating Shop.

2.1.4 AOPC 5: Former Building 218 and Building 291 Photography Labs

Former Building 218 was located in the southern portion of JPL directly west of current Building 202. Building 291 is located in the southern portion of JPL.

2.2 Site History

JPL is a NASA facility for research and development of space exploration, including rocket propellant design and testing, spacecraft material and equipment design, assembly and testing, and research related to alternative energy sources and pollution control (Ebasco Services, Inc. [Ebasco], 1988). JPL was originally founded in 1944 in partnership with the Guggenheim Aeronautical Laboratory at the California Institute of Technology (GALCIT) and the U.S. Army to develop rocket-based weapons, guided missiles, and solid rocket propellant. Activities at JPL supported the launch of the U.S.'s first satellite in 1958. In recent decades, JPL has functioned as NASA's primary center for unmanned interplanetary exploration and assists with aeronautical research and development (Ebasco, 1988 as cited in Tetra Tech, 2021).

The history of each AOPC being investigated as part of the PFAS SI is provided below.

2.2.1 AOPC 1: Emergency Landing Facility

According to the 2021 PA Report, the current heliport area was paved and housed antennae by 1964. In addition, aerial photographs reviewed during the PA indicate that the heliport may have been present as early as 1972 but did not appear on a site map until 1986. Aqueous film-forming foam (AFFF) was stored in Building 242A (covered shed adjacent to the helipad and Building 243) to support emergency response for a potential helicopter fire. The PA Report found limited information regarding the type of AFFF stored or the period during which the AFFF was stored in Building 243A. They learned of a one-time training exercise that was conducted by JPL and the LACoFD during which AFFF was applied on the helipad. The PA was unable to determine the timing of the exercise through records review, but interviews indicated it was before 2010. Once the training exercise was completed, the AFFF was washed from the helipad and directed to the southern edge of the helipad toward the sloped edge of the mesa. The AFFF-containing wash water may have been diverted through a storm drain at the southwestern corner of the helipad, which empties downslope in a catchment drain at the bottom of the hill and/or it may have washed down the side of the mesa south of the Emergency Landing Facility. AFFF-containing wash water from the uphill mesa could have potentially entered storm drain inlets located on the slope of the mesa below the southern edge of the helipad. These inlets appear to ultimately discharge to the off-Site Arroyo Seco (Tetra Tech, 2021).

2.2.2 AOPC 2 and 3: Waste Disposal Areas (Seepage Pits and Waste Pits)

When JPL was operated by GALCIT and the U.S. Army, 40 seepage pits (collectively AOPC 2) and 4 waste pits (collectively AOPC 3) were used for liquid and solid waste disposal. The seepage pits were used from approximately 1945 to 1960 to dispose of a variety of liquid wastes associated with laboratory operations, including sanitary wastes, solvents, paints, wastewater from parts cleaning, and other chemicals. The waste pits were used within the same period to dispose of materials such as wood, glass,

metal parts and shavings, drums of chemical wastes, and other hazardous and municipal wastes and were designed as open, bermed areas that were later backfilled. The seepage pits were constructed as open boreholes, often lined with brick, that were designed to have liquids seep directly into the soils. Plumbing from sinks and drains in the buildings at JPL were piped directly to the seepage pits. Many seepage pits also had cleanouts outside the building where liquids could be dumped directly into the pits. Historical operations in buildings connected to various seepage pits include propellant preparation and testing, and laboratories for hydraulics and solid fuels. The exact materials that were disposed into seepage pits were not well documented but based on historical operations at JPL and the period of seepage and waste pit use, it is possible that PFAS-containing materials were also disposed in AOPCs 2 and 3 (Tetra Tech, 2021). Use of seepage pits was discontinued in the 1950s and other materials disposed into seepage pits have been addressed as part of the JPL CERCLA program (NASA, 2007; NASA, 2018).

2.2.3 AOPC 4: Building 170 Fabrication Shop

Building 170 was constructed in the early 1960s and expanded in the late 1960s or early 1970s. A small metal plating shop was formerly located within the southeast portion of the building that was used for electroplating and chrome plating as recently as the early 1990s. Liquids used in the plating process were reportedly discharged to a floor drain in the plating room and passed through a below ground clarifier on the southern side of Building 170 prior to discharge to the sanitary sewer. The room housing the plating shop was renovated in 2016 and the floor was raised, covering the floor drain with wooden floorboards. The room is currently used to wash and clean parts made in the fabrication shop (Tetra Tech, 2021).

According to the USEPA, PFAS were used as a surfactant, wetting agent, and mist suppressing agent for chrome plating, and PFAS were used to improve the quality of electroless plating of copper and stabilize coating baths for depositing nickel-boron layers. Further, the USEPA identified PFAS use to treat metal surfaces to prevent corrosion, reduce mechanical wear, and enhance aesthetic appearance. Lastly, machine parts were at times cleaned after nickel plating with a solution containing PFOS. Therefore, Building 170 was identified as an AOPC based on potential use of PFAS in the fabrication shop.

2.2.4 AOPC 5: Former Building 218 and Building 291 Photography Labs

Former Building 218 and current Building 291 formerly housed photography labs. Former Building 218 was constructed in the late 1960s or early 1970s and demolished sometime between 2015 and 2018. Building 291 was constructed in the late 1960s or early 1970s. Building 291 was also titled Procurement Services (1970s and 1980s) and Compensation (1990s and possibly early 2000s). No information regarding the operational period of or details about the activities in the photography labs was found during the PA (Tetra Tech, 2021). These buildings were identified as an AOPC due to their potential to house photolithology processes and the use of PFAS in photographic solutions.

2.3 Past Site Investigations

Numerous environmental investigations including remedial investigations pertaining to OU1, OU2 and OU3 have been carried out under the CERCLA program and are available on the NASA JPL electronic repository of related documents available at http://jplwater.nasa.gov.

As part of the various remedial investigations, a groundwater monitoring program has been in place at JPL since August 1996 and has been expanded as the number of monitoring wells was also expanded. Currently the monitoring program is made up of 25 monitoring wells and 82 different sampling points. JPL monitoring wells are sampled on a quarterly basis to maintain a comprehensive understanding of the subsurface conditions within OU1 and OU3 groundwater. Historically, PFAS analyses were not conducted on any of the JPL groundwater monitoring wells prior to NASA's PFAS SI.

Pasadena Water and Power (PWP) sampled untreated groundwater from Arroyo Well and Well 52 in April and May 2020. PFBS was detected in Arroyo Well at 3.20 ng/L (April) and 3.10 ng/L (May). In

April, PFBS and PFHxS were detected in Well 52 at 3.10 ng/L and 2.00 ng/L, respectively. No other PFAS were detected in Arroyo Well and Well 52 above the laboratory reporting limits, which were 2.00 ng/L for all six PFAS. The April and May 2020 detections of PFBS and PFHxS are below the May 2024 tap water USEPA RSLs, USEPA proposed NPDWR levels, and the SWRCB NLs.

PFAS sampling at the LAWC treatment system was performed in August 2023. Samples were collected from the two extraction wells, LAWC#5 and LAWC#6, at the combined plant influent, at the IX effluent, and at the LGAC effluent. Low levels of PFOA, PFOS, PFBA, PFHxA, PFNA, PFBS, and PFHxS were detected in LAWC#5, LAWC#6, and the combined plant influent. PFUDA, PFDoA, PFTeDA, and HFPO-DA were not detected in any sample. Only one sample, LAWC#6, contained PFOS in excess of the MCL (4 ng/L). The PFOS concentration in LAWC#6 was 4.6 ng/L. The combined plant influent concentration of PFOS was 3.5 ng/L and the treated water samples were below detection (<0.088 ng/L), equating to >97% removal by the treatment system. Table 2-1 summarizes the results of sampling for PFAS at the LAWC treatment system in August 2023.

A PA for PFAS was carried out for JPL and was completed in 2021. The PA involved extensive records review, interview of key JPL personnel, a Site visit, development of an initial CSM and recommendations of AOPCs for further assessment.

2.4 PFAS Site Inspection (SI)

NASA conducted PFAS SI sampling in late 2022 and finalized the PFAS SI Report in February 2024 (NASA, 2024). As part of the SI, twelve soil samples were collected from six boring locations and 16 groundwater samples were collected from five monitoring wells. Soil and groundwater samples were analyzed by APPL in Clovis, California, a DoD Environmental Laboratory Accreditation Program (ELAP) accredited laboratory. Samples were analyzed by EPA Method 537-modified by LC-MS/MS.

During SI activities the uppermost sampling port (i.e., Screen 1) in multiport wells MW-4, MW-12, MW-17, and MW-24 were dry and could not be sampled. In addition, shallow standpipe wells MW-5 and MW-16 contained insufficient water (i.e., dry) to collect a sample.

Low levels (below screening levels) of PFOA, PFNA, PFBS, PFHxS, and PFOS were detected in all monitoring wells sampled at the JPL Site, with the exception that PFNA was not detected in MW-4. HFPO-DA was not detected in any monitoring well at the JPL Site. Groundwater sampling results are presented in Table 2-2. The screening levels presented in Table 1 1 (see Section 1.2) were exceeded in two samples (PFOA in MW-12-2 and PFOS in MW-17-3; table shows primary and duplicate sample results for MW-17-3).

Low levels of PFOA, PFBA, PFHxA, PFNA, PFBS, PHXS, and PFOS were detected in one or more soil samples. HFPO-DA was not detected in any soil samples. Soil sampling results are summarized in Table 2-3. The screening levels presented in Table 1-1 (see Section 1.2) were exceeded in soil borings 1, 2, 3, and 6. The PFOA levels in soil borings 4 and 5 were non-detect; however, the screening level is set below the reporting limit. It should be noted that since the PFAS SI Report was finalized, the RSL for PFOA has been revised and is now four orders of magnitude lower. The RSL (TR=1E-6, THQ=1) for PFOA was lowered from 190 ng/L to 0.019 ng/L.

Figures 2-3 and 2-4 show the locations of soil borings and groundwater wells sampled as part of the PFAS SI at JPL. Table 2-2 and Table 2-3 summarize the results with exceedances of recent USEPA MCLs for groundwater and recent USEPA residential RSLs for soil highlighted in yellow.

Table 2-1. LAWC Treatment System PFAS Results from Samples Collected in August 2023

PFAS Compound	LAWC#5 (ng/L)		LAWC#6 (ng/L)		Combined Influent (ng/L)		IX Effluent (ng/L)		LGAC Effluent (ng/L)		Screening Value (ng/L)
PFBA	0.57	J	0.75	J	0.62	J	0.71	J	0.59	J	1,800[a]
PFPeA	0.48	J	1.3		0.85		1.0		0.63	J	--
PFHxA	0.39		0.98		0.65		0.14	J	0.13	J	990[a]
PFHpA	0.33	J	0.56		0.46		0.088	U	0.088	U	--
PFOA	0.76		1.3		1.0		0.078	J	0.088	U	4[b]
PFNA	0.099	J	0.26	J	0.20	J	0.088	U	0.088	U	10[b]
PFDA	0.089	U	0.050	J	0.088	U	0.088	U	0.088	U	--
PFUDA	0.089	U	0.089	U	0.088	U	0.088	U	0.088	U	600[a]
PFDoA	0.089	U	0.089	U	0.088	U	0.088	U	0.088	U	100[a]
PFTrDA	0.089	U	0.089	U	0.088	U	0.088	U	0.088	U	--
PFTeDA	0.089	U	0.089	U	0.088	U	0.088	U	0.088	U	2,000[a]
PFBS	0.58		1.1		0.82		0.088	U	0.088	U	500[c]
PFPeS	0.22	J	0.36		0.28	J	0.088	U	0.088	U	--
PFHxS	1.2		1.9		1.5		0.088	U	0.088	U	10[b]
PFHpS	0.050	J	0.11	J	0.098	J	0.088	U	0.088	U	--
PFOS	2.5		**4.6**		3.5		0.067	J	0.088	U	4[b]
PFNS	0.18	U	0.18	U	0.18	U	0.18	U	0.18	U	--
PFDS	0.089	U	0.089	U	0.088	U	0.088	U	0.088	U	--
4:2FTS	0.18	U	0.18	U	0.18	U	0.18	U	0.18	U	--
6:2FTS	0.089	U	0.089	U	0.088	U	0.088	U	0.088	U	--
8:2FTS	0.27	U	0.27	U	0.27	U	0.26	U	0.26	U	--
PFOSA	0.089	U	0.057	J	0.056	J	0.073	J	0.054	J	--
NMeFOSA	0.89	U	0.89	U	0.88	U	0.88	U	0.88	U	--
NEtFOSA	0.89	U	0.89	U	0.88	U	0.88	U	0.88	U	--
NMeFOSAA	0.089	U	0.089	U	0.088	U	0.088	U	0.088	U	--
NEtFOSAA	0.089	U	0.089	U	0.088	U	0.088	U	0.088	U	--
NMeFOSE	0.53	U	0.53	U	0.53	U	0.53	U	0.53	U	--
NEtFOSE	0.53	U	0.53	U	0.53	U	0.53	U	0.53	U	--
HFPO-DA	0.44	U	0.45	U	0.44	U	0.44	U	0.44	U	10[b]
ADONA	0.27	U	0.27	U	0.27	U	0.26	U	0.26	U	--
9Cl-PF3ONS	0.27	U	0.27	U	0.27	U	0.26	U	0.26	U	--
11Cl-PF3OUDS	0.27	U	0.27	U	0.27	U	0.26	U	0.26	U	--

J = estimated value; U = not detected

(a) USEPA RSL (TR=1E-06, THQ=0.1); (b) USEPA MCL; (c) SWRCB NL

Table 2-2. Groundwater PFAS Results from SI Sampling in 2022

Sample Location	Sample Date	Sample Number	PFOA (ng/L)	PFNA (ng/L)	PFBS (ng/L)	PFHxS (ng/L)	PFOS (ng/L)	HFPO-DA (GenX Chemicals) (ng/L)	NPDWR HI
MW-4-1	--	DRY	NS	NS	NS	NS	NS	NS	
MW-4-2	11/28/2022	MW-4-S2-112822	**1.10**	0.18 U	**2.90**	**2.00**	**0.20 J**	0.90 U	0.33
MW-4-4	11/28/2022	MW-4-S4-112822	**0.40 J**	0.18 U	**0.39 J**	**0.28 J**	**0.15 J**	0.91 U	0.14
MW-4-5	11/28/2022	MW-4-S5-112822	**0.27 J**	0.19 U	**0.79 J**	**0.42 J**	**0.14 J**	0.93 U	0.16
MW-4-5	11/28/2022	DUP-1-112822	**0.94 J**	0.18 U	**4.90**	**0.44 J**	0.18 U	0.88 U	0.16
MW-5	--	DRY	NS	NS	NS	NS	NS	NS	
MW-12-1	--	DRY	NS	NS	NS	NS	NS	NS	
MW-12-2	11/28/2022	MW-12-S2-112822	**9.50**	**1.20**	**7.40**	**0.73**	**3.80**	0.91 U	0.30
MW-12-3	11/28/2022	MW-12-S3-112822	**1.40**	0.18 U	**0.24 J**	**0.41 J**	**0.62 J**	0.92 U	0.16
MW-12-4	11/28/2022	MW-12-S4-112822	**2.10**	0.19 U	**0.23 J**	**0.25 J**	**1.10**	0.93 U	0.14
MW-12-5	11/28/2022	MW-12-S5-112822	**1.10**	**3.50**	**0.45 J**	**0.36 J**	**2.00**	0.89 U	0.48
MW-15	11/30/2022	MW-15-113022	**2.50**	**0.88**	**0.97**	**0.32 J**	**1.50**	0.85 U	0.21
MW-16	--	DRY	NS	NS	NS	NS	NS	NS	
MW-17-1	--	DRY	NS	NS	NS	NS	NS	NS	
MW-17-2	11/29/2022	MW-17-S2-112922	**0.23 J**	0.18 U	**1.30**	**0.54 J**	**0.83**	0.89 U	0.17
MW-17-3	11/29/2022	MW-17-S3-112922	**2.30**	**0.37 J**	**2.20**	**1.40**	**6.60**	0.90 U	0.28
MW-17-3	11/29/2022	DUP-3-112922	**2.00**	**0.53 J**	**2.40**	**1.40**	**5.90**	0.88 U	0.30
MW-17-4	11/29/2022	MW-17-S4-112922	**2.30**	**0.36 J**	**0.50 J**	**1.20**	**2.00**	0.89 U	0.26
MW-17-5	11/29/2022	MW-17-S5-112922	**1.50**	0.17 U	**0.47 J**	**1.30**	**2.00**	0.87 U	0.25
MW-24-1	--	DRY	NS	NS	NS	NS	NS	NS	
MW-24-2	11/29/2022	MW-24-S2-112922	**0.68 J**	0.17 U	**0.84**	**2.30**	**0.33 J**	0.85 U	0.36
MW-24-2	11/29/2022	DUP-2-112922	**0.83 J**	0.17 U	**0.65 J**	**2.20**	**0.55 J**	0.84 U	0.35
MW-24-3	11/29/2022	MW-24-S3-112922	**2.30**	**0.31 J**	**0.36 J**	**0.82**	**0.70**	0.85 U	0.21
MW-24-4	11/29/2022	MW-24-S4-112922	**0.26 J**	0.17 U	0.17 U	0.17 U	0.17 U	0.86 U	0.12
MW-24-5	11/29/2022	MW-24-S5-112922	**0.21 J**	0.18 U	0.18 U	0.18 U	0.18 U	0.88 U	0.13
USEPA MCL (April 2024) (ng/L)			4	10 HI<1	HI<1	10 HI<1	4	10 HI<1	1
SWRCB DDW NL (ng/L)			5.1	NE	500	3	6.5	NE	--

NS = Not Sampled; NE = Not Established; bold = detection; J = estimated concentration; U = not detected

Table 2-3. Soil PFAS Results from SI Sampling in 2022

Sample Location	Sample Date	Sample Number	PFOA (µg/kg)	PFNA (µg/kg)	PFBS (µg/kg)	PFHxS (µg/kg)	PFOS (µg/kg)	HFPO-DA (GenX Chemicals) (µg/kg)
Soil Boring-1 (0.5 feet)	11/30/2022	SB-1-0.5-113022	**0.52 J**	**2.70**	0.12 U	0.17 U	**0.66 J**	0.23 U
Soil Boring-1 (2.0 feet)	11/30/2022	SB-1-2.0-113022	**2.20**	**2.20**	0.10 U	0.15 U	**0.13 J**	0.20 U
Soil Boring-2 (0.5 feet)	11/30/2022	SB-2-0.5-113022	**3.50**	**0.45 J**	0.11 U	0.17 U	**0.15 J**	0.22 U
Soil Boring-2 (2.0 feet)	11/30/2022	SB-2-2.0-113022	**10.00**	**1.20**	0.11 U	0.16 U	**0.19 J**	0.22 U
Soil Boring-3 (0.5 feet)	11/30/2022	SB-3-0.5-113022	**0.40 J**	**0.24 J**	0.10 U	0.15 U	0.10 UJ	0.21 U
Soil Boring-3 (2.0 feet)	11/30/2022	SB-3-2.0-113022	**4.60**	**0.59 J**	**0.13 J**	0.15 U	**0.39 J**	0.20 U
Soil Boring-4 (0.5 feet)	11/30/2022	SB-4-0.5-113022	0.15 U	0.10 U	0.10 U	0.15 U	**1.80 J**	0.20 U
Soil Boring-4 (2.0 feet)	11/30/2022	SB-4-2.0-113022	0.15 U	0.10 U	0.10 U	0.15 U	**0.13 J**	0.20 U
Soil Boring-5 (0.5 feet)	11/30/2022	SB-5-0.5-113022	0.15 U	0.10 U	0.10 U	0.15 U	**1.70 J**	0.19 U
Soil Boring-5 (2.0 feet)	11/30/2022	SB-5-2.0-113022	0.14 U	0.09 U	0.09 U	0.14 U	0.09 UJ	0.18 U
Soil Boring-5 (2.0 feet)	11/30/2022	DUP-1-113022	0.15 U	0.10 U	0.10 U	0.15 U	0.10 UJ	0.20 U
Soil Boring-6 (0.5 feet)	11/30/2022	SB-6-0.5-113022	0.19 U	0.12 U	0.12 U	**0.90 J**	**22.00 J**	0.25 U
Soil Boring-6 (0.5 feet)	11/30/2022	DUP-2-113022	**0.28 J**	**0.19 J**	0.12 U	**1.50**	**48.00 J**	0.24 U
Soil Boring-6 (2.0 feet)	11/30/2022	SB-6-2.0-113022	**0.16 J**	0.10 U	0.10 U	**2.40**	**1.50 J**	0.20 U
USEPA RSL for Residential Soil (November 2024) (µg/kg)			0.019	19	1900	130	0.63	23
USEPA RSL for Industrial Soil (November 2024) (µg/kg)			0.078				8.2	

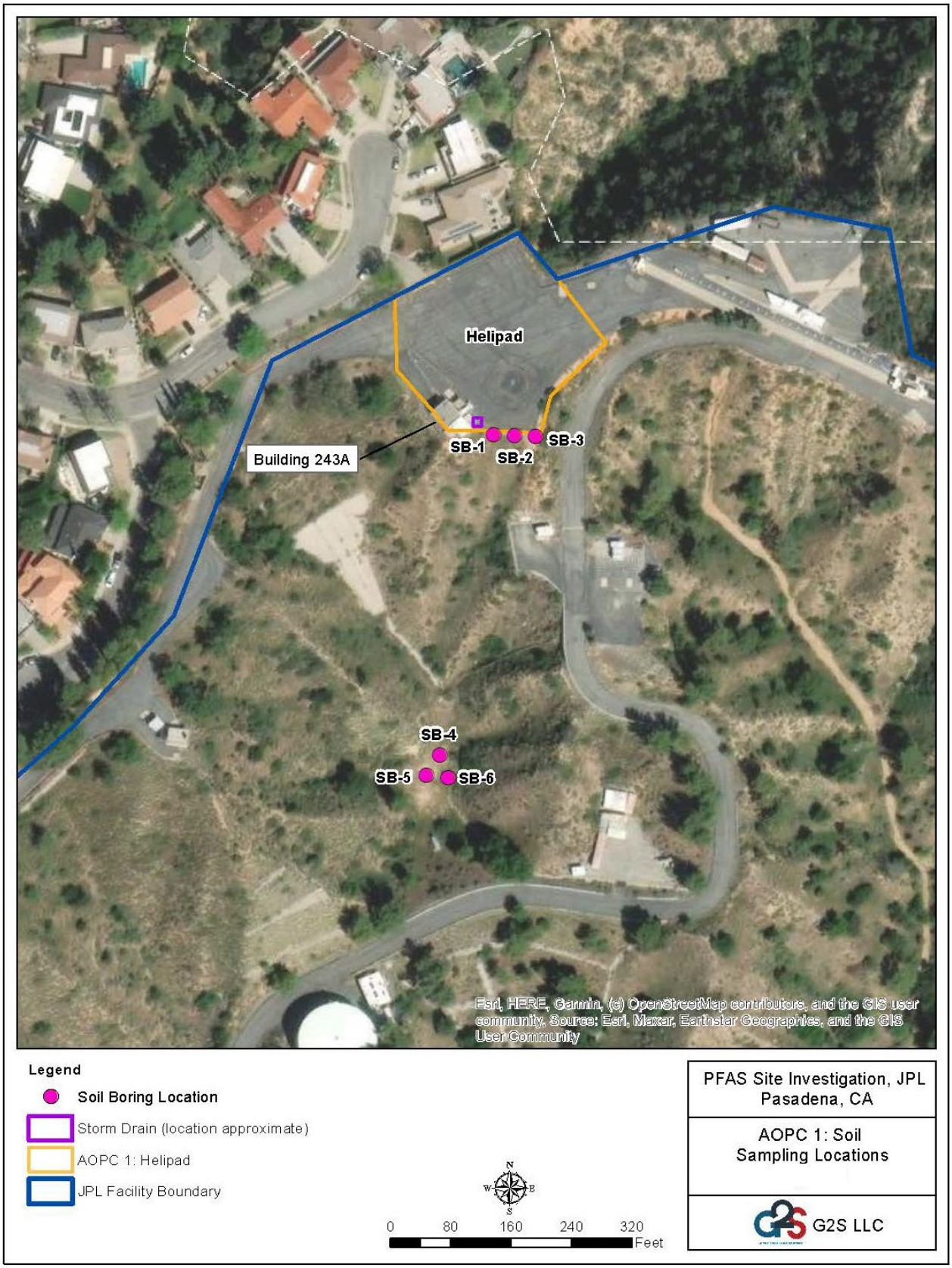

Figure 2-3. AOPC 1: Soil Sampling Locations.

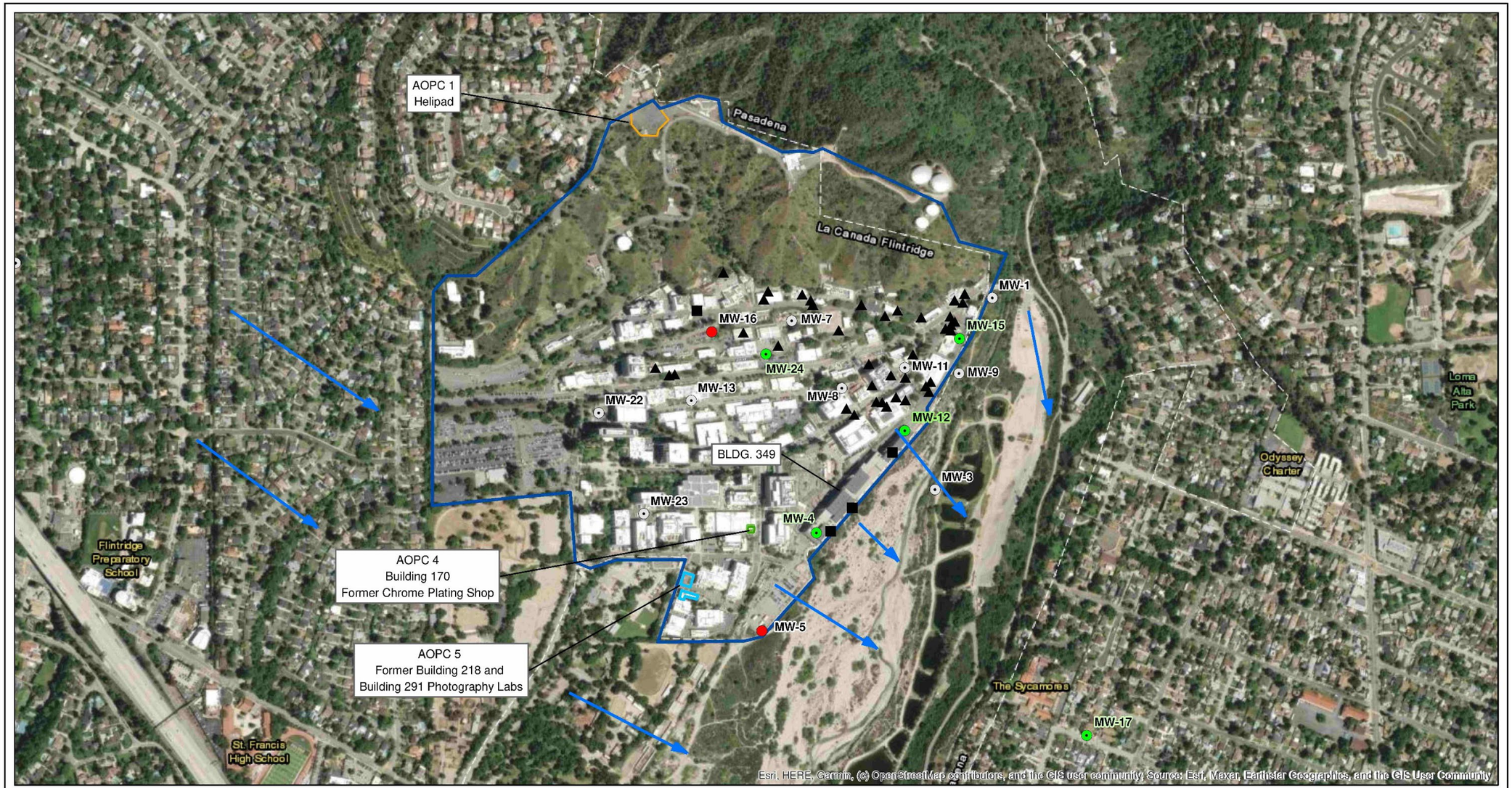

Figure 2-4. AOPCs 1, 2 and 3, 4, and 5: Groundwater Sampling Locations

The PFAS analytical results, included as part of the scope of the SI, confirmed the presence of PFAS constituents in soil and groundwater at the JPL Site and downgradient of the JPL Facility at concentrations in excess of USEPA MCLs and California SWRCB NLs screening criteria (see Section 1.2). Specifically, PFAS are present in AOPCs 1, 2, 3, and 4 (the monitoring well associated with determining the presence or absence of PFAS in AOPC 5 was not sampled because it was dry). PFOA and PFOS are present in soil above screening criteria in AOPC 1, and PFOS is present in groundwater above screening criteria in AOPCs 2 and 3. In addition, PFOA is present in groundwater above screening criteria in AOPCs 2 and 3.

Sampling of drinking water wells by local water purveyors (City of Pasadena and LAWC) demonstrate that PFAS are present in one or more of their untreated drinking water wells that are part of the JPL CERCLA cleanup program. The City of Pasadena MHTS and LAWC treatment system currently use granular activated carbon and perchlorate selective ion exchange media to treat groundwater extracted from drinking water wells. Although these systems were not specifically designed for PFAS removal, the treatment technologies are proven to be effective for removal of PFAS from groundwater.

Based on the results of the SI at JPL, NASA conducted a comprehensive PFAS sampling of monitoring wells within and near the JPL Facility in March 2024. During this comprehensive PFAS sampling event, the most comprehensive analytical method, USEPA Method 1633, was used for PFAS analysis. The results of the comprehensive PFAS sampling are documented in this report.

3 ENVIRONMENTAL SETTING

The following sections provide information regarding the environmental setting for JPL including the climate, topography and surface features, geology, hydrogeology, surface water features, and land use. The information in this section is drawn from previous Remedial Investigations for OU1, OU2, and OU3 at NASA JPL, and provides a baseline of information and the context to interpret PFAS results and findings.

3.1 Climate

JPL is located in an area with a Mediterranean climate at an elevation of 1,100 ft above sea level. The average temperature over the course of a year in Pasadena is 64 degrees Fahrenheit (°F). The average summer high is 88°F with a winter low of 46°F. Summers are hot, arid, and clear, whereas winters are cool, wet, and partly cloudy. JPL receives approximately 21 inches of rain a year, with most of the precipitation received between November and April. Most of the rainfall occurs in February, with an average of 3.2 inches of rain over the course of the month. (Tetra Tech, 2021)

3.2 Topography and Surface Features

JPL is located in Los Angeles County, California, encompassing approximately 176 acres in the San Gabriel Mountains east of the City of Los Angeles (Figure 3-1). JPL consists of office buildings, laboratories, and other facilities related to propulsion research and development. The JPL property is divided into two main areas: a relatively undeveloped northern area and the main campus, which encompasses the remainder of the property. Elevations of JPL range from approximately 1,080 to 1,280 ft above mean sea level (amsl) within the main campus to 1,560 ft amsl near the northern boundary. Steep hills and slopes generally separate the northern portion from the main JPL campus. Hills continue from the base of the high elevation northern portion of JPL down into and throughout the main campus, ultimately leveling off to the south/southeast. A mesa is present in the northern area of JPL, and a helipad for emergency use and radio and antenna testing facilities are located on the mesa. (Tetra Tech, 2021)

3.3 Geology

The geology of JPL is well understood. JPL is located in the far northwestern region of the San Gabriel Valley along the southern flank of the San Gabriel Mountains (Figure 3-2). The San Gabriel Mountains are part of the Transverse Ranges geomorphic province, which is comprised of east-west trending mountain ranges resulting from north-south compression and deformation (Foster Wheeler Environmental Corporation [FWEC], 1999a; FWEC, 1999b). The San Gabriel Valley, like other valleys in the region, is filled with Quaternary alluvial deposits of Pleistocene to Holocene age (approximately 2.5 million years old [Ma] to present). In the vicinity of JPL, these deposits extend from the ground surface to a depth of approximately 600 to 2,000 feet, depending on proximity to the San Gabriel Mountains and relationship to underlying faults (FWEC, 1999a). These alluvial deposits are typically poorly sorted sands and gravels with some discontinuous lenses of finer (fine sand and silt) and coarser (cobbles and boulders) material. The alluvial deposits overlie the regional basement rock, a leucrocratic granodiorite of Cretaceous age (approximately 65 to 122 Ma), which is light gray to buff colored and has a fine- to medium-grained crystalline texture (Dibblee, 1989; FWEC, 1999a). This basement rock also constitutes the San Gabriel Mountains and outcrops in some areas near JPL on steeper slopes on the north end of the Site and along the Arroyo Seco (Dibblee, 1989)

Lithology at JPL is characterized as medium to coarse-grained sand and gravel interbedded with fine sands and silts consistent with the regional alluvial deposits (FWEC, 1999a). Relatively thin intervals of cobbles and boulders are present throughout the alluvial sequence and represent higher energy depositional environments (e.g., stream channels). Detailed characterization of the JPL lithology was

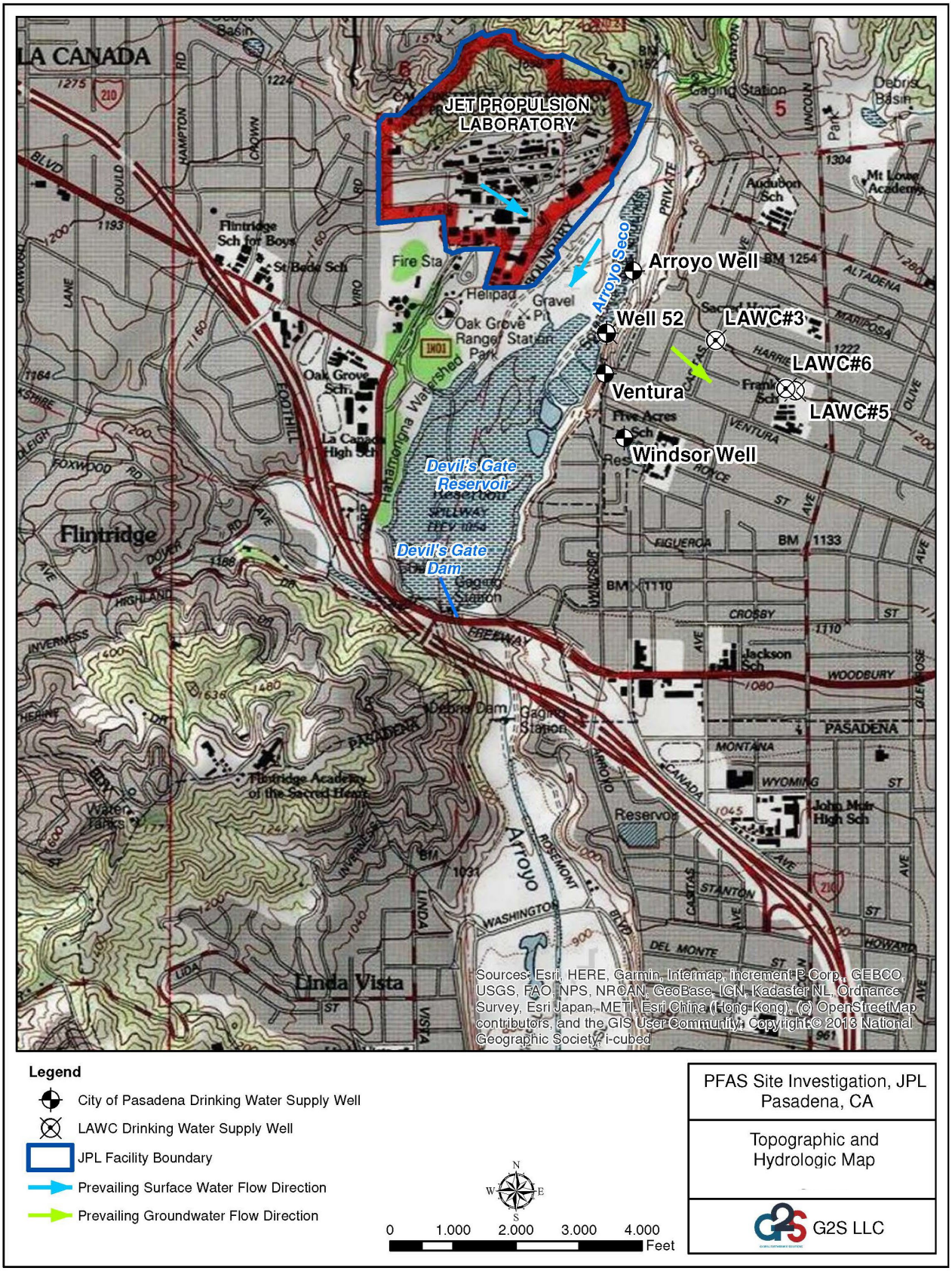

Figure 3-1. Topographic and Hydrologic Map

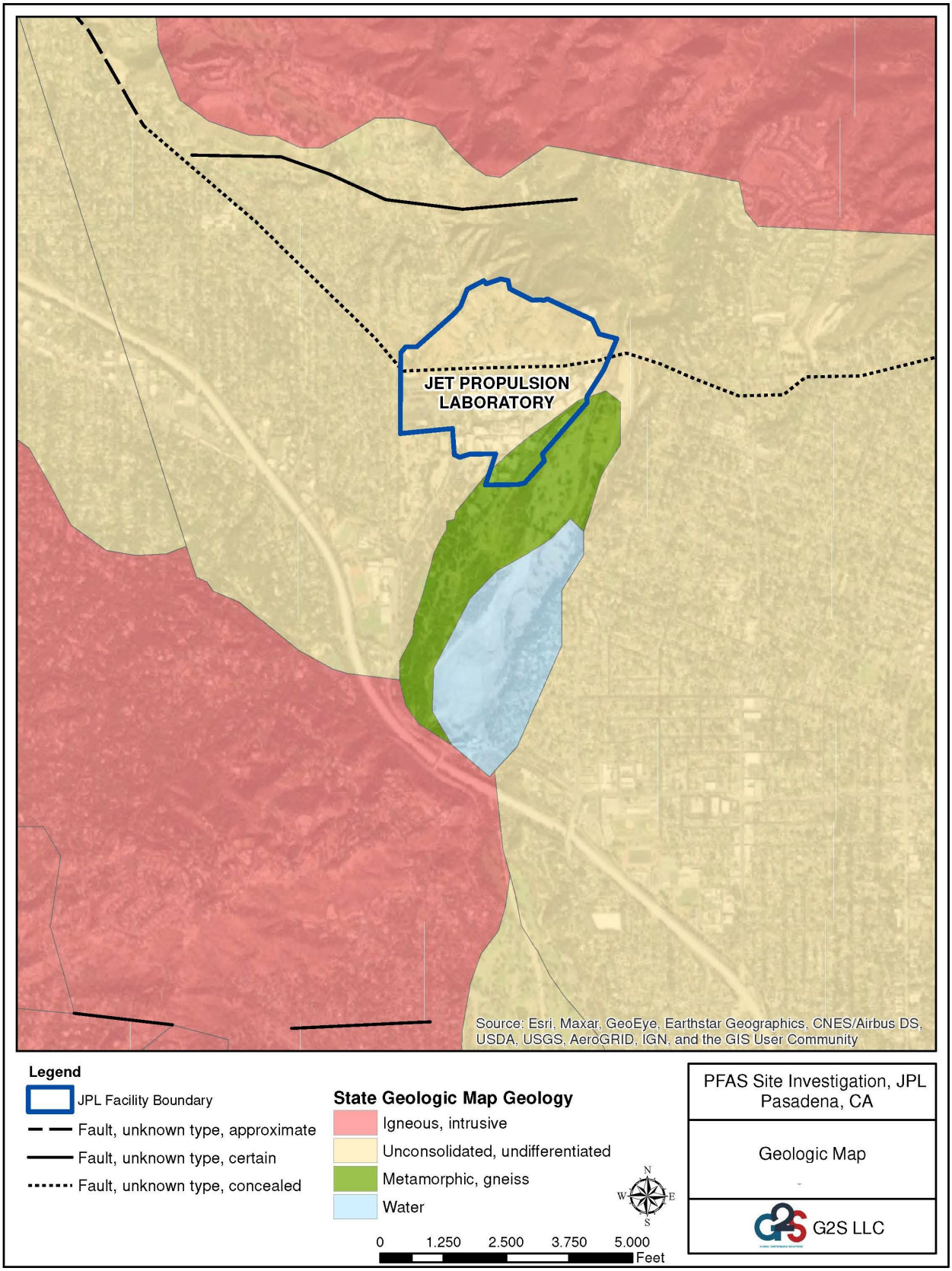

Figure 3-2. Geologic Map

conducted during the installation of the on- and off-site monitoring well network at JPL (FWEC, 1999a), and the discontinuous layers of finer grained (silty) material at depth are used to define the aquifer layer boundaries, which are described in section 3.4 below.

Multiple mapped faults are located at JPL and in the nearby area (Dibblee, 1989; FWEC, 1999a; FWEC, 1999b; Morton and Yerkes, 1987). The Tujunga Fault (also referred to as the JPL Thrust Fault) cuts east-west across the main JPL property and other unnamed fault traces run outside the JPL boundary to the north in a similar orientation. These faults are broadly referred to as the Sierra Madre Fault Zone. The JPL Thrust Fault represents a north-south boundary between shallow bedrock and deeper alluvium (NASA, 2018). North of the fault, bedrock occurs within 2 to 100 feet of ground surface, with groundwater primarily present in joints and fractures within the shallow bedrock. Due to its low porosity, this shallow bedrock is considered non-water bearing and separate from the JPL groundwater system (NASA, 2018). Therefore, the bedrock north of the JPL Thrust Fault is not a possible migration pathway for contaminants into the JPL groundwater system (NASA 2018). South of the JPL Thrust Fault, groundwater occurs in the deeper aquifer layers described in Section 3.4 (NASA, 2018). Further to the north in the San Gabriel Mountains, the south branch of the San Gabriel Fault trends northwest-southeast (Tetra Tech, 2021).

3.4 Hydrogeology

JPL is located within a groundwater basin known as the Raymond Basin, which is adjacent to the San Fernando Valley and San Gabriel Valley Basins (State of California Department of Water Resources [DWR], 2004a; DWR, 2004b; DWR, 2004c). Groundwater drawn from the Raymond and San Fernando Valley groundwater basins is used for drinking water in communities surrounding JPL. Drinking water supply wells (also referred to as production wells) in both the Raymond and San Fernando Valley Basins are located within a 4-mile radius of JPL (Appendix B; NASA, 2019a). Based on prior hydrogeologic investigations of the Raymond Basin, there are four distinct aquifer layers in the area surrounding JPL (FWEC, 1999a; FWEC, 1999b; NASA, 2019b): the upper Older Fanglomerate Series; the lower Older Fanglomerate Series; the Pacoima Formation; and the Saugus Formation.

In most areas, only the first three aquifer layers are present; however, in areas where the crystalline basement is deeper, the fourth and deepest alluvial aquifer layer (the Saugus Formation) is present. These aquifers, while similar in their alluvial composition, are defined by observed differences in hydraulic head during pumping of production wells in the vicinity of JPL. The differing responses to pumping at different screen depths, along with subtle differences in geologic composition, have been used to define the aquifer boundaries (FWEC, 1999a; FWEC, 1999b).

The shallowest two aquifers are the upper and lower Older Fanglomerate Series, which are sometimes simply referred to collectively as the Older Fanglomerate Series. These aquifers are present in the Cenozoic basin-filling alluvial deposits described above and underlie the current surface alluvium (FWEC, 1999a). These deposits range in thickness from 300 to 800 feet in the vicinity of JPL. The composition of the alluvial deposits that comprise the Older Fanglomerate Series is similar to that of recent alluvial and stream channel deposits in the area. The Older Fanglomerate Series is subdivided into upper and lower parts based on inferred age and spatial relationship to present-day stream channels. The composition of the upper and lower parts of the series is generally the same, with lithology dominated by fluvial arkosic sands (i.e., sands composed of less than 25 percent [%] feldspar grains) with abundant gravel and boulders. The upper and lower sections of the Older Fanglomerate Series are inferred to be separated, at least locally, by fine-grained (silt-rich) layers of relatively low permeability. As mentioned above, the boundary between the upper and lower Older Fanglomerate has been distinguished based on the hydraulic response to pumping of nearby production wells screened at different depths (FWEC, 1999a; FWEC, 1999b).

The third aquifer layer is the Pacoima Formation, which lies, in most areas around JPL, unconformably upon the granodiorite basement. In some areas where the regional basement is deeper, the Pacoima Formation lies unconformably atop a fourth alluvial aquifer layer, described below. This formation is characterized by fluvial sands with gravel and boulders and is differentiated from the overlying Older Fanglomerate Series by characteristic dark reddish-orange weathering. This formation is 200 to 300 feet thick in the vicinity of JPL.

The fourth aquifer layer, the Saugus Formation, is present in some areas of the Raymond Basin between the Pacoima Formation and crystalline basement rock. The Saugus Formation is up to 200 feet thick and is composed of arkosic sand with some pebbles and areas that are more conglomeratic. The differentiation of the Saugus and overlying formations is not clearly defined. The formations are generally defined based on the degree of sorting and the composition of lithic clasts in the sediments. Broadly, the Saugus Formation represents a lower-energy depositional environment (e.g., floodplain) relative to the overlying fanglomerate deposits.

Observation and monitoring wells are screened in all four aquifer layers, and groundwater present in the first (shallowest) aquifer layer is considered to be under unconfined conditions. Drinking water supply wells within 4 miles of JPL are also screened within all four aquifer layers. Recharge in the vicinity of JPL occurs naturally through precipitation and through flooding of the Arroyo Seco spreading grounds with water during the rainy season (FWEC, 1999a). In the vicinity of JPL, depth to groundwater in the shallowest aquifer is approximately 200 feet (NASA, 2018), although it ranges between approximately 20 feet and 270 feet due to the steep topography present at JPL and the effects of seasonal groundwater recharge in the Arroyo Seco spreading grounds to the southeast of JPL (Figure 3-1) and groundwater pumping from the nearby municipal production wells (FWEC, 1999a). Depth to groundwater in monitoring wells located at the northern extent of the Arroyo Seco are typically 80 to 120 feet shallower than the surrounding water table (NASA, 2018). At this location, groundwater mounding attributed to recharge and faulting results in depths to water between approximately 80 and 120 feet (NASA, 2018).

Deeper groundwater in the second to fourth aquifer layers may be under semi-confined conditions due to local lenses of fine-grained material separating some layers. These lenses are discontinuous and occur at a range of depths throughout the stratigraphic sequence. The influence of these fine-grained layers on local hydrogeologic conditions is observed in hydraulic head differences in deeper, multiport monitoring wells (FWEC, 1999a). During periods when production wells are extracting groundwater in the area, hydrographs from multiport monitoring wells indicate that downward migration of groundwater would be expected. When production wells are not extracting groundwater, the hydraulic head in deeper aquifer layers can temporarily be equal to or above that of shallower aquifer layers in some monitoring wells (FWEC, 1999a). The hydraulic response recorded at the monitoring wells during these pumping events suggests a semi-confined nature for these deeper aquifers; however, vertical hydraulic communication between the aquifers appears to occur given the presence of perchlorate and various VOCs in deeper aquifer layers and the spatially discontinuous nature of the confining layers (FWEC, 1999a; NASA, 2019a). Hydraulic conductivity values were estimated during large-scale pump testing completed in 2001. Horizontal conductivity values were estimated to be 14.4 feet per day (ft/day), 28.2 ft/day, 27.9 ft/day, and 3.9 ft/day in the upper Older Fanglomerate Series, lower Older Fanglomerate Series, Pacoima Formation, and Saugus Formation, respectively. Vertical conductivity between the upper and lower Older Fanglomerate Series was estimated at 0.0092 ft/day, between the lower Older Fanglomerate Series and Pacoima Formation at 0.0060 ft/day, and between the Pacoima and Saugus formations at 0.011 ft/day.

The direction of groundwater flow in the vicinity of JPL is dynamic due to the influences of natural seasonal groundwater recharge, groundwater recharge in the Arroyo Seco spreading grounds, and groundwater pumping from municipal production wells in the immediate JPL vicinity, with groundwater pumping having the most pronounced influence (FWEC, 1999a). Throughout most of the year,

groundwater flow in the aquifers is predominantly to the southeast (NASA, 2019a) towards the pumping City of Pasadena municipal supply wells. The groundwater production wells are typically shut down for a relatively short period of time during the wet, winter season, during which time the groundwater flow direction has been observed to reverse flow towards the west across JPL. Although the duration of these flow reversal can span multiple weeks, they generally last for only a period of days (FWEC, 1999a). Further, based on measurements of contaminants in JPL monitoring wells there does not appear to be significant contaminant migration to the west (FWEC, 1999a; NASA, 2003).

Beneficial uses for groundwater in the aquifers of the Raymond and San Fernando Valley Basins have been designated by the Los Angeles Regional Water Quality Control Board (LARWQCB) in their Basin Plan (LARWQCB, 2014). In both the Raymond and San Fernando Valley Basins, beneficial uses exist, and are protected under the Basin Plan, for municipal, industrial service supply, industrial process supply, and agricultural purposes. (Tetra Tech, 2021)

3.5 Surface Water Features

JPL is located in an urban setting, and rainfall in the area is generally captured by engineered storm drain systems. Runoff from the San Gabriel Mountains above JPL is transferred via a network of underground storm drains to the Arroyo Seco. Runoff collected on JPL is directed via a network of underground storm drains that lead to 13 discharge points along the east/southeastern JPL property boundary that outfall to the Arroyo Seco. Some storm drains on JPL are directed to the sanitary sewer, but most are directed to the Arroyo Seco. The largest stormwater discharge outfall from JPL is located at the southeastern corner of Building 349 (Building 349 is shown on Figure 2-4).

The Devils Gate Dam is located south of JPL along the Arroyo Seco and north of Interstate 210. The area upstream from the dam along the Arroyo Seco is referred to as Devils Gate Reservoir. Water levels in the reservoir fluctuate throughout the year as rainfall is received and allowed to flow through the dam. Significant portions of the reservoir bed are not inundated with water throughout the year. During wet periods, surface water is periodically diverted to the Arroyo Seco spreading grounds along the eastern banks of the reservoir. These areas serve to provide groundwater recharge to the Raymond Basin. The Arroyo Seco is channelized downstream from the Devils Gate Dam and drains into the Los Angeles River. The main pathways for surface water in the area are downstream or down-system flow in natural or engineered waterways, percolation into alluvial aquifers, and evaporation.

Beneficial uses for Arroyo Seco surface water have been identified in the LARWQCB Basin Plan (LARWQCB, 2014). The designations include existing, intermittent, and potential beneficial uses for different parts of the Arroyo Seco water course; these three categories are to be protected under the Basin Plan. In the immediate vicinity of JPL, beneficial uses are designated for the upper and lower portions of Devils Gate Reservoir along the Arroyo Seco; these include potential (municipal), intermittent (groundwater recharge and municipal), and existing (wildlife habitat) uses. Recreational activities such as swimming and boating are not among the beneficial uses identified for the Arroyo Seco waterway in the vicinity of JPL. (Tetra Tech, 2021)

3.6 Land Use

JPL is a NASA facility for research and development of space exploration, including rocket propellant design and testing, spacecraft material and equipment design, assembly and testing, and research related to alternative energy sources and pollution control (Ebasco Services, Inc. [Ebasco], 1988). In recent decades, JPL has functioned as NASA's primary center for unmanned interplanetary exploration and assists with aeronautical research and development (Ebasco, 1988). The area of JPL is zoned as Public/Semi-Public (City of La Cañada Flintridge, 2016). There is no residential use of the property.

The land use within a 1-mile radius of JPL is residential, recreational, and commercial. The Los Angeles County Fire Camp #2 (a Los Angeles County-operated station established to respond to fires, floods, and other natural or manmade disasters) and the Hahamongna Watershed Park are located adjacent to and south of JPL. Potentially sensitive receptors located within a 1-mile radius of JPL include 42 daycare centers, 4 schools (public and private), 6 schools/day care centers, a community center, and the Angeles National Forest (Tetra Tech, 2021).

4 FIELD ACTIVITIES AND ANALYTICAL PROTOCOL

This section details the field activities conducted as part of the PFAS groundwater investigation in March 2024 at the JPL Facility. The investigation was recommended in the Final SI Report (NASA, 2024), following initial soil and groundwater sampling in November 2022.

The following subsections provide an account of the sampling locations, methodologies, and protocols employed during the March 2024 field activities. This information serves as the foundation for the subsequent analysis and recommendations presented in later sections of this report.

4.1 Groundwater Sampling Locations

The groundwater sampling locations for the PFAS groundwater investigation were selected based on our understanding of site characteristics, including groundwater flow patterns and chemical concentration distribution, informed by over 20 years of quarterly groundwater monitoring data dating back to the 1990s. Nearly all wells in the JPL groundwater monitoring well network were sampled, except MW-1 (redundant with MW-9 and MW-15) and MW-25 and MW-26 (both are well outside the known extent of chemicals originating from JPL). In addition, the deepest well screens (i.e., Screens 4 and 5) of some multiport wells were not sampled due to the minimal occurrence of chemicals originating from JPL in samples collected from the deepest screened intervals.

The groundwater monitoring network at the JPL Facility consists of two types of wells:

1. Shallow standpipe wells with a single screen.
2. Deep multiport wells, known as Westbay™ wells, which contain up to five discrete sampling locations.

Table 4-1 below provides a detailed overview of the monitoring well network, including well types and sampled intervals. Figure 4-1 shows the locations of the JPL groundwater monitoring wells.

The following subsection details the specific wells sampled during the March 2024 comprehensive groundwater sampling event, including both shallow standpipe and Westbay™ wells.

4.2 Sampling Procedures

Groundwater samples were collected March 11 through 21, 2024 from NASA JPL monitoring wells (MWs) located both on- and off-facility. Samples were collected from MW-3 (Screens 1 to 4), MW-4 (Screens 1 to 4), MW-5 to MW-10, MW-11 (Screens 1 to 3), MW-12 (Screens 1 to 4), MW-13, MW-14 (Screens 1 to 4), MW-15, MW-16, MW-17 (Screens 1 to 4), MW-18 (Screens 1 to 4), MW-19 (Screens 1 to 3), MW-20 (Screens 1 to 4), MW-21 (Screens 1 to 3), MW-22 (Screens 1 to 3), MW-23 (Screens 1 to 3), and MW-24 (Screens 1 to 3).

As a safety precaution, the air in the breathing zone was monitored with a photoionization detector (PID) or equivalent as each well cover was removed, ensuring that any escaping volatile organic compounds (VOCs) did not pose an adverse health effect to the field sampling team. The PID was calibrated according to manufacturer's requirements, with calibration data recorded in the instrument use log. Since two different well types were sampled for PFAS compounds, sampling procedures are described separately in the following subsections: Section 4.2.1 covers sampling of shallow standpipe wells and Section 4.2.2 covers sampling of the Westbay™ wells.

Table 4-1. Monitoring Well Identification, Screened Interval, and Well Type

Well ID	Screen 1	Screen 2	Screen 3	Screen 4	Screen 5	Single	Well Type
MW-1	Was Not Sampled – Redundant to MW-9 and MW-15						Shallow Standpipe
MW-2	Abandoned						
MW-3	X	X	X	X			Westbay™ Multiport
MW-4	X	X	X	X			Westbay™ Multiport
MW-5						X	Shallow Standpipe
MW-6						X	Shallow Standpipe
MW-7						X	Shallow Standpipe
MW-8						X	Shallow Standpipe
MW-9						X	Shallow Standpipe
MW-10						X	Shallow Standpipe
MW-11	X	X	X				Westbay™ Multiport
MW-12	X	X	X	X			Westbay™ Multiport
MW-13						X	Shallow Standpipe
MW-14	X	X	X	X			Westbay™ Multiport
MW-15						X	Shallow Standpipe
MW-16						X	Shallow Standpipe
MW-17	X	X	X	X			Westbay™ Multiport
MW-18	X	X	X	X			Westbay™ Multiport
MW-19	X	X	X				Westbay™ Multiport
MW-20	X	X	X	X			Westbay™ Multiport
MW-21	X	X	X				Westbay™ Multiport
MW-22	X	X	X				Westbay™ Multiport
MW-23	X	X	X				Westbay™ Multiport
MW-24	X	X	X				Westbay™ Multiport
MW-25	Was Not Sampled – Outside of the Extent of Chemicals Originating from JPL						Westbay™ Multiport
MW-26	Was Not Sampled – Outside of the Extent of Chemicals Originating from JPL						Westbay™ Multiport

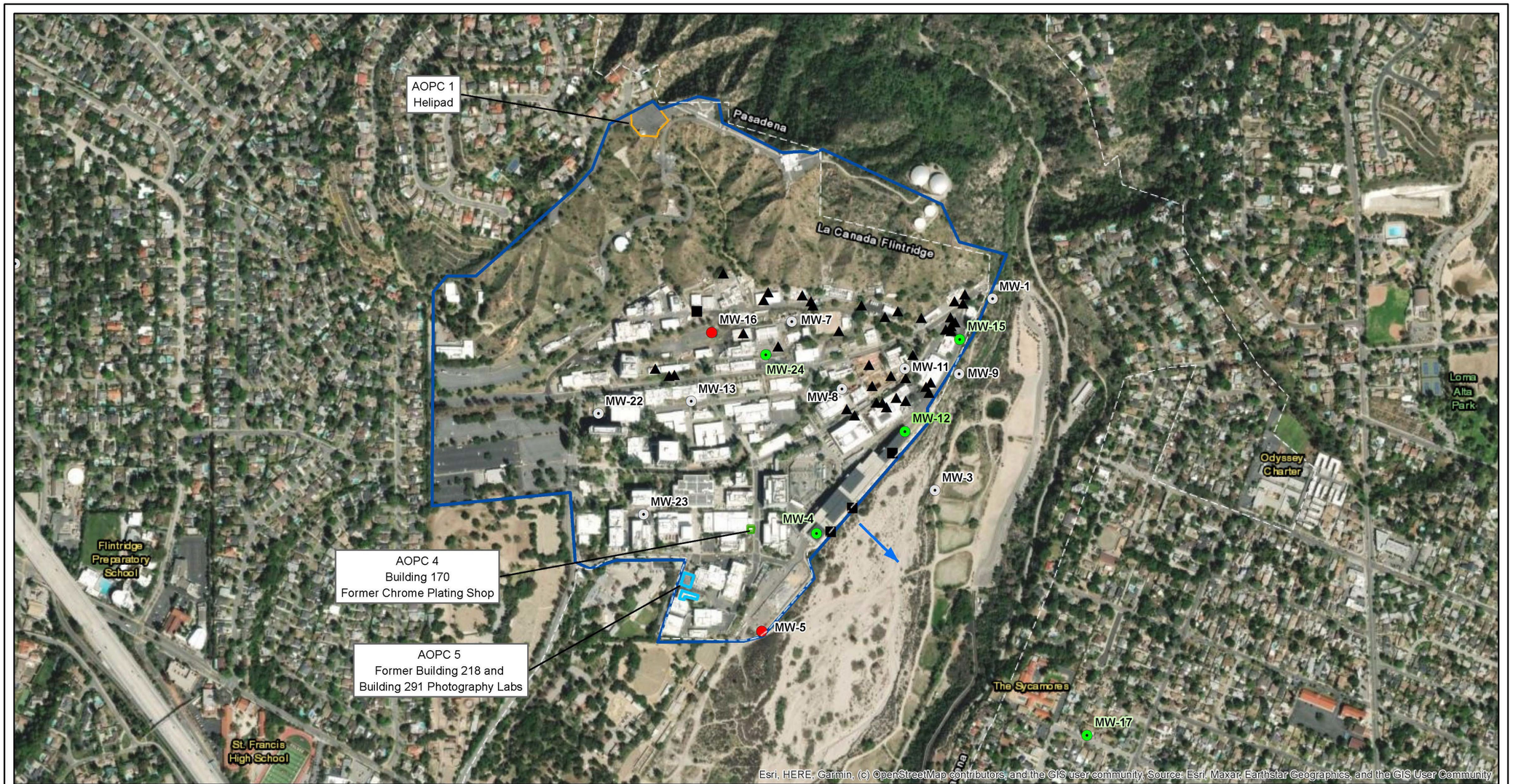

Figure 4-1. AOPCs 1, 2 and 3, 4, and 5: Groundwater Sampling Locations

4.2.1 Shallow Well Sampling

For shallow standpipe wells, the sampling procedure began with a groundwater-level measurement taken from the well before purging in accordance with G2S's PFAS Specific Standard Operating Procedure (SOP). This measurement was documented on the field log sheet. Brand-new high-density polyethylene (HDPE) tubing was connected to the PFAS-free non-dedicated bladder pump, and the well was purged using the low flow/minimal drawdown method.

The recovered groundwater was monitored for temperature, pH, specific conductivity, turbidity, dissolved oxygen (DO), and oxidation-reduction potential (ORP). Groundwater sampling equipment was calibrated before use, and the resulting data was recorded on a test equipment calibration log. Depth to water measurements and field parameters were closely monitored and documented on the field log sheet. Purging continued until parameters met stabilization criteria in accordance with the SOP.

Upon stabilization, sampling was initiated. Groundwater samples were collected directly into two laboratory-provided 250 mL HDPE containers from the discharge tubing.

Screened intervals for the shallow wells are provided in Table 4-2.

4.2.2 Westbay® Multiport Well Sampling

For Westbay™ multiport wells, the sampling procedure utilized a specialized apparatus consisting of an electrically activated valve opening assembly (sampling probe) connected to four 250-mL stainless steel tube-shaped containers. This apparatus was first prepared by cleaning and evacuating. The probe and containers were then lowered to the sampling port using an electric winch.

Upon reaching the port, the operator used a control unit to activate the valve opening assembly, connecting the sampling probe to the sampling port. The sampling valve in the probe was opened, allowing groundwater to flow through the probe and enter the sample container. Once the container was full, the sampling valve was closed, the arms were retracted, and the sampling probe and sample containers were raised to the surface.

The sample was then transferred to two laboratory-provided 250 mL HDPE sample containers. Following this, the sampling probe and containers were cleaned, and the procedure was repeated for additional ports or wells as necessary.

Screened intervals and sampling port depths for the multiport wells are provided in Table 4-2.

4.2.3 Sample Handling, Analysis, and Documentation

For both well types, the sample handling, analysis, and documentation procedures were consistent. After collection, sample containers were sealed, labeled, and packed on ice in insulated coolers. Samples were then shipped via FedEx to Agriculture & Priority Pollutants Laboratories (APPL) under chain of custody (CoC) protocol. All samples were analyzed for PFAS by EPA Method 1633.

Groundwater sampling activities were thoroughly documented on Groundwater Sampling Logs, which can be found in Appendix D. These logs include depth to water measurements, field parameters, and other relevant sampling information. Calibration data for sampling equipment was recorded on test equipment calibration logs, also included in Appendix D.

Table 4-2. Multiport Well Identification, Screened Interval, and Sampling Port Depth

Well ID	Screened Interval (ft bgs)	Sampling Port (ft bgs)
MW-3 (Screen 1)	170 – 180	172.00
MW-3 (Screen 2)	250 – 260	252.00
MW-3 (Screen 3)	344 – 354	346.00
MW-3 (Screen 4)	555 – 565	558.00
MW-4 (Screen 1)	147 – 157	150.00
MW-4 (Screen 2)	237 – 247	240.00
MW-4 (Screen 3)	318 – 328	322.00
MW-4 (Screen 4)	389 – 399	392.00
MW-5	85 – 135	--
MW-6	195 – 245	--
MW-7	225 – 275	--
MW-8	155 – 205	--
MW-9	18 – 68	--
MW-10	105 – 155	--
MW-11 (Screen 1)	140 – 150	149.00
MW-11 (Screen 2)	250 – 260	259.00
MW-11 (Screen 3)	420 – 430	429.00
MW-12 (Screen 1)	135 – 145	140.00
MW-12 (Screen 2)	240 – 250	243.00
MW-12 (Screen 3)	315 – 325	323.00
MW-12 (Screen 4)	430 – 440	436.00
MW-13	180 – 230	--
MW-14 (Screen 1)	205 – 215	207.00
MW-14 (Screen 2)	275 – 285	277.00
MW-14 (Screen 3)	380 – 390	382.00
MW-14 (Screen 4)	453 – 463	456.00
MW-15	19 – 69	--
MW-16	230 – 280	--
MW-17 (Screen 1)	246 – 256	250.00
MW-17 (Screen 2)	366 – 376	370.00
MW-17 (Screen 3)	466 – 476	468.00
MW-17 (Screen 4)	578 – 588	582.00
MW-18 (Screen 1)	266 – 276	270.00
MW-18 (Screen 2)	326 – 336	330.00
MW-18 (Screen 3)	421 – 431	424.00
MW-18 (Screen 4)	561 – 571	564.00
MW-19 (Screen 1)	240 – 250	242.00
MW-19 (Screen 2)	310 – 320	314.00
MW-19 (Screen 3)	390 – 400	392.00
MW-20 (Screen 1)	228 – 238	230.00
MW-20 (Screen 2)	388 – 398	392.00
MW-20 (Screen 3)	558 – 568	562.00
MW-20 (Screen 4)	698 – 708	700.00
MW-21 (Screen 1)	86 – 96	90.00
MW-21 (Screen 2)	156 – 166	161.00
MW-21 (Screen 3)	236 – 246	240.00
MW-22 (Screen 1)	239 – 249	245.00
MW-22 (Screen 2)	324 – 334	329.00
MW-22 (Screen 3)	384 – 394	389.00
MW-23 (Screen 1)	170 – 180	174.00
MW-23 (Screen 2)	250 – 260	254.00
MW-23 (Screen 3)	315 – 325	319.00
MW-24 (Screen 1)	275 – 285	279.00
MW-24 (Screen 2)	370 – 380	373.00
MW-24 (Screen 3)	430 – 440	435.00

4.2.4 Total Sample Counts

In total, 91 samples (55 primary groundwater samples, 8 field duplicates, 8 matrix spike/matrix spike duplicates [MS/MSDs], 9 field blanks, 9 equipment blanks, and 2 source blanks) were collected and analyzed for PFAS compounds using EPA Method 1633 by LC-MS/MS. All analyses were conducted in accordance with the quality control procedures detailed in Section 5.

As noted above, the number of samples collected from each well varied based on the well type and specific site considerations. For multiport wells, samples were collected from multiple screens, reflecting the different depths and potentially varying groundwater conditions. MW-1 was not sampled due to its proximity to MW-9 and MW-15, making it redundant. MW-25 (Screens 1 to 5) and MW-26 (Screens 1 and 2) were excluded as they are located outside the extent of chemicals originating from JPL. Additionally, certain deeper screens in various wells (MW-3 Screen 5, MW-4 Screen 5, MW-11 Screens 4 and 5, MW-12 Screen 5, MW-14 Screen 5, MW-17 Screen 5, MW-18 Screen 5, MW-19 Screens 4 and 5, MW-20 Screen 5, MW-21 Screens 4 and 5, MW-22 Screens 4 and 5, MW-23 Screens 4 and 5, and MW-24 Screens 4 and 5) were not sampled as part of this investigation because they generally contain low concentrations of chemicals of concern based on historical data.

4.3 Analytical Methods and Data Validation

This section outlines the laboratory analysis and data validation procedures employed for the groundwater samples collected during the groundwater investigation.

Groundwater samples were analyzed by APPL in Clovis, California, a DoD Environmental Laboratory Accreditation Program (ELAP) accredited laboratory. Samples were analyzed using EPA Method 1633 by liquid chromatography-tandem mass spectrometry (LC-MS/MS). This method is currently the best available technique for PFAS analysis, providing acceptable detection limits for 43 PFAS compounds. All 43 PFAS compounds were analyzed for each sample collected during the investigation. The laboratory analytical reports for the PFAS samples collected during the groundwater investigation are included in Appendix B.

Following laboratory analysis by APPL, third-party data validation was performed by an independent subcontractor, Laboratory Data Consultants, Inc. (LDC) of Carlsbad, California. All samples underwent Level III data validation, which includes a thorough review of sample results, quality control data, and compliance with method and project requirements. Additionally, 10% of the samples were subjected to Level IV data validation, which involves a more comprehensive evaluation including a review of raw data and calculations. This rigorous validation process ensures the highest level of data quality and reliability for the groundwater investigation. The data validation packages are included in Appendix C.

4.4 Analytical Results

This section presents the validated analytical results for six key PFAS compounds (PFOA, PFOS, PFHxS, PFNA, HFPO-DA, and PFBS) that have established MCLs and/or California NLs. These compounds are the focus of NASA's detailed analysis due to their regulatory significance and potential health impacts.

The following subsections provide an analysis of the six key PFAS compounds, including their concentrations in the sampled wells and comparisons to relevant regulatory standards. This analysis serves as the foundation for assessing potential PFAS impacts at the JPL Site.

Analytical results for the remaining PFAS constituents are provided in tables at the conclusion of this report, offering a complete picture of the nature and extent of PFAS in groundwater at the site.

PFOA was detected in 52 of the 55 samples at concentrations ranging from 0.2 J ng/L to 27 ng/L. Eleven samples (20%) exceeded the EPA MCL of 4 ng/L, with the highest concentration found in MW-23-1.

PFOS, detected in 42 samples, had concentrations ranging from 0.29 J ng/L to 20 ng/L. Seven samples (12.7%) exceeded the MCL of 4 ng/L, with MW-9 having the highest concentration.

PFHxS was detected in 52 samples at levels between 0.066 J ng/L and 17 ng/L. Three samples (5.5%) exceeded the MCL of 10 ng/L, with MW-23-2 having the highest concentration.

PFNA was detected in 17 samples at concentrations ranging from 0.09 J ng/L to 4.4 ng/L. No samples exceeded the MCL of 10 ng/L, with the maximum concentration detected in MW-9.

HFPO-DA was not detected above the reporting limit in any of the samples. PFBS, which does not have an individual MCL, was found in 50 samples at concentrations up to 21 ng/L in MW-23-2.

The Hazard Index, calculated for mixtures containing two or more of PFHxS, PFNA, HFPO-DA, and PFBS, exceeded the MCL of 1.0 in three samples: MW-21-1, MW-23-1, and MW-23-2.

Spatially, higher concentrations of PFAS compounds were generally observed in wells MW-9, MW-21, and MW-23. The majority of wells showed at least some level of PFAS, indicating the widespread presence of these compounds across the JPL monitoring network.

Compared to the 2022 sampling event (Table 2-2), the recent results show a general increase in PFAS concentrations across the site, particularly for PFOA and PFOS. For example, PFOA in MW-4 (Screen 2) increased from a maximum of 1.10 ng/L in 2022 to 5.7 ng/L in 2024. PFOS in MW-15 increased from 1.50 ng/L to 7.6 ng/L. PFOA and PFOS increased in MW-24 (Screen 3) from 2.30 ng/L to 7.9 ng/L (PFOA) and from 0.70 ng/L to 5.8 ng/L (PFOS). More sampling is needed to understand if the general increase is due to seasonal changes or possibly the use of a different PFAS analytical method (USEPA Method 1633).

PFHxS concentrations remained relatively stable with some fluctuations across different screens. PFNA showed slight increases in some wells but remained at low levels overall, with the highest increase observed in MW-15 (from 0.88 ng/L to 2.2 ng/L). HFPO-DA continued to be non-detect across all sampled wells and screens in both sampling events. PFBS showed variable trends, with increases in some wells (e.g., MW-4 Screen 2 from 2.90 ng/L to 12 ng/L) and decreases in others (e.g., MW-12 Screen 2 from 7.40 ng/L to 6.80 ng/L).

Analytical results for the six key PFAS compounds are summarized in Table 4-4.

4.4.1 Specific Findings for PFOA

PFOA concentrations were detected above the federal MCL of 4.0 ng/L in several monitoring wells. Notably, MW-23 (Screen 1) exhibited the highest concentration at 27.0 ng/L, while MW-9 showed a concentration of 17.0 ng/L. Other wells, including MW-4 (Screens 2 and 3), MW-12 (Screen 2), MW-15, MW-19 (Screen 2), MW-21 (Screens 1 and 3), MW-23 (Screen 2), and MW-24 (Screen 3), had concentrations ranging from 4.7 to 9.3 ng/L.

PFOA was detected at concentrations below the MCL in various wells. For instance, MW-3 (Screens 1 to 4) had concentrations ranging from 0.27 J ng/L to 0.80 ng/L. MW-4 (Screen 1) and MW-4 (Screen 4) detected levels at 0.44 J ng/L and 2.9 ng/L, respectively. Several other wells, including MW-5, MW-6, MW-8, MW-10, MW-11 (Screens 1 to 3), MW-12 (Screens 1 and 3), MW-13, MW-14 (Screens 1 to 3), MW-17 (Screens 1 to 4), MW-18 (Screens 1 to 4), MW-19 (Screens 1 and 3), MW-20 (Screens 1 to 4),

MW-21 (Screen 2), MW-22 (Screens 1 to 3), MW-23 (Screen 3), and MW-24 (Screens 1 and 2), exhibited concentrations ranging from 0.20 J ng/L to 3.2 ng/L.

Table 4-3. Groundwater PFAS Results from the Groundwater Investigation

Sample Location	Sample Date	Sample Number	PFOA (ng/L)	PFOS (ng/L)	PFHxS (ng/L)	PFNA (ng/L)	HFPO-DA (GenX Chemicals) (ng/L)	PFBS (ng/L)	NPDWR HI
MW-3-1	3/14/2024	MW-3-1	0.27 J	0.79	0.25 J	0.36 U	0.73 U	0.34 J	0.137
MW-3-2	3/14/2024	MW-3-2	0.56	3.40 J	1.40	0.10 J	0.74 U	3.30	0.241
MW-3-3	3/14/2024	MW-3-3	0.66	2.80	1.30	0.12 J	0.73 U	3.30	0.231
MW-3-4	3/14/2024	MW-3-4	0.80	2.90	1.40	0.13 J	0.74 U	3.30	0.244
MW-4-1	3/12/2024	MW-4-1	0.44 J	1.70 J	0.27 J	0.37 U	0.73 U	2.10	0.141
MW-4-2	3/12/2024	MW-4-2	5.70	1.40 J	**4.50**	0.37 U	0.74 U	12.00	0.617
	3/12/2024	DUP-2-031224	5.70	1.20 J	**4.20**	0.09 J	0.77 U	13.00	0.559
MW-4-3	3/12/2024	MW-4-3	4.70	1.10 J	**4.00**	0.37 U	0.75 U	12.00	0.562
MW-4-4	3/12/2024	MW-4-4	2.90	0.76 J	2.50	0.09 J	0.75 U	7.50	0.366
MW-5	3/19/2024	MW-5	1.20 J	5.40	0.51	0.37 U	0.73 U	3.00	0.168
MW-6	3/19/2024	MW-6	0.83 J	0.38 U	1.30	0.38 U	0.76 U	1.90	0.259
MW-7	3/21/2024	MW-7	0.36 U	0.36 U	0.36 U	0.36 U	0.71 U	0.36 U	0.147
	3/21/2024	DUP-8-032124	0.35 U	0.35 U	0.35 U	0.35 U	0.70 U	0.35 U	0.144
MW-8	3/20/2024	MW-8	0.54 J	2.30	0.10 J	0.36 U	0.72 U	0.73	0.119
MW-9	3/20/2024	MW-9	17.00	20.00	1.10	4.40	0.73 U	6.60	0.639
MW-10	3/19/2024	MW-10	0.85 J	13.00	0.87	0.36 U	0.72 U	0.81	0.205
	3/19/2024	DUP-5-031924	0.93 J	14.00	0.92	0.37 U	0.74 U	0.76	0.214
MW-11-1	3/15/2024	MW-11-1	2.70	3.60	0.67	0.74	0.74 U	2.00	0.223
MW-11-2	3/15/2024	MW-11-2	1.30	1.70	0.64	0.36 U	0.72 U	0.68	0.179
MW-11-3	3/15/2024	MW-11-3	1.50	0.74	0.14 J	0.20 J	0.74 U	0.77	0.110
MW-12-1	3/18/2024	MW-12-1	1.40	2.40	0.27 J	0.37	0.75 U	0.50	0.142
	3/18/2024	DUP-4-031824	1.50	2.00	0.25 J	0.34 J	0.74 U	0.47	0.136
MW-12-2	3/18/2024	MW-12-2	7.10	1.40	0.64	0.56	0.73 U	6.80	0.204
MW-12-3	3/18/2024	MW-12-3	0.86 J	0.85 J	0.32 J	0.36 U	0.72 U	0.20 J	0.144
MW-12-4	3/18/2024	MW-12-4	0.37 U	0.37 U	0.07 J	0.37 U	0.73 U	0.37 U	0.118
MW-13	3/21/2024	MW-13	1.90	0.37 U	0.96	0.37 U	0.75 U	1.20	0.219
	3/21/2024	DUP-6-032124	2.00	0.37 UJ	0.94	0.37 U	0.75 U	1.20	0.217
MW-14-1	3/12/2024	MW-14-1	0.72 J	0.37 UJ	1.50	0.37 U	0.75 U	2.50	0.280
MW-14-2	3/12/2024	MW-14-2	0.66 J	0.37 U	1.70	0.37 U	0.74 U	1.70	0.301
MW-14-3	3/12/2024	MW-14-3	2.40	0.52	1.50	0.37 U	0.73 U	1.00	0.277
MW-14-4	3/12/2024	MW-14-4	0.39 J	0.37 UJ	0.37 J	0.37 U	0.75 U	0.20 J	0.153
MW-15	3/20/2024	MW-15	5.90	7.60	0.93	2.20	0.71 U	2.10	0.395
MW-16	3/21/2024	MW-16	0.36 U	0.36 U	0.36 U	0.36 U	0.72 U	0.36 U	0.148
	3/21/2024	DUP-7-032124	0.36 U	0.36 U	0.36 U	0.36 U	0.72 U	0.36 U	0.148
MW-17-1	3/15/2024	MW-17-1	0.37	1.20	0.12 J	0.37 U	0.74 U	0.10 J	0.124

Sample Location	Sample Date	Sample Number	PFOA (ng/L)	PFOS (ng/L)	PFHxS (ng/L)	PFNA (ng/L)	HFPO-DA (GenX Chemicals) (ng/L)	PFBS (ng/L)	NPDWR HI
MW-17-2	3/15/2024	MW-17-2	0.26 J	1.10	0.49	0.37 U	0.74 U	1.90	0.166
MW-17-3	3/15/2024	MW-17-3	0.98	6.00	1.60	0.34 J	0.73 U	1.90	0.286
	3/15/2024	DUP-3-031524	1.00	4.00	1.30	0.28 J	0.74 U	2.00	0.247
MW-17-4	3/15/2024	MW-17-4	0.66	1.60	1.80	0.37 U	0.74 U	0.33 J	0.311
MW-18-1	3/18/2024	MW-18-1	0.44 J	0.86	0.19 J	0.37 U	0.74 U	0.19 J	0.132
MW-18-2	3/18/2024	MW-18-2	0.39 J	0.78 J	0.29 J	0.37 U	0.74 U	0.37	0.143
MW-18-3	3/18/2024	MW-18-3	2.50	2.10	0.57	0.29 J	0.73 U	2.80	0.167
MW-18-4	3/18/2024	MW-18-4	0.56 J	0.37 U	0.19 J	0.37 U	0.73 U	0.05 J	0.131
MW-19-1	3/13/2024	MW-19-1	0.54 J	1.40	0.49	0.09 J	0.74 U	0.39	0.138
MW-19-2	3/13/2024	MW-19-2	4.90	2.10	**5.60**	0.15 J	0.76 U	3.20	0.715
MW-19-3	3/13/2024	MW-19-3	3.20	1.30	**5.00**	0.15 J	0.76 U	1.40	0.647
MW-20-1	3/19/2024	MW-20-1	0.68 J	0.62 J	0.58	0.36 U	0.72 U	0.69	0.173
MW-20-2	3/19/2024	MW-20-2	1.70 J	9.40	**3.00**	0.37	0.73 U	1.30	0.444
MW-20-3	3/19/2024	MW-20-3	0.95 J	1.00 J	0.88	0.37 U	0.73 U	1.60 J	0.209
MW-20-4	3/19/2024	MW-20-4	0.70 J	0.37 U	0.37 U	0.37 U	0.73 U	0.37 U	0.151
MW-21-1	3/13/2024	MW-21-1	9.30	0.38 J	**12.00**	0.37 U	0.74 U	7.40	1.448
MW-21-2	3/13/2024	MW-21-2	2.80	1.20	**4.80**	0.36 U	0.71 U	6.80	0.644
MW-21-3	3/13/2024	MW-21-3	5.20	3.10	**4.40**	0.12 J	0.74 U	5.30	0.578
MW-22-1	3/14/2024	MW-22-1	0.54	0.37 U	1.10	0.37 U	0.74 U	3.30	0.235
MW-22-2	3/14/2024	MW-22-2	0.22 J	0.37 J	0.96 J	0.37 U	0.73 U	0.41	0.217
MW-22-3	3/14/2024	MW-22-3	0.41	0.37 U	0.63 J	0.39 J	0.78 U	0.23 J	0.187
MW-23-1	3/11/2024	MW-23-1	27.00	3.70 J	**12.00**	0.38	0.71 U	9.60	1.447
MW-23-2	3/11/2024	MW-23-2	4.90	0.43 J	**17.00**	0.36 U	0.73 U	21.00	2.008
MW-23-3	3/11/2024	MW-23-3	0.33 J	0.29 J	0.47 J	0.38 U	0.75 U	0.25 J	0.165
MW-24-1	3/11/2024	MW-24-1	0.20 J	0.44 J	0.066 J	0.37 U	0.75 U	0.37 U	0.120
MW-24-2	3/11/2024	MW-24-2	0.95	0.61	2.40	0.36 J	0.73 U	0.80	0.376
	3/11/2024	DUP-1-031124	0.94	0.47	2.50	0.37 U	0.74 U	0.80	0.389
MW-24-3	3/11/2024	MW-24-3	7.90	5.80	1.50	1.10	0.78 U	7.80 J	0.359
USEPA MCLs (April 2024) (ng/L)			4	4	10 HI<1	10 HI<1	10 HI<1	HI<1	1
SWRCB DDW NL (ng/L)			5.1	6.5	3 **(In bold)**	NE	NE	500	--

NS = Not Sampled; NE = Not Established; bold = detection; J = estimated concentration; U = not detected

PFOA was not detected in MW-7, MW-12 (Screen 4), MW-14 (Screen 4), and MW-16 with reporting limits ranging from 0.35 ng/L to 0.37 ng/L.

4.4.2 Specific Findings for PFOS

PFOS concentrations were detected above the federal MCL of 4.0 ng/L in several monitoring wells. Notably, MW-9 exhibited the highest concentration at 20.0 ng/L. Other wells exceeding the federal MCL, including MW-5, MW-10, MW-15, MW-17 (Screen 3), MW-20 (Screen 2), and MW-24 (Screen 3) had concentrations ranging from 5.4 to 13.0 ng/L.

PFOS was detected at concentrations below the MCL in various wells. For instance, MW-3 (Screens 1 to 4) had concentrations ranging from 0.79 ng/L to 3.4 J ng/L. MW-4 (Screens 1 to 4) detected levels between 0.76 J ng/L and 1.7 J ng/L. Several other wells, including MW-8, MW-11 (Screens 1 to 3), MW-12 (Screens 1 to 3), MW-14 (Screen 3), MW-17 (Screens 1, 2, and 4), MW-18 (Screens 1 to 3), MW-19 (Screens 1 to 3), MW-20 (Screens 1 and 3), MW-21 (Screens 1 to 3), MW-23 (Screens 1 to 3), and MW-24 (Screens 1 and 2) exhibited concentrations ranging from 0.29 J ng/L to 3.7 ng/L.

PFOS was not detected in MW-6, MW-7, MW-12 (Screen 4), MW-13, MW-14 (Screens 1, 2, and 4), MW-16, MW-18 (Screen 4), MW-20 (Screen 4), and MW-22 (Screens 1 to 3).

4.4.3 Specific Findings for PFHxS

PFHxS concentrations were detected above the federal MCL of 10.0 ng/L in a few monitoring wells. Notably, MW-23 (Screen 2) exhibited the highest concentration at 17.0 ng/L. Other wells, including MW-21 (Screen 1) and MW-23 (Screen 1), had concentrations of 12.0 ng/L each.

PFHxS was detected at concentrations below the MCL in various wells. For instance, MW-3 (Screens 1 to 4) had concentrations ranging from 0.25 J ng/L to 1.4 ng/L and MW-4 (Screens 1 to 4) had concentrations ranging from 0.27J ng/L to 4.5 ng/L. Several other wells, including MW-5, MW-6, MW-8, MW-9, MW-10, MW-11 (Screens 1 to 3), MW-12 (Screens 1 to 4), MW-13, MW-14 (Screens 1 to 4), MW-15, MW-17 (Screens 1 to 4), MW-18 (Screens 1 to 4), MW-19 (Screens 1 to 3), MW-20 (Screens 1 to 3), MW-21 (Screens 2 and 3), MW-22 (Screens 1 to 3), MW-23 (Screen 3), and MW-24 (Screens 1 to 3) exhibited concentrations ranging from 0.07J ng/L to 5.6 ng/L.

PFHxS was not detected in MW-7, MW-16, and MW-20 (Screen 4).

4.4.4 Specific Findings for PFNA

PFNA was detected at concentrations below the federal MCL of 10.0 ng/L across all monitored wells. For example, MW-9 exhibited the highest concentration at 4.4 ng/L. The only other wells with concentrations above 1.0 ng/L included MW-15 and MW-24 (Screen 3) at concentrations of 2.2 ng/L and 1.1 ng/L, respectively. The rest of the wells with PFNA detections, including MW-3 (Screens 2 to 4), MW-4 (Screens 2 and 4), MW-11 (Screens 1 and 3), MW-12 (Screens 1 and 2), MW-17 (Screen 3), MW-18 (Screen 3), MW-19 (Screens 1 to 3), MW-20 (Screen 2), MW-21 (Screen 3), MW-22 (Screen 3), MW-23 (Screen 1), and MW-24 (Screen 2) exhibited concentrations ranging from 0.09 J ng/L to 0.74 ng/L.

PFNA was not detected in MW-3 (Screen 1), MW-4 (Screens 1 to 3), MW-5, MW-6, MW-7, MW-8, MW-10, MW-11 (Screen 2), MW-12 (Screens 3 and 4), MW-13, MW-14 (Screens 1 to 4), MW-16, MW-17 (Screens 1, 2, and 4), MW-18 (Screen 1, 2, and 4), MW-20 (Screens 1, 3, and 4), MW-21 (Screens 1 and 2), MW-22 (Screens 1 and 2), MW-23 (Screens 2 and 3), and MW-24 (Screen 1).

4.4.5 Specific Findings for HFPO-DA

HFPO-DA was not detected in any of the monitored wells at reporting limits ranging from 0.70 ng/L to 0.78 ng/L.

4.4.6 Specific Findings for PFBS

PFBS concentrations were detected at varying levels across the site. The highest concentration was found in MW-23 (Screen 2) at 21.0 ng/L. Other wells, including MW-4 (Screens 2 to 4), MW-21 (Screen 1), MW-23 (Screen 1), and MW-24 (Screen 3), had concentrations ranging from 7.4 ng/L to 13.0 ng/L.

Additional detections were noted in MW-3 (Screens 2 to 4), MW-5, MW-9, MW-12 (Screen 2), MW-19 (Screen 2), MW-21 (Screens 2 and 3), and MW-22 (Screen 1), with concentrations ranging from 3.0 ng/L to 6.8 ng/L. Lower concentrations were found in various wells, such as MW-3 (Screen 1), MW-4 (Screen 1), MW-6, MW-8, MW-10, MW-11 (Screens 1 and 3), MW-12 (Screens 1 and 3), MW-13, MW-14 (Screens 1 to 4), MW-15, MW-17 (Screens 1 to 4), MW-18 (Screens 1 to 4), MW-19 (Screens 1 and 3), MW-20 (Screens 1 to 3), MW-22 (Screens 2 and 3), MW-23 (Screen 3), MW-24 (Screen 2), with concentrations ranging from 0.05 J ng/L to 2.8 ng/L.

PFBS was not detected in MW-7, MW-12 (Screen 4), MW-16, MW-20 (Screen 4), and MW-24 (Screen 1) with reporting limits between 0.35 ng/L and 0.37 ng/L.

4.4.7 Hazard Index Analysis

The HI is a calculation used to assess the potential health risks associated with exposure to a mixture of PFAS compounds. It is calculated by summing the ratios of the concentration of each applicable PFAS to its respective health-based water concentration. For this analysis, the Hazard Index includes four PFAS compounds: HFPO-DA (Gen X), PFBS, PFNA, and PFHxS.

The EPA has established an MCL of 1.0 for the four compounds considered as part of the Hazard Index. In our analysis, three samples exceeded this MCL:

1. MW-21-1 (Hazard Index: 1.448)
2. MW-23-1 (Hazard Index: 1.447)
3. MW-23-2 (Hazard Index: 2.008)

It is important to note that this Hazard Index calculation is based on a single sampling event. For regulatory compliance, the running annual average of the Hazard Index should be calculated using samples collected over a year. If this running annual average exceeds 1.0, it would be considered a violation of the proposed HI MCL.

4.5 Decontamination Procedures

Field sampling equipment, including Westbay™ sample probe assembly and sample containers, water level probe, bladder pump, and other non-dedicated equipment used at each sample location were decontaminated between use. The field sampling crew used Liquinox® detergent which is PFAS-free, potable water, distilled water, and laboratory-supplied certified PFAS-free water during decontamination of non-dedicated sampling equipment.

4.6 Instrument Calibration Procedures

All field instruments were calibrated prior to sampling according to manufacturer's specifications and instrument calibration was checked and documented on-site daily. Calibration standard(s), dates, times, and all calibration results were recorded in the field log.

4.7 Investigation Derived Wastes (IDW)

During the groundwater investigation, G2S generated potentially contaminated IDW that included the following:

- Used personal protective equipment (PPE),
- Disposable sampling equipment,
- Decontamination fluids,
- Purged groundwater.

Used PPE and disposable sampling equipment was double bagged and placed in municipal refuse dumpster. These wastes are not considered hazardous and were sent to the local landfill.

Decontamination fluids (residual contaminants, water with non-phosphate detergent) and purged groundwater (contaminants, water) were containerized and transferred to NASA's OU-1 source area groundwater treatment system for processing.

5 QUALITY ASSURANCE (QA) / QUALITY CONTROL (QC)

All work performed under this task order adhered to the site-specific UFP-QAPP which is included as Appendix A of NASA's SI Work Plan (NASAa, 2022) that was prepared to define a project-specific set of procedures and performance criteria to assure delivery of data that met the acceptable scientific and engineering standards and project quality objectives.

Measures of quality included the appropriateness and accuracy of the sample collection; adherence to sample handling protocols; the quality and appropriateness of the laboratory analysis; and the representativeness of the data with respect to the study objectives. Method 1633 requires a field blank per every sample set. A sample set is composed of samples collected from the same sample site and at the same time.

Field and laboratory QC samples were collected and analyzed to fulfill quality requirements. Proper sample collection and handling procedures were utilized to ensure the integrity of the analytical results.

The field QA/QC samples collected for JPL groundwater monitoring included field duplicate samples, equipment rinsate blanks, source blanks, and field blanks. The QC sample results were used for the qualitative evaluation of the data. Table 5-1 summarizes analytical results for the QC samples collected during the groundwater investigation.

5.1 Field Duplicate Samples

Duplicate samples were collected to evaluate the precision of the sample collection process. Duplicate samples for PFAS were collected from monitoring wells MW-4 (Screen 2), MW-7, MW-10, MW-12 (Screen 1), MW-13, MW-16, MW-17 (Screen 3), and MW-24 (Screen 2). The analytical results for the field duplicate samples were comparable to the results of the original groundwater samples for PFAS, with the following exceptions:

- PFOS results in the MW-17 (Screen 3) duplicate pair (6.0 ng/L vs. 4.0 ng/L) and MW-24 (Screen 2) duplicate pair (0.61 ng/L vs. 0.47 ng/L).
- PFHxS results in the MW-17 (Screen 3) duplicate pair (1.6 ng/L vs. 1.3 ng/L).
- PFNA results in the MW-4 (Screen 2) duplicate pair (non-detect vs. 0.09J ng/L).

For this study, duplicate samples with a Relative Percent Difference (RPD) of 20% or greater were considered significant and reported. This threshold is commonly used in environmental sampling and provides a consistent criterion for evaluating the precision of duplicate samples. The source of the differences could not be determined.

5.2 Equipment Rinsate Blanks

Equipment rinsate blanks were collected each day that non-dedicated sampling equipment was used. The equipment rinsate blanks, consisting of laboratory-provided PFAS-free water run through the sampling equipment after decontamination, were analyzed for PFAS to monitor possible cross-contamination of the samples due to inadequate decontamination.

PFOA was detected in the equipment blank collected on March 19, 2024 (i.e., EB-7-031924) at an estimated concentration of 0.93 J ng/L. PFOA was also detected in the equipment blank collected on March 19, 2024 (i.e., EB-8-032024) at an estimated concentration of 0.42 J ng/L. The source of the PFAS contamination in the equipment rinsate blanks could not be determined. Detected PFAS concentrations in the equipment rinsate blanks were compared to the detected concentrations in the associated monitoring wells during the data validation process to determine if data validation qualifiers were necessary. Validation qualifiers were added by the data validators to select PFOA and PFOS analytical results. No other PFAS constituents were detected in the equipment rinsate blanks as shown in Table 5-1.

Table 5-1. QA/QC Sample Results (Groundwater Sampling)

Sample Location	Sample Date	Sample Number	PFOA (ng/L)		PFNA (ng/L)		PFBS (ng/L)		PFHxS (ng/L)		PFOS (ng/L)		HFPO-DA (GenX Chemicals) (ng/L)	
Source Blank-1	3/11/2024	SB-1-031124	0.36	U	0.36	U	0.36	U	0.36	U	0.36	U	0.72	U
Source Blank-2	3/18/2024	SB-2-031824	0.37	U	0.37	U	0.37	U	0.37	U	0.37	U	0.74	U
Field Blank-1	3/11/2024	FB-1-031124	0.37	U	0.37	U	0.37	U	0.37	U	0.37	U	0.73	U
Field Blank-2	3/12/2024	FB-2-031224	0.38	U	0.38	U	0.38	U	0.38	U	0.38	U	0.76	U
Field Blank-3	3/13/2024	FB-3-031324	0.38	U	0.38	U	0.38	U	0.38	U	0.38	U	0.75	U
Field Blank-4	3/14/2024	FB-4-031424	0.38	U	0.38	U	0.38	U	0.38	U	0.38	U	0.76	U
Field Blank-5	3/15/2024	FB-5-031524	0.37	U	0.37	U	0.37	U	0.37	U	0.37	U	0.75	U
Field Blank-6	3/18/2024	FB-6-031824	0.39	U	0.39	U	0.39	U	0.39	U	0.39	U	0.78	U
Field Blank-7	3/19/2024	FB-7-031924	0.37	U	0.37	U	0.37	U	0.37	U	0.37	UJ	0.75	U
Field Blank-8	3/20/2024	FB-8-032024	0.38	U	0.38	U	0.38	U	0.38	U	0.38	UJ	0.76	U
Field Blank-9	3/21/2024	FB-9-032124	0.37	U	0.37	U	0.37	U	0.37	U	0.37	U	0.73	U
Equipment Blank-1	3/11/2024	EB-1-031124	0.37	U	0.37	U	0.37	U	0.37	U	0.37	U	0.74	U
Equipment Blank-2	3/12/2024	EB-2-031224	0.39	U	0.39	U	0.39	U	0.39	U	0.39	U	0.78	U
Equipment Blank-3	3/13/2024	EB-3-031324	0.38	U	0.38	U	0.38	U	0.38	U	0.38	U	0.76	U
Equipment Blank-4	3/14/2024	EB-4-031424	0.37	U	0.37	U	0.37	U	0.37	U	0.37	U	0.74	U
Equipment Blank-5	3/15/2024	EB-5-031524	0.36	U	0.36	U	0.36	U	0.36	U	0.36	U	0.72	U
Equipment Blank-6	3/18/2024	EB-6-031824	0.35	U	0.35	U	0.35	U	0.35	U	0.35	U	0.70	U
Equipment Blank-7	3/19/2024	EB-7-031924	**0.93**	**J**	0.36	U	0.36	U	0.36	U	0.36	UJ	0.72	U
Equipment Blank-8	3/20/2024	EB-8-032024	**0.42**	**J**	0.37	U	0.37	U	0.37	U	0.37	U	0.74	U
Equipment Blank-9	3/21/2024	EB-9-032124	0.37	U	0.37	U	0.37	U	0.37	U	0.37	U	0.74	U

5.3 Field Blanks

During groundwater sampling activities, field blanks were collected each day for a total of nine (i.e., FB-1-031124, FB-2-031224, FB-3-031324, FB-4-031424, FB-5-031524, FB-6-031824, FB-7-031924, FB-8-032024, and FB-9-032124). The field blanks consisted of a small sample vial filled with PFAS-free water by the laboratory. For each day of groundwater sampling, the screw top of the vial was removed for the duration of sampling. After groundwater samples were collected, the vial was capped.

- No PFAS constituents were detected in the field blanks.

5.4 Source Blanks

Two source blanks (i.e., SB-1-031124 and SB-2-031824) which consisted of distilled water used by sampling personnel for equipment decontamination were collected during the sampling event. This QC sample serves as a check for any contamination present in the source water.

- No PFAS constituents were detected in the source blanks.

6 MIGRATION/EXPOSURE PATHWAYS AND TARGETS

This section evaluates the potential for migration and exposure pathways in groundwater associated with the JPL Site. The environmental setting including climate, topography and surface features, geology, hydrogeology, surface water features, and land use are discussed in Section 3.0 of this report.

Based on the hydrogeological setting (Sections 3.4), the main aquifer system for the JPL area is provided by the alluvial basin-filling sediments of the Raymond Basin. Based on previous investigations and remedial actions associated with the JPL Site, it is known that groundwater flows southeast from the site toward Altadena. There wells owned by the City of Pasadena and LAWC that are downgradient of the JPL Site and are known to contain chemicals originating from JPL. The nature and extent of chemicals has been established and remedies are in place to treat chemicals originating from the JPL Site. The Final ROD (NASA, 2018) establishes a three-system groundwater treatment remedy with the OU-1 treatment system addressing the source area, the MHTS addressing the mid-plume area, and the LAWC treatment system addressing the leading edge of the chemical plume originating from JPL.

Like other chemicals originating from the JPL Site, dissolved PFAS at JPL would migrate in groundwater toward the southeast (downgradient) toward the City of Pasadena MHTS wells and the LAWC wells. Previous investigations have found that VOCs, including carbon tetrachloride, trichloroethene, and tetrachloroethene, and perchlorate released at JPL have impacted groundwater in these wells. The MHTS and LAWC Treatment System wells are considered primary potential receptors and are part of NASA's CERCLA OU-3 Final Remedy (NASA, 2018). Based on the most recent Five-Year Review, this remedy is working effectively, and VOC and perchlorate levels are relatively low and decreasing (NASA, 2022b).

The MHTS wells include Arroyo, Well 52, Ventura, and Windsor wells owned by the City of Pasadena. The LAWC Treatment System wells include LAWC#3, LAWC#5, and LAWC#6 owned by LAWC. The MHTS wells are located within or immediately east of the Arroyo Seco and LAWC's are further east. Since groundwater flow direction at JPL is to the southeast, potential release of PFAS in groundwater at the JPL facility would migrate downgradient to PWP's and LAWC's wells. Groundwater extraction of these wells prevents further downgradient migration of chemicals originating from the JPL CERCLA Site (NASA, 2018; NASA, 2022b).

The CSM for contaminant migration at JPL identifies seepage pits and waste pits as a primary source for contaminants of concern (COCs), which migrate into soil and subsequently down to groundwater through the highly permeable vadose zone in dissolved phase via surface water infiltration. If PFAS were released into the vadose zone overlying the alluvial aquifer south of the JPL Thrust Fault, they would migrate through the vadose zone due to surface water infiltration and into the shallowest aquifer. Therefore, potential PFAS impacts to shallow groundwater would be extracted and treated at the OU1 Source Area Treatment System or migrate downgradient and be treated at the MHTS or LAWC Treatment System. There is no migration pathway to groundwater north of the JPL Thrust Fault, so any release of PFAS in the high elevation northern area of JPL would have to be carried south of the JPL Thrust Fault before infiltrating the vadose zone to impact the underlying alluvial aquifer, which is unlikely.

Pumping tests and hydrogeologic observations suggest semi-confined groundwater conditions in the lower three aquifer units of the Raymond Basin. Despite this, vertical transmission of contaminants from JPL has been observed, implying that all four aquifer layers could be affected by potential chemical releases. The intermediate aquifer layers (the lower Older Fanglomerate Series and the Pacoima Formation) currently have the highest concentrations of site-related chemicals.

6.1 Sample Locations

As part of NASA's investigation, groundwater samples were collected and analyzed for PFAS using USEPA Method 1633. All monitoring wells within and immediately downgradient of the JPL Site were sampled, except MW-1. MW-1 and the deeper screens of several monitoring wells were not sampled because other chemicals originating from JPL had not been detected in these locations. Note, MW-2 was replaced by MW-14 in the late 1990s and MW-2 was abandoned.

6.2 Groundwater Migration Pathway Analytical Results

In March 2024, samples were collected from 55 NASA groundwater monitoring locations and analyzed for 43 PFAS constituents. Table 6-1 summarizes results from each monitoring well and known information about the migration pathway near that well. All potential migration is within capture zones of the MHTS, LAWC treatment system, or source area treatment system. There are a few instances where a constituent is outside of the JPL plume and representative of a source other than JPL.

Table 6-1. Summary of PFAS Results and Migration Pathways

Well ID	PFAS Summary	SI AOPC	Migration Summary
MW-3 (Screens 1, 2, 3, 4)	• No PFAS detections above MCLs/NLs		• Downgradient of former seepage/waste pits • Located in the capture zone of the MHTS
MW-4 (Screens 1, 2, 3, 4)	• PFOA > MCL in Screens 2 and 3; Max = 5.7 ng/L • PFHxS > NL in Screens 2 and 3; Max = 4.5 ng/L	AOPCs 1, 2, 3, and 4	• Downgradient of former seepage/waste pits • Downgradient of former chrome plating operation • Located in the capture zone of the MHTS
MW-5	• PFOS > MCL; 5.4 ng/L	AOPC 5	• Downgradient of former photography labs • Located in the capture zone of the MHTS
MW-6	• No PFAS detections above MCLs/NLs		• Located in west parking lot, upgradient of former seepage/waste pits
MW-7	• No PFAS detections above MCLs/NLs		• Located near and within the capture zone of the Source Area Treatment System
MW-8	• No PFAS detections above MCLs/NLs		• Located downgradient of Source Area Treatment System • Located in the capture zone of the MHTS
MW-9	• PFOA > MCL; 17 ng/L • PFOS > MCL: 20 ng/L		• Shallow well located above the JPL thrust fault, in the north-eastern portion of JPL, downgradient of former seepage/waste pits • Historically ND for VOCs and perchlorate • Located in the capture zone of the MHTS and LAWC System
MW-10	• PFOS > MCL; 14 ng/L		• Located on the southern portion of JPL • Upgradient of MW-5 • Located in the capture zone of the MHTS
MW-11 (Screens 1, 2, 3)	• No PFAS detections above MCLs/NLs		• Downgradient of former seepage/waste pits • Located in the capture zone of the MHTS
MW-12 (Screens 1, 2, 3, 4)	• PFOA > MCL in Screen 2; 7.1 ng/L	AOPCs 2 and 3	• Located on the eastern portion of JPL, downgradient of former seepage/waste pits • Located in the capture zone of the MHTS
MW-13	• No PFAS detections above MCLs/NLs		• Located near and within the capture zone of the Source Area Treatment System
MW-14 (Screens 1, 2, 3, 4)	• No PFAS detections above MCLs/NLs		• Located on far west side of facility • Upgradient well for the JPL Site • Located in the capture zone of the MHTS and LAWC System
MW-15	• PFOA > MCL; 5.9 ng/L • PFOS > MCL; 7.6 ng/L	AOPCs 2 and 3	• Shallow well located above the JPL thrust fault, in the north-eastern portion of JPL, downgradient of former seepage/waste pits • Historically ND for VOCs and perchlorate • Located in the capture zone of the MHTS and LAWC System

Well ID	PFAS Summary	SI AOPC	Migration Summary
MW-16	• No PFAS detections above MCLs/NLs	AOPCs, 1, 2, and 3	• Located near and within the capture zone of the Source Area Treatment System
MW-17 (Screens 1, 2, 3, 4)	• PFOS > MCL in Screen 3; 6 ng/L	AOPCs 2 and 3	• Located outside JPL facility in between the MHTS and LAWC Treatment System • Located in the capture zone of the LAWC Treatment System
MW-18 (Screens 1, 2, 3, 4)	• No PFAS detections above MCLs/NLs		• Located outside JPL facility • Located in the capture zone of the LAWC Treatment System
MW-19 (Screens 1, 2, 3)	• PFOA > MCL in Screen 2; 4.9 ng/L • PFHxS > NL in Screen 2 and 3; Max 5.6 ng/L		• Located outside JPL facility • Located outside of the JPL chemical plume, representative of non-JPL source
MW-20 (Screens 1, 2, 3, 4)	• PFOS > MCL in Screen 2; 9.4 ng/L • PFHxS = NL in Screen 2; 3 ng/L		• Located outside JPL facility • Located outside of the JPL chemical plume, likely representative of non-JPL source
MW-21 (Screens 1, 2, 3)	• PFOA > MCL in Screens 1 and 3; Max 9.3 ng/L • PFHxS > MCL in Screen 1; 12 ng/L • PFHxS > NL in Screens 2 and 3; Max 4.8 ng/L		• Located outside JPL facility • Located outside of the JPL chemical plume, representative of non-JPL source
MW-22 (Screens 1, 2, 3)	• No PFAS detections above MCLs/NLs		• Located in the west-central portion of the JPL facility • Located in the capture zone of the MHTS and LAWC System
MW-23 (Screens 1, 2, 3)	• PFOA > MCL in Screens 1 and 2; Max 27 ng/L • PFHxS > NL and MCL in Screens 1 and 2; Max 17 ng/L		• Located in the south-western portion of the JPL facility • Located in the capture zone of the MHTS and LAWC System
MW-24 (Screens 1, 2, 3)	• PFOA > MCL in Screen 3; 7.9 ng/L • PFOS > MCL in Screen 3; 5.8 ng/L	AOPCs 2 and 3	• Located near the Source Area Treatment System • Source area system treats the shallower portions of the aquifer, not those represented by Screen 3 • Screen 3 located in the capture zone of the MHTS and LAWC System

See Figure 1 in Appendix A for the location of all Monitoring Wells. See Figure 4-1 for the locations of AOPCs, seepage pits, and waste pits.

6.3 Groundwater Migration Pathway Conclusions

PFAS is present at low levels in groundwater throughout the JPL groundwater monitoring network. PFAS appears to originate from JPL in most wells. It is important to note that PFAS appears to originate from sources outside of JPL as well because it is present in wells that are upgradient, cross-gradient, or outside the JPL site (i.e., MW-14, MW-19, MW-20, and MW-21). The understanding of groundwater flow near JPL has been evaluated extensively (NASA, 2003; NASA, 2008; NASA, 2022b) and these wells are outside of the JPL Site.

Groundwater at JPL is captured by the Source Area Treatment System, the MHTS, or the LAWC Treatment System as part of the Final Groundwater Remedy at JPL (NASA, 2018; NASA, 2022b). PFAS in JPL groundwater migrates to one of these three groundwater extraction systems. These systems were installed and operated as part of the JPL CERCLA Program because they are effective at capturing chemicals in groundwater from the JPL Site.

In summary, data collected in this investigation along with decades of previous investigations demonstrate that the exposure pathways related to groundwater with potential PFAS impacts from JPL

sources are the same as those previously documented for the JPL Final Groundwater Remedy (NASA, 2018). The Final Groundwater Remedy is effective for containing groundwater impacted by JPL chemicals. PFAS have been detected in MHTS and LAWC wells; however, only PFOS in untreated groundwater from LAWC#6 has been detected at a concentration slightly above the PFAS MCL.

The treatment technologies that are in place for all three JPL treatment systems (i.e., Source Area Treatment System, MHTS, and LAWC System) include LGAC treatment and IX treatment (using perchlorate selective resin). These two treatment technologies are effective for addressing several PFAS and have been demonstrated to remove PFAS (see Table 2-1) at LAWC.

7 SUMMARY AND CONCLUSIONS

This section summarizes data from the PFAS groundwater investigation at JPL and provides conclusions regarding subsequent actions at JPL associated with PFAS.

7.1 Summary

PFAS is present at low levels in groundwater throughout the JPL groundwater monitoring network:

- PFOA was detected in 52 of the 55 samples at concentrations ranging from 0.2 J ng/L to 27 ng/L. Eleven samples (20%) exceeded the EPA MCL of 4 ng/L, with the highest concentration found in MW-23-1.
- PFOS, detected in 42 samples, had concentrations ranging from 0.29 J ng/L to 20 ng/L. Seven samples (12.7%) exceeded the MCL of 4 ng/L, with MW-9 showing the highest concentration.
- PFHxS was detected in 52 samples at levels between 0.066 J ng/L and 17 ng/L. Three samples (5.5%) exceeded the MCL of 10 ng/L, with MW-23-2 having the highest concentration.
- PFNA was detected in 17 samples at concentrations ranging from 0.09 J ng/L to 4.4 ng/L. No samples exceeded the MCL of 10 ng/L, with the maximum concentration detected in MW-9.
- HFPO-DA was not detected above the reporting limit in any of the samples. PFBS, which does not have an individual MCL, was found in 49 samples at concentrations up to 21 ng/L in MW-23-2.
- The Hazard Index, calculated for mixtures containing two or more of PFHxS, PFNA, HFPO-DA, and PFBS, exceeded the MCL of 1.0 in three samples: MW-21-1, MW-23-1, and MW-23-2.

The PFAS in groundwater presumed to originate from JPL is located within the capture zones of the existing treatment systems that make up the CERCLA Final Remedy for groundwater. Specifically, NASA's Final Remedy consists of three groundwater extraction and treatment systems: the Source Area Treatment System, the MHTS, and the LAWC Treatment System. NASA's investigation also demonstrates that other PFAS sources exist in the basin because PFAS was detected in wells located upgradient, cross-gradient, and outside of the JPL Site.

The three groundwater treatment systems utilize treatment technologies that are proven effective for PFAS removal.

7.2 Conclusions

Based on the results of the groundwater investigation at JPL, NASA recommends the following actions:

- Incorporate PFAS sampling into the groundwater monitoring program at JPL to track concentration trends of these compounds. This will begin in 2025. This is consistent with the approach used at JPL for other emerging compounds including 1,2,3-trichloropropane and 1,4-dioxane. USEPA Method 1633 will be used for PFAS analysis.
- Coordinate with the City of Pasadena and LAWC on routine sampling of extraction wells to understand any variability in concentrations.
- Prepare a Proposed Plan and ROD Amendment to incorporate PFAS monitoring and treatment into the Final Remedy for Groundwater at JPL.

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