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FINAL

RECORD OF DECISION FOR THE OPERABLE UNIT 1 ON-FACILITY GROUNDWATER AND THE OPERABLE UNIT 3 OFF-FACILITY GROUNDWATER

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
JET PROPULSION LABORATORY
PASADENA, CALIFORNIA

EPA ID# CA9800013030

PREPARED FOR:

National Aeronautics and Space Administration
Management Office, Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, California 91109

February 2018

PART I: DECLARATION

Site Name and Location

SITE NAME:	Jet Propulsion Laboratory (JPL)
EPA ID NUMBER:	CA9800013030; Federal Facility Agreement Docket Number 1998-27
LOCATION:	4800 Oak Grove, Pasadena, California
SITE TYPE:	Federal Facility; Government-owned, contractor-operated
LEAD AGENCY:	National Aeronautics and Space Administration (NASA)
LEAD REGULATORY AGENCY:	U.S. Environmental Protection Agency (U.S. EPA), Region 9
	SUPPORTING AGENCIES: State of California Environmental Protection Agency (Cal/EPA), Department of Toxic Substances Control (DTSC); and California Regional Water Quality Control Board (RWQCB), Los Angeles Region
OPERABLE UNIT:	Operable Unit (OU) 1, On-Facility Groundwater OU3, Off-Facility Groundwater

Statement of Basis and Purpose

This Record of Decision (ROD) is published under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), 42 United States Code (USC) § 9601 et seq. This decision document presents the response action selected by NASA and U.S. EPA with the concurrence of the supporting agencies (DTSC and RWQCB) for the on-facility groundwater (OU1) (including the source area) at JPL and the off-facility groundwater downgradient of JPL (OU3). The response action was selected in accordance with CERCLA, as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA), and the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), 40 Code of Federal Regulations (CFR) 300.400 et seq. and California Health and Safety Code § 25356.1. The response action was selected based upon information available in the Administrative Record.

The supporting agencies, consisting DTSC and the RWQCB, concur with the response action recommended in this ROD.

Assessment of the Site

The response action selected in this ROD is expected to achieve protection of human health and the environment from actual or threatened releases of hazardous substances into the environment. The selected response action is necessary to remove chemicals of concern (COCs) from the aquifer being used by the local community (Lincoln Avenue Water Company [LAWC] and the City of Pasadena) for drinking water, as well as to protect the environment from the additional migration of chemicals in groundwater outside the JPL fence line.

Description of the Selected Remedy

NASA's selected remedy for groundwater is to continue operating the interim remedies for OU1 and OU3. The interim remedies include groundwater extraction, treatment, and reinjection at the OU1 source area, as well as operation of treatment systems to remove perchlorate and VOCs from pumped groundwater at four City of Pasadena and two LAWC drinking water wells (NASA, 2007b and 2007c). The three systems have proven effective and will continue to remove COCs from groundwater including perchlorate and volatile organic compounds (VOCs). NASA's selected remedy also includes the addition of various institutional controls (ICs) to ensure impacted groundwater within the JPL site is not utilized without appropriate evaluation and/or treatment. This remedy also includes continuation of the existing groundwater monitoring program that was established in collaboration with supporting agencies. The groundwater monitoring will monitor the performance and effectiveness of the remedy.

The OU1 (on-facility) treatment system consists of three groundwater extraction wells, ex situ treatment using liquid-phase granular activated carbon (LGAC) to remove VOCs and a fluidized bed reactor (FBR) to treat perchlorate, and re-injection of treated water into injection wells. The extraction and injection wells are located in the north-central portion of the JPL facility. The design capacity of the OU1 treatment system is 300 gallons per minute (gpm). The OU1 treatment system has been operating since 2005 as the interim remedial action for OU1 (NASA, 2007b).

The LAWC system, which is part of the interim remedy for OU3, includes two extraction wells (LAWC#3 and LAWC#5), LGAC treatment for VOCs, and ion exchange for treatment of perchlorate, with a maximum capacity of 2,000 gpm. The treated water is used as a source of drinking water for LAWC customers. The system has been operating effectively since 2004. Operation of the LAWC treatment plant is funded by NASA as part of the interim remedial action for OU3 (NASA, 2007c).

The Monk Hill Treatment System (MHTS), which is also part of the interim remedy for OU3, consists of four extraction wells (Arroyo Well, Well 52, Ventura Well, and Windsor Well), LGAC treatment for VOCs and ion exchange for treatment of perchlorate with a maximum capacity of 7,000 gpm. The treated water is used as a source of drinking water for City of Pasadena residents. The system has been operated effectively since 2011. Operation of the MHTS is funded by NASA as part of the interim remedial action for OU3 (NASA, 2007c).

Continuation of the current systems is the selected final remedy because the systems have consistently treated chemicals to below cleanup levels for OU1 and established drinking water criteria for OU3, including maximum contaminant levels (MCLs). Historical operating data demonstrate that there has been a decreasing trend in perchlorate and VOC concentrations in the extracted groundwater over the duration of operation, demonstrating the effectiveness of the interim remedies. In addition, operation of the current systems will not degrade the surrounding natural resources (e.g., the Arroyo Seco). Based on this information, the existing OU1 and OU3 treatment systems are considered protective of human health and the environment and are effectively working to remove site-related chemicals from the groundwater aquifer. In addition, these systems have been effective in containing chemicals originating from JPL, and the OU3 systems have restored use of a valuable groundwater resource for the Altadena and Pasadena communities near JPL.

In addition to continuing to operate the three existing treatment systems, the selected remedy also includes implementation of ICs via an agreement with the Raymond Basin Management Board and/or the State of California. The agreements would include commitments that require the agency to notify NASA of any proposed new extraction wells in the Monk Hill subarea, and that NASA evaluate the impact of any proposed extraction wells within/near the capture zones on the remedies for OU1 and OU3. In addition, NASA will conduct annual reviews of new well permits in the Monk Hill subarea as an additional control to prevent inadvertent exposure to chemicals.

It should be noted that NASA has completed cleanup of contaminant source material in soil at JPL. A soil vapor extraction system successfully treated concentrations of VOCs in soil (OU2). The specified cleanup objectives were achieved, and completion of the OU2 cleanup activities was documented in the Remedial Action Report (NASA, 2007a). In remediating the soil, NASA enhanced the overall site cleanup strategy by eliminating the source of VOCs that could migrate to groundwater. This ROD identifies the selected remedy for OU1 and OU3.

Statutory Determinations

These response actions are protective of human health and the environment; they fully address the statutory mandate for permanence and treatment; they employ treatment technologies to reduce toxicity, mobility, and volume; they comply with the federal and state applicable or relevant and appropriate requirements (ARARs); and they are cost-effective.

Because this remedy will not result in hazardous substances, pollutants, or contaminants remaining on site above levels that allow for unlimited use and unrestricted exposure, a statutory review is not required. However, as a matter of policy, a review will be conducted within five years after initiation of remedial action and every five years thereafter until the remedial actions are complete to ensure that the remedy is, or will be, protective of human health and the environment.

ROD Data Certification Checklist

The following information is included in Part II: Decision Summary of this ROD. Additional information can be found on the Administrative Record Web site (available at http://jplwater.nasa.gov) or at the four information repositories (see Part III Responsiveness Summary for locations). An IC checklist is provided as Appendix A.

- COCs and their concentrations in source area groundwater (OU1) and off-facility groundwater (OU3), Section 5.3
- Baseline risk represented by the chemicals in OU1 and OU3 groundwater, Section 7.0
- Cleanup levels for the COCs in OU1 and OU3 groundwater, Section 12.4
- How source materials in OU1 and OU3 groundwater will be addressed, Section 9.2
- Current and reasonably anticipated future land use assumptions, Section 6.1
- Current and potential future beneficial uses of surface and groundwater, Section 6.2
- Potential land and groundwater use that will be available as a result of the remedy, Section 12.4
- Estimated capital, annual operation and maintenance (O&M), total present worth costs, and discount rate, Section 12.3
- Number of years that the remedy is expected to operate, Section 12.1
- Key factors considered in selecting the remedy, Section 10.0

FOR THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION JET PROPULSION LABORATORY:

Marcus Watkins

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5-1-2017
Date

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Los Angeles Region

Aug. 23, 2017
Date

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APPENDICES

FIGURES

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ACRONYMS AND ABBREVIATIONS

ARAR	applicable or relevant and appropriate requirement
ATSDR	Agency for Toxic Substances and Disease Registry
BDAT	best demonstrated available technology
Cal/EPA	California Environmental Protection Agency
Caltech	California Institute of Technology
CCR	California Code of Regulations
CEQA	California Environmental Quality Act
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CFR	Code of Federal Regulations
CIS	Community Information Session
COC	chemical of concern
COPC	chemical of potential concern
Cr^{+6}	hexavalent chromium
CWC	California Water Code
DCA	dichloroethane
DDW	Division of Drinking Water
DTSC	Department of Toxic Substances Control
ERA	ecological risk assessment
ESD	Explanation of Significant Differences
FBR	fluidized bed reactor
FWEC	Foster Wheeler Environmental Corporation
gpm	gallon per minute
HHRA	human health risk assessment
HI	hazard index
HMX	high-velocity military explosive
HQ	hazard quotient
IARC	International Agency for Research on Cancer
IC	institutional control
JPL	Jet Propulsion Laboratory
LAWC	Lincoln Avenue Water Company
LDR	land disposal restriction
LGAC	liquid-phase granular activated carbon

MCL	maximum contaminant level
MHTS	Monk Hill Treatment System
MOA	memorandum of agreement
NASA	National Aeronautics and Space Administration
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NDMA	n-nitrosodimethylamine
NDPA	n-nitrosodi-n-propylamine
NDPHA	n-nitrosodiphenhlamine
NEPA	National Environmental Policy Act
NL	notification level
NPL	National Priorities List
O&M	operation and maintenance
OU	Operable Unit
PCE	tetrachloroethene
PWP	Pasadena Water and Power
RAO	remedial action objective
RBMB	Raymond Basin Management Board
RCLWA	Rubio Canon Land and Water Association
RCRA	Resource Conservation and Recovery Act
RDX	royal demolition explosive
RI	Remedial Investigation
ROD	Record of Decision
RWQCB	Regional Water Quality Control Board
SARA	Superfund Amendments and Reauthorization Act
SCAQMD	South Coast Air Quality Management Board
SDWA	Safe Drinking Water Act
SVOC	semivolatile organic compound
TCE	trichloroethene
TCP	trichloropropane
TNT	2,4,6-trinitrotoluene
UCL	upper confidence level
USC	United States Code
U.S. EPA	United States Environmental Protection Agency
VOC	volatile organic compound
WDR	waste discharge requirement

PART II: DECISION SUMMARY

1.0 Site Name, Location, and Description

SITE NAME:	Jet Propulsion Laboratory (JPL)
EPA ID NUMBER:	CA9800013030; Federal Facility Agreement Docket Number 1998-27
LOCATION:	4800 Oak Grove, Pasadena, California
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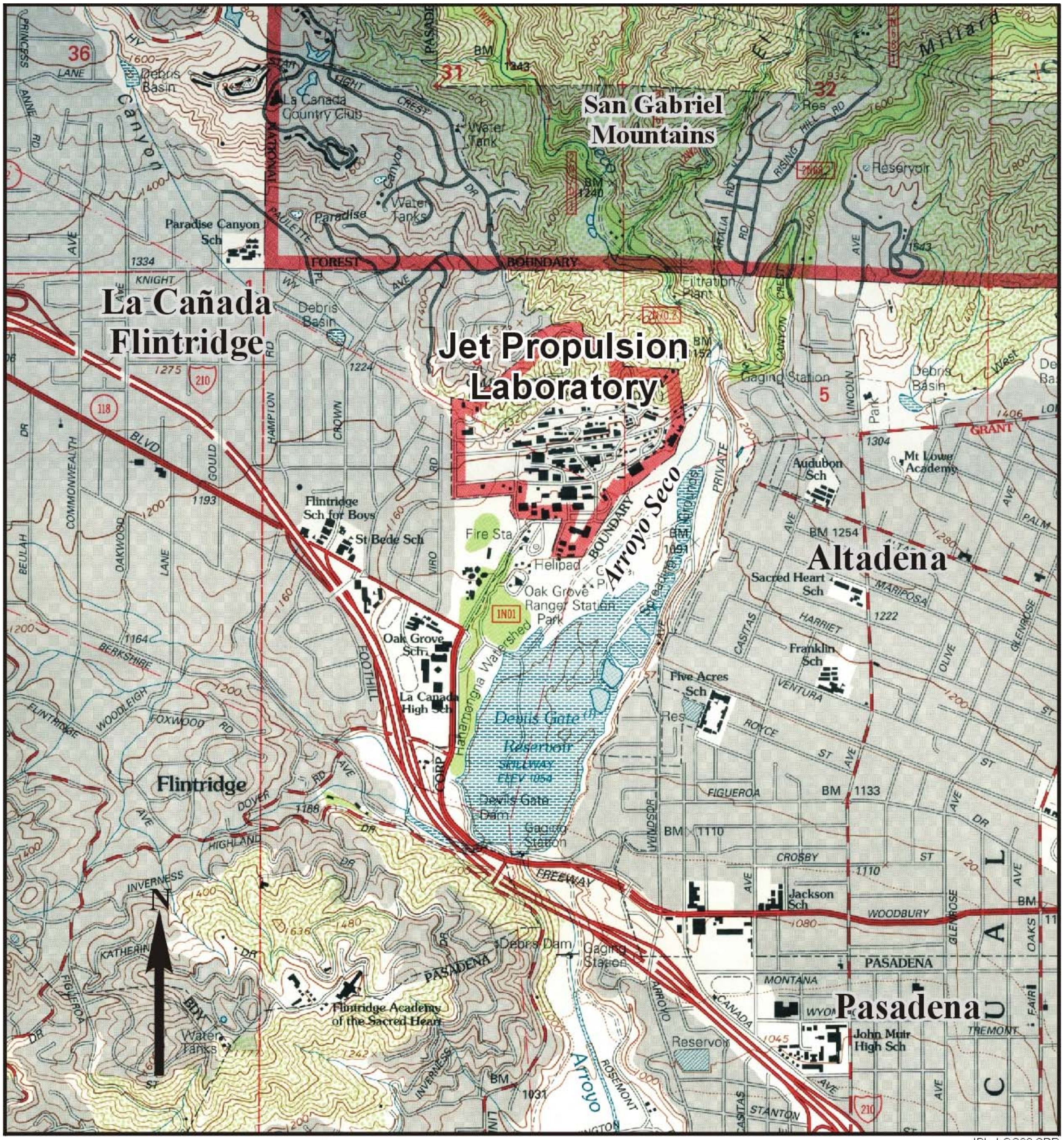
OPERABLE UNIT:	Operable Unit 1 (OU1), On-Facility Groundwater Operable Unit 3 (OU3), Off-Facility Groundwater

NASA is the lead federal agency for implementing and funding remedial activities at JPL. U.S. EPA, DTSC, and RWQCB provide independent oversight and technical assistance.

NASA JPL is a federally-funded research and development facility in La Cañada Flintridge, California, currently operated under contract by 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 Deep Space Tracking Network.

Located in Los Angeles County, JPL adjoins the incorporated cities of La Cañada-Flintridge and Pasadena, and is bordered on the east by the unincorporated community of Altadena. A federally-owned facility, JPL encompasses approximately 170 acres of land and more than 150 buildings and other structures. Approximately 156 acres of the total 170 acres are federally-owned. The remaining land is leased for parking from the Flintridge Riding Club. Development at JPL is primarily located on the southern half, in two regions – an early-developed northeastern area and a later-developed southwestern area. Figure 1-1 shows the JPL facility and surrounding area.



Source: USGS Pasadena 7½-Minute Quad, 1995.
Note: (1) Devil's Gate Reservoir is dry most of the year.

Scale in Miles
0 0.5 1

Figure 1-1. Map of JPL and the Surrounding Area

2.0 Site History

During historic operations at JPL, various chemicals (including chlorinated solvents, solid rocket fuel propellants, cooling tower chemicals, sulfuric acid, Freon™, and mercury) and other materials were used at the JPL facility. During the 1940s and 1950s, liquid wastes from materials used and produced at JPL (such as solvents, solid and liquid rocket propellants, cooling tower chemicals, and analytical laboratory chemicals) were disposed of into seepage pits, a practice considered common at the time. The remedial investigation (RI) for on-facility soil (defined as OU2) identified 40 seepage pits, five waste pits, and four discharge points at the facility that were used during historic operations (Foster Wheeler Environmental Corporation [FWEC], 1999b). Some of the seepage pits received volatile organic compounds (VOCs) and other waste materials, which are currently found in groundwater beneath and adjacent to JPL. In the late 1950s and early 1960s, a sanitary sewer system was installed at JPL to handle sewage and wastewater. During this time, the seepage pits were closed and their use for sanitary and chemical waste disposal was discontinued. Today, laboratory chemical wastes are either recycled or sent off facility for treatment and disposal at regulated, Resource Conservation and Recovery Act (RCRA)-permitted hazardous waste facilities.

In 1980, the analyses of groundwater revealed the presence of VOCs in City of Pasadena water-supply wells located southeast of JPL in the Arroyo Seco. At about the same time, VOCs were detected in two water-supply wells used by the Lincoln Avenue Water Company (LAWC), located east of the Arroyo Seco (FWEC, 1999a). As a result, NASA initiated an investigation to evaluate VOCs originating from the JPL facility.

In 1988, a preliminary assessment/site inspection was completed at JPL, which indicated that further site characterization was warranted (Ebasco, 1988). Subsequent site investigations were conducted at JPL (Ebasco, 1990a; Ebasco, 1990b) and VOCs were detected in on-facility groundwater at levels above drinking water standards. In 1992, JPL was placed on the National Priorities List (NPL) of sites subject to regulation under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) (47180-47187 *Federal Register*, Vol. 57, No. 199 [1992]). As part of this effort, NASA divided the site into three separate areas referred to as OUs. Designated by numbers, OU1 consists of on-facility groundwater (the "source area"), OU2 consists of on-facility soils (location of source material), and OU3 consists of off-facility groundwater adjacent to JPL.

After being placed on the NPL, an RI (FWEC, 1999a; FWEC, 1999b) was conducted at the JPL site to characterize the nature and extent of chemicals in soil and groundwater, and assess both human health and ecological risk. Chemicals originating at JPL were not found in off-site soils or surface water. During the RI, a quarterly groundwater monitoring program was initiated in August 1996 to monitor VOCs and other chemicals, including perchlorate, metals, anions, cations, and other field parameters. Historical groundwater monitoring activities have indicated that four chemicals of concern (COCs; carbon tetrachloride, trichloroethene [TCE], tetrachloroethylene, and perchlorate) have been detected in JPL monitoring wells at concentrations above the state and federal drinking water standards for each chemical. Carbon tetrachloride, TCE, and perchlorate continue to be consistently detected above state and federal drinking water standards. The perchlorate, carbon tetrachloride, and TCE plumes originating from JPL currently extend approximately 1 mile east-southeast of the source area (NASA, 2014a). Analytical results from the groundwater monitoring program are summarized in quarterly reports and technical memoranda that are available in the information repositories and on the CERCLA website (http://jplwater.nasa.gov).

In the early 1990s, NASA funded treatment facilities for LAWC and the City of Pasadena to remove VOCs from drinking water wells that were affected by chemicals from JPL. Then, in the late 1990s and early 2000, NASA conducted pilot testing of several technologies to determine the most effective means to address dissolved perchlorate in groundwater. The technologies tested included reverse osmosis, a fluidized bed reactor (FBR), packed bed reactors, in situ bioremediation, and ion exchange (FWEC, 2000; NASA, 2003a). Due to the depth and extent of the chemicals in groundwater, in situ (below ground) treatment is not cost-effective at the JPL facility; therefore, groundwater must be pumped from the ground, treated aboveground, and re-injected or used for drinking water.

A draft Feasibility Study was completed in January 2000 (FWEC, 2000) to evaluate potential response actions for groundwater at the JPL site. In addition, extensive groundwater modeling and aquifer testing (NASA, 2003b) at and adjacent to the JPL site were conducted to characterize the complex groundwater conditions and groundwater flow.

Based on the earlier pilot tests, NASA installed a demonstration treatment plant in early 2005 located in the source area on the JPL property. The system was subsequently expanded as the interim remedial action for OU1 in 2007. NASA and the regulators completed and signed the Interim Record of Decision (ROD) for OU1 in February 2007 (NASA, 2007b). The system consists of liquid-phase granular activated carbon (LGAC) treatment to remove VOCs and an FBR to remove perchlorate. Treated water is re-injected into the ground and is not used for drinking water purposes. Figure 2-1 shows the layout of the OU1 system, including locations of extraction and injection wells.

Since system startup in early 2005, the OU1 treatment system has successfully treated more than 3,300 acre feet of groundwater, removing approximately 1,800 pounds of perchlorate and 40 pounds of VOCs. Influent perchlorate concentrations at the OU1 system have decreased significantly, from approximately 2,300 µg/L in February 2005 to approximately 25 µg/L in August 2014. Concentrations of perchlorate and VOCs at the effluent of the OU1 system (i.e., treated water) are consistently non-detect. In addition, operation of the source area treatment system appears to have resulted in a significant reduction of chemicals of concern in wells MW-7, MW-16, and MW-24, which are located within the treatment zone (i.e., within the area of influence for the extraction wells).

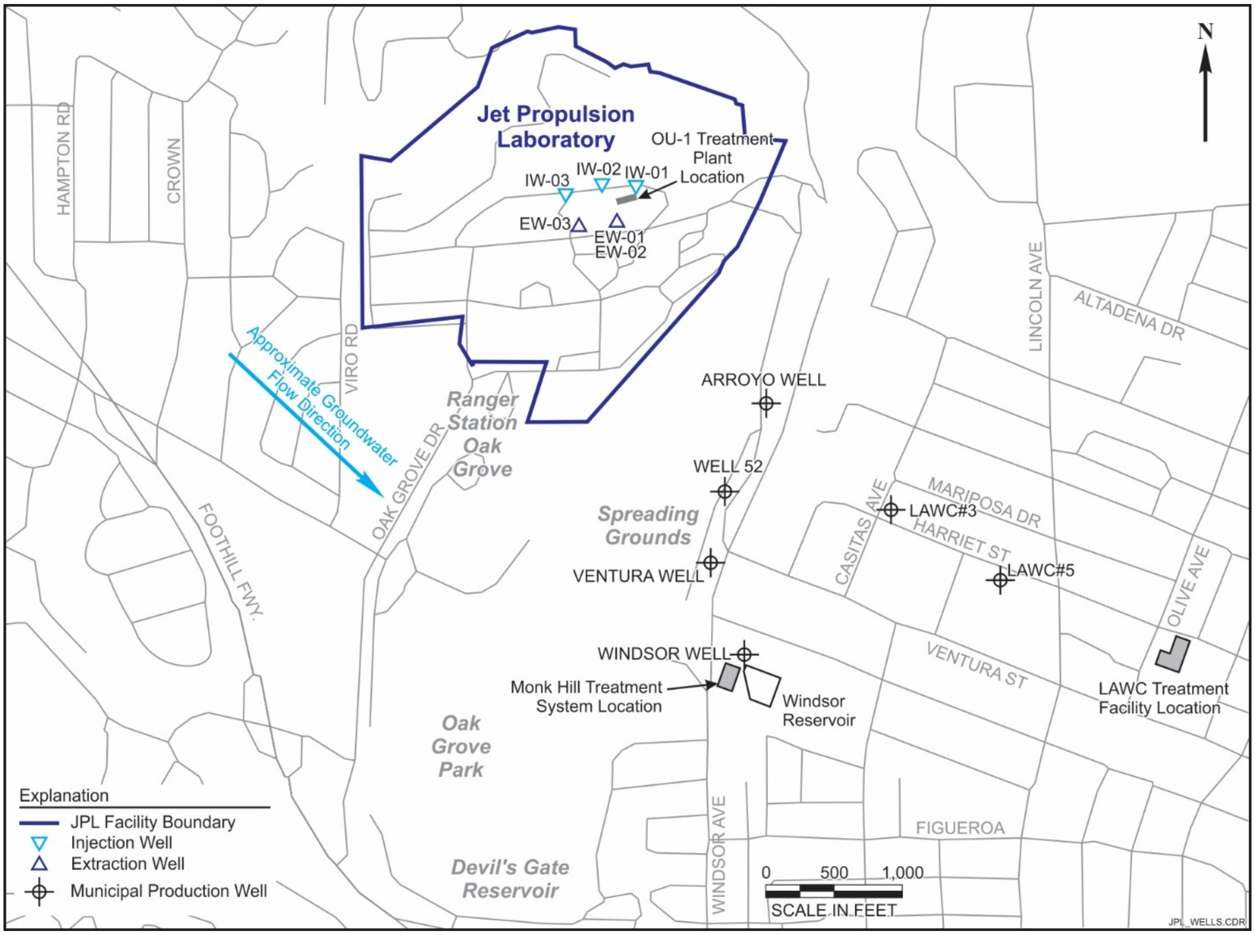


Figure 2-1. Location of OU1 and OU3 Groundwater Treatment Systems

In July 2004, NASA implemented a removal action directed at the off-facility groundwater (OU3) to achieve quick, protective results and allow LAWC to continue use of its wells during the high-demand summer months. This was accomplished by funding additional treatment facilities at LAWC to remove perchlorate in addition to VOCs. The perchlorate removal system uses an ion exchange technology that has worked well, successfully treating over 20,400 acre feet of groundwater, removing approximately 1,060 pounds of perchlorate and 230 pounds of VOCs. Based on the success of the LAWC removal action and the need for similar perchlorate and VOC treatment at four City of Pasadena wells, NASA issued the Proposed Plan for OU3 in April 2006 that consisted of continued funding for operation of the LAWC treatment system, as well as funding for construction and operation of a treatment system for groundwater from the four City of Pasadena drinking water wells located just east of JPL near the Arroyo Seco. Public comments were received and addressed and an Interim ROD for OU3 was executed in August 2007 (NASA, 2007c).

In accordance with the Interim ROD for OU3, NASA implemented an interim remedial action to also remove perchlorate and VOCs from four City of Pasadena drinking water wells beginning in 2011. The Monk Hill Treatment System (MHTS) began operation in July 2011 and has successfully treated approximately 12,800 acre feet of groundwater, removing approximately

900 pounds of perchlorate using ion exchange and 92 pounds of VOCs using granular activated carbon. MHTS has a 7,000 gallon per minute (gpm) treatment capacity, although the actual treatment rate is dependent on demand.

Groundwater treated by the current LAWC system and MHTS achieves all applicable drinking water requirements. Influent chemical concentrations at both systems are decreasing over time. Recent data show chemical concentrations have decreased by 50% or more compared to the highest influent chemical concentrations. Operation of these treatment systems will continue as part of the final remedy for OU3.

Appendix B provides a list of documents contained in the Administrative Record for OU1 and OU3 that are associated with this ROD.

3.0 Community Participation

For more than a decade, NASA has engaged in outreach to residents of the communities surrounding JPL, updating them on the status of the cleanup efforts for the JPL CERCLA site by holding public meetings, sending out newsletters, maintaining a website (http://jplwater.nasa.gov), preparing annual summaries of investigation and clean-up efforts, and meeting with and listening to community groups, individuals, health care and local government representatives, and water purveyors. A *Community Involvement Plan Update* was finalized in June 2014 (NASA, 2014c).

In January 2004, public meetings were held to inform the public and JPL employees about the progress of cleanup activities that included describing several possible treatment technologies and alternatives to treat perchlorate and VOCs beneath the JPL facility. A newsletter on the project was also mailed to more than 15,000 residents of communities surrounding JPL.

In April 2004, a public meeting was held to discuss questions about potential public health effects associated with chemicals in the groundwater near JPL. Newsletters were distributed to more than 15,000 local residents in August 2004 and March 2005 describing cleanup actions funded by NASA at the two LAWC wells. In addition, numerous fact sheets were prepared to address specific questions from the community. All newsletters and fact sheets are available at the JPL CERCLA Program website (http://jplwater.nasa.gov).

A community information session (CIS) was held in March 2005, providing an opportunity for attendees to speak with NASA project staff and contractors involved in the cleanup. The CIS included a series of displays describing the site background and treatment options among other topics. The OU3 systems (the existing treatment plant for LAWC and the then-proposed MHTS) also were discussed at this session.

On November 16, 2005, a public meeting was held to provide information, and receive public comments on a Proposed Plan for the OU1 source area groundwater treatment system as an interim remedy. On May 3, 2006, a public meeting was held to provide information, and receive public comments on a Proposed Plan for the off-facility OU3 treatment systems as an interim remedy. Responsiveness summaries were prepared following the public comment period for each Proposed Plan and included with the respective Interim RODs for OU1 and OU3.

Since 2006, progress of the OU1 system, LAWC plant, and MHTS has continued to be communicated to the community via newsletters, annual year-in-reviews, site tours, and the JPL CERCLA Program website. NASA also worked closely with the City of Pasadena prior to and during construction of the MHTS (2008 through 2011) to obtain community feedback on the treatment system location, landscaping, and construction mitigation measures (e.g., noise, dust).

On October 29, 2014, NASA issued the Proposed Plan for Groundwater Remediation at NASA JPL, which presented the preferred alternative for cleanup of OU1 and OU3 groundwater. A public meeting was held on November 12, 2014 to present the Proposed Plan and to allow the public to comment or ask questions about the preferred alternative. Residents were informed of the public meeting and the public comment period through newspaper ads, flyers posted throughout the community, and by postcard mailings to more than 5,000 local residents on NASA's mailing list.

Based on requests from the public, NASA extended the public comment period from December 3, 2014 to January 30, 2015 and then again to March 3, 2015. Residents were informed of the public comment period extensions via a newspaper ad (first extension only), a mailing to over 5,000 local residents on NASA's mailing list (first extension only), e-mail notifications, and website postings.

NASA continues to regularly update its website (http://jplwater.nasa.gov) with news and information about the cleanup program. Official documents related to the cleanup can be found in the Administrative Record section of the website and via the computers found at these Information Repositories:

La Cañada Flintridge Public Library
4545 Oakwood Ave.
La Cañada Flintridge, CA 91011
(818) 790-3330

Pasadena Central Library
285 East Walnut St.
Pasadena, CA 91101
(626) 744-4052

Altadena Public Library
600 East Mariposa Ave.
Altadena, CA 91001
(626) 798-0833

JPL Library
(JPL Employees Only)
Building 111, Room 112
(818) 354-4200

4.0 Scope and Role of Response Action

As the responsible agency, NASA has conducted a number of detailed investigations and studies on the site and adjacent areas since the early 1990s. These studies have helped NASA identify and understand the type and extent of chemicals in soil and groundwater. As part of this effort, NASA divided the site into three separate areas referred to as OUs. Designated by numbers, OU1 consists of on-facility groundwater (the “source area”), OU2 consists of source material in on-facility soils, and OU3 consists of off-facility groundwater adjacent to JPL.

NASA has already implemented several cleanup initiatives to accelerate the remediation of on-facility soils and groundwater at JPL. A soil vapor extraction system successfully treated concentrations of VOCs in soil (OU2). The specified cleanup objectives were achieved, and completion of the OU2 cleanup activities was documented in the Remedial Action Report (NASA, 2007a). In remediating the soil, NASA enhanced the overall site cleanup strategy by eliminating the source of VOCs that could migrate to groundwater. NASA investigated perchlorate in the vadose zone as part of previous remediation efforts (Arcadis, 2004) and determined that perchlorate was not present in the vadose zone having been effectively flushed through the course-grained geology down to groundwater. This ROD identifies the selected remedy for OU1 and OU3.

An on-facility extraction, treatment, and re-injection system was implemented as an interim remedial action and is currently operating within the JPL fence line (OU1) to remediate water in the source area groundwater located underneath the JPL property. Remediating the source area is a critical part of the overall site cleanup strategy for restoring the aquifer because the majority of the chemical mass that would eventually migrate to the nearby drinking water wells is located within this area. Remediation of the off-facility groundwater (OU3) consists of wellhead treatment. The treatment systems, also operating as an interim remedial action for OU3, remove VOCs and perchlorate from two LAWC drinking water wells and four City of Pasadena drinking water wells. The final response action selected for OU3 in this ROD is necessary to address COCs in the aquifer being used by the local community to meet drinking water standards (i.e., maximum contaminant levels [MCLs]). In addition, active treatment provides hydraulic control to prevent the migration of chemicals in groundwater.

The overall site cleanup program at JPL takes into account the interrelationship of the three OUs. Figure 4-1 depicts a conceptual representation of the overall cleanup program that has been developed to achieve cleanup of the aquifer.

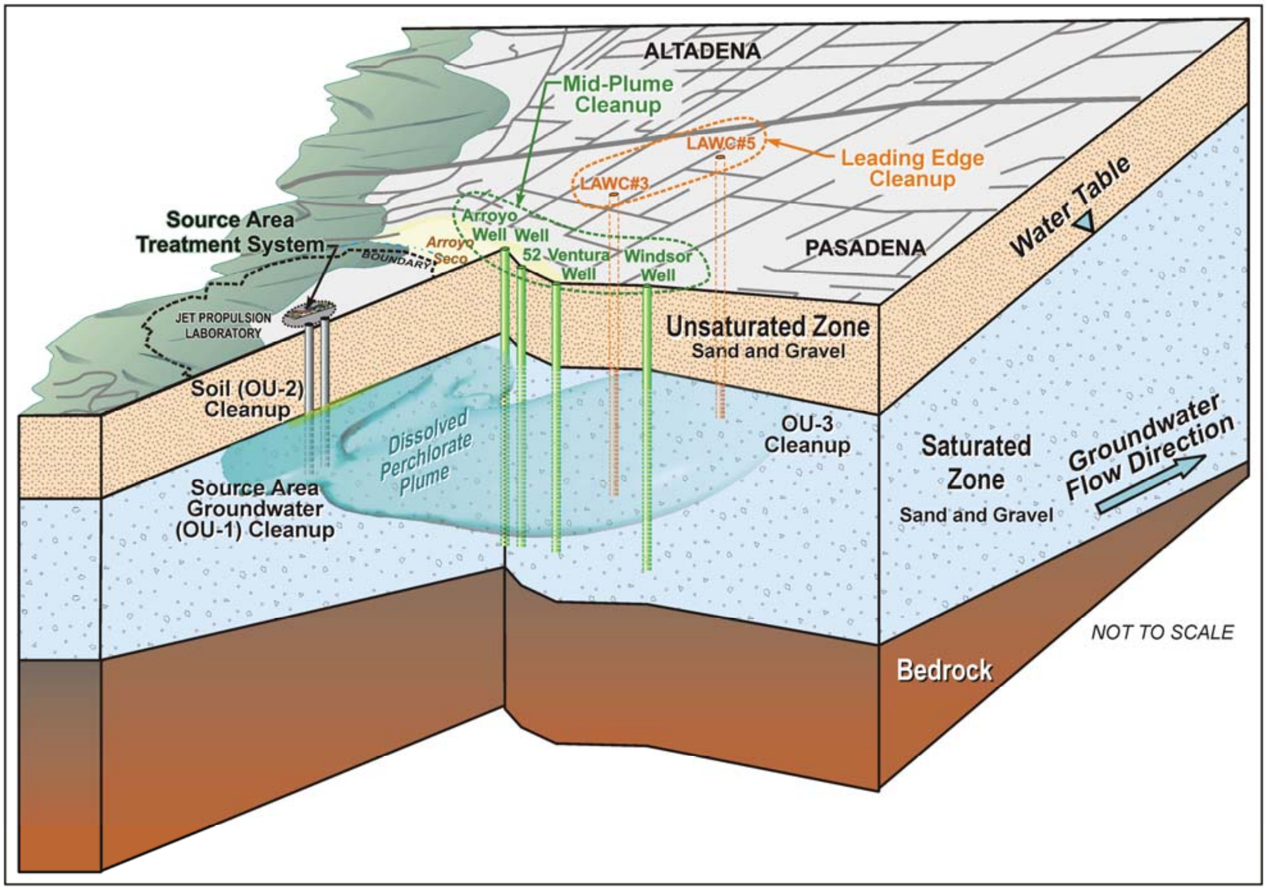


Figure 4-1. Conceptual Representation of the Comprehensive Groundwater Cleanup Program at JPL

5.0 Site Characteristics of OU1 Source Area and OU3 Off-Facility Area

5.1 OU1 and OU3 Area Setting

An in-depth description of the area setting of OU1 and OU3, including a detailed discussion of the regional demographics, climate, physiography, geology, hydrology, hydrogeology, natural resources, and cultural resources can be found in the *National Environmental Policy Act of 1969 (NEPA) Values Assessment* (NASA, 2006a), in the *Final Remedial Investigation (RI) for OU1 and OU3* (FWEC, 1999a), and in NASA's additional investigation technical memorandum (NASA, 2007d).

5.1.1 Geology

The areas identified as OU1 and OU3 lie within the San Gabriel Valley, immediately south of the southern edge of the San Gabriel Mountains. The Sierra Madre Fault system separates the San Gabriel Mountains to the north from the San Gabriel Valley to the south. A significant component of the Sierra Madre Fault system crosses the JPL site in the form of the JPL Thrust Fault which runs east-west across the middle of the site. The JPL Thrust Fault represents a boundary between shallow bedrock and a deeper alluvial aquifer. North of the fault, depths to bedrock range from approximately 2 feet to more than 100 feet bgs, and groundwater primarily occurs in joints and fractures in this shallow bedrock. Because the bedrock is of low porosity, it is considered non-water bearing and does not represent a significant component of the groundwater system nor a possible contaminant migration pathway. South of the JPL Thrust Fault, groundwater occurs in deeper alluvial deposits which have been divided into four layers that are separated by noncontiguous, low permeability silt layers. This alluvial aquifer is ultimately underlain by deeper bedrock, ranging from 550 feet bgs to more than 725 feet bgs (NASA, 2003b).

Based on information obtained during the RI for OU1 and OU3 (FWEC, 1999a), four primary "hydrogeologic layers" of the aquifer, or "aquifer layers", were delineated above the crystalline basement complex (leucocratic granodiorite). The four aquifer layers present within the OU1 and OU3 area include the upper and lower sections of the Older Fanglomerate Series (aquifer layers 1 and 2, respectively), the Pacoima Formation (aquifer layer 3), and the Saugus Formation (aquifer layer 4). A description of each of these soil/rock types from the RI for OU1 and OU3 (FWEC, 1999a) is presented below.

Leucocratic Granodiorite

The dominant crystalline rock type comprising the basement complex beneath OU1 and OU3 is a light gray to buff, fine- to medium-grained leucocratic granodiorite with a hypidiomorphic texture. Its typical composition is plagioclase, 60% to 75%; potassium-feldspar, 5% to 15%; quartz, 10% to 15%; biotite, 2% to 10%, and a trace of magnetite. This rock type is widely distributed and recognized by its light color and resistance to chemical weathering. Data on the depth to the crystalline basement complex from deep JPL monitoring wells and nearby municipal production wells have shown that the crystalline basement complex generally dips to the north and east beneath JPL.

Saugus Formation
The Saugus Formation lies on top of the crystalline basement rocks at the far eastern edge of the subject area. The Saugus Formation is typically composed of arkosic sand, pebbly arkosic sand, and conglomeratic arkosic sand that range from light-brown to light-gray in color. The three principal criteria that can be used to identify the Saugus Formation include: (1) the combination of lithic clast types in the Saugus Formation is different from that of younger units, (2) the Saugus beds are typically not as well graded as those of younger units, and (3) the Saugus beds have generally resulted from a relatively low energy floodplain depositional environment compared to younger formations.

Pacoima Formation
The Pacoima Formation lies unconformably on the crystalline basement complex beneath most of OU1 and OU3, and on the Saugus Formation at the far eastern edge of the area. This unit is typically composed of fluvial conglomeratic arkosic sand that contains significant amounts of gravel and some boulders. Its color is light brown where unaffected by weather, but can range from orange to dark reddish-orange with significant weathering. Beneath OU1 and OU3, it is estimated that the Pacoima Formation is approximately 200 to 300 feet thick.

Older Fanglomerate Series
Overlying the Pacoima Formation throughout OU1 and OU3 is the Older Fanglomerate Series. This series is composed of light-brown to gray to dark-brown fluvial arkosic sands with abundant gravel and boulders.

5.1.2 Hydrology and Hydrogeology

The following information regarding hydrology and hydrogeology within the OU1 and OU3 area is provided from the RI for OU1 and OU3 (FWEC, 1999a) and the JPL Groundwater Modeling Report (NASA, 2003b).

The San Gabriel Valley has been divided into distinct groundwater basins, one of which is the Raymond Basin where JPL is located. The Raymond Basin is further divided into three separate hydrologic subareas, of which JPL is located in the Monk Hill subarea (FWEC, 1999a). The Arroyo Seco, an intermittent streambed, lies within the Monk Hill subarea, immediately to the east and southeast of the JPL site. Within the Arroyo Seco is a series of surface impoundments, known as the Arroyo Seco Spreading Basins, which are located to the east of the JPL facility near the City of Pasadena production wells. When available, surface water in the Arroyo Seco is diverted to these basins and infiltrated to recharge groundwater (NASA, 2003b).

The aquifer beneath JPL is generally considered unconfined. The groundwater table is located approximately 200 ft below ground surface. However, the groundwater table elevations in wells located at the mouth of the Arroyo Seco (MW-1, MW-9, and MW-15) are consistently between 80 and 120 feet higher than the surrounding water table, indicating a significant groundwater mound is present in this area. This groundwater mound has been attributed to recharge from the mouth of the Arroyo Seco (FWEC, 1999a), and also the presence of an unknown fault in this area acting as a hydraulic barrier below the mouth of the Arroyo Seco (NASA, 2003b).

The aquifer is a bedrock channel continuous with the Monk Hill basin to the west, and running east north of the Monk Hill Dike (a bedrock ridge beneath the Arroyo Seco south of Devil's Gate). The north limit of the aquifer is the foot of the San Gabriel Mountains. This consists of an upper block of crystalline bedrock thrust over alluvium by the Sierra Madre Fault. Underneath the fault plane is a continuation of the aquifer to the north. Based on water level and soil-type data, the aquifer has been divided into four "aquifer layers", with geology as discussed above. In general, the aquifer layers were identified based on historical hydrographs from the deep JPL wells based on how silt-rich intervals influence the hydraulic heads in the aquifer during periods of pumping of the nearby municipal wells. The upper three aquifer layers are present beneath JPL, and the fourth layer is found in the bottom screen interval of the easternmost off-facility JPL monitoring well. Aquifer layer 1 comprises the upper 75 to 100 ft of the aquifer and includes the water table. Aquifer layers 2, 3, and 4 are separated from Layer 1 by thin silt-rich intervals, approximately 300, 500, and 800 ft deep, respectively (FWEC, 1999a).

Groundwater flow patterns are complex, due primarily to pumping of the Pasadena municipal production wells near the JPL facility (FWEC, 1999a; NASA, 2003b). Groundwater flows east from the upper Monk Hill basin towards the Arroyo Seco. Where the eastward-flowing water crosses beneath the Arroyo Seco, drainage from the upper Arroyo Seco above the Sierra Madre thrust plate infiltrates to groundwater in recharge areas along the Arroyo above Devil's Gate Dam. In wet years, a substantial recharge mound builds up between Devil's Gate dam and the mountain, and flows southeast. In dry years and the summer months, the recharge mound may disappear. An unusual feature beneath JPL is eastward flow of water beneath the thrust plate and the Arroyo Seco in the overthrust alluvium. Groundwater recharge in very wet winters essentially replaces most of the shallow groundwater until the dry season. At the MHTS, and east of the Arroyo Seco, groundwater is pumped by a series of high-capacity wells. Hydraulic parameters were estimated from large-scale pump testing completed in 2001 to support the JPL groundwater modeling effort. Horizontal conductivity values were estimated at 14.4 ft/day, 28.2 ft/day, 27.9 ft/day, and 3.9 ft/day in aquifer layers 1 through 4, respectively. Vertical conductivity values were estimated for the area between layers 1 and 2; between layers 2 and 3; and between layers 3 and 4 at 9.2×10^{-3} ft/day, 6.0×10^{-3} ft/day, and 1.1×10^{-2} ft/day, respectively (NASA, 2003b).

5.2 Sources of Chemicals in Groundwater at JPL

Various seepage pits and other areas were identified at JPL as possible locations used for chemical waste disposal during historic operations during the 1940s and 1950s. Figure 5-1 shows the locations of the 40 seepage pits, five waste pits, and four discharge points previously identified in the RI (FWEC, 1999b). Eleven of these locations are located above the groundwater source area addressed in this ROD (seepage pits 17-22, 26-28, 30 and waste pit 3).

Seepage pits were used to dispose of liquid and sanitary wastes from buildings during historic operations through the 1940s and 1950s at JPL. Solvents (including carbon tetrachloride and TCE) were routinely used in repairing, cleaning, and maintaining equipment and machinery at the facility, and other chemicals including petroleum hydrocarbons, cooling-tower chemicals, laboratory chemicals, and liquid rocket fuel propellants were historically used at the site. Given the history of operations at the JPL site, it is possible that the seepage pits received these solvents and other chemicals for disposal (FWEC, 1999b). It is believed that the seepage pits were backfilled between 1960 and 1963, when JPL installed a sewer system (Agency for Toxic Substances and Disease Registry [ATSDR], 1999). The seepage pits at which chemicals were released are the source of chemicals found in groundwater at the JPL facility.

Five waste pits and four discharge points were also identified as potential sources of chemicals during the expanded site investigation and RI (Figure 5-1). The first waste pit area reportedly received small amounts of spent solvent, mercury, and other wastes that were intermittently dumped in this area. The second waste pit was reportedly used primarily for the disposal of glass and metal shavings during the late 1940s and 1950s. The third waste pit was located at a former salvage storage area and was reportedly used for the disposal of solvents. The final two waste pits were trenches identified during an aerial photography review which were located outside of the JPL boundary. Historical information on their use or contents is not available (FWEC, 1999b).

Discharge points to the Arroyo were reported in city of Pasadena Water Department field inspection reports dated August 26, 1948 and February 27, 1961 (FWEC, 1999b). Discharge of a yellow oily substance that was fairly clear and free of objectionable odor was reported at the first location. At the second location, there was evidence of a previous discharge in the form of a channel blackened with a deposit of dark, odorless, pigment-like material. The third discharge originated as bleedoff, containing sodium chromate, from Cooling Tower No. 118 and emptied into the Arroyo from a storm drain. The fourth discharge consisted of a black, coal-tar-like substance with a strong objectionable odor that resembled petroleum derivatives, and was located in a small sump area but not of sufficient quantity to reach the Arroyo stream bank proper (FWEC, 1999b).

As part of the expanded site inspection and RI for soils (Ebasco, 1990a; FWEC, 1999b), soil sampling and test pits were performed at former surface water discharge points and former waste disposal areas near the Arroyo Seco. Results from this extensive soil sampling effort indicated that there was negligible risk to potential human and ecological receptors in the Arroyo Seco from the low levels of metals and hydrocarbons in soil. In addition, no VOCs, semivolatile organic compounds (SVOCs), pesticides, or polychlorinated biphenyls were detected in surface sediment samples in the Arroyo Seco (perchlorate analysis was not performed as part of the RI for soils). Soil sampling performed in 2013 in the Arroyo Seco as part of the *Final Environmental Impact Report for the Devil's Gate Reservoir Sediment Removal and Management Project* (Los Angeles County Flood Control District, 2013), supported NASA's data that soils and sediments in the Arroyo Seco have not been impacted by JPL (perchlorate was not detected during the 2013 sampling). A more detailed discussion of soil sampling strategy and results can be found in the OU2 RI (FWEC, 1999b) and the final OU2 ROD (NASA, 2002).

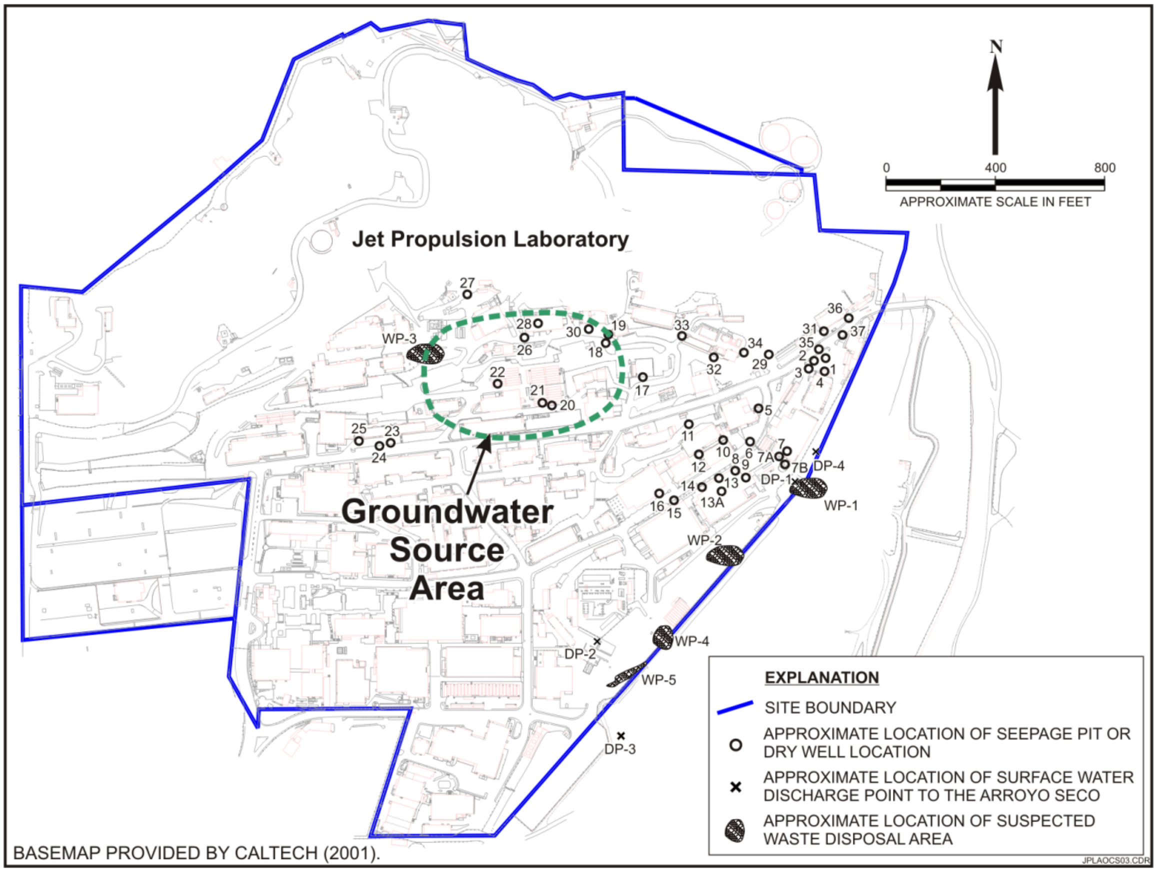


Figure 5-1. Potential Historical Chemical Waste Disposal Locations at the JPL Facility

The nature and extent of VOCs, perchlorate, metals, and other organic constituents were determined through groundwater sampling conducted at the facility during the expanded site inspection and RI for OU1 and OU3 (Ebasco, 1990a; FWEC, 1999a). In 1990, 10 groundwater monitoring wells were installed during the expanded site inspection and VOCs were subsequently detected at concentrations above drinking water standards. As a result, a more comprehensive RI for OU1 and OU3 was completed during which 13 additional groundwater monitoring wells were installed. A total of 18 wells were installed for OU1 (MW-1, MW-3 through MW-16, MW-22, MW-23, and MW-24) and another five were installed for OU3 (MW-17, -18, -19, -20, and -21) (Figure 5-2). Of the total 23 wells, 10 wells are shallow standpipe wells that have a single screened interval at the groundwater table, and the other 13 wells are deep, multi-port wells that contain five screened intervals. All five of the OU3 wells are deep multi-port wells.

Over the course of the RI, groundwater samples were collected from the JPL monitoring wells a total of 10 times between June 1994 and January 1998. Samples collected during the RI were analyzed for VOCs, SVOCs, Title 26 metals, strontium, hexavalent chromium, aluminum, cyanide, total petroleum hydrocarbons (MW-4 only), gross alpha/gross beta (MW-13 only), perchlorate, tributyltin (select wells), and general minerals (major anions and cations). The RI concluded that carbon tetrachloride, TCE, 1,2-dichloroethane (DCA), and perchlorate were detected at concentrations exceeding state and federal MCLs. Based on the analytical data, elevated VOCs and perchlorate concentrations were primarily found in monitoring wells located on site (MW-7, MW-13, MW-16, and MW-24) and to the east of JPL around the Pasadena and Lincoln Avenue municipal production wells (MW-17, MW-18, and MW-19) (FWEC, 1999a). The long-term groundwater monitoring program at JPL began in June 1996 during the OU1 and OU3 RI and continues today. Further discussion of the nature and extent of chemicals in groundwater at JPL is provided in the following section.

5.3 Nature and Extent of Chemicals in Groundwater at JPL

During the initial phases of the RI, comprehensive suites of analyses were performed. These included VOCs; SVOCs; Title 26 metals; additional metals analyses for strontium, aluminum, and hexavalent chromium (Cr^{+6}); cyanide; gross alpha/gross beta radiation; and total petroleum hydrocarbons. During the long-term monitoring that has occurred for more than 20 years, various analyses were added or removed based on previous results, new information, and to support drinking water permit considerations for the LAWC treatment system and MHTS. Analyses during the on-going groundwater monitoring now primarily include VOCs, perchlorate, metals (arsenic, lead, chromium [Cr and Cr^{+6}]), and other organic compounds including 1,4-dioxane, 1,2,3-trichloropropane (1,2,3-TCP) and n-nitrosodimethylamine (NDMA). The groundwater monitoring wells that are sampled as part of the long-term groundwater monitoring program are shown on Figure 5-2, along with groundwater elevations and flow directions measured during the second quarter 2015 event conducted in April 2015. Appendix C contains a summary of the results associated with the groundwater monitoring program.

To support preparation of the source water assessment required under the State of California Policy Memorandum 97-005, a comprehensive monitoring event was conducted by NASA in December 2002 and January 2003 for select JPL monitoring wells to provide supplemental water quality data based on the analyses requested by the California State Water Resources Control Board Division of Drinking Water (DDW). Chemical constituents that were not routinely analyzed during the long-term quarterly groundwater monitoring events were included in this comprehensive sampling event. The JPL monitoring wells selected for the comprehensive groundwater monitoring event located in OU3 included: MW-17 (Screens 3 and 4), MW-18 (Screens 3 and 4), MW-19 (Screens 3 and 5), MW-21 (Screens 3 and 5), and MW-24 (Screen 2). California DDW participated in the selection of the wells and analytical methods.

Chemicals selected during the comprehensive monitoring event that were not detected (or not analyzed for) in the historical JPL monitoring data obtained during the RI and long-term monitoring program included 2,4,6-trinitrotoluene (TNT), high-velocity military explosive (HMX); royal demolition explosive (RDX); n-nitrosodiphenylamine (NDPHA); n-nitrosodi-n-propylamine (NDPA), and NDMA. In addition, 1,2,3-TCP and 1,4-dioxane also were detected during the comprehensive event as well as in previous monitoring events. Table 5-1 summarizes the maximum concentrations of these chemicals detected in samples collected from the OU3 groundwater monitoring wells.

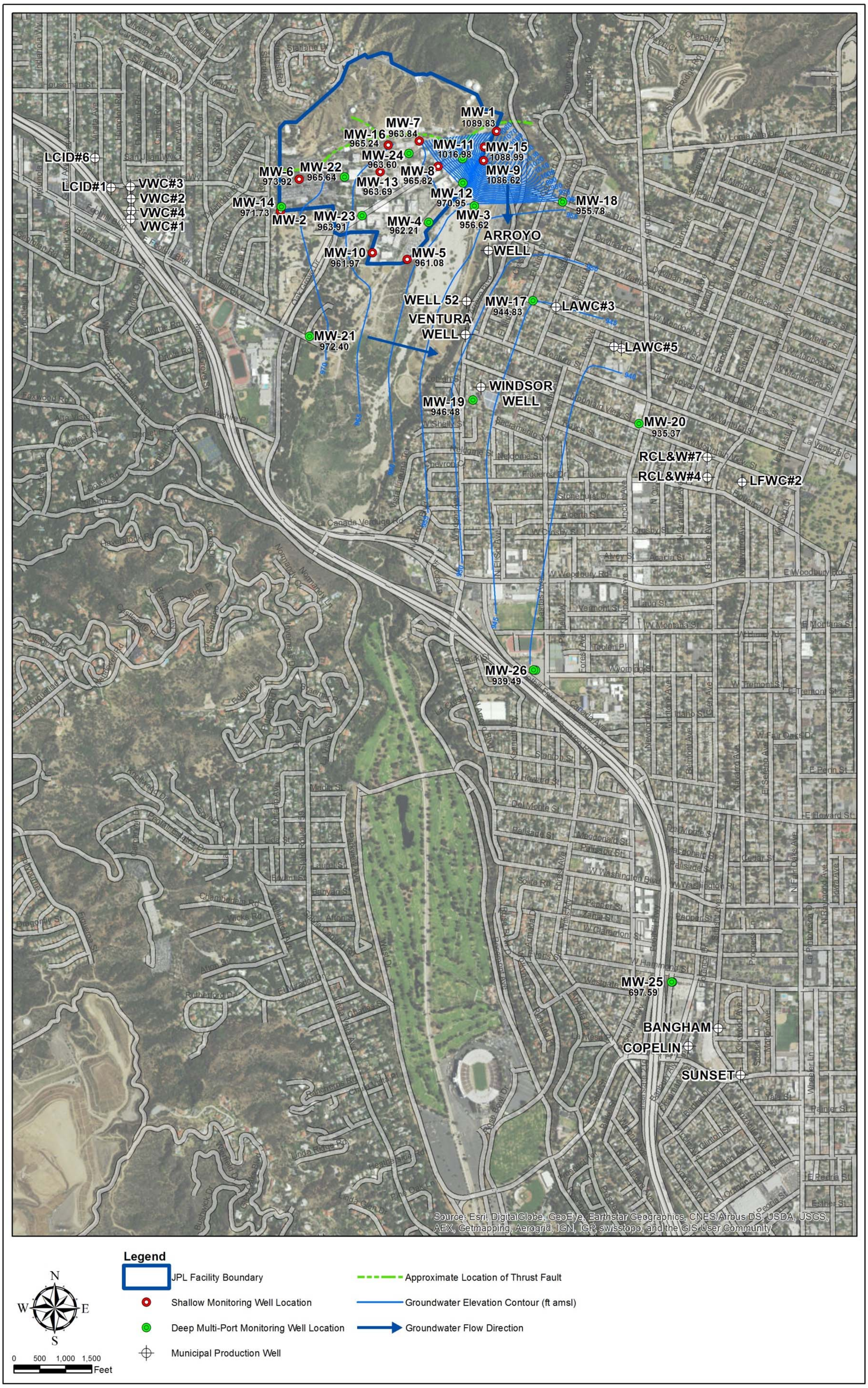


Figure 5-2. Location of JPL Groundwater Monitoring Wells and Nearby Municipal Production Wells

Table 5-1. Summary of Maximum Concentrations of Chemicals Detected in Off-Facility Groundwater during the Comprehensive Monitoring Event (December 2002 to January 2003)

Chemical	Notification Level[a] (µg/L)	Maximum Detected Concentration (µg/L)	Date of Maximum	Monitoring Well (Screen)
1,2,3-TCP	0.005	0.071	Jan. 2003	MW-18(4)
TNT	1	<0.11	NA	NA
HMX	350	<0.19	NA	NA
RDX	0.3	<0.19	NA	NA
NDMA	0.01	0.0016	Dec. 2002	MW-21(5)
NDPHA	0.01	0.00617	Dec. 2002	MW-19(5)
NDPA	0.01	<0.005	NA	NA
2,4-Dinitrotoluene	NA	<0.14	NA	NA
1,4-Dioxane	1	1.9	Dec. 2002	MW-18(4)

(a) Notification levels have been referenced because neither federal nor state MCLs exist for any of the emerging constituents.
NA – not applicable

Based on the results of this monitoring event, there was some concern that low levels of 1,2,3-TCP and 1,4-dioxane may be present in the raw water at the LAWC and MHTS. As part of the drinking water permits for the two systems, periodic monitoring of the raw water for these compounds is required by California DDW. To date, all samples collected at Arroyo Well, Well 52, Ventura Well, LAWC#3, and LAWC#5 have been non-detect for 1,2,3-TCP (i.e., <0.005 µg/L) and 1,4-dioxane (i.e., <1 µg/L). Windsor Well has not yet been used during system operation due to elevated nitrate levels, so samples have not been collected. Periodic monitoring will continue as part of system operations.

In 2004, two additional monitoring wells (MW-25 and MW-26) were installed further downgradient of the existing OU3 monitoring network as part of an additional investigation to evaluate perchlorate detections outside of the Monk Hill subarea and determine the full extent of chemicals originating from JPL. Perchlorate has been detected in City of Pasadena production wells (Sunset, Bangham, Copelin, Garfield, and Villa; collectively referred to as the Sunset Reservoir wells), located approximately 3 to 4 miles downgradient of the JPL facility. The additional investigation included four different activities: (1) installation of two new monitoring wells (MW-25 and MW-26), (2) groundwater modeling, (3) analysis of groundwater monitoring well data dating back to the early 1990s and analysis of production well water quality data dating back to 1940, and (4) a perchlorate isotope study. Upon completion of the additional investigation, NASA considered additional information and comments provided by the City of Pasadena and held several technical discussions with the City of Pasadena, the U.S. EPA, and State regulatory agencies. Based on the following information, NASA concluded that (1) the chemicals from the JPL facility are captured within the Monk Hill subarea, and (2) the perchlorate detected at the Sunset Reservoir wells is of a different origin than that used at, and originating from, JPL (NASA, 2007d; 2008).

- Groundwater modeling conducted by NASA and the Raymond Basin Management Board (RBMB) indicates that dissolved perchlorate originating from JPL would be contained by the production wells located in the Monk Hill subarea and not migrate to the Sunset Reservoir wells (NASA, 2003b; Geoscience, 2004); therefore, this line of evidence indicates an origin of perchlorate in the Sunset Reservoir area that is not associated with JPL.
- Groundwater cation and anion concentration data from within the Raymond Basin dating back to the early 1900s were evaluated to determine temporal and spatial differences in groundwater geochemistry. Three separate water types were determined to be present in the Monk Hill subarea during the RI (FWEC, 1999a) and were confirmed during the additional OU3 investigation (NASA, 2007d). Groundwater geochemistry from the Sunset Reservoir Wells indicates an influence by Colorado River water which has historically been imported to the area by water suppliers and, thus, the Colorado River water has been identified as a potential source of perchlorate in groundwater near the Sunset Reservoir Wells. Mixing of the imported river water and native groundwater was observed in the historical groundwater geochemistry data and is supported by the groundwater, strontium, and tritium isotope analysis collected as part of the additional investigation (NASA, 2007d).
- As part of the additional investigation, perchlorate isotope analysis was performed to fingerprint perchlorate sources based on the ratios of different isotopes (e.g., $^{18}O/^{16}O$ and $^{37}Cl/^{35}Cl$). The perchlorate isotope data indicate that the JPL perchlorate isotopic fingerprint is distinct within the Raymond Basin and that the perchlorate isotopic signature in the water from wells near Sunset Reservoir is different than the JPL perchlorate isotope signature.

NASA will continue to monitor groundwater between the JPL site and the Sunset Reservoir wells as part of the long-term monitoring program under the final remedy. Data from this monitoring will be evaluated, at a minimum, as part of the five-year reviews for JPL.

Ongoing groundwater monitoring activities have identified four COCs that continue to be detected in JPL monitoring wells at concentrations above the state and federal drinking water standards for each chemical: carbon tetrachloride, TCE, tetrachloroethene (PCE), and perchlorate. The chemical and physical properties of these COCs (Table 5-2) can be used to predict the propensity of the compounds to partition between environmental phases. The following information was originally provided in the RI (FWEC, 1999). Partitioning of a particular VOC between water, air and soil can be estimated using the VOC's aqueous solubility value (water), Henry's Law constant (K_H) and vapor pressure (air), and its organic carbon partition coefficient (K_{OC}) [which can be estimated by measuring its octanol-water partition coefficient (K_{OW})] (soil). The aqueous solubility value gives the maximum amount of (mass) of a chemical that is soluble within a given volume of water. Compounds with solubility values less than 1 mg/L are generally considered insoluble in water, while compounds with values greater than 10,000 mg/L are considered highly soluble. The vapor pressure of a chemical is a measure of the chemical's tendency to volatilize. Vapor pressures greater than 1 millimeter of mercury (mm Hg) indicate volatility, whereas chemicals ranging from 1 to 0.001 mm Hg are considered semi-volatile, and those with vapor pressures less than 0.001 mg Hg are considered nonvolatile. It is noted that the classification of volatility by vapor pressure does not necessarily correspond to the laboratory classification of compounds as either volatile or semi-volatile (base-neutral-acid extractable) target analyses. The specific Henry's Law constant for a given compound provides a measure of the tendency of that compound to volatilize from an aqueous solution. For volatile compounds, higher values of Henry's Law constants are associated with an increased volatilization from water. Chemicals that are readily volatilized from groundwater or surface water have constants exceeding10^{-3} atmosphere-cubic meters/mole (atm-m^3/mol), whereas compounds with low volatility have constants less than 10^{-7} atm-m^3/mol.

The single most important characteristic for estimating adsorption of an organic contaminant by a soil is the soil's organic carbon (C) content. The K_{OW} defines the propensity of a compound to partition into octanol in an octanol/water system. Since octanol is considered to represent the sorptive properties of soil organic matter, the K_{OW} can provide an estimate of the tendency for a chemical to sorb to soil organic matter. The greater the value of K^{OW}, the greater the tendency for adsorption. Compounds with Log(K_{OW}) values generally greater than 3 are preferentially sorbed into the soil phase in soil/water systems. Compounds with Log(K_{OW}) values less than 1 are considered to weakly partition into the soil phase, and values between 1 to 3 denote moderate affinity for the soil phase. Actual partitioning of VOCs into the soil phase will be highly dependent on the organic carbon content of the soil.

Table 5-2. Chemical and Physical Properties for COCs at OU1 and OU3 (FWEC, 1999a)

Analyte	Density (g/mL)	Aqueous Solubility (mg/L)	Vapor Pressure (mm Hg)	Henry's Law Constant (atm-m^3/mol)	Octanol-water Partition Coefficient (Log[K_{OW}])
Carbon Tetrachloride	1.594	800	113	0.0293	2.73
TCE	1.46	1,100	77	0.0117	2.53
PCE	1.63	150	19	0.0685	2.53
Perchlorate	2.02	Soluble	NA	NA	NA

NA: not available

Figures 5-3 through 5-8 show the extent of COCs above the cleanup goals at the JPL site. An estimate of the quantity and volume of the COCs in groundwater was calculated using results from recent groundwater monitoring. Approximately 82,300 acre-feet of water contains COCs at concentrations above the state and federal MCLs. A total of approximately 300 pounds of perchlorate and 60 pounds of carbon tetrachloride are present within the area where MCLs are exceeded. PCE was not recently detected at concentrations above the MCLs, and the mass of TCE in the area with concentrations above the MCLs is estimated to be less than 1 pound. The occurrence of these chemicals in each area of the JPL site is discussed further in the following subsections (NASA, 2015).

5.3.1 Current Concentrations in On-Facility Source Area Wells

On-facility source area wells consist of wells that have historically contained the highest concentration of site-related chemicals. This group of wells is located within the JPL facility (on-facility) and consists of monitoring wells MW-7, MW-13, MW-16 and MW-24. Background data are also presented in this section, based on groundwater data obtained from upgradient Valley Water Company Wells 01, 02, and 03.

The source area treatment system has been operating since 2005 and addresses groundwater beneath the JPL facility which has historically contained the highest concentrations of perchlorate and VOCs (i.e., the source area). Operation of the source area treatment system appears to have resulted in a significant reduction of chemicals of interest in wells MW-7, MW-16 and MW-24, which are located within the treatment zone (Table 5-3). Results from the most recent sampling for the second quarter 2015, conducted in April/May 2015, are summarized below (NASA, 2015).

Table 5-3. OU1 Source Area Monitoring Well Concentrations

Source Area Monitoring Well Concentrations		MW-7	MW-13	MW-16	MW-24	Upgradient (1)
		µg/L				
Current Levels (Apr-May 2015)	Perchlorate	7.4	1,500	*2.5*	66.0	5.0
	Carbon Tetrachloride	<0.5	<0.5	<0.5	<0.5	<0.5
	TCE	<0.5	<0.5	<0.5	<0.5	2.0
Prior to OU1 Startup	Perchlorate	4,810	51.5	322	4,880	4.2
	Carbon Tetrachloride	51.4	*0.4*	<0.5	7.8	<0.5
	TCE	8.7	1.4	<0.5	1.6	0.7
Historic Highs	Perchlorate	13,300	2,100	13,100	4,880	7.4
	Carbon Tetrachloride	310	70	200	58	<0.5
	TCE	48	73	43	15	4.8

(1) Upgradient concentrations identified as maximum concentrations from Valley Water Company Wells 1, 2 and 3.
Italicized values were below detection limits and reported as "J" values.

Perchlorate Analytical Results

Perchlorate concentrations were reported above the state MCL of 6.0 µg/L in MW-7 (7.4 µg/L), MW-13 (1,500 µg/L) and MW-24 (Screen 1 [66.0 µg/L]) during the second quarter 2015. Perchlorate concentrations have been highly variable at MW-13 over the last nine years and continue to be closely evaluated during the ongoing groundwater monitoring program. Perchlorate was detected at estimated concentrations of 2.5J µg/L in MW-16 and 4.1J µg/L at MW-24 (Screen 2) during the second quarter 2015, and perchlorate was not detected in MW-24 (Screens 3, 4, and 5). Perchlorate concentrations have remained stable in the upgradient area around Valley Water Company Wells 01, 02, and 03, with a maximum historic concentration of 7.4 µg/L and a current concentration of 5.0 µg/L measured during the April/May 2015 sampling.

VOC Analytical Results

Concentrations of all VOCs of concern (carbon tetrachloride, PCE and TCE) were below the respective state and federal MCLs in all source area wells during the second quarter 2015.

Carbon tetrachloride and TCE were not detected in any of the on-facility source area wells. PCE was detected below the state and federal MCL of 5.0 µg/L in MW-13 (0.3J µg/L) and MW-24 (Screen 2 [0.2 µg/L]). Maximum concentrations of PCE and TCE were higher in the upgradient wells (i.e., Valley Water Company Wells), with current reported concentrations of 1.4 µg/L and 2.0 µg/L respectively. Carbon tetrachloride was not detected in the upgradient wells.

5.3.2 Current Concentrations in Other On-Facility Wells

This well group consists of monitoring wells MW-6, MW-8, MW-11, MW-22 and MW-23. These wells are located on the JPL facility but outside the source area.

Perchlorate Analytical Results
During the second quarter 2015, perchlorate was detected above the state MCL of 6.0 µg/L in MW-8 (71.0 µg/L). Perchlorate was detected at estimated values below the state MCL in MW-6 (2.9J µg/L), MW-22 (Screens 1 through 3 [3.1J µg/L, 3.0J µg/L, and 1.9J µg/L, respectively) and MW-23 (Screens 1 through 3 [3.9J µg/L, 1.8J µg/L and 3.2J µg/L, respectively]). Perchlorate was not detected in MW-11 (Screens 1 through 5), MW-22 (Screens 4 and 5), or MW-23 (Screens 4 and 5).

VOC Analytical Results
Carbon tetrachloride was not detected above the state MCL (0.5 µg/L) in any of the other on-facility wells during the second quarter 2015. TCE and PCE were also not detected above the state and federal MCL of 5.0 µg/L in any of the other on-facility wells during the second quarter 2015.

5.3.3 Current Concentrations in Perimeter Off-Facility Wells

The perimeter off-facility wells are located near the JPL fence line along the perimeter of the property. This group of wells consists of MW-1, MW-3, MW-4, MW-5, MW-9, MW-10, MW-12, MW-14 and MW-15 (Figure 5-2). Well MW-2 has not been sampled as part of the groundwater monitoring program. It was replaced by MW-14 in 1994.

Perchlorate Analytical Results
Concentrations of perchlorate were reported above the state MCL (6.0 µg/L) during the second quarter 2015 at wells MW-3 (Screen 2 [33.0 µg/L]), MW-4 (Screen 2 [7.2 µg/L]), and MW-14 (Screen 3[6.0 µg/L]). Perchlorate was either non-detect or detected below the state MCL at all other perimeter off-facility wells during the second quarter 2015 (MW-1, MW-3 [Screens 1, 3, 4, and 5], MW-4 [Screens 1, 3, 4, and 5], MW-5, MW-9, MW-10, MW-12, MW-14 [Screens 1, 2, 4 and 5], and MW-15).

VOC Analytical Results
During the second quarter 2015, TCE was detected above the state and federal MCL (5.0 µg/L) in only one perimeter off-facility well, MW-10 (6.8 µg/L). In all other wells, TCE was either non-detect or detected below the state and federal MCL. Carbon tetrachloride was only detected above the state MCL (0.5 µg/L) in one well, MW-12 (Screen 4 [2.0 µg/L]). PCE was not detected above the state and federal MCL (5.0 µg/L) in any of the perimeter off-facility wells during the second quarter 2015.

5.3.4 Current Concentrations in Off-Facility Wells

The off-facility wells consist of monitoring wells MW-17, MW-18, MW-19, MW-20, MW-21, MW-25 and MW-26 (Figure 5-2). These wells are located near and down gradient of the two off-facility treatment plants: MHTS and LAWC treatment system. Daily operation of the MHTS began in February 2011. Operation of the LAWC system began in July 2004. During the second quarter 2015, the uppermost sampling ports (i.e., Screen 1) in multi-port monitoring wells MW-18, MW-20 and MW-21 were dry and could not be sampled. These well screens were dry due to declining water levels associated with the drought in California.

Perchlorate Analytical Results

Perchlorate was detected above the state MCL (6.0 µg/L) during the second quarter 2015 at MW-18 (Screens 3 [20.0 µg/L] and 4 [13.0 µg/L]) and MW-25 (Screens 1 through 4 [9.3 µg/L, 14.0 µg/L, 11.0 µg/L and 9.3 µg/L, respectively]). Perchlorate was either non-detect or detected at a concentration below the state MCL in all other off-facility JPL wells. Perchlorate was detected above the state MCL (6.0 µg/L) from production wells near the JPL off-facility wells during the second quarter 2015 sampling at LAWC#3 (17.0 µg/L), LAWC#5 (10.0 µg/L), and Arroyo Well (15.5 µg/L).

VOC Analytical Results

Carbon tetrachloride was detected above the state MCL (0.5 µg/L) in MW-18 (Screens 3 [4.4 µg/L] and 4 [1.9 µg/L]). No other carbon tetrachloride detections occurred in the off-facility wells during the second quarter 2015. Carbon tetrachloride was detected above the state MCL (0.5 µg/L) from production wells near the JPL off-facility wells during the second quarter 2015 sampling at LAWC#3 (1.8 µg/L), LAWC#5 (1.3 µg/L), and Arroyo Well (0.9 µg/L). TCE and PCE were either non-detect or detected below the state and federal MCL (5.0 µg/L) at all JPL off-facility wells. Additionally, TCE was detected above the state and federal MCL from a production well near the JPL off-facility wells during the second quarter 2015 sampling at Well 52 (6.1 µg/L), and PCE was either not analyzed, non-detect or below the state and federal MCL (5.0 µg/L) for all of the production wells.

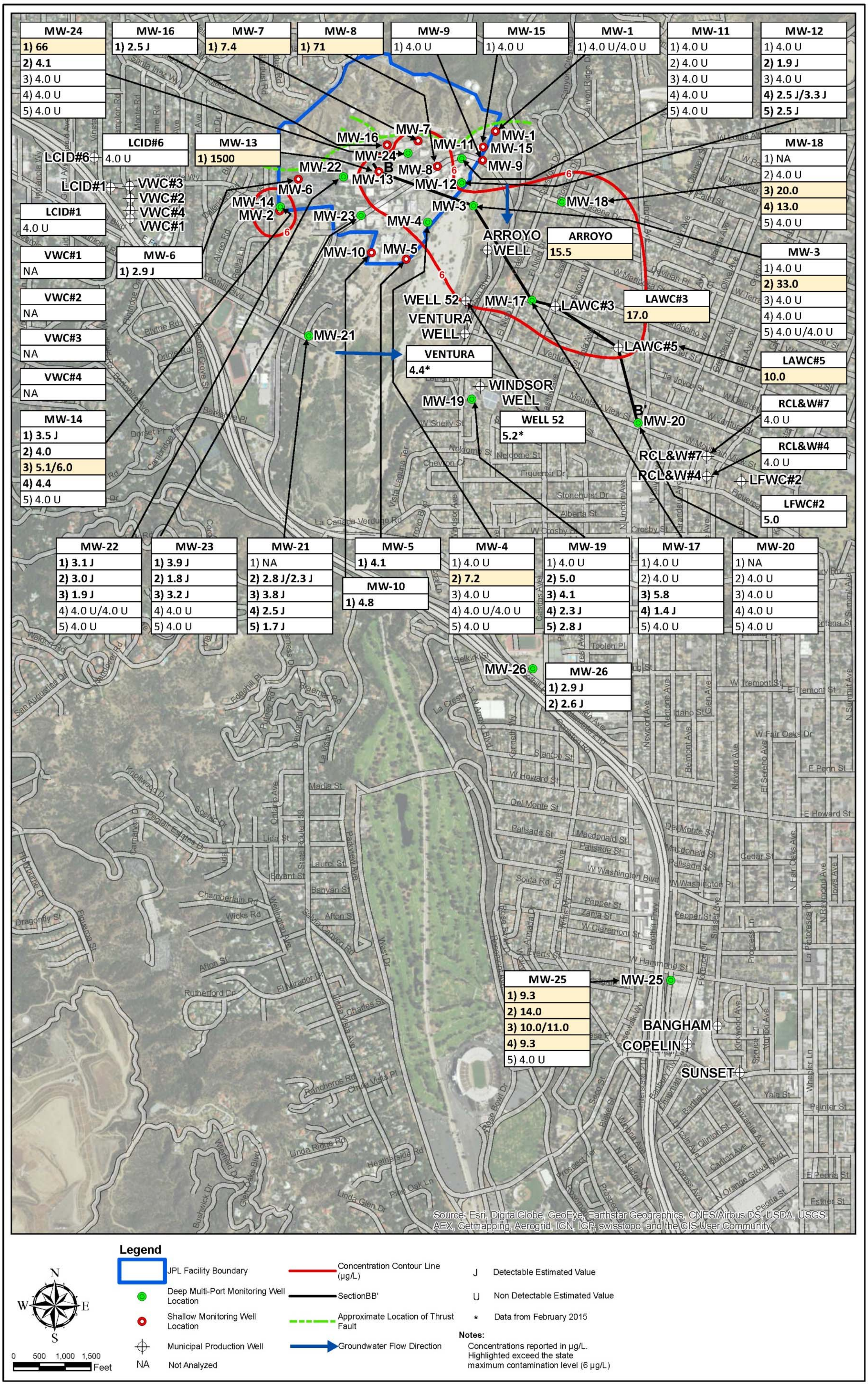


Figure 5-3. Horizontal Extent of Perchlorate in Groundwater, April/May 2015

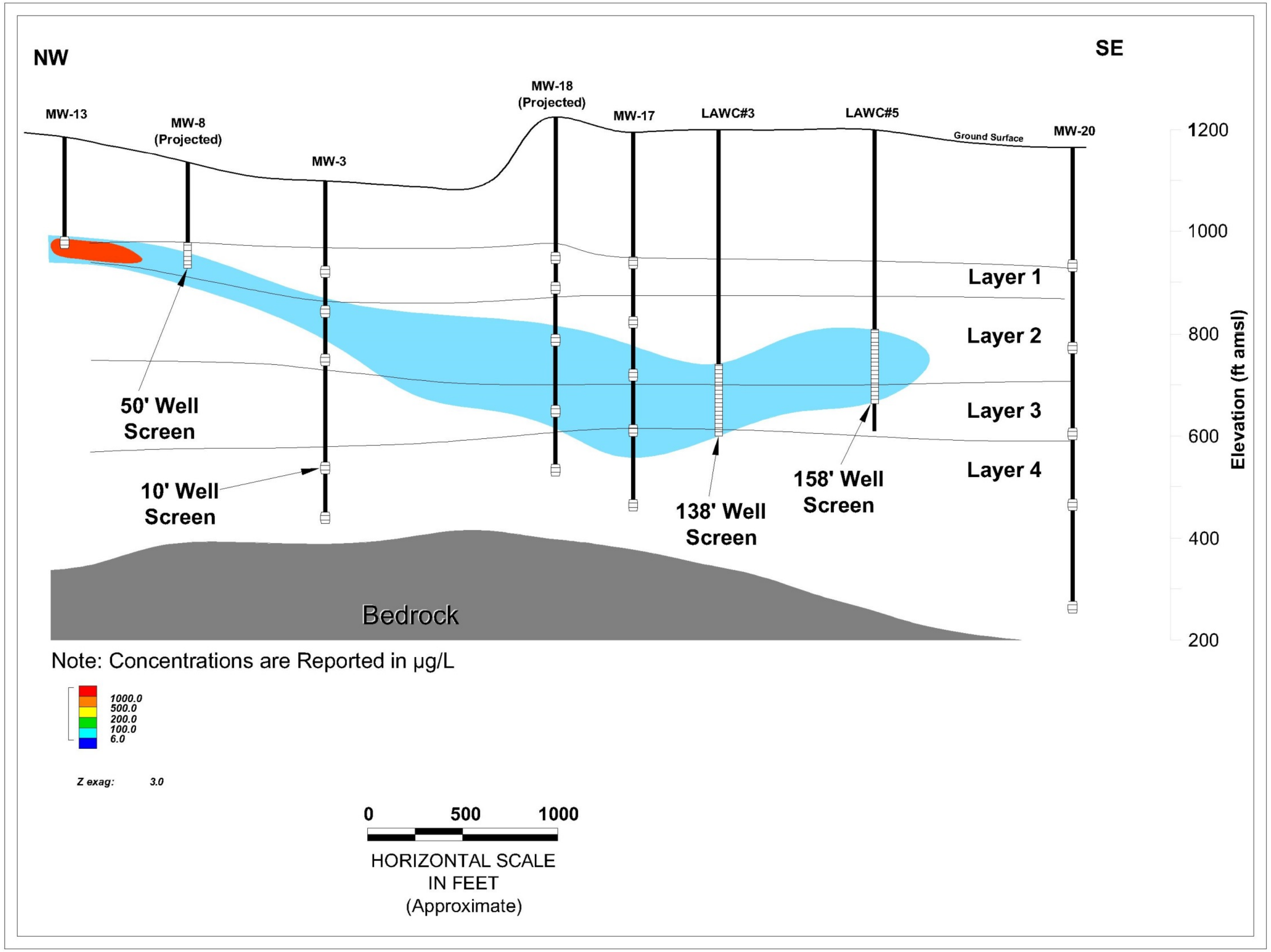


Figure 5-4. Vertical Extent of Perchlorate in Groundwater, April/May 2015

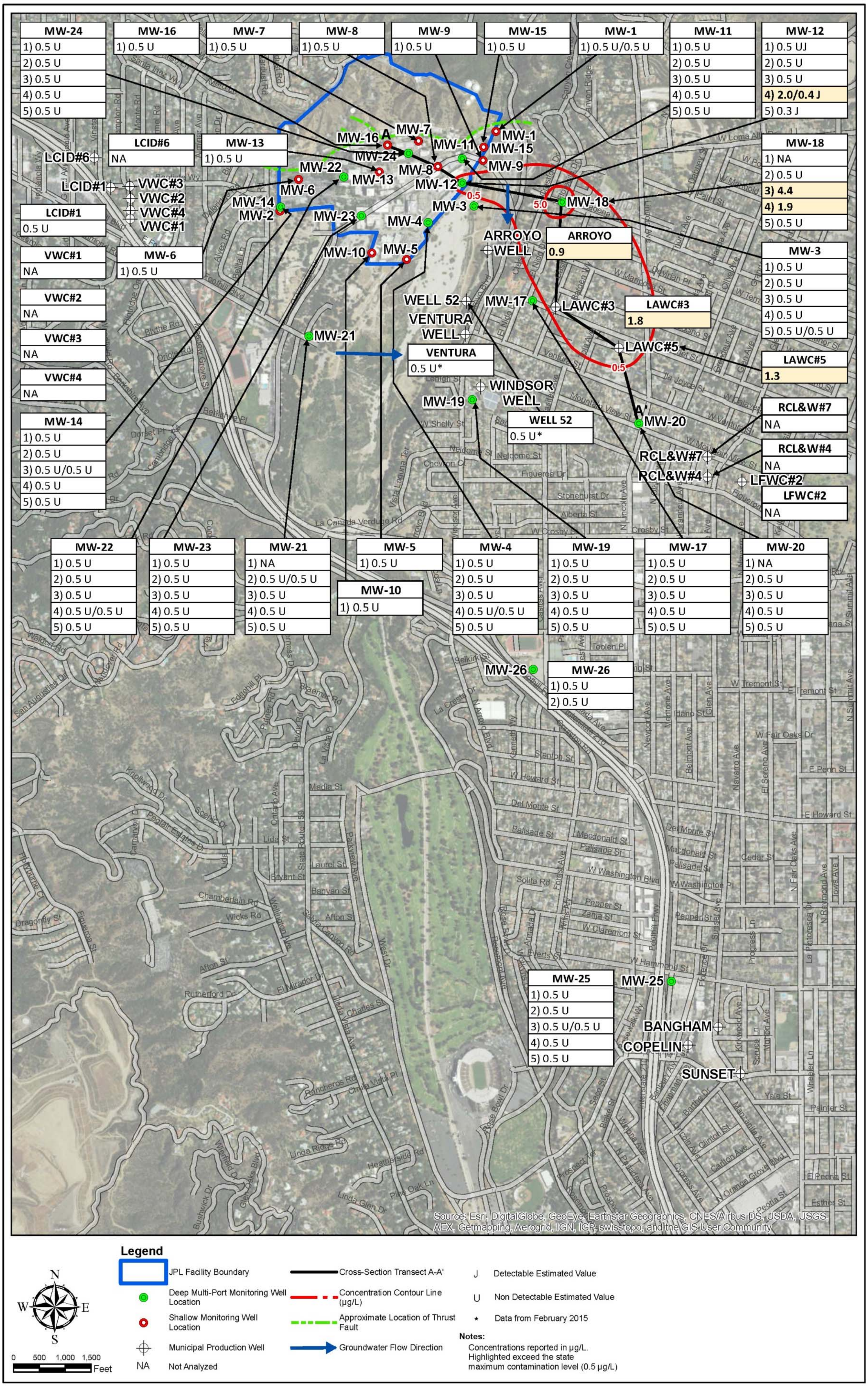


Figure 5-5. Horizontal Extent of Carbon Tetrachloride in Groundwater, April/May 2015

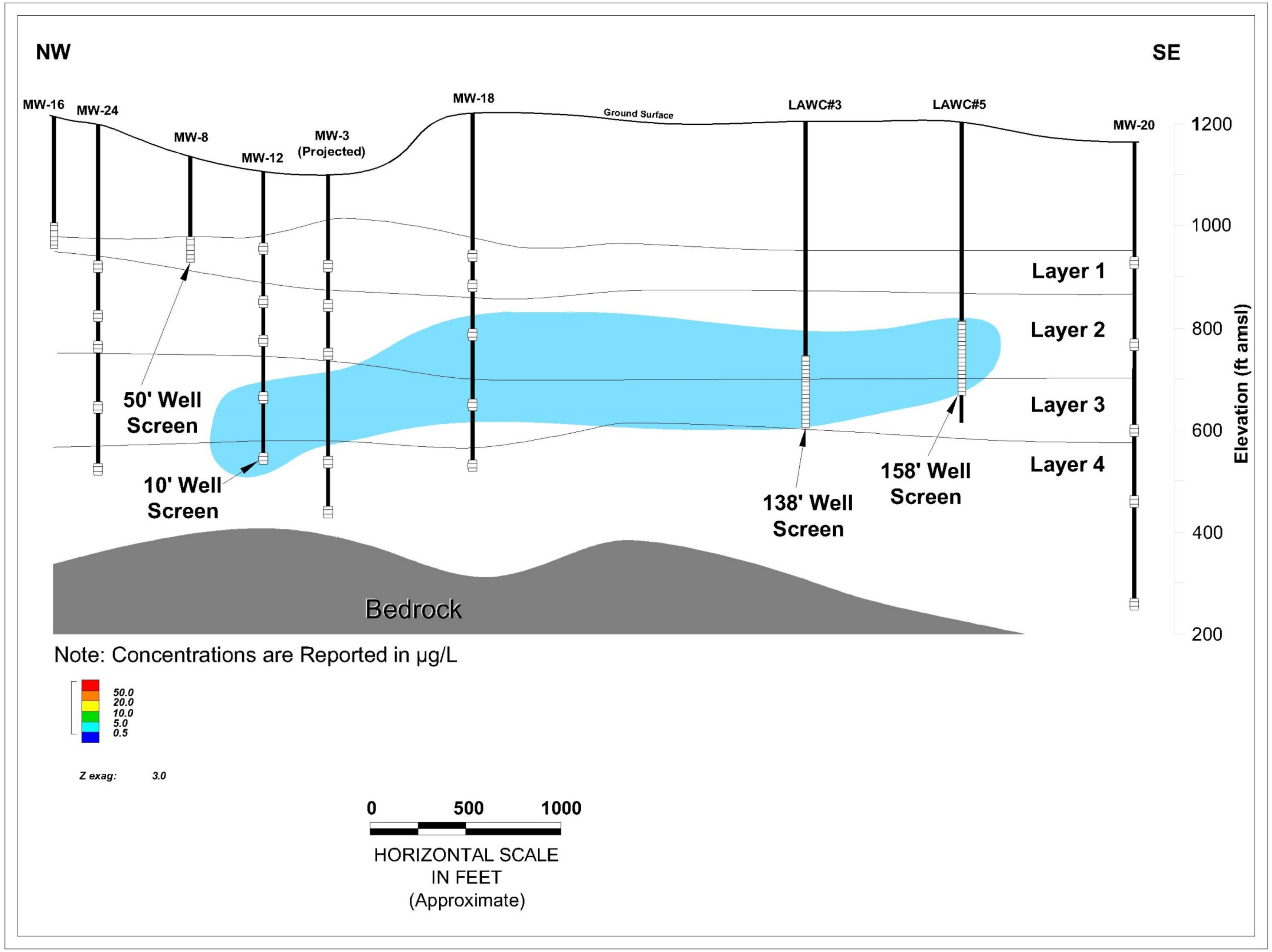


Figure 5-6. Vertical Extent of Carbon Tetrachloride in Groundwater, April/May 2015

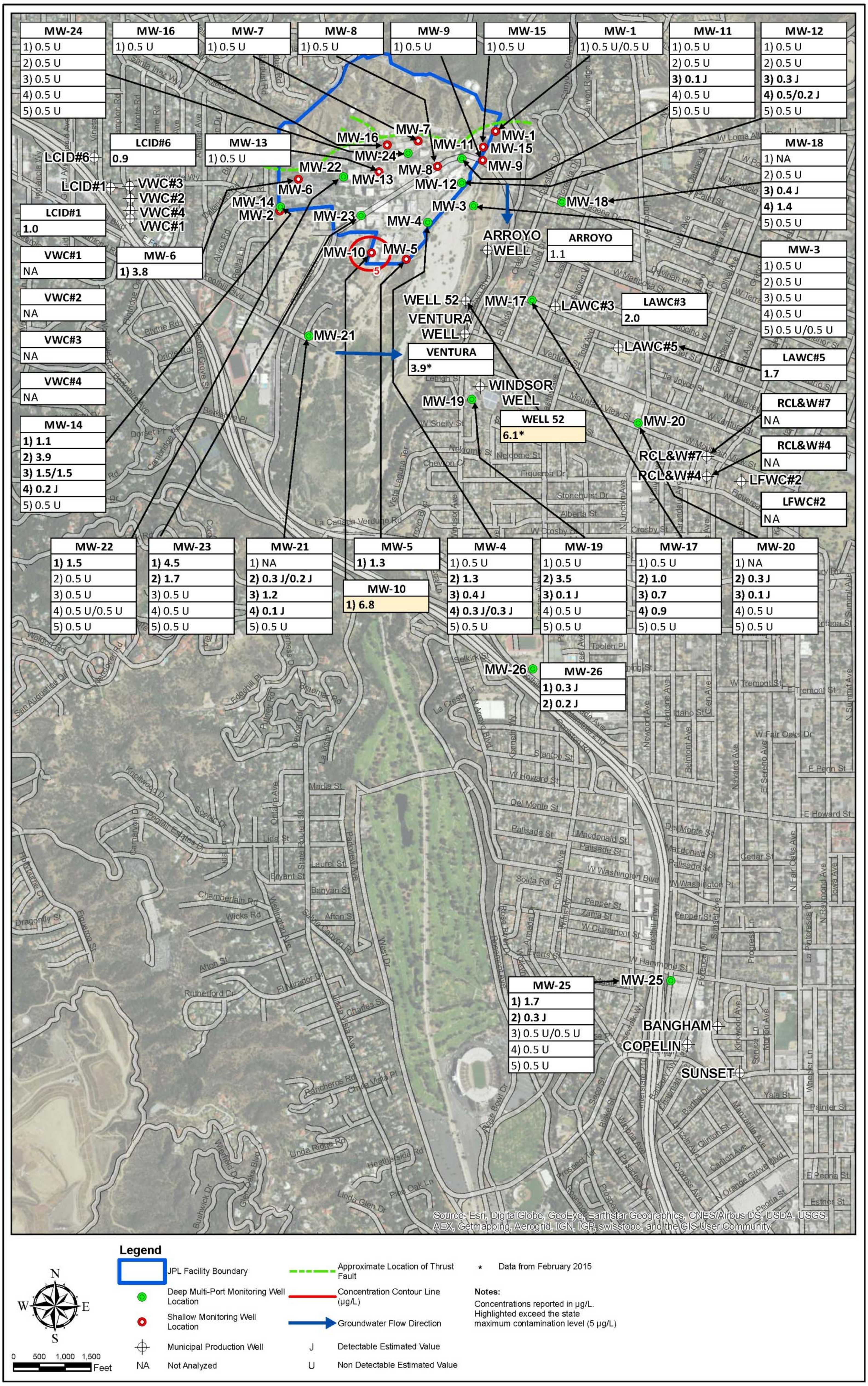


Figure 5-7. Extent of Trichloroethene in Groundwater, April/May 2015

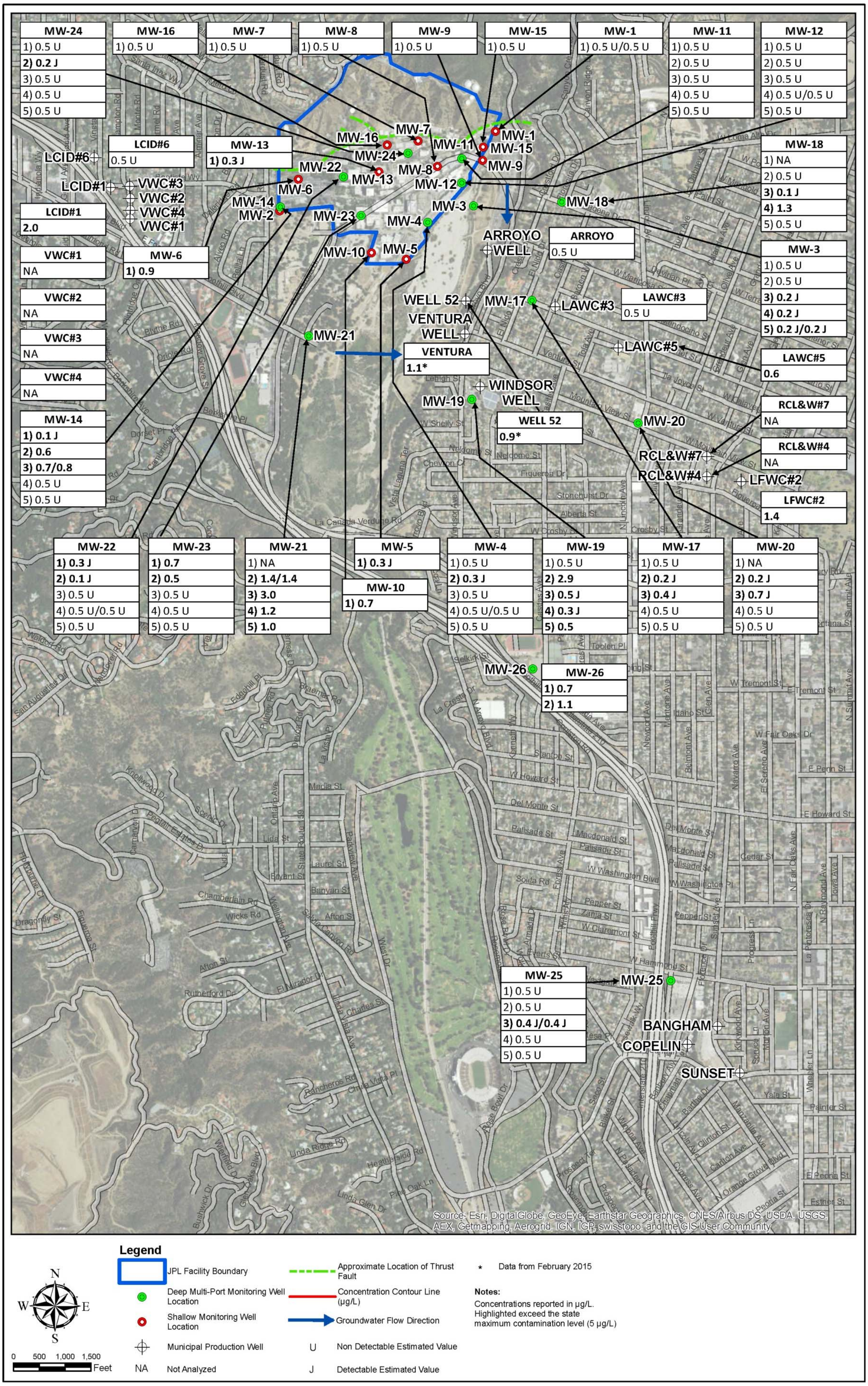


Figure 5-8. Extent of Tetrachloroethene in Groundwater, April/May 2015

5.4 Conceptual Site Model

Figure 5-9 is a conceptual site model for the transport of VOCs and perchlorate from the JPL historic seepage pits to groundwater. A summary of the potential migration pathways and fate and transport processes for chemicals associated with JPL is shown in Figure 5-10. The fate and transport characteristics and the potential for downgradient migration of chemicals, particularly carbon tetrachloride, TCE, and perchlorate, were described in detail in the RI Report (FWEC, 1999a). Infiltration and percolation of rainfall, which causes vertical downward flow of VOCs from the vadose zone to groundwater, appears to be the principal transport mechanism by which chemicals are introduced to groundwater at JPL. Soil vapor diffusion and advection also play a role as VOC transport mechanisms within the vadose zone. Thereafter, chemicals are mixed and transported in groundwater via a variety of physical and chemical processes.

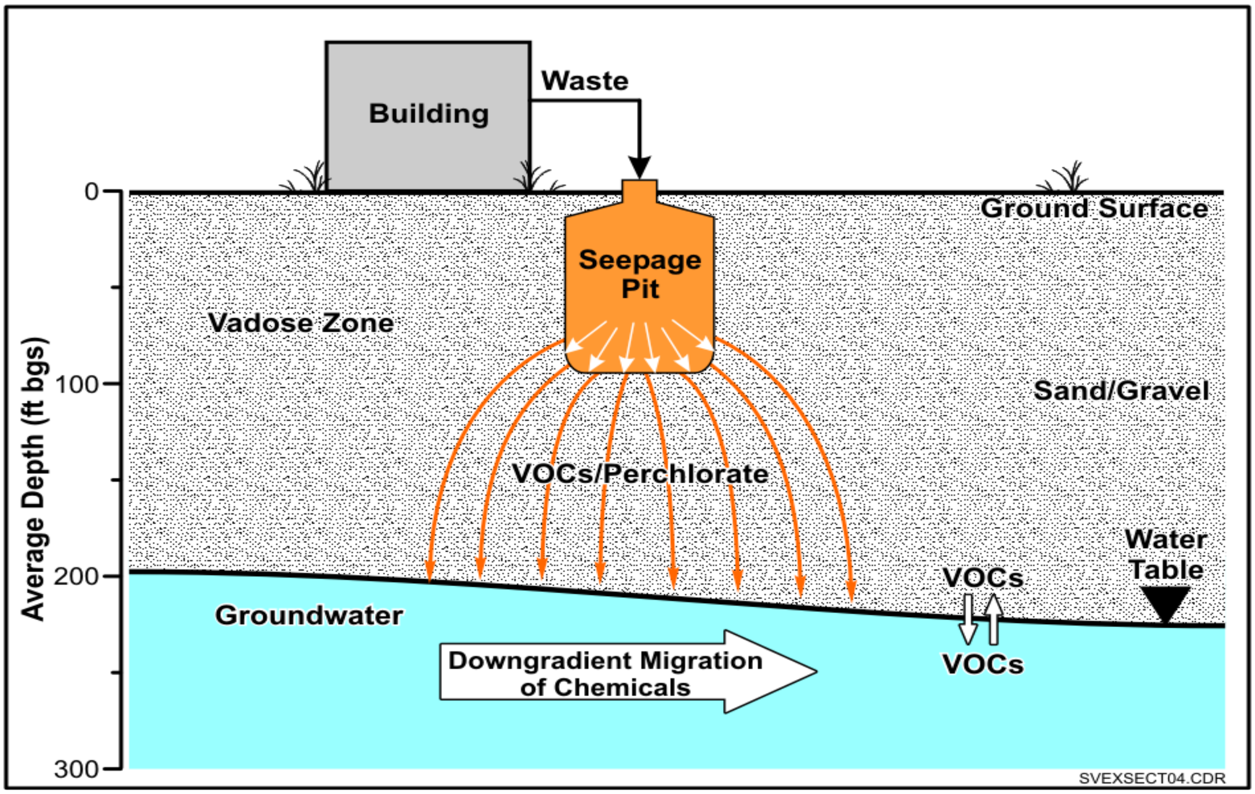


Figure 5-9. Conceptual Site Model for Transport of Chemicals

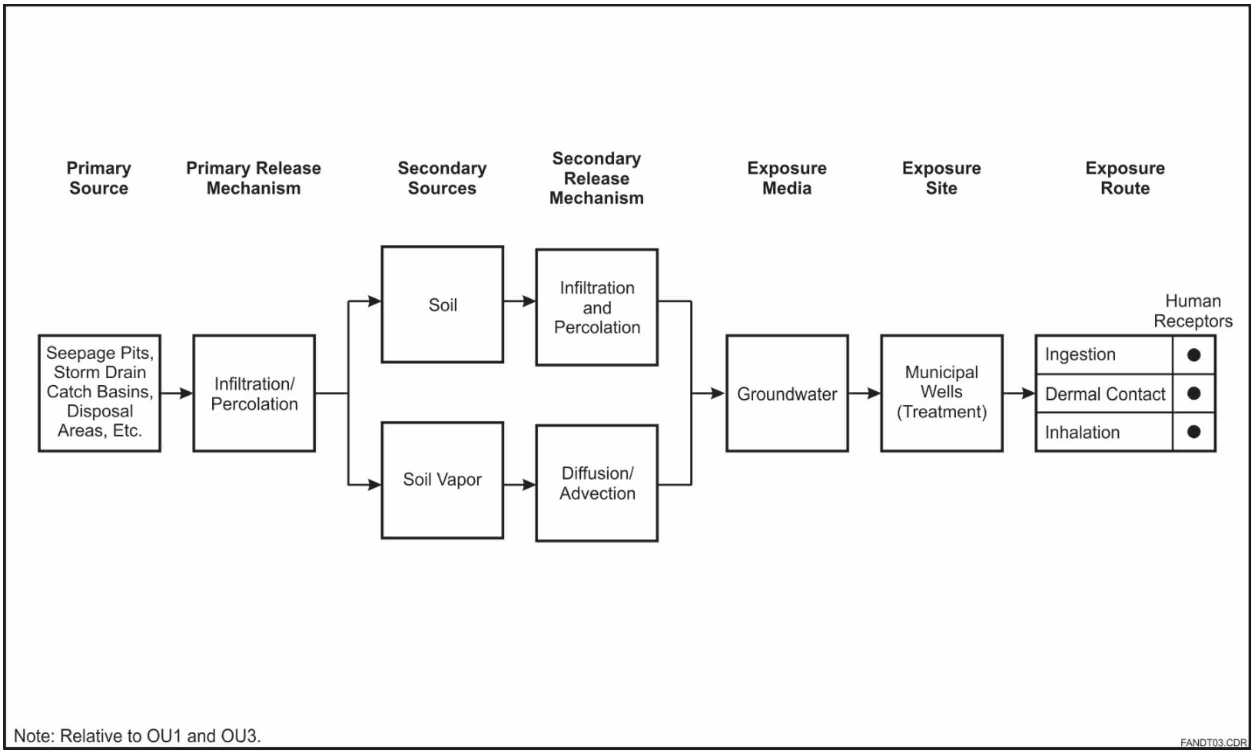


Figure 5-10. Chemical Fate and Transport Conceptual Diagram

5.4.1 Fate and Transport Modeling

With the RI data and subsequent groundwater monitoring data collected since 1995, the fate and transport of the groundwater constituents at JPL are generally well known. Even so, fate and transport modeling during the RI considered the possibility of carbon tetrachloride, TCE, and perchlorate migrating further downgradient from the JPL facility, beyond their known limits of extent, with natural groundwater gradients present only during periods when the Pasadena and other nearby municipal wells are not operating and inhibiting further downgradient migration. The point source location for constituent migration modeling was chosen as MW-17, aquifer layer 2, because carbon tetrachloride, TCE, and perchlorate were consistently detected above MCLs at this location. The constituent path from MW-17 to MW-20 was selected for the model simulations because MW-20 is downgradient from MW-17 under natural flow conditions and there are no known physical barriers between these two points. Therefore, this path was assumed to provide an appropriate estimate of off-facility migration.

The modeling runs were carried out using SOLUTE™ (Version 4.04) software for each of the three constituents listed above (FWEC, 1999a). In these runs, source concentrations and several input parameters were based on actual facility information or on literature values that were considered to be representative of facility conditions. Table 5-4 summarizes the hydrogeologic and contaminant point source input parameters used in the model. The groundwater velocity used (0.15 ft/day) is based on the estimated porosity used (20%), and observed groundwater gradient in aquifer layer 2 when the City of Pasadena and other production wells were not operating, and the average hydraulic conductivity values estimated from aquifer tests conducted on layer 2 well screens. Even though constituent retardation will occur to some extent, an unrealistically conservative retardation factor of 1.0, which represents a case where there is no retardation, was used. Longitudinal dispersivity was estimated at 500 feet, based on published values for areas with similar lithologies. All input parameters were the same for all simulations with the exception of the initial constituent concentrations, which reflected actual detected values (FWEC, 1999a).

Table 5-4. Input Parameters for Fate and Transport Modeling (FWEC, 1999a)

Parameter	Site-Specific Data Available?	Known/Measured/Assumed Value[a]
<u>Hydrogeologic Information</u>		
Groundwater velocity (ft/d)	Yes	0.15
Porosity (%)	No	20
Hydraulic gradient (ft/ft)	Yes	0.005
Longitudinal dispersivity (ft)	No	500
Retardation factor	No	1.0
Hydraulic Conductivity (ft/d)	Yes	6.0
<u>Contaminant Point Source Information</u>		
Number of contaminant sources	Yes	1 (MW-17)
Initial aquifer concentration (µg/L)	Yes	0
Contaminant source concentration[b]	Yes	Carbon tetrachloride: 6.6 µg/L TCE: 23 µg/L Perchlorate: 55 µg/L
Duration of solute pulse (yrs)	No	20
Aquifer half-life (yrs)	No	0

a: Where site specific data were not available, assumptions were made based on conservative literature values.
b: Highest concentration of analyte detected in MW-17 during OU1 and OU3 RI (FWEC, 1999a).

Results of the simulations are presented in detail in the RI (FWEC, 1999a). The simulations predicted that with an initial carbon tetrachloride concentration of 6.6 µg/L (maximum detected in MW-17 during the RI), under the defined conditions (no pumping), and with general input parameters based on conservative assumptions, the MCL of 0.5 µg/L would be exceeded in 20 years at MW-20. Similarly, modeling simulations using conservative input assumptions predicted that an initial TCE concentration of 23 µg/L at MW-17 (maximum detected in MW-17 during the RI), would result in a concentration equal to the MCL (5.0 µg/L) at MW-20 after 31 years. With regard to perchlorate, the model indicated that an initial concentration of 55 µg/L at MW-17 (maximum detected in MW-17 during the RI) would result in a concentration at MW-20 equal to the notification level of 18 µg/L (the California DDW notification level at the time the RI fate and transport modeling work was performed) after 40 years.

The results of the fate and transport modeling used actual observed maximum concentrations for carbon tetrachloride, TCE, and perchlorate during the RI. The results indicated that even under conservative assumptions, it would take long periods of time for these constituents to migrate downgradient of non-pumping Pasadena and other nearby municipal production wells at concentrations above state or federal MCLs. Chemical fate and transport modeling was performed as part of NASA's additional investigation (NASA, 2003b; 2007d; 2008) and NASA concluded that chemicals originating from JPL are contained by the Pasadena and LAWC municipal production wells. The modeling exercise conducted as part of NASA's additional investigation was performed using the finite element three-dimensional flow and transport model FEFLOW. The JPL groundwater model encompasses a 4,560-acre area that includes the Monk Hill portion of the Raymond Basin. Vertically, the JPL model was created with four layers corresponding to the four hydrostratigraphic units (zones) as identified in Section 5.1.2. The model calibration was based on average groundwater flow conditions for the JPL area (NASA, 2008). EPA, DSTC, and RWQCB concurred with NASA's approach and findings associated with the additional investigation.

Since that time, California has established a state MCL for perchlorate of 6 µg/L and the perchlorate concentrations in MW-20 have occasionally exceeded the state MCL. However, during the second quarter 2015 facility-wide groundwater sampling efforts, perchlorate was not detected in MW-20 (NASA, 2015).

5.4.2 Exposure Pathways

The groundwater at the JPL facility (i.e., OU1 area) is not extracted for distribution within the facility and workers at the facility do not have access to untreated water from the site. Thus, there is no exposure pathway to groundwater. Hypothetically, the exposure mechanisms to groundwater would have to involve accessing untreated well water with subsequent ingestion (drinking), dermal (skin) contact, and inhalation of vapors from domestic water sources. For the human health risk assessment (HHRA), potential exposures to chemicals in on-facility groundwater at JPL were quantitatively evaluated for the hypothetical on-facility resident (age-adjusted adult exposed 350 days per year for 70 years) and child resident (6 years). The HHRA was done using health protective assumptions (e.g., overestimating exposure potential and assuming it could be a residential exposure) to determine the need for remediation. NASA has no intent to use JPL for residential purposes. However, to provide the most conservative and protective results, direct exposures through ingestion, dermal contact, and inhalation of vapors from water sources were evaluated as exposure pathways to a hypothetical residential receptor.

There is no reasonable way for residents living in the areas overlying OU3 to come in contact with chemicals in untreated groundwater. The chemicals are located in groundwater more than 200 feet below ground surface and does not recharge surface water bodies. Thus, there is no exposure via surface water. Groundwater pumped from nearby water production wells must meet strict state and federal water quality standards prior to distribution to consumers. Production wells that have shown perchlorate and VOCs in the pumped groundwater have treatment in place (i.e., LAWC and the City of Pasadena Monk Hill subarea wells). No direct exposure pathways to OU3 groundwater were identified in the OU1/OU3 RI report for the human or ecological receptors (FWEC, 1999a). The only possible exposure pathway would be if a water treatment system malfunctioned. The redundancies that are built into the treatment systems and continuous monitoring make this exposure pathway highly unlikely.

For the ecological risk assessment (ERA), an assessment of ecological risks was completed at the JPL facility. The assessment concluded that no groundwater exposure pathways to plants and animals are possible at OU1 or OU3. Therefore, it was concluded that no further characterization of ecological risks to plants and animals due to groundwater impact was warranted. More information on the results of the HHRA and ERA is included in the RI report (FWEC, 1999a).

6.0 Current and Potential Future Land and Resource Uses (OU1 and OU3)

JPL is a federally-owned research and development center operated by Caltech and administered by NASA. It is the federal government's lead center for research and development related to robotic exploration of the solar system. In addition to NASA work, tasks for other federal agencies are conducted at JPL in areas such as remote sensing.

6.1 Land Uses

JPL comprises approximately 170 acres of land. Of these 170 acres, about 156 acres are federally owned. The remaining land is leased for parking from the City of Pasadena and the Flintridge Riding Club. Presently, more than 150 structures and buildings occupy JPL. Total usable building space is approximately 1,330,000 ft^2. The main developed area of JPL is the southern half, which can be divided into two general areas − the northeastern early-developed area and the southwestern later-developed area. Most of the northern half of JPL is not developed because of steeply sloping terrain (see Figure 1-1).

The northeastern early-developed part of JPL is currently used for project support, testing, and storage. The southwestern later-developed portion is used mostly for administrative, management, laboratory, and project functions. Further development of JPL is constrained because of steeply sloping terrain to the north, the Arroyo Seco to the south and east, and residential development to the west.

Located at the northern boundary of JPL is the Gould Mesa area. This area has widely separated small buildings and is used primarily for antenna testing. The distance between buildings is a result of the terrain and the need to isolate transmitting and receiving equipment. The relatively steep mountainside between Gould Mesa and the developed area at JPL is unpopulated.

The primary land use in the areas surrounding JPL is residential and light commercial. Industrial areas, such as manufacturing, processing, and packaging, are limited. The closest residential properties are those located along the western fence line of JPL. The nearest off-facility buildings are the Flintridge Riding Club and Fire Camp #2, both located approximately 100 yards from the southern border of JPL. The total number of buildings within 2 miles of JPL is about 2,500, primarily residential and community (e.g., schools, daycare centers, churches).

Land use at JPL and in the areas surrounding JPL is not expected to change significantly in the foreseeable future.

6.2 Surface and Groundwater Uses

There are no permanent surface water bodies within the boundaries of JPL. Seasonal rains may result in intermittent flows through the Arroyo Seco wash, which is located to the east of JPL. The entire JPL facility drains into the Arroyo Seco via storm drains and surface runoff. In addition, stormwater runoff from parts of La Cañada Flintridge combines with that of JPL prior to discharge to the Arroyo Seco. Within the Arroyo Seco, a series of surface impoundments are used as surface water collection and spreading basins for groundwater recharge.

The groundwater at the JPL facility is not currently extracted for distribution within the facility. Groundwater beneath the Arroyo Seco and within the capture zones of the production wells is a current source of drinking water. The Raymond Basin Watershed, Monk Hill subarea, where JPL is located, provides an important source of potable water for many communities in the area (Pasadena, La Cañada-Flintridge, and Altadena) (FWEC, 2000). These communities are expected to grow at a modest rate for the foreseeable future and the demand for groundwater as drinking water is expected to continue.

7.0 Summary of Site Risks

7.1 Summary of Human Health Risk Assessment at OU1

The HHRA was completed based on the results of the RI to evaluate the potential risks to human health associated with hypothetical exposure to chemicals in untreated groundwater beneath the JPL facility. It is important to note that because groundwater is in a deep aquifer and does not recharge surface water bodies within the area of concern, and because water purveyors treat impacted groundwater before use, there is no complete or direct pathway for exposure to JPL groundwater. Nevertheless, at the request of U.S. EPA and DTSC risk assessors, a health protective hypothetical residential use scenario was evaluated during the RI (FWEC, 1999a) using U.S. EPA risk assessment guidance. It is assumed in the risk assessment that humans use untreated groundwater beneath JPL for potable purposes. Vapor intrusion to indoor air was not evaluated in the 1999 HHRA. However, remediation of VOCs in soil was completed in 2007 (NASA, 2007a). In addition, a screening level evaluation of the vapor intrusion pathway was performed and showed that the potential for adverse effects associated with the vapor intrusion pathway is low (see Appendix D). Detailed results and methodologies used are presented in the RI (FWEC, 1999a). To ensure that human health is adequately protected, health protective (i.e., overestimating) exposure point concentrations and toxicity assumptions were used in estimating potential cancer risks and noncancer hazards.

For carcinogenic compounds, the exposure risk is expressed as the incremental probability of an individual developing cancer over a lifetime as a result of exposure to the carcinogen. These risks are expressed in scientific notation (e.g., an excess lifetime cancer risk of 1.0×10^{-6} indicates that an individual experiencing the conservative maximum exposure estimate has a 1 in 1,000,000 chance of developing cancer as a result of site-related exposure). According to the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), 1.0×10^{-6} is defined as the point of departure (i.e., the target level of risk for determining remediation) and the NCP-defined generally acceptable range is 1.0×10^{-6} to 1.0×10^{-4} (U.S. EPA, 1989a).

For noncarcinogenic compounds, risks are evaluated by comparing an exposure level over a specified time period (e.g., lifetime) with a reference dose or level that is not expected to cause any harmful effects. The ratio of the chronic daily intake to the reference dose is called a hazard quotient (HQ). The sum of all of the HQs for each chemical compound with the same endpoint is referred to as the hazard index (HI). An HI less than 1.0 indicates that toxic, noncarcinogenic effects from all chemical constituents and exposure routes are unlikely (U.S. EPA, 1989a).

The two hypothetical receptors chosen to model risk from hypothetical exposure to untreated groundwater at the JPL site were the residential adult and child. Residential land use is associated with the greatest exposure duration, and therefore the most conservative choice for calculating potential risk associated with exposure to untreated groundwater at the JPL site. Noncancer hazards and cancer risks were calculated based on a 6-year exposure for the child and a 30-year age-adjusted exposure averaged over 70 years for the adult. Exposure to untreated chemicals of concern in groundwater was evaluated for ingestion, inhalation, and dermal contact at each JPL monitoring well. It was assumed that the receptors were exposed to the maximum detected or 95 percent upper confidence level (UCL) concentration of chemicals of concern (whichever was higher) in each well for 350 days per year. The exposure scenario is a hypothetical situation that does not reflect realistic current or future land-use scenarios because there are no direct exposure pathways for humans to interact with untreated groundwater in the study area.

The evaluation of noncancer hazards for the child receptor show that with the exception of four on-facility monitoring wells (MW-7, -13, -16 and -24), all other monitoring wells produced HI values less than 10. Analysis of the HI values based on target organ effects indicates that nine monitoring wells (MW-3, -4, -7, -8, -10, -12, -13, -16, and -24) produced HI values that exceeded the criterion value of 1.0 (see Table 7-1). In these wells, carbon tetrachloride and perchlorate were consistently the predominant chemicals contributing to the excess noncancer hazard.

Evaluation of cancer risks for JPL OU1 monitoring wells shows that greater than half of the wells had cancer risk values that fall within U.S. EPA's range for acceptable levels of risk of 10^{-6} to 10^{-4} (see Table 7-1). Four wells did not have cancer risks associated with them because no carcinogenic compounds were detected during RI sampling efforts. Six wells had cancer risk values greater than 10^{-4}, of which two wells (MW-7 and MW-16) had cancer risks greater than 10^{-3}. Monitoring well MW-3 slightly exceeded the U.S. EPA acceptable risk range ($>10^{-4}$) and the constituent contributing to the majority of the risk was arsenic. Arsenic is a naturally-occurring metal and the arsenic detections reflect natural concentrations of the analyte. This is supported by the fact that concentrations of arsenic in excess of the drinking water MCL of 0.010 mg/L have been detected only in the deepest screened intervals of MW-3, MW-11, and MW-17. In addition, arsenic concentrations are below the MCL in all OU1 and OU3 extraction wells. Three other JPL OU1 monitoring wells had total cancer risks greater than 10^{-4} (MW-12, MW-13 and MW-24). A variety of chemicals contributed to the total cancer risk value of these wells.

Predominant chemical contributors in these wells were as follows: MW-12 (carbon tetrachloride); MW-13 (carbon tetrachloride and hexavalent chromium); and MW-24 (carbon tetrachloride). The two OU1 wells with the highest total cancer risk were MW-7 (risk = 2.2×10^{-3}) and MW-16 (risk = 1.4×10^{-3}). In these wells, carbon tetrachloride accounted for 91 percent and 86 percent, respectively, of the total risk value. These two wells also have the highest noncancer hazard values (HI values of 190 and 220, respectively).

Table 7-1. Summary of Noncancer Hazard Index and Cancer Risk for OU1 Monitoring Wells

Monitoring Well	Hazard Index	Major Chemical Contributor	Risk	Major Chemical Contributor
MW-3	2.1	arsenic, perchlorate	1.1E-04	arsenic, bromodichloromethane, carbon tetrachloride, chloroform
MW-4	8.5	carbon tetrachloride, perchlorate	7.7E-05	1,1-DCE, 1,2-DCA, carbon tetrachloride, chloroform, TCE
MW-6	<1.0	none	4.0E-06	PCE
MW-7	190	carbon tetrachloride, perchlorate	2.2E-03	1,1-DCE, 1,2-DCA, carbon tetrachloride, chloroform, Cr^{6+}, PCE, TCE
MW-8	6.3	carbon tetrachloride, perchlorate	5.5E-05	carbon tetrachloride, chloroform, TCE
MW-10	3.2	perchlorate, nitrate	1.3E-05	chloroform, PCE, TCE
MW-11	<1	none	1.1E-05	carbon tetrachloride, chloroform
MW-12	8.9	carbon tetrachloride, perchlorate	1.6E-04	carbon tetrachloride, chloroform
MW-13	47	carbon tetrachloride, perchlorate	5.5E-04	1,1-DCE, 1,2-DCA, carbon tetrachloride, chloroform, Cr^{6+},TCE
MW-14	<1	none	3.1E-06	chloroform, PCE
MW-16	220	carbon tetrachloride, perchlorate	1.4E-03	1,1-DCE, 1,2-DCA, carbon tetrachloride, chloroform, Cr^{6+}, PCE, TCE
MW-22	<1	none	3.2E-06	PCE
MW-23	<1	none	5.3E-06	chloroform, PCE, TCE
MW-24	65	carbon tetrachloride, perchlorate	5.2E-04	1,2-DCA, arsenic, carbon tetrachloride, chloroform, TCE

NASA recognizes that there have been updates to risk assessment methodology since completing the HHRA in 1999 (e.g., 2011 updates to the toxicological criteria for TCE and mutagenic mode of action). Therefore, a screening level assessment was conducted to evaluate the impacts on the risk assessment methodology updates and the remediation efforts that have occurred since 1999. The updated screening-level risk evaluation is provided in Appendix D. The screening level risk evaluation revealed the following:

- Groundwater concentrations for the COPCs and COCs have generally decreased since 1999.
- Hexavalent chromium is currently one of the primary COPCs contributing to excess cancer risk, whereas it was not in the 1999 HHRA. In addition, on July 1, 2014, the State Water Resources Control Board established a new MCL for hexavalent chromium of 10 µg/L. The highest levels of hexavalent chromium have been detected in the shallow source area wells (MW-7, MW-13, and MW-16) and concentrations in the MHTS and LAWC system have historically been non-detect. Over the past two years, concentrations of hexavalent chromium have been below the new MCL in all JPL monitoring wells.
- Total estimated cancer risks and hazards remain similar within each well, but the primary COPCs contributing to that excess risk and hazard are different as a result of differences in groundwater concentrations and toxicity criteria since the 1999 HHRA.

Theoretical risks to human health predicted by this assessment are likely to be an overestimation of actual risk due to the hypothetical land use assumed, as well as the fact that active treatment has now occurred for a number of years resulting in lower chemical concentrations currently remaining on site. A health assessment conducted by the ATSDR determined that on- and off-facility groundwater at JPL does not pose a present or future public health hazard because wellhead treatment and water blending are used by local water purveyors to meet stringent drinking water standards prior to distribution of the water for public use (ATSDR, 1999). Unlike state and federal guidance that requires exposures to untreated groundwater be evaluated in the HHRA, the ATSDR health assessment evaluated whether residents are actually being exposed currently, or may possibly be exposed in the future, to chemicals present in groundwater at JPL.

7.2 Summary of Human Health Risk Assessment at OU3

The HHRA evaluated the potential risks to human health associated with hypothetical exposure to chemicals in untreated groundwater beneath the JPL facility. It is important to note that because groundwater is in a deep aquifer and does not recharge surface water bodies within the area of concern, and because water purveyors treat impacted groundwater before use, there is no direct exposure to groundwater. Nevertheless, a hypothetical residential use scenario was evaluated during the OU1/OU3 RI (FWEC, 1999a) using U.S. EPA risk assessment guidance. It was assumed in the risk assessment that humans use untreated groundwater beneath JPL for potable purposes. Vapor intrusion to indoor air was not evaluated in the 1999 HHRA. However, remediation of VOCs in soil was completed in 2007 (NASA, 2007a). In addition, a screening level evaluation of the vapor intrusion pathway was performed and showed that the potential for adverse effects associated with the vapor intrusion pathway is low (see Appendix D). Detailed results and methodologies used are presented in the OU1/OU3 RI (FWEC, 1999a). To ensure that human health is adequately protected, upper bound exposure point concentrations and toxicity assumptions were used in estimating potential cancer risks and noncancer health hazards.

Twelve chemicals were identified as chemicals of potential concern (COPCs) and evaluated in the risk assessment. The COPCs included: arsenic, Cr^{6+}, lead, nitrate, perchlorate, 1,1-dichloroethene, 1,2-dichloroethane, bromodichloromethane, carbon tetrachloride, chloroform, PCE, and TCE.

Risks are estimated as probabilities for COPCs that are considered carcinogens. The excess lifetime cancer risk is the incremental increase in the probability of developing cancer associated with exposures to contaminated media at the site over a lifetime. For example, a risk of 1×10^{-6} represents that there is one additional person in a million that will develop cancer as a result of exposure to the carcinogen over and above the background rate of developing cancer. The upper bound excess lifetime cancer risks derived in the risk assessment are compared to the risk range of 10^{-4} (one in ten thousand) to 10^{-6} (one in a million) (U.S. EPA, 1990).

Residential receptors were chosen to model exposure from hypothetical contact with chemicals in untreated groundwater at the JPL site. The residential receptors evaluated in the risk assessment included a hypothetical exposure scenario evaluating an age-adjusted adult receptor (24 years as an adult and 6 years as a child, for a total of 30 years) for exposure to carcinogens and a child receptor (age 0-6 years) for noncarcinogens. Exposure to untreated chemicals of concern in groundwater was evaluated for ingestion, inhalation, and dermal contact at each JPL monitoring well. It was assumed that the receptors were exposed to the maximum detected or 95 percent UCL concentration of chemicals of concern (whichever was higher) in each well for 350 days per year. The exposure scenario is a hypothetical situation that does not reflect realistic current or future land-use scenarios because there are no direct exposure pathways for humans to interact with untreated groundwater in the study area.

Results for the hypothetical child receptor indicated that in the absence of cleanup, noncancer hazards were above 1 in four of the five OU3 monitoring wells (see Table 7-2). However, in two of the wells with HIs above 1 (i.e., MW-18 and MW-20), chemical-specific HQs were all less than 1. Major chemical contributors in MW-17 and MW-21 were identified as perchlorate and TCE.

Results of the cancer risk evaluation for OU3 monitoring wells show that total estimated cancer risks (see Table 7-2) fall within U.S. EPA's range for acceptable levels of risk (1×10^{-6} to 1×10^{-4}). Of the seven COPCs identified as major contributors to cancer risk, the percent contribution to total risk was highest for arsenic, TCE, and PCE in wells where these COPCs were detected. Where arsenic was detected (MW-18 and MW-20), the total risk contribution ranged from 50% to 90% even though the arsenic exposure concentrations were less than the federal drinking water standard of 10 µg/L. Arsenic occurs naturally in groundwater and the detections reflect natural concentrations. As noted in the OU1/OU3 RI (FWEC, 1999a), for both noncancer hazard and cancer risk estimates, only carbon tetrachloride, perchlorate, and TCE were present in OU3 wells at levels exceeding state and federal drinking water standards. Bromodichloromethane, chloroform, and PCE concentrations were below drinking water standards in OU3 monitoring wells.

Lead exposure in groundwater was evaluated separately using DTSC models to estimate blood-lead levels in adults and children. All estimated blood-lead levels were below the DTSC benchmark level of 10 µg/dL.

The ATSDR conducted site visits in 1997 to assess the potential for public health hazards associated with the groundwater adjacent to the JPL facility. ATSDR identified the following primary community concerns: 1) future groundwater and drinking water quality and 2) increased incidence of Hodgkin's disease. Following a careful evaluation of available data, ATSDR determined that the VOCs in groundwater do not present a past, present, or future public health concern to JPL employees or nearby residents. On-facility groundwater has never been used as a source of drinking water and area water purveyors regularly monitor to ensure that water meets the federal and state water quality goals. Based on an analysis performed by the ATSDR, it was also determined unlikely that perchlorate in groundwater posed a past public health hazard (ATSDR, 1999). Unlike state and federal guidance that requires the evaluation in an HHRA of exposures to untreated groundwater, the ATSDR evaluated whether residents are actually being exposed currently, or may possibly be exposed in the future, to chemicals present in groundwater at JPL.

Table 7-2. Summary of Noncancer Hazard Index and Cancer Risk for OU3 Monitoring Wells

Monitoring Well	Hazard Index	Major[(1)] Chemical Contributor	Risk	Major[(2)] Chemical Contributor
MW-17	8	perchlorate, TCE	8×10^{-5}	bromodichloromethane, carbon tetrachloride, chloroform, Cr^{6+}, TCE
MW-18	3	none	1×10^{-4}	arsenic, carbon tetrachloride, chloroform, Cr^{6+}, PCE, TCE
MW-19	<1	none	1×10^{-5}	bromodichloromethane, carbon tetrachloride, chloroform, Cr^{6+}, PCE
MW-20	2	none	7×10^{-5}	arsenic, bromodichloromethane, chloroform
MW-21	2	perchlorate	2×10^{-5}	PCE, TCE

(1) Defined as those chemicals having an HQ > 1.
(2) Defined as those chemicals having an individual total risk level greater than 1×10^{-6}.

NASA recognizes that there have been updates to risk assessment methodology since completing the HHRA in 1999 (e.g., 2011 updates to the toxicological criteria for TCE). Therefore, a screening level assessment was conducted to evaluate the impacts on the risk assessment methodology updates and the remediation efforts that have occurred since 1999. The updated screening-level risk evaluation is provided in Appendix D.

7.3 Summary of Ecological Risk Assessment

An assessment of ecological risks was completed at JPL that qualitatively evaluated potential ecological receptors, COPCs, and potentially completed exposure pathways for soil, soil vapor, and groundwater. A scoping assessment of ecological risks also was completed to qualitatively evaluate potential ecological receptors, COPCs, and potentially complete exposure pathways for groundwater. Groundwater typically underlies the ecological receptors at depths of approximately 200 ft or more, and for this reason, there are no plausible groundwater exposure pathways to plants and animals. It was concluded that no further characterization of ecological risks to plants and animals due to groundwater exposure was warranted as there were no complete exposure pathways (FWEC, 1996).

The assessment used a habitat approach as the basis for identifying potentially complete pathways between areas of impact and specific plant and animal species that may occupy the facility. Potentially affected habitats within or adjacent to the JPL facility include: urban landscape, chaparral, riparian, wetlands, southern oak woodland, and desert wash. A wide variety of plant and animal species were catalogued during field surveys. The COPCs evaluated for groundwater were the metals and VOCs that were detected in the groundwater during the RI.

The chaparral and southern oak woodland habitats are found only in the San Gabriel Mountains to the north of the JPL facility. Because no impact was known or suspected within the chaparral and southern oak woodland habitats, no potential exposure pathways were identified for these habitats. The riparian, desert wash, and wetland habitats occur off facility (OU3) only, and groundwater typically underlies these habitats at depths of approximately 100 ft or more. For this reason, there were no plausible groundwater exposure pathways to plants and animals within riparian, desert wash, or wetland habitats identified during the ERA. The urban landscape habitat is the predominant on-facility JPL habitat. Constituents in groundwater are found at depths between approximately 100 to 250 ft and groundwater does not recharge on-facility surface water bodies. Therefore, no groundwater exposure pathways to plants and animals were identified.

Therefore, it was concluded that no further characterization of ecological risks to plants and animals due to groundwater impact was warranted because there were no complete exposure pathways from groundwater to on-facility biota.

7.4 Basis for Action

The groundwater beneath the JPL facility contains elevated levels of chemicals that represent a continuing source. The basis for the response action is to address COCs in the aquifer being used by the local community to meet drinking water standards (i.e., MCLs). In addition, active treatment provides hydraulic control to prevent the migration of chemicals in groundwater. Source area groundwater (i.e., OU1) treatment improves the effectiveness and efficiency of the overall groundwater response action by significantly reducing chemical mass in groundwater that could migrate off facility.

The response action selected in this ROD is necessary to protect public health or welfare or the environment from actual or threatened releases of contaminants from this site which may present an imminent and substantial endangerment to public health and welfare.

8.0 Remedial Action Objectives (OU1 and OU3)

Based on the current and reasonably anticipated future use of OU3 groundwater as drinking water and the presence of VOCs and perchlorate in OU1/OU3 groundwater above health-based drinking water standards, the following remedial action objectives (RAOs) have been identified for OU1 and OU3 groundwater at the JPL CERCLA site:

1. Protect human health and the environment by preventing exposure to VOCs (carbon tetrachloride and TCE) and perchlorate in groundwater originating from JPL.
2. Restore beneficial use of groundwater containing VOCs and perchlorate originating from JPL.
3. Prevent further migration of carbon tetrachloride, TCE, and perchlorate beyond the current extent.

These RAOs protect human health and the environment, preventing exposure to VOCs and perchlorate in groundwater by restoring beneficial use of groundwater and preventing further contaminant migration.

The current extent of carbon tetrachloride, TCE, and perchlorate, and the boundary of OU3 are shown in Figure 8-1.

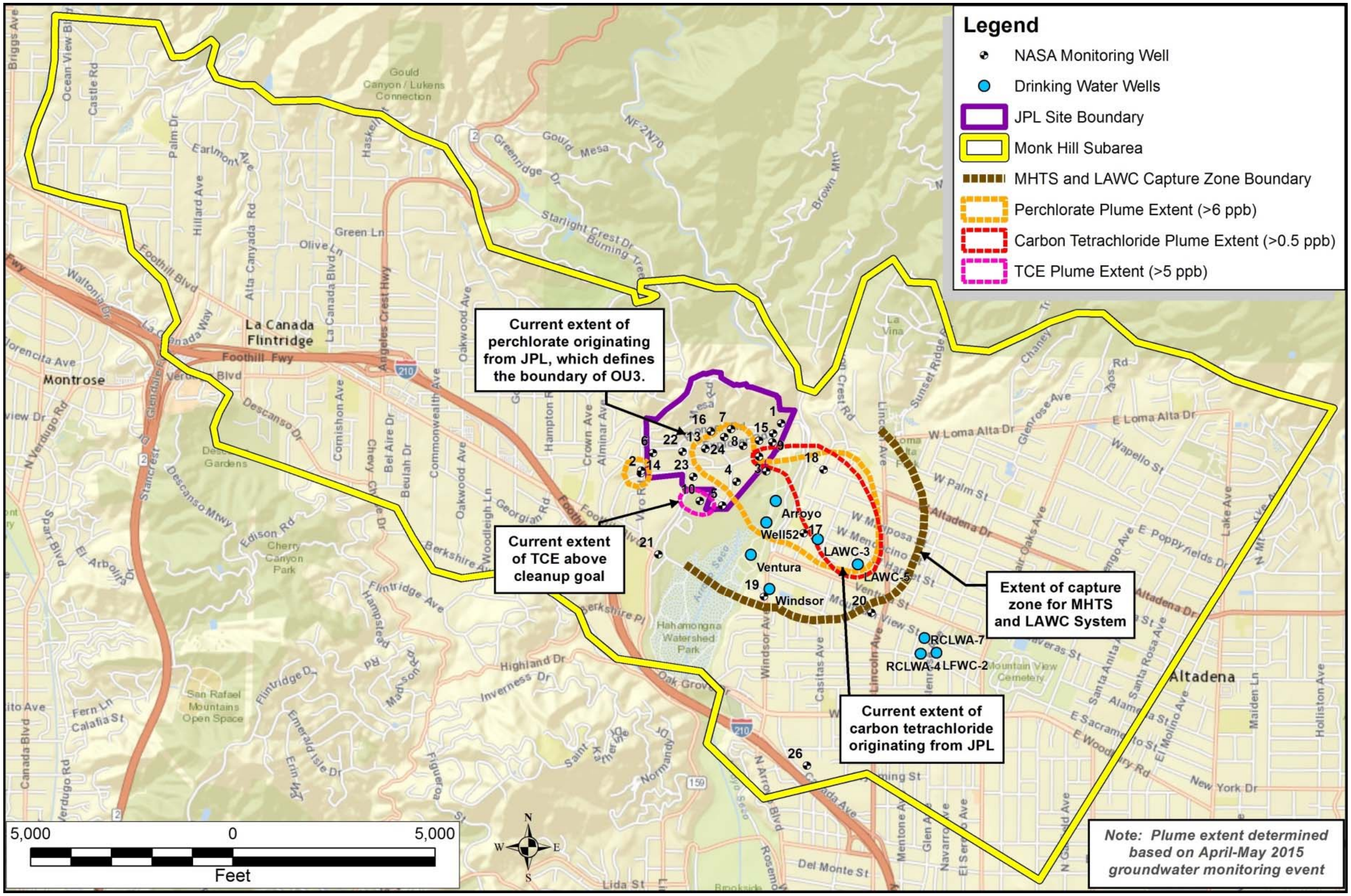


Figure 8-1. Boundary of OU3 as Defined by the Extent of the Chemical Plume Originating from JPL Exceeding the Remedial Goals

9.0 Description of Alternatives (OU1 and OU3)

An analysis of possible treatment technologies and alternatives had been done to implement the interim remedies at OU1 and OU3 (NASA, 2007b; 2007c). In addition, NASA prepared a focused feasibility study to assess potential remedial alternatives against the NCP evaluation criteria and determine their ability to attain the identified RAOs (NASA, 2014a). Two alternatives were identified and evaluated in the focused feasibility study, including Alternative 1: No Action and Alternative 2: Groundwater Extraction with Aboveground Treatment and ICs. These alternatives are described in the following sections.

9.1 Alternative 1: No Action

In accordance with the requirements of the NCP and CERCLA, the No Action alternative is presented to serve as the baseline condition on which to compare other remedial alternatives. This alternative would entail no active remediation of groundwater at OU1 or OU3. Monitoring would also not be a component of this alternative. No periodic reviews would be conducted to evaluate the protectiveness of this alternative. There would be no costs associated with implementing this alternative.

9.1.1 Description of Remedy Components

The No Action alternative would prevent use of OU1 and OU3 groundwater as a drinking water source and may result in migration of chemicals if the Pasadena Water and Power (PWP) and LAWC wells in the Monk Hill subarea were not operating. In addition, while there would be no direct exposure pathway to human or ecological receptors at OU1 or OU3, groundwater monitoring and modeling have demonstrated that chemicals present in groundwater could migrate downgradient and impact other water purveyors. Under the No Action alternative, no remedial action would be completed to reduce chemicals in groundwater at OU1 or OU3, and no monitoring would be conducted.

9.1.2 Common Elements and Distinguishing Features

Because no monitoring would be conducted under this No Action alternative, there would be no evaluation of protectiveness of human health and the environment. No applicable or relevant and appropriate requirements (ARARs) are applicable under this alternative because ARARs apply to “any removal or remedial action conducted entirely on-site” and “no action” is not a removal or remedial action (CERCLA sec. 121[e], 42 USC § 9621[e]). CERCLA Section 121 (42 USC § 9621) cleanup standards for selection of a Superfund remedy, including the requirement to meet ARARs, would not be triggered by the No Action alternative. Therefore, a discussion of compliance with ARARs is not appropriate for the No Action alternative.

9.1.3 Expected Outcomes

The No Action alternative is not a treatment or containment technology and would not be expected to reduce the toxicity, mobility, or volume of chemicals of concern at OU1 or OU3. Under the No Action alternative, no remediation of OU1 or OU3 would be performed except that which occurs naturally due to chemical/biological degradation, dispersion, advection, and sorption. The No Action alternative would not remove COCs from the aquifer being used by the local community for drinking water, nor would it protect the environment from the additional migration of chemicals in groundwater outside the JPL fence line. The No Action alternative would not meet the RAOs for OU1 or OU3.

This alternative would not meet the threshold criterion of overall protection of human health and the environment and does not trigger an ARAR determination. Therefore, an analysis of the balancing criteria is not required.

9.2 Alternative 2: Groundwater Extraction with Aboveground Treatment and Institutional Controls

Alternative 2 is comprised of groundwater extraction, aboveground treatment, and discharge of treated water, consistent with the current interim remedies. Three treatment systems are currently operating at the JPL site: (1) the OU1 source area treatment system, (2) the OU3 MHTS, which consists of LGAC for VOC treatment and ion exchange for perchlorate treatment, and (3) the OU3 LAWC treatment system which also consists of LGAC for VOC treatment and ion exchange for perchlorate treatment. Alternative 2 also includes the addition of various formalized ICs. These ICs will be in addition to the adjudicated water rights currently in place and enforced by the Raymond Basin Management Board, to ensure impacted groundwater within the JPL site will not be utilized without appropriate evaluation and/or treatment. In addition, this alternative includes continuation of the routine groundwater monitoring program to monitor remedy performance and effectiveness.

Alternative 2 is protective of human health and the environment and is designed to contain and treat chemicals in the source area groundwater to prevent further migration of source area chemicals that will adversely impact the downgradient drinking water supply. Monitoring results show that there has been a decreasing trend in perchlorate and VOC concentrations in the extracted groundwater over the duration of the OU1 system operation, and the system has consistently treated these chemicals to below the discharge criteria (NASA, 2012).

Alternative 2 will meet all ARARs identified for this remedial action (see Section 12.2). Discharge requirements for all treatment systems have been consistently achieved, as documented in the routine operating reports and recent five-year review (NASA, 2012). In addition, concentrations of TCE and perchlorate in treated water from the MHTS and LAWC treatment systems have been non-detect, demonstrating that these systems will continue to achieve the TCE and perchlorate MCLs in the future regardless of any potential change to either MCL. Concentrations in the groundwater have been shown to be decreasing over time, demonstrating that achieving MCLs within the aquifer can be achieved. In addition, all waste disposal for the OU1 and OU3 interim remedies will continue to be conducted in accordance with disposal requirements identified as part of the ARAR evaluation.

The current operation of the OU1 treatment system has significantly reduced the chemical concentrations within the source area. Based on removal of three pore volumes of groundwater within the boundary of the JPL chemical plume, it is estimated that it may take another 15 to 20 years to achieve the remedial goals in JPL groundwater (OU3). At OU3, groundwater extraction and treatment removes COCs from the aquifer being used by the local community (LAWC and the City of Pasadena) for drinking water, and provides hydraulic control to prevent the migration of chemical mass in groundwater. The monitoring data obtained to date indicate that the system is operating as intended, with perchlorate and VOC levels below detection limits following ion exchange and LGAC treatment.

9.2.1 Description of Remedy Components

OU1 and OU3 Treatment Systems – For OU1, Alternative 2 consists of groundwater extraction wells, ICs, LGAC treatment to remove VOCs, FBR treatment to remove perchlorate, and re-injection of treated water. For OU3, the alternative consists of groundwater extraction from existing production wells, LGAC treatment to remove VOCs, and ion exchange treatment to remove perchlorate. The treated water is then disinfected and used for potable water by PWP and LAWC.

In January 2000, NASA completed a draft Feasibility Study that identified and evaluated various groundwater cleanup alternatives for both the source area and in off-facility areas adjacent to the JPL facility (FWEC, 2000). In addition, a literature review was conducted to assess the development status of various biological, physical, chemical, and thermal treatment technologies used for the removal of perchlorate from groundwater (NASA, 2006b). As part of this effort, NASA also conducted a number of different pilot tests to see which technologies might be the most promising for use at the JPL site. The technologies tested included reverse osmosis, FBR, packed bed reactors, in situ bioremediation, and ion exchange.

Due to the depth and extent of the chemicals in groundwater as well as the location and density of buildings at JPL, in situ bioremediation is not practical or cost-effective at JPL. Therefore, groundwater must be pumped from the ground and treated aboveground. The best aboveground perchlorate treatment depends on several factors, including the perchlorate concentrations that exist, specific site conditions, and other considerations. Two perchlorate treatment processes have been proven at full-scale application at JPL and other sites: FBR and ion exchange.

FBR is cost-effective for relatively high concentrations of perchlorate and at locations where continuous operation can be achieved, such as the source area beneath JPL. The FBR contains carbon particles covered with a coating of bacteria that destroy perchlorate. The primary advantages of this system are the destruction of perchlorate and relatively low operational cost.

Ion exchange consists of small plastic beads, or resin, in a tank. As the water passes through the tank, perchlorate attaches to the resin. After enough perchlorate attaches to the resin, the resin is removed and sent to a licensed disposal facility, and new resin is added. Ion exchange is the only perchlorate removal technology that has been used for drinking water systems in California. Ion exchange is more cost-effective at low perchlorate levels, such as those found in groundwater off facility, and it is more appropriate for operations where the flowrate is varied, such as the MHTS and the LAWC treatment system.

The U.S. EPA has identified air stripping and LGAC as the best technologies to use for aboveground treatment of groundwater containing VOCs, referring to these as “presumptive technologies” (U.S. EPA, 1996). U.S. EPA expects these technologies to be used for removal of

VOCs at "all appropriate sites." LGAC treatment is currently in place at JPL and is working effectively as part of all three treatment systems.

Based on the concentration of chemicals to be treated (higher concentrations at the source area in OU1 and lower concentrations downgradient at OU3), the technologies selected as part of the interim remedies to achieve the aboveground treatment are different for OU1 and OU3. Also, the end use of the treated groundwater from OU1 and OU3 are different. Treated groundwater from OU1 is re-injected into the aquifer and treated groundwater from OU3 is used by PWP and LAWC for drinking water.

Groundwater Monitoring – A groundwater monitoring program is currently in place and groundwater monitoring will continue until RAOs are achieved. The existing JPL monitoring well network is sufficient to monitor the three-dimensional extent of the chemical plumes in OU1 and OU3. A total of 25 monitoring wells are currently sampled on either a quarterly or semi-annual basis (NASA, 2015), including well MW-25 located downgradient of OU3 near the Sunset Reservoir wells. Fifteen of the 25 wells in the JPL groundwater monitoring network are multi-level wells that monitor up to five zones within the aquifer. Altogether, there are 82 discrete sampling locations. In addition, the JPL monitoring well network is supplemented by performance data from production wells in the Monk Hill subarea. For example, NASA funds weekly monitoring for perchlorate at Rubio Canon Land and Water Association (RCLWA) production wells RCL&W#4 and RCL&W#7.

The location and frequency of monitoring may change in the future with concurrence from the regulatory agencies based on changing site conditions over time.

Institutional Controls – The remedy includes ICs to ensure impacted groundwater within the JPL site is not utilized without appropriate evaluation and/or treatment. ICs will be implemented via a legal agreement with the Raymond Basin Management Board (RBMB) and/or the State of California. The agreements will include commitments that require the agency to notify NASA of any proposed new extraction wells in the Monk Hill Subarea, and that NASA evaluate the impact of any proposed extraction wells within/near the capture zones on the remedies for OU1 and OU3. In addition, NASA will conduct annual reviews of new well permits in the Monk Hill Subarea as an additional control to prevent exposure to chemicals. ICs are discussed further in Section 12.2.

9.2.2 Common Elements and Distinguishing Features

This remedial alternative has been successfully implemented as the interim remedial actions for both OU1 and OU3 since 2004 and 2005. The treatment systems have been operating effectively, and all required permitting is currently in place for operation of the treatment systems. In addition, the regulatory agency and community have previously accepted this alternative, further increasing the administrative implementability of this alternative.

This alternative addresses the regulatory preference for remedial actions that permanently and significantly reduce the toxicity, mobility, or volume of contamination through treatment. The FBR, which treats perchlorate from source area groundwater at OU1, meets the U.S. EPA preference for reduction in toxicity, mobility, and volume by permanently destroying the perchlorate through biological treatment. At OU3, perchlorate is not permanently degraded, but rather mobility and volume of the chemical is reduced through adsorption of perchlorate onto the ion exchange resin, resulting in clean groundwater. Similarly, the mobility and volume of VOCs is reduced through treatment at OU1 and OU3 by adsorption onto the LGAC media, resulting in clean groundwater. Spent ion exchange and LGAC media is properly disposed in accordance with federal laws at approved facilities.

For OU1, the actual annual operating costs have typically ranged from approximately $800,000 to $1,000,000. This cost includes labor, materials, laboratory costs, well rehabilitation, and reporting/project management.

For OU3, the actual annual costs incurred for O&M of the LAWC treatment system have typically ranged from approximately $800,000 to $900,000. Actual annual costs for the MHTS O&M ranged from approximately $3,300,000 to $3,700,000. These costs include labor, materials, equipment leases, electricity, laboratory costs, and reporting/project management. The ongoing costs of the existing groundwater monitoring program are estimated at $595,000 per year.

Costs for implementation of the additional ICs added by this final ROD are estimated at $175,000, inclusive of $100,000 for IC remedial design and MOAs, and $75,000 for IC monitoring (15 years at $5,000 per year).

Costs for O&M of all three groundwater extraction and treatment systems and groundwater monitoring were accounted for and authorized as part of the Interim RODs for OU1 and OU3 (NASA, 2007b and 2007c). Only costs for additional ICs are authorized in this Final ROD.

9.2.3 Expected Outcomes

The extraction, treatment, and re-injection alternative is expected to permanently reduce the volume of VOCs and perchlorate at OU1, and to reduce the chemical mass in groundwater that migrates off facility. Thus, the treatment alternative is expected to meet RAOs for OU1 and to improve the effectiveness and efficiency of the selected remedy for OU3.

A treatment system using ion exchange and LGAC is currently operating at LAWC, and the MHTS is currently treating groundwater extracted from the City of Pasadena Monk Hill subarea production wells. These systems have been effective in removing perchlorate and VOCs from pumped water, meeting all federal and state drinking water standards.

In addition, these systems have been effective in preventing migration of chemicals beyond LAWC#5. Perchlorate and VOCs originating from JPL are contained within the Monk Hill Subarea of the Raymond Basin by the drinking water production wells that are associated with the OU3 treatment systems (i.e., MHTS and LAWC treatment system). The next set of downgradient production wells is owned by RCLWA. NASA funds weekly monitoring of the RCLWA production wells. The highest detection of perchlorate in these wells was 3.1 µg/L, and no TCE or carbon tetrachloride has been detected in the RCLWA wells. Data from the RCLWA wells demonstrate that operation of the OU3 interim remedy is effectively preventing further migration of chemicals in groundwater.

Based on this information, it is expected that implementation of Alternative 2 will achieve the RAOs by removing COCs from the aquifer being used by the local community (LAWC and the City of Pasadena) for drinking water and protecting the environment from the additional migration of chemicals in groundwater outside the JPL fence line. This alternative includes two centralized treatment plants which will allow for immediate drinking water use of the groundwater in the Monk Hill subarea. Based on the current rate of chemical removal and data collected over the past 10 years, the selected alternative is likely to operate for 10 to 20 more years.

10.0 Summary of Comparative Analysis of Alternatives (OU1 and OU3)

This section compares the relative performance of the remedial alternatives presented here against one another based on the NCP evaluation criteria. This comparative analysis considers the advantages and disadvantages of each alternative and identifies key trade-offs that were considered when selecting the remedy.

10.1 Comparison of Remedial Alternatives Using Evaluation Criteria

This section uses the nine evaluation criteria to compare and evaluate the response action alternatives for on-facility and off-facility groundwater. Table 10-1 summarizes the screening results of the two alternatives evaluated for OU1 and OU3: 1) Alternative 1: No Action and 2) Alternative 2: Groundwater Extraction with Aboveground Treatment and ICs.

10.2 Protection of Human Health and the Environment

This criterion assesses whether an alternative provides adequate public health and environmental protection, and describes how health and environmental risks posed by the site will be eliminated, reduced, or controlled through treatment, engineering controls, or other means.

Although there are no human health or ecological exposure pathways for chemicals in groundwater at OU1, Alternative 1 (No Action) would not address the chemicals known to be in groundwater at OU1, and these chemicals may adversely impact the downgradient area at OU3 in terms of life-cycle costs and time of operation.

The No Action alternative is not considered protective of human health and the environment at OU3, where chemicals are present in groundwater at concentrations above the MCLs and groundwater is used as a drinking water source.

Alternative 2, Groundwater Extraction with Aboveground Treatment and ICs, has been implemented as the interim remedy at both OU1 and OU3. Data collected to date for these treatment systems have demonstrated that they can effectively treat extracted groundwater to the required discharge criteria, and that operation of the systems has resulted in decreased concentrations of chemicals within the groundwater at both OU1 and OU3. Alternative 2 is considered to have a high degree of overall protection of human health and the environment.

10.3 Compliance with ARARs

Compliance with ARARs addresses whether a remedial alternative meets all pertinent federal and state environmental requirements. An alternative must comply with ARARs, or be covered by a waiver.

No activities are conducted as part of the No Action alternative; therefore, an ARARs determination was not conducted for this alternative.

Table 10-1. Summary of the Comparative Analysis for OU1 and OU3

NCP Evaluation Criterion	Alternative 1: No Action	Alternative 2: Groundwater Extraction with Aboveground Treatment and ICs
Overall Protection of Human Health and the Environment	Not protective of human health and the environment because chemicals are present in groundwater above MCLs and groundwater is used as a drinking water source.	High level of overall protection of human health and the environment. Data collected to date from implementation of the interim remedial actions demonstrate that groundwater extraction with aboveground treatment is effective.
Compliance with ARARs	ARARs determination not conducted because no activities are conducted as part of this alternative.	Complies with all chemical-, location-, and action-specific ARARs identified for OU1 and OU3.
Long-Term Effectiveness and Permanence	Does not provide long-term effectiveness in achieving RAOs because chemicals would remain in groundwater at levels exceeding drinking water MCLs.	High level of long-term effectiveness and permanence, as data from operation of the interim remedial actions show that Alternative 2 is effective in containing the chemical plumes and preventing exposure to chemicals in groundwater originating from JPL, and monitoring data indicate decreasing chemical levels in the groundwater in OU1.
Reduction in Toxicity, Mobility, or Volume through Treatment	Does not meet the U.S. EPA preference for remedial actions that permanently and significantly reduce toxicity, mobility, or volume of contamination through treatment.	Reduction in mobility and/or volume of chemicals is achieved through aboveground treatment using FBR, LGAC, and ion exchange.
Short-Term Effectiveness	Does not have any impacts to the community, site workers, and the environment during remedy implementation because no actions are performed.	Some short-term impacts are possible (e.g., increase in traffic and noise, site worker safety concerns), although these impacts are mitigated to the greatest extent possible.
Implementability	Highly implementable because no action is taken.	Highly implementable (technically and administratively) because systems have already been constructed and are operating effectively under approved interim RODs.
Cost	No cost.	Additional costs associated with this Final ROD are estimated at approximately $175,000. These costs are considered reasonable for implementation of ICs.

Implementation of Alternative 2 will comply with all chemical-, location-, and action-specific ARARs identified for OU1 and OU3. Long-term groundwater monitoring data have shown that operation of the treatment systems has reduced groundwater concentrations within the treatment zone (specifically for the OU1 source area treatment system and the LAWC treatment system). This indicates that the chemical-specific ARARs identified (state and federal MCLs) can be achieved through continued implementation of this remedy. Also, proper system monitoring and maintenance will enable NASA to ensure that all action-specific ARARs continue to be met (e.g., achieving all discharge requirements, adhering to waste disposal requirements, etc.). Based on this evaluation, Alternative 2 meets both CERCLA threshold criteria.

10.4 Long-term Effectiveness and Performance

Long-term effectiveness addresses the ability of an alternative to maintain reliable protection of human health and the environment over time, including the degree of certainty that the alternative will prove successful.

Implementation of the No Action alternative does not provide long-term effectiveness in achieving the final RAOs because no action would be completed and chemicals would remain in groundwater and drinking water.

Monitoring data collected over several years of operation for the OU1 and OU3 treatment systems indicate a general decreasing trend in perchlorate and VOC concentrations in both the extracted groundwater and groundwater within the treatment zones as measured at various monitoring wells. Operating data have also demonstrated the consistent achievement of goals for treated groundwater (waste discharge requirements [WDRs] for OU1 and MCLs for OU3).

At OU1, concentrations of TCE within the treatment zone monitoring wells (i.e., MW-7, MW-13, MW-16, and MW-24) are now below the state and federal MCL (5.0 μg/L), and concentrations of carbon tetrachloride are near the state MCL of 0.5 μg/L (maximum concentration of 0.7 μg/L in one treatment zone monitoring well). Perchlorate concentrations in MW-7 and MW-24 have declined from 13,300 μg/L and 4,880 μg/L to concentrations of 35.0 μg/L and 9.9 μg/L, respectively. These data demonstrate that operation of the OU1 treatment system has significantly reduced the chemical concentrations within the source area.

Perchlorate and VOC concentrations are also showing decreasing concentrations within the groundwater at OU3. At MW-17 (located between MHTS and LAWC production wells), monitoring data indicate that there is a decreasing trend in perchlorate and carbon tetrachloride concentrations over time. TCE concentrations in MW-17 continue to be relatively stable and below the MCL. In addition, perchlorate has not been detected at concentrations above the MCL and no increasing trends have been observed at the RCLWA production wells, which are located downgradient of the LAWC wells. Data from the RCLWA wells along with data from MW-17 demonstrate that operation of the OU3 interim remedy is effectively preventing further migration of chemicals in groundwater.

Operation of the two drinking water treatment systems at OU3 will be effective for the long term. The systems permanently remove chemicals from groundwater by extracting the groundwater and treating it to remove VOCs and perchlorate before the drinking water is provided to customers. Results from routine monitoring of the treatment systems have demonstrated that perchlorate and VOC concentrations are consistently below detection limits following ion exchange and LGAC treatment at the MHTS and LAWC treatment systems. The system controls have proven to be reliable, and monitoring and system oversight required by CERCLA and the OU3 drinking water permits will ensure safe operation continues. Implementation of ICs will further enhance long-term effectiveness by ensuring exposure to chemicals in groundwater does not occur if a new well is installed in the Monk Hill subarea.

Based on the current rate of chemical removal and data collected over the past 10 years, the selected alternative is likely to operate for 10 to 20 more years. The technologies and equipment proposed have proven to be effective over such a duration. It is estimated that at the end of this duration, groundwater chemical concentrations will be below the cleanup goals, thus making the groundwater suitable for drinking water without additional treatment for VOCs and perchlorate. The long-term effectiveness of Alternative 2 is considered high.

10.5 Reduction of Toxicity, Mobility, or Volume through Treatment

The evaluation of this criterion addresses the statutory preference for selecting remedial actions that employ treatment technologies to permanently and significantly reduce toxicity, mobility, and volume of chemicals in groundwater.

The No Action alternative would leave chemicals in the groundwater to spread and further impact groundwater. Therefore, this alternative does not meet the U.S. EPA preference for remedial actions that permanently and significantly reduce the toxicity, mobility, or volume of contamination through treatment.

Alternative 2 uses treatment that permanently and irreversibly removes chemicals from the groundwater, thereby reducing the volume and mobility of chemicals in groundwater around JPL. The FBR, which treats perchlorate from source area groundwater at OU1, meets the U.S. EPA preference for reduction in toxicity and volume by degrading the perchlorate through biological treatment. At OU3, the perchlorate treatment technology transfers perchlorate from the groundwater to the ion exchange media. VOCs are also transferred from groundwater to carbon media at the OU1 and OU3 treatment systems. The ion exchange and carbon media will be properly disposed (either at an approved landfill or via thermal treatment) in accordance with federal and state regulations as is currently the case for the OU1 and OU3 treatment systems. Alternative 2 will reduce toxicity, mobility, and volume of affected groundwater.

10.6 Short-term Effectiveness

The evaluation of short-term effectiveness addresses how well human health and the environment are protected from impacts during the construction and implementation of a remedial alternative, and the length of time until protectiveness is achieved.

The No Action alternative would not have any impacts to the community, site workers, and the environment during remedy execution since no action would be taken for this alternative. However, the No Action alternative does not reduce existing impacts from the chemicals in groundwater.

Because the treatment systems included in Alternative 2 were previously installed as part of the interim remedies, short-term impacts are limited to continued operation of these systems. Operation of the systems will present minimal risks to workers, the public, and the environment. The systems are designed to shut down in case of malfunction and automatically alert operating staff if a shutdown occurs. The chemicals in the extracted water will be removed by the aboveground treatment system in accordance with state and federal regulations. Because the treatment systems included in Alternative 2 were previously installed as part of the interim remedies, protectiveness has already been achieved. Even so, based on current estimates, the selected alternative is likely to operate for 10 to 20 more years and potential short-term impacts to the community and site works will continue throughout this duration.

Potential short-term impacts to the community as a result of the selected alternative are primarily related to truck traffic associated with system maintenance (e.g., LGAC and ion exchange media changeout). Other community impacts may include noise associated with pump operation or other maintenance activities such as well rehabilitation. These short-term noise impacts are mitigated to the greatest extent possible through the use of sound dampening engineering controls.

Potential short-term impacts to site workers are safety concerns during routine treatment system O&M. These risks are mitigated to the maximum extent practical through the use of personal protective equipment as required based on site conditions (e.g., hearing protection when working under high decibel circumstances).

The potential for unacceptable risk due to exposure to untreated groundwater will be mitigated in the selected alternative through the existing adjudicated water rights within the basin and ICs which will further control groundwater extraction.

10.7 Implementability

Evaluation of implementability addresses the technical and administrative feasibility of implementing an alternative, including an evaluation of the availability of technologies, services, and materials required during implementation.

The No Action alternative is highly implementable from a technical perspective, as no action would be taken. However, this alternative has a low administrative implementability rating because regulatory concurrence would not be possible with chemicals in groundwater remaining within a drinking water aquifer above MCLs.

The treatment systems incorporated under Alternative 2 are highly implementable from both a technical and administrative perspective. The systems have already been constructed and are currently being operated as part of the interim remedies for OU1 and OU3. Therefore, implementation of Alternative 2 consists of continued operation of the three existing treatment systems and establishing ICs. The treatment systems have been operating effectively, and continued operation of the systems is considered highly implementable. All required permitting is currently in place for operation of the treatment systems, and the community and regulatory agencies have previously reviewed and accepted this alternative, further increasing the administrative implementability of this alternative.

JPL is located in the Monk Hill subarea of the Raymond Basin. In 1944, the Superior Court of California approved the Raymond Basin Judgment, which adjudicated the rights to groundwater production to preserve the safe yield of the groundwater basin. The City of Pasadena and LAWC will continue to be subject to the extraction, reporting, and monitoring requirements associated with the Raymond Basin Judgment, which is administered by the RBMB. The water rights allocated to LAWC and the City of Pasadena have been sufficient to contain the migration of chemicals originating from JPL (NASA, 2007a).

While NASA is not a party to the adjudication, NASA has worked closely with the RBMB, designing the OU1 treatment plant to minimize the amount of wastewater. Since 2005, NASA has re-injected 99.9% of the treated groundwater. The small quantity of wastewater that is generated is reported to the RBMB on a monthly basis.

Current drought conditions have resulted in the groundwater table dropping to a point that Well 52 at the MHTS and Extraction Well No. 1 at the OU1 treatment system are currently not able to operate. Even so, the Arroyo Well at the MHTS, Extraction Wells No. 2 and 3 at OU1, and both LAWC wells have continued to operate. These wells are constructed deeper in the aquifer. If continued severe drought conditions impact the ability of the treatment plants to operate, the pump intakes in the extraction wells may need to be lowered, or new extraction wells installed if the groundwater monitoring data demonstrate that plume containment cannot be maintained.

10.8 Cost

Evaluation of cost addresses the total cost of the remedial action, including capital and O&M costs.

There is no cost associated with the No Action alternative.

Alternative 2 includes continued operation of the OU1 source area treatment system and also the two OU3 drinking water treatment systems. For OU1, actual annual O&M costs have ranged from approximately $800,000 to $1,000,000. This cost includes labor, materials, laboratory costs, well rehabilitation, and reporting/project management.

For OU3, actual annual costs incurred for O&M of the LAWC treatment system have ranged from approximately $800,000 to $900,000. The actual annual O&M costs for the MHTS have ranged from approximately $3,300,000 to $3,700,000. LAWC and MHTS costs include labor, materials, equipment, leases, electricity, laboratory costs, and reporting.

The ongoing cost for the existing groundwater monitoring program are estimated at $595,000 per year.

Costs for implementation of the additional ICs added by this final ROD are estimated at $175,000, inclusive of $100,000 for IC remedial design and MOAs, and $75,000 for IC monitoring (15 years at $5,000 per year).

Costs for O&M of all three systems and groundwater monitoring were accounted for and authorized as part of the Interim RODs for OU1 and OU3 (NASA, 2007b and 2007c). Only costs for additional ICs are authorized in this Final ROD. Therefore, the current present value costs for additional ICs under Alternative 2 are estimated at $175,000. These costs are considered reasonable to achieve the RAOs at the JPL site.

10.9 State Acceptance

The State has expressed its support for Alternative 2. The State does not believe that Alternative 1 provides adequate protection of human health and the environment.

10.10 Community Acceptance

During the public comment period, the community expressed its support for Alternative 2. The community did not consider Alternative 1 to be adequately protective. Community acceptance is based on comments received and the Responsiveness Summary included in this ROD as Part III.

11.0 Principal Threat Waste

The NCP establishes an expectation that U.S. EPA will use treatment to address the principal threats posed by a site wherever practicable. Principal threat wastes are those source materials considered to be highly toxic or highly mobile wastes that cannot be reliably contained. A source material is material that includes or contains hazardous substances, pollutants, or contaminants that act as a reservoir for migration of contamination to groundwater, surface water, or air, or acts as a source for direct exposure. Contaminated groundwater generally is not considered to be a source material; however, NAPLs in groundwater may be viewed as source material. At JPL, OU1 and OU3 are associated with contaminated groundwater and NAPL has not been detected in groundwater. Therefore, principal threat wastes are not considered to be present within OU1 and OU3.

12.0 Selected Remedy (OU1 and OU3)

12.1 Rationale for Selected Remedy

Based on the evaluation of threshold and primary balancing criteria in Section 10.0, Alternative 2 is the most effective remedial alternative for removal of chemicals of concern from groundwater at JPL. The No Action alternative is not appropriate because there would be no removal of COCs from the aquifer, and further migration of chemicals in groundwater would not be controlled. Therefore, the RAOs would not be met.

Alternative 2 is designed to contain and treat chemicals in the source area groundwater and prevent further migration of source area chemicals that would adversely impact the downgradient drinking water supply. For OU1 under Alternative 2, LGAC treatment will remove VOCs, FBR treatment will remove perchlorate, and the treated water will be re-injected into the aquifer. For OU3, Alternative 2 will consist of extracting groundwater from existing production wells, using LGAC treatment to remove VOCs, using ion exchange treatment to remove perchlorate, and the treated water will be disinfected and utilized as potable water with the PWP and LAWC distribution systems. Alternative 2 will comply with all ARARs identified for this remedial action.

The selected alternative will achieve the RAOs, protecting human health from exposure to VOCs and perchlorate originating from JPL. There has been a general decreasing trend in perchlorate and VOC concentrations in both the extracted groundwater and groundwater in the treatment zone over the duration of system operation for both OU1 and OU3. It is estimated that it may take another 10 to 20 years to achieve the remedial goals in groundwater. Because the groundwater treatment system has already been installed, there are minimal short-term impacts from maintenance of the system. The treatment facility has proven to be implementable and effective. Results from periodic monitoring of the treatment systems, as well as NASA’s ongoing groundwater monitoring program, will be used to monitor the effectiveness of the selected alternative.

12.2 Description of the Selected Remedy

NASA's and U.S. EPA's selected alternative for groundwater at JPL is to continue operating the three existing treatment systems in OU1 and OU3. The three systems have operated very effectively and will continue to remove COCs including perchlorate and VOCs from groundwater. NASA's and U.S. EPA's selected alternative also includes the addition of various formalized ICs to ensure impacted groundwater within the JPL site is not utilized without appropriate evaluation and/or treatment. In addition, this alternative includes continuation of the routine groundwater monitoring program to monitor remedy performance and effectiveness.

The OU1 (on-facility) treatment system consists of three groundwater extraction wells, ex situ treatment using LGAC to remove VOCs and an FBR to treat perchlorate, and re-injection of treated water into injection wells located at the JPL facility.

The design capacity of this treatment plant is 300 gpm. The on-facility treatment plant is currently operated by NASA as the interim remedial action for OU1. To date, the system has treated more than 3,300 acre feet of groundwater, removing approximately 1,800 pounds of perchlorate and 40 pounds of VOCs.

The LAWC system includes two extraction wells (LAWC#3 and LAWC#5), LGAC treatment for VOCs, and ion exchange for treatment of perchlorate, with a maximum capacity of 2,000 gpm. The treated water is used as a source of drinking water for LAWC customers. The system has been operating effectively since 2004, treating approximately 20,400 acre feet of groundwater, removing approximately 1,060 pounds of perchlorate and 230 pounds of VOCs. Operation of the LAWC treatment plant is funded by NASA as part of the interim remedial action for off-facility groundwater (OU3).

The MHTS consists of extraction wells (Arroyo Well, Well 52, Ventura Well, and Windsor Well), LGAC treatment for VOCs and ion exchange for treatment of perchlorate, with a maximum capacity of 7,000 gpm. The treated water is used as a source of drinking water for City of Pasadena customers. The system has been operating effectively since 2011, treating approximately 12,800 acre feet of groundwater, removing approximately 900 pounds of perchlorate and 92 pounds of VOCs. Operation of the MHTS is funded by NASA as part of the interim remedial action for off-facility groundwater (OU3).

U.S. EPA guidance recommends the identification of post-construction refinements as part of the ROD (U.S. EPA, 1999). These refinements are intended to be relatively minor changes to the remedy. Listing specific remedy refinements in the ROD serves to communicate the anticipated full scope of the remedy to all parties, and also minimizes the likelihood that an Explanation of Significant Differences (ESD) or ROD Amendment will be needed. For the JPL site, the following post-construction refinements have been identified:

- Modify extraction rates in some or all extraction wells.
- Cease extraction from some wells.
- Add or remove extraction or re-injection wells.
- Add or remove monitoring wells.
- Refine or modify treatment plant components.

This alternative is selected because historical operating data demonstrate that there has been a decreasing trend in perchlorate and VOC concentrations in the extracted groundwater and groundwater in the treatment zone over the duration of operation, and the systems have consistently treated chemicals to below established discharge criteria for OU1 and established drinking water criteria for OU3, including MCLs. Based on this information, the existing treatment systems at OU1 and OU3 are considered protective of human health and the environment and are effectively working to remove site-related chemicals from the groundwater in an aquifer being used by the local community (LAWC and the City of Pasadena) for drinking water. In addition, these systems have been effective in containing chemicals originating from JPL, and the OU3 systems have restored use of a valuable resource for the Altadena and Pasadena communities.

The operating strategy (e.g., flow rates and groundwater extraction well locations) and aboveground treatment technologies applied in these treatment systems could change in the future, with involvement and concurrence from the regulatory agencies, to ensure treatment is accomplished in the most cost-effective manner. Some examples of these types of changes include:

- Influent perchlorate concentrations in the OU1 source area could decrease to a point where it is more cost effective to treat source area groundwater using ion exchange rather than the FBR.
- New wells are added to one or more of the systems to improve chemical mass removal or system reliability.
- Concentrations in the OU1 source area are reduced to a point where residual levels of VOCs and perchlorate are more cost-effectively addressed by the OU3 systems.

NASA will be the federal agency responsible for implementing, maintaining, reporting on, and enforcing the ICs. The performance objective for ICs at JPL is to prevent use of untreated groundwater until cleanup levels are met, and to maintain the integrity of the selected remedy by ensuring that future changes (i.e., new pumping wells) in the Monk Hill subarea do not adversely impact hydraulic control of the OU1 and OU3 plume. ICs will be maintained until the concentration of hazardous substances in the soil and groundwater are at such levels to allow for unrestricted use and exposure.

Under the selected remedy, ICs will be established to further restrict groundwater extraction that could result in exposure to chemicals in groundwater at OU1 or OU3, or that could negatively impact the OU1 or OU3 remedy. Within 60 days of signing this ROD, NASA will send a written request (and provide a copy to U.S. EPA) to RBMB and California DDW to enter into a memorandum of agreement (MOA) or other agreements securing the commitment from these agencies to notify NASA of any proposed new extraction wells in the Monk Hill subarea, and that NASA, in coordination with the agencies, will evaluate the impact of any proposed extraction wells within/near the capture zones on the implemented remedies at OU1 and OU3. In addition, in the written request, NASA will offer to conduct annual reviews of new well permits in the Monk Hill subarea as an additional control to evaluate and prevent potential exposure to site-related chemicals. These two activities are additional controls to help prevent exposure to contaminated groundwater. Although NASA may later transfer these procedural responsibilities to another party by contract, property transfer agreement, or through other means, NASA shall retain ultimate responsibility for remedy integrity.

Raymond Basin adjudication (enforced by the RBMB) manages extraction of groundwater from the basin and must be notified of new groundwater wells installed in the Raymond Basin. In addition, groundwater treatment systems in California are required to obtain a drinking water permit from California DDW that ensures system owners are providing clean water to customers. New groundwater wells trigger a permit amendment or a new permit. NASA will establish MOAs with RBMB and California DDW so that NASA is notified of any new groundwater wells installed in the Raymond Basin.

In addition, NASA will conduct annual reviews of new well permits issued in the Monk Hill subarea to determine if they may adversely impact protection of human health or effectiveness of the remedy. Annual reviews will include obtaining well data from the California DDW, Los Angeles County Public Health Department, City of Pasadena well permitting desk, the State Water Resource Control Board, and the California Department of Water Resources. These, and other resources as appropriate, will be reviewed by NASA on an annual basis to determine if new wells have been installed or proposed that will require further evaluation with respect to the OU1 and OU3 remedies.

An IC remedial design will be prepared within 90 days of ROD signature; NASA shall prepare and submit to U.S. EPA for review and approval an IC remedial design that shall contain implementation and maintenance actions, including periodic inspections.

12.3 Estimated Remedy Costs

The groundwater treatment systems were constructed as part of the interim RODs for OU1 and OU3; therefore, the only capital costs for this ROD are IC remedial design and MOAs. O&M costs are shown in Tables 12-1 through 12-3, and costs associated with continuing the groundwater monitoring program, shown in Table 12-4. The O&M costs for each technology are the recurring or periodic costs incurred during the operating life of the system. This cost includes labor, materials, laboratory costs, equipment leases, electricity, well rehabilitation, and reporting/project management. For OU1, the annual O&M cost during implementation of the interim ROD has typically ranged from approximately $800,000 to $1,000,000. For OU3, the annual O&M cost of the LAWC treatment system has typically ranged from approximately $800,000 to $900,000 and for the MHTS treatment system has ranged from $3,300,000 to $3,700,000. Costs associated with the routine groundwater monitoring program are estimated at $595,000 per year. It should be noted that the costs for O&M of all three systems and groundwater monitoring (presented in Tables 12-1 through 12-4) were accounted for and authorized as part of the Interim RODs for OU1 and OU3.

Table 12-1. Estimate of Annual Operation and Maintenance Costs for OU1

Field Program	Quantity	Unit	Unit Cost	Total Cost
On-site Labor	1	Per Year	$113,800	$113,800
Chemicals	1	Lot	$128,202	$128,202
Bag Filters	5	Case of 50	$213.50	$1,068
Carbon	1	Per Year	$52,800	$52,800
Electricity	12	Per Month	$3,000	$36,000
Laboratory-Performance	12	Per Month	$12,043	$144,516
Laboratory- Sanitary Sewer	24	Per Event	$1051.75	$25,242
Other Rental/Disposal	1	Lot	$39,800	$39,800
Well rehabilitation	2	Per Year	$25,500	$51,000
Reporting/Project Management	1	Per Year	$232,600	$232,600
Annual O&M Cost				**$825,028**

Table 12-2. Estimate of Annual Operation and Maintenance Costs for the MHTS

Description	Annual Total
Engineering Labor	$199,000
Field Labor	$148,000
Laboratory Fees	$7,000
Carbon Treatment	$867,000
Ion Exchange Treatment	$1,619,000
Pre-Filters	$31,000
Misc. Equipment	$33,000
Misc. Services	$9,000
Excess Energy Costs (Ventura Booster)	$148,000
Dept. of Public Health Billing	$9,000
Treated Water	$300,000
GRAND TOTAL	**$3,370,000**

Table 12-3. Estimate of Annual Operation and Maintenance Costs for the LAWC Treatment System

Description	Annual Total
Facility Inspection	$46,000
Water Sampling Analysis	$65,000
Water Sampling Collection	$14,000
Maintenance	$41,000
Carbon Changeout	$152,000
Ion Exchange Treatment Cost	$244,000
Ion Exchange-Carbon Associated Cost	$54,000
Chemical Cost	$21,000
Administration	$4,000
Excess Energy Costs	$2,000
Auto Costs	$1,000
Incremental Costs	$161,000
Dept. of Public Health Billing	$13,000
GRAND TOTAL	**$818,000**

Table 12-4. Estimate of Annual Groundwater Monitoring

Description	Annual Total
Project Management, Technical Support, and Reporting	$185,000
Field Labor	$120,000
Laboratory Analytical	$250,000
Data Validation	$30,000
Materials	$10,000
GRAND TOTAL	**$595,000**

Additional actions associated with the selected remedy include IC implementation. Costs for implementation of ICs are estimated at $175,000, inclusive of $100,000 for IC remedial design and MOAs, and $75,000 for IC monitoring (15 years at $5,000 per year). Therefore, the current present value costs for the selected remedy are estimated at $175,000 (Table 12-5). Again, costs for O&M of all three systems and groundwater monitoring were accounted for and authorized as part of the Interim RODs for OU1 and OU3 (NASA, 2007b and 2007c). Only costs for additional actions are authorized in this Final ROD.

Table 12-5. Present-Worth Estimate of Total Costs for the Selected Remedy

Description	Capital Costs	Annual O&M Costs	Total Cost[a]
IC Implementation	$100,000	$75,000	$175,000
		Grand Total	**$175,000**

(a) Represents total cost in excess of costs already accounted for as part of the Interim RODs (NASA, 2007b and 2007c). Costs already accounted for in the Interim RODs include the OU1 Treatment System (Table 12-1), LAWC Treatment System (Table 12-2), MHTS (Table 12-3), and Groundwater Monitoring (Table 12-4).

12.4 Expected Outcomes of the Selected Remedy

The response action for OU1 is intended to provide source treatment and containment to prevent migration of chemicals off facility and improve efficiency and reduce cleanup times for OU3. It is anticipated that the response action will restore the use of these municipal drinking water wells, reduce concentrations of perchlorate and VOCs from groundwater, and prevent further migration of chemicals in the groundwater from the JPL facility.

Performance objectives have been established to achieve the RAOs. The performance of the system will be evaluated and optimized on a continuing basis and the information regarding the amount of VOCs and perchlorate removed will be reported to the regulatory agencies as needed to effectively evaluate system performance objectives. The City of Pasadena and LAWC will continue to report system performance data to California DDW on a monthly basis.

The performance objectives include the following:

- Reduction of overall VOC (carbon tetrachloride, TCE, and PCE) and perchlorate concentrations within the groundwater monitoring wells and extraction wells compared to baseline levels so that the treated water can be supplied as drinking water to the residents and customers of the City of Pasadena and LAWC. See Table 12-6 for the applicable drinking water standards for these chemicals.
- Asymptotic mass removal achieved after appropriate system optimization. Asymptotic conditions will have been reached when the upper portion of the cumulative mass removal curve approaches zero.
- Operate the LAWC and City of Pasadena centralized treatment systems until carbon tetrachloride, TCE, PCE, and perchlorate concentrations in the extracted water are consistently reduced to levels that no longer exceed applicable drinking water standards.

Table 12-6. Summary of Applicable Drinking Water Standards for COCs

Analyte	Federal MCL (40 CFR § 141.61) µg/L	California MCL (CCR Title 22, § 64444) µg/L
Carbon tetrachloride	5	0.5
TCE	5	5
PCE	5	5
Perchlorate	NA	6

The existing groundwater monitoring network will be evaluated during the remedial design phase to determine if sufficient coverage is available to monitor changes in the lateral and vertical distribution of VOCs and perchlorate, as well as the effectiveness of cleanup. Additional groundwater monitoring wells will be installed as necessary to monitor effectiveness of the response action.

In addition, NASA will continue to fund VOC and perchlorate monitoring of the RCLWA production wells. Data from the RCLWA wells provides confirmation that chemicals in groundwater are not migrating, thus confirming the selected remedy is effective in containing the perchlorate and VOC plume originating from JPL.

After the performance objectives have been achieved, the OU1 and OU3 treatment systems may be idled and groundwater monitoring will continue to evaluate rebound. If rebound of chemical concentrations occurs in the LAWC and City of Pasadena production wells above drinking water standards, NASA will reinitiate funding. In addition, the system will be idled if MCLs are achieved in the source area. When performance objectives have been achieved and it is determined that no rebound of chemical concentrations occurred, NASA will shut down the OU1 and OU3 treatment systems upon approval by the U.S. EPA, DTSC, and RWQCB and would end the funding agreements with the City of Pasadena and LAWC. The City of Pasadena and LAWC may decide to continue treatment; however, it would be an action taken outside the CERCLA process.

Minimal environmental impacts are expected from implementation of the OU1 and OU3 response actions. Groundwater treatment will have no adverse impacts on threatened or endangered species, cultural resources, floodplains, or wetlands. NASA expects no adverse human health impacts from this CERCLA action to occur in any off-facility community, including minority and low-income communities. With system implementation, increases in JPL traffic will be minimal and consist of transportation of supplies for continued system operation to and from the JPL facility, resulting in insignificant transportation impacts. There will be no measurable impact on the local economy as a result of system implementation, and thus, no socioeconomic impacts are anticipated. Also, there will be no irreversible and irretrievable commitment of resources and the cost of remediation is justified to protect the existing source of drinking water.

Additional information regarding the anticipated socioeconomic, transportation, natural resources, and environmental justice impacts associated with the implementation of the OU1 response action are discussed in the NEPA values assessment (NASA, 2006a).

13.0 Statutory Determinations

13.1 Protection of Human Health and the Environment

Alternative 2 is designed to contain and treat chemicals in the source area groundwater to prevent further migration of source area chemicals that will adversely impact the downgradient drinking water supply. Monitoring results show that there has been a decreasing trend in perchlorate and VOC concentrations in the extracted groundwater over the duration of the OU1 system operation, and the system has consistently treated these chemicals to below the discharge criteria (NASA, 2012). Based on this information, the existing treatment system at OU1 is considered protective of human health and the environment.

Groundwater with aqueous concentrations of perchlorate and VOCs is located over 200 ft below ground surface and is treated prior to drinking water use at the LAWC treatment system and MHTS. Therefore, at this time, there is no exposure to untreated groundwater at the JPL site. However, if groundwater is not pumped and treated, VOCs and perchlorate may continue to migrate further within the Raymond Basin. Similar to OU1, stable or decreasing trends have been noted in perchlorate and VOC concentrations at the OU3 LAWC treatment system since it began operation in 2004 and at the MHTS since it began operation in 2011. Both systems have consistently treated chemicals in the extracted groundwater to concentrations below the MCLs (NASA, 2012). Based on this information, the existing MHTS and LAWC treatment systems at OU3 are considered protective of human health and the environment. Alternative 2 does generate concentrated perchlorate and VOC waste in the form of spent ion exchange resin and carbon, respectively; however, this waste stream is easily managed and can be disposed of safely in accordance with state and federal requirements.

13.2 Compliance with ARARs

Alternative 2 will comply with all ARARs identified for this remedial action, as described below. Discharge requirements for all treatment systems have been consistently achieved, as documented in the routine operating reports and recent five-year review (NASA, 2012). Further, concentrations of TCE in treated water from the MHTS and LAWC treatment systems have been non-detect, demonstrating that these systems will continue to achieve the TCE MCL in the future regardless of any potential change to the MCL. Concentrations in the groundwater have been shown to be decreasing over time, demonstrating that achieving MCLs within the aquifer can be achieved. In addition, all waste disposal for the OU1 and OU3 interim remedies will continue to be conducted in accordance with disposal requirements identified as part of the ARAR evaluation.

Compliance with ARARs addresses whether a response action alternative meets all pertinent federal and state environmental statutes and requirements. This section presents ARARs associated with RCRA, the South Coast Air Quality Management Board (SCAQMD), the Safe Drinking Water Act (SDWA), guidance set forth by the California DDW, and local requirements of the City of Pasadena for construction and water use. In accordance with U.S. EPA guidance, only those requirements that are ARARs to the response action are presented (U.S. EPA, 1999; Table 13-1). Because the JPL site is on the NPL, the site is subject to the provisions of CERCLA as amended by SARA.

13.2.1 Federal Regulations and Policy

Federal Safe Drinking Water Act and Federal MCLs. Treated water intended for drinking water use must comply with the federal ARARs associated with domestic use (federal MCL for PCE, TCE and carbon tetrachloride in drinking water as promulgated by U.S. EPA under the SDWA at 40 CFR § 141.61[a] and [c]). Therefore, the SDWA is an ARAR for the treated effluent water from the LAWC and City of Pasadena treatment systems. However, MCLs are not "applicable" ARARs for groundwater at NASA sites, but rather MCLs are generally considered relevant and appropriate as remedial goals for current or potential drinking water sources. Therefore, MCLs are potential chemical-specific federal ARARs for the final groundwater remedial action at OU1 and OU3.

RCRA Underground Injection Control. Section 3020 of RCRA applies to the underground injection in the context of RCRA and CERCLA cleanups, such as that included as part of the selected remedy for OU1. RCRA Section 3020(a) bans underground injection into or above a geologic formation that contains an underground source of drinking water. However, RCRA Section 3020(b) provides an exemption from that ban if certain conditions are met (U.S. EPA, 2002). These conditions include the following:

- The re-injection is part of a response action under Section 104 or 106 of CERCLA, or part of RCRA corrective action intended for site cleanup;
- The groundwater is treated to substantially reduce chemicals prior to such re-injection; and
- The cleanup will, upon completion, be protective of human health and the environment.

The groundwater is treated prior to re-injection during operation of the OU1 treatment system, which is included in the selected remedy. Based on this, activities at OU1 would be exempt from the RCRA underground injection control ban.

RCRA Land Disposal Restrictions. The applicability of RCRA land disposal restrictions (LDRs) to groundwater re-injection performed during an RCRA corrective action or CERCLA response action is also a consideration (see RCRA Sections 3004 (f), (g), and (m), and 40 CFR Parts 148 and 268). Groundwater undergoing re-injection may contain regulated chemicals; thus, the issue could be raised as to whether re-injection of groundwater should meet treatment standards identified as best demonstrated available technology (BDAT). An interpretation of the applicability of the RCRA LDRs is provided in a U.S. EPA memorandum titled "Applicability of Land Disposal Restrictions to RCRA and CERCLA Ground Water Treatment Reinjection" (U.S. EPA, 1989b). This memorandum explains that even though the LDR provisions address the same activity as RCRA Section 3020, U.S. EPA interprets the provisions of RCRA Section 3020 to be applicable instead of LDR provisions (U.S. EPA, 1989b).

Table 13-1. Summary of ARARs Relevant to the Selected Remedy for OU1 and OU3

Authority	Requirement	Status	Definition	Action Taken to Satisfy Requirement
Chemical-Specific ARARs				
Federal	Safe Drinking Water Act, Drinking Water MCLs – 40 CFR Part 141	Relevant and Appropriate	MCLs are legally enforceable standards that apply to public water systems. Primary standards protect public health by limiting the levels of contaminants in drinking water.	All groundwater will be treated to meet the most stringent state and federal drinking water requirements. MCLs are independently applicable requirements (not ARARs) for water purveyors. See Table 12-6 for numeric cleanup levels for carbon tetrachloride, TCE, and perchlorate.
State	California Safe Drinking Water Act of 1976, State MCLs – H&SC Section 4010.1 and 4026 – 22 CCR 64432.3 and 64444	Relevant and Appropriate	State MCLs are enforceable, regulatory standards under the California SDWA and must be met by all public drinking water systems to which they apply.	
Federal	Hazardous Waste Identification Criteria – 40 CFR 261	Applicable	Defines RCRA hazardous waste.	All spent media will be adequately characterized to determine if it qualifies as RCRA hazardous waste, and if so, spent media will be disposed of at a RCRA-permitted facility.
State	Hazardous Waste Identification Criteria – 22 CCR 66261.24	Applicable, if more stringent than 40 CFR 261	Defines non-RCRA (California) hazardous waste.	All spent media will be adequately characterized to determine if it qualifies as non-RCRA (California) hazardous waste, and if so, spent media will be disposed of at a facility permitted to accept non-RCRA (California) hazardous waste.
Action-Specific ARARs				
State	State Water Resources Control Board Resolution 68-16	Applicable	General waste discharge requirements associated with any groundwater re-injection during remedial activities.	Treated groundwater from the OU1 treatment system must meet the WDRs prior to re-injection to the aquifer.
State	State Water Resources Control Board Resolution 92-49 Section III.G.	Disputed	Requires remediation of the contaminated groundwater to the lowest concentration levels of constituents technically and economically feasible to protect beneficial uses, but not more stringent than needed to achieve background levels.	While not agreeing that the resolution qualifies as an ARAR, NASA meets the standard by voluntarily performing a Technical and Economic Feasibility Analysis (TEFA) that demonstrated that cleanup to background is not feasible. See discussion in Section 13.2.2.
Location-Specific ARARs				
There are no location-specific ARARs associated with the selected remedy.				

Another potential issue is whether LDR treatment standards are relevant and appropriate for treated groundwater that is re-injected as part of a CERCLA response action. U.S. EPA believes that the ultimate purpose of treatment is to restore the groundwater to drinking water conditions; thus, standards that have been developed to establish drinking water quality levels (e.g., MCLs) are to be used. Therefore, promulgated drinking water standards should be used where available. If no promulgated drinking water standard exists, then relevant and appropriate requirements such as health-based standards or LDR treatment standards should be used (U.S. EPA, 1989b).

RCRA Hazardous Waste Identification Criteria. These criteria (40 CFR 261) are promulgated by the federal government to define RCRA hazardous waste. A RCRA hazardous waste is a waste that appears on one of the four hazardous wastes lists (F-list, K-list, P-list, or U-list), or exhibits at least one of four characteristics (of hazardous waste): ignitability, corrosivity, reactivity, or toxicity. Hazardous waste is regulated under RCRA Subtitle C. This requirement may apply to the disposal of ion exchange and LGAC media and other process waste. The spent media will be characterized in accordance with RCRA and will be disposed of accordingly.

13.2.2 State Regulations and Policy

This section describes applicable State regulations and policy as they apply to groundwater remediation at the JPL CERCLA site. The State Water Resource Control Board has published guidance, titled *Compilation of Water Quality Goals* (2011), which contains information to help understand California's water quality standards adopted to protect the beneficial uses of surface water and groundwater resources. The following regulations and WDRs apply to OU1 and OU3.

California Safe Drinking Water Act and State MCLs. California has established standards that apply to sources of public drinking water, under the California SDWA of 1976 (H&SC Sections 4010.1 and 4026[c]). State MCLs are set forth in California Code of Regulations (CCR) Title 22, Section 64444. Some state MCLs are more stringent than the corresponding federal MCLs. In these instances, the more stringent state MCLs are applicable to the remedial action at JPL. NASA has determined that the substantive provisions of the standards in CCR Title 22, Section 64444 are relevant and appropriate to the final remedy for groundwater because VOCs and perchlorate will be removed from drinking water to meet the requirements of the California SDWA.

Non-RCRA (California) Hazardous Waste Identification Criteria. These criteria (CCR Title 22 Section 66261.24) are promulgated by the State of California to define non-RCRA (California) hazardous waste. A non-RCRA (California) hazardous waste can be identified as a listed waste, or as a waste that exhibits hazardous characteristics (ignitability, corrosivity, reactivity, and toxicity). This requirement may apply to the disposal of ion exchange and LGAC media. The spent media will be characterized in accordance with California hazardous waste requirements and will be disposed of accordingly.

RWQCB General Waste Discharge Requirements. General WDRs associated with groundwater re-injection during remedial activities are provided by the RWQCB Los Angeles Region in Order No. R4-2014-0187, *General Waste Discharge Requirements for Groundwater Remediation at Petroleum Hydrocarbon Fuel and/or Volatile Organic Compound Impacted Sites* (RWQCB, 2014). These general WDRs are applicable to in situ groundwater remediation or the extraction of groundwater with aboveground treatment and re-injection of treated groundwater to the same aquifer zone. The requirements contained in Order No. R4-2014-0187 are consistent with all water quality control policies, plans, and regulations in the California Water Code (CWC) and the revised Water Quality Control Plan (Basin Plan) for the Los Angeles Region (RWQCB, 1994). The general WDRs are intended to protect and maintain the existing beneficial uses of the receiving groundwater and are consistent with the anti-degradation provisions of State Water Resources Control Board Resolution No. 68-16 and Resolution No. 88-63.

RWQCB Order No. R4-2014-0187 requires that groundwater re-injection shall not adversely impact the receiving groundwater in terms of water quality and chemical concentrations at a "compliance point, downgradient and outside the application area." The application area at JPL is the same as the source zone (i.e., the 8-acre by 100-ft thick portion of the aquifer containing elevated levels of VOCs and perchlorate). Impacts to the water quality and chemical concentrations of the receiving groundwater will be evaluated as part of NASA's groundwater monitoring program at JPL based on analytical results from samples collected from monitoring wells located inside the application area (i.e., source area), wells located outside the source area but still within the plume of COCs, and wells located outside the current plume of COCs. Groundwater will be treated prior to re-injection (see Section 9.0) to reduce concentrations of COCs. All re-injected water will be treated to concentrations cleaner than the receiving water. The electron donor to be used will be the same as, or similar in nature to, carbon sources/electron donors listed in RWQCB Order No. R4-2014-0187. This action will comply with the substantive requirements associated with groundwater re-injection in the general WDRs and State Water Resources Control Board Resolution 68-16.

State Water Resources Control Board Policies and Procedures for Cleanup and Abatement of Discharges. The RWQCB requested inclusion of State Water Resources Control Board Resolution 92-49 as an Applicable Action-Specific ARAR at JPL. Resolution 92-49 would direct the groundwater to be cleaned up to background, or if that is not reasonable, to an alternative level that is the most stringent level that is economically and technologically feasible in accordance with Title 23, California Code of Regulations (CCR) Section 2550.4.

NASA Position

NASA has determined that the requirement in Resolution 92-49 ("Policies and Procedures for Investigation and Cleanup and Abatement of Discharges under Water Code Section 13304") to "clean up and abate the effects of discharges in a manner that promotes attainment of either background water quality, or the best water quality that is reasonable if background levels of water quality cannot be restored" is not an ARAR for the purpose of this remedial action. Notwithstanding this determination (see the U.S. EPA and RWQCB positions discussed below), NASA has met the intent of Resolution 92-49 by conducting a TEFA (included as Appendix E) in accordance with CCR, Title 23, Section 2550.4, Chapter 15.

All remedial actions under CERCLA must, as a threshold matter, be determined by the lead agency to be necessary to protect human health and/or the environment from unacceptable risk, and must furthermore be appropriate and relevant to the circumstances of a site release (42 USC Section 9621(a)(1) and (d)(1)). Both CERCLA and the NCP focus on cleaning up groundwater, where practicable and achievable within a reasonable timeframe, to a standard that will restore the designated uses of the groundwater, not to the lowest standard achievable regardless of risk (42 USC Section 9621(d)(2)(B)(i) and 40 CFR Section 300.430(a)(1)(iii)(F)).

Regarding applicability, and without prejudice to NASA's position above, the California non-degradation provisions are not applicable in this case because they are designed and directed towards State agencies that are directing cleanup under State law. State non-degradation provisions are also not ARARs in this case because: MCL standards that are set at zero are categorically not relevant and appropriate (40 CFR Section 300.430(e)(2)(i)(c)). Additionally, because background levels for some substances at issue in the JPL cleanup would be zero, such background levels in California non-degradation provisions are similarly not relevant and appropriate.

40 CFR Section 300.430 (e)(2)(i)(C)) and 40 CFR Section 300.400(g)(2)(vii) together require that a potentially relevant and appropriate requirement for groundwater reasonably relate, that it be relevant and appropriate, to the beneficial use of the groundwater being addressed. As discussed above, California non-degradation provisions requiring that cleanup standards be set at zero or the lowest standard technically and economically feasible, are not reasonably related, in the instant case, to any actual or potential use of the water or risks to users thereof. CCR provisions are designed for specific and discreet units that manage hazardous waste, such as landfills, surface impoundments, and other similar transfer, treatment, storage or disposal units, thus they are not reasonably related to the diffuse release sites located at JPL. Although tables in this ROD may contain information showing COCs to the RWQCB and comparison of these COCs to Water Quality Objectives, including secondary MCLs, the presentation of these data do not constitute an admission by NASA that Water Quality Objectives are ARARs.

U.S. EPA Position

U.S. EPA agrees that State Water Resources Control Board Resolution 92-49 is in part a potential ARAR for groundwater remediation. U.S. EPA does not believe that Resolution 92-49 is "Applicable" where NASA is the lead response agency, because by its terms, Resolution 92-49 applies to actions taken by the State Water Resources Control Board and the Regional Water Quality Control Boards. In particular, it is U.S. EPA's position that Section III.G., which contains a narrative requirement that "dischargers cleanup and abate the effects of discharges in a manner that promotes attainment of background water quality, or the highest water quality which is reasonable" may be relevant and appropriate in that it directs the establishment of a substantive, quantitative standard or criteria for cleanup of contaminated groundwater that is a potential source of drinking water.

Although the substantive cleanup requirement in Resolution 92-49 may be relevant and appropriate, it is U.S. EPA's position that the manner of implementation that has been proposed by the RWQCB, a TEFA to evaluate the practicability of achieving background level concentrations, is not a potential ARAR, because it identifies methods and procedures by which substantive determinations are made. "Requirements that prescribe methods and procedures by which substantive requirements are made effective for purposes of a particular environmental program are administrative, and are therefore not ARARs." NCP Preamble, 55 Fed. Reg. 8742 at 8756 (emphasis added). See 40 CFR §300.400(g). Further, because the potential ARAR is a narrative standard, the implementation of the potential ARAR will be left to the lead agency. As the lead agency, NASA will exercise its discretion to determine the cleanup level and the methods and procedures by which the cleanup level would be made effective, in this case, with reference to the Remedial Investigation and Feasibility Study. In this case, NASA voluntarily performed a TEFA that demonstrates that it is not economically feasible and may not be technically feasible to achieve background concentrations.

RWQCB Position

The RWQCB has identified State Water Resources Control Board Resolution 92-49 and CCR, Title 23, Section 2550.4 as proposed ARARs for determining cleanup standards for groundwater contamination at JPL. NASA and the RWQCB disagree about whether these RWQCB requirements are ARARs for this cleanup.

With regard to Resolution 92-49, the RWQCB asserts that this resolution is an ARAR for remedial actions of the contaminated groundwater and complies with CCR, Title 23, Section 2550.4. Furthermore, the RWQCB does not believe that the application of Resolution 92-49 is strictly limited to Section III.G. In this case, Resolution 92-49 requires remediation of the contaminated groundwater to the lowest concentration levels of constituents technically and economically feasible, which must at least protect the beneficial uses of groundwater, but not be more stringent than is necessary to achieve background levels of constituents in groundwater.

With regard to State Water Resources Control Board Resolution 68-16, the RWQCB asserts that this resolution is an ARAR for the actual or proposed injection of any discharge of waste into groundwater and is not strictly limited to a discharge of waste to treat contaminants. Waste is defined pursuant to Water Code Section 13050, subdivision (d), and includes, but is not limited to, the injection of any chemical or reagent to facilitate the protection or restoration of all beneficial uses of the groundwater. A discharge also occurs where polluted groundwater migrates to areas of high quality groundwater. In short, discharges subject to Resolution 68-16 including the continuing migration of any in situ treatment reagents or other waste as to waters of the State at levels that exceed water quality objectives or impact beneficial uses. “Waters of the State” includes surface and groundwater pursuant to Water Code section 13050, subdivision (e). With respect to CCR, Title 23, Division 3, Chapter 15, the RWQCB asserts that Chapter 15 regulates all discharges of hazardous waste to land that may affect water quality. A “waste management unit” is defined in Chapter 15 as “an area of land, or a portion of a waste management unit, at which waste is discharged” (23 CCR section 2601). Pursuant to Water Code section 13050, subdivision (d), the definition of “waste” is extremely broad and includes the injection of one or more chemicals to groundwater to the extent that there is a discharge to an “area of land.”

23 CCR Section 2550.4 requires the consideration of beneficial uses when establishing cleanup levels above background. The factors to be considered by NASA in performing a TEFA for groundwater are listed under Section 2550.4(d). Section 2550.6 requires monitoring for compliance with remedial action objectives for three years from the date of achieving cleanup levels. Section 2550.10 requires implementation of corrective action measures that ensure Title

23 cleanup levels are achieved through the zone affected by the release by removing waste constituents or by treating them in place.

With respect to the Basin Plan, the Los Angeles Water Board asserts that Chapter 2, Beneficial Uses, Chapter 3, Water Quality Objectives, and the sections in Chapter 4, Strategic Planning and Implementation entitled “Remediation of Pollution” and “Well Investigations” are ARARs and apply to determine the appropriate cleanup level in groundwater to protect beneficial uses and to meet water quality objectives.

The Los Angeles Water Board asserts that the taste and odor water quality objective specified in the Basin Plan for the Los Angeles Region allows sufficient flexibility to require compliance with secondary MCLs on a case-by-case basis. In this particular case, the RWQCB is not asserting that compliance with secondary MCLs must be demonstrated but reserves the discretion to interpret the narrative water quality objective to require compliance with secondary MCLs for other remedial actions. Secondary MCLs for taste and odor are based on drinking water standards specified in Table 64449-A (Secondary Maximum Contaminant Levels – Consumer Acceptance Limits) and Table 64449-B of Section 64449 (Secondary Maximum Contaminant Levels – Ranges) and an interpretation of the taste and odor narrative water quality established for groundwater in Chapter 3 of the Basin Plan.

In short, (1) Resolution 92-49; (2) Chapter 2, Beneficial Uses, Chapter 3, Water Quality Objectives, and the sections “Remediation of Pollution” and “Well Investigations” from Chapter 4, Strategic Planning and Implementation of the Basin Plan; and (3) 23 CCR Division 3, Chapter 15; are applicable requirements because they specifically address remedial actions taken in order to protect the quality of the waters of the State. They are substantive requirements that are legally enforceable, of general applicability, and are more stringent than federal requirements.

The RWQCB understands that NASA will continue to comply with the substantive requirements of Order No. R4-2014-0187, General Waste Discharge Requirements for Groundwater Remediation at Petroleum Hydrocarbon and/or Volatile Organic Compound Impacted Sites, and any amendments thereto that impose substantive requirements, as to the extraction of groundwater with aboveground treatment and re-injection of treated groundwater to the same aquifer zone where extraction occurred.

Technical and Economic Feasibility Analysis (TEFA)

NASA conducted a TEFA for achieving cleanup standards more stringent than Federal and State primary MCLs for groundwater cleanup (see Appendix E). The results of the TEFA indicated that achieving background levels for constituents in the groundwater; although likely technically feasible, is not economically feasible. All parties agree that the groundwater cleanup levels established in this Record of Decision, as supported by the TEFA, provides substantive compliance with State Water Resource Control Board Resolution 92-49 and CCR, Title 23, Section 2550.4. Resolution 92-49 and CCR, Title 23, Section 2550.4 are intended to result in cleanup to the lowest standard that is technically and economically feasible and that will protect beneficial uses of the “Waters of the State”. All parties agree that, at this time, standards for COCs in the groundwater are State and Federal MCLs, whichever is more stringent.

Summary

The parties desire to avoid disputing the issue of whether certain provisions of State law are ARARs and the parties acknowledge that one factor specified in the NCP for determining the relevance and appropriateness of any requirement is variance, waiver or exemption provisions specified in the requirement (40 CFR Section 333.430(g)(2)(v)). Accordingly, without prejudice to the positions of the respective parties, which all parties have respectively preserved and reserved, in this particular case, NASA conducted an analysis of the technical and economic feasibility of achieving cleanup standards more stringent than MCLs. In doing so, NASA is neither directly nor indirectly acknowledging that either concentration levels below MCLs or a TEFA are ARARs. NASA has determined that it is not technologically or economically feasible to clean the groundwater at JPL to background concentrations for all substances released at the sites, and that it is not necessary to do so, in this particular case, to protect human health and the environment. Further, as a result of the TEFA and review by U.S. EPA, DTSC, and the RWQCB, all parties agree that groundwater cleanup levels established in this ROD in this particular case are the lowest concentrations feasible. Based in part on information in the TEFA, the U.S. EPA, DTSC, and the RWQCB agree with the TEFA analysis and determination that, in this particular case, the CERCLA and NCP compliant cleanup standards shall be the Federal or State Primary MCLs, whichever are more stringent. DTSC and the RWQCB further concur that the cleanup standards will not pose a substantial threat to human health or the environment.

13.2.3 Other Regulatory Requirements

Because the drinking water treatment plants constituting the selected remedy at OU3 are leased and operated by the City of Pasadena and LAWC, a number of regulations need to be complied with in addition to NASA's requirements under CERCLA. In addition, any actions that take place off site (such as at the LAWC treatment plant) are still subject to all independently applicable laws.

California Code of Regulations Titles 17 and 22. The City of Pasadena and LAWC are required to comply with all applicable regulations associated with drinking water identified in CCR Titles 17 and 22. This includes obtaining certification of treatment plant operators and a permit to operate the system from the state.

California Department of Public Health Policy Memo 97-005. *Policy Memo 97-005: Policy Guidance for Direct Domestic Use of Extremely Impaired Sources* (California DDW, 1997) provides guidance by which California DDW evaluates proposals, establishes appropriate permit conditions, and approves the use of a source for any direct potable use within a CERCLA OU. According to California DDW policy, drinking water downgradient of the JPL facility is considered an "extremely impaired source" because it meets the following criteria as quoted in the policy: (1) a chemical exceeds three times its associated MCL or notification level (NL) based on acute health effects, and (2) the drinking water is considered threatened due to the proximity to known chemicals in the groundwater from the JPL facility. California DDW guidance is applicable to the City of Pasadena and LAWC as part of purveying drinking water. This policy requires additional documentation from the drinking water purveyor prior to restoring use of the drinking water supply wells. California DDW Policy Memo 97-005 was addressed during design and implementation of the OU3 interim response action (NASA, 2010).

California Environmental Quality Act. As part of construction of the LAWC and MHTS facilities, the City of Pasadena and LAWC were required to comply with the California Environmental Quality Act (CEQA). A CEQA assessment was conducted during the design of the MHTS (as part of the OU3 interim action) to evaluate the potential impacts to the following environmental factors: aesthetics, biological resources, hazards and hazardous materials, mineral resources, public services, utilities/service systems, agricultural resources, cultural resources, hydrology/water quality, noise, recreation, air quality, geology/soils, land use/planning, population/housing, and transportation/traffic. This was completed and approved prior to construction of the MHTS to ensure that work was conducted in such a way that environmental impacts associated with the treatment plant were addressed.

Local Permit Requirements. The Windsor Reservoir site is located within the city limits of Pasadena, and as part of the MHTS construction, the City of Pasadena was required to obtain local permits prior to constructing the new treatment facility. These included a Conditional Use Permit and a Building Permit. LAWC also complied with the construction permitting requirements of the County of Los Angeles during construction of the LAWC treatment system. Any modifications to these existing systems would have to comply with local permit requirements.

13.2.4 Legal Considerations

Adjudicated Groundwater Rights. JPL is located in the Monk Hill subarea of the Raymond Basin. In 1944, the Superior Court of California approved the Raymond Basin Judgment, which adjudicated the rights to groundwater production to preserve the safe yield of the groundwater basin. Adjudication refers to the practice of land owners and other parties allowing the courts to settle disputes over how much groundwater can rightfully be extracted. In an adjudicated groundwater basin, the court appoints a Watermaster to administer the court judgment and determine an equitable distribution of water that will be available for extraction each year. The RBMB, made up of representatives of the water purveyors, oversees the management and protection of the Raymond Basin. A total of six Raymond Basin water purveyors, including the City of Pasadena and LAWC, operate wells in the Monk Hill subarea. The City of Pasadena and LAWC will continue to be subject to the extraction, reporting, and monitoring requirements associated with the Raymond Basin Judgment.

NASA has worked closely with the RBMB, PWP, and LAWC to ensure that treated groundwater is used in the most beneficial manner. For the MHTS and LAWC systems, treated groundwater is used for drinking water supply and quantities are reported to the RBMB in accordance with the adjudication. All wastewater generated by the OU3 systems is treated as required to meet surface water discharge requirements and discharged to the Arroyo Seco where it infiltrates back into the aquifer.

While NASA is not a party to the adjudication, NASA has worked closely with the RBMB, designing the OU1 treatment plant to minimize the amount of wastewater. Since 2005, NASA has re-injected 99.9% (2,853 extracted and 2,850 acre feet re-injected) of the treated groundwater, and the small quantity of wastewater that is generated is reported to the RBMB on a monthly basis.

13.2.5 Other Applicable Requirements

CERCLA Offsite Rule. The off-site rule (40 CFR 300.440) applies to any response action involving the off-site transfer of CERCLA wastes. Therefore, the off-site rule will apply to disposal of spent LGAC and other process waste associated with the source area treatment system. The purpose of the off-site rule is to avoid having CERCLA wastes from response actions authorized or funded under CERCLA contribute to present or future environmental problems by directing these wastes to management units determined to be environmentally sound (preamble to final Off-Site Rule, 58 *Federal Register* 49200, 49201, Sept. 22, 1993). All waste will therefore be disposed of at a facility that is permitted to accept waste from the CERCLA site.

13.3 Cost-Effectiveness

Cost-effectiveness is determined by comparing the cost of all alternatives being considered with their overall effectiveness to determine whether costs are proportional to the effectiveness achieved. The overall effectiveness of a remedial alternative is determined by evaluating (1) long-term effectiveness and permanence, (2) reduction in toxicity, mobility, or volume through treatment, and (3) short-term effectiveness. Table 13-2 presents a comparison of costs and effectiveness of Alternative 1 (No Action) and Alternative 2 (Active Treatment).

Alternative 1 is not effective over the long term because, under this alternative, VOCs and perchlorate in the groundwater can continue to migrate into off-facility areas, and groundwater from the four City of Pasadena Monk Hill subarea production wells and LAWC production wells LAWC#3 and LAWC#5 cannot be used for drinking water purposes. Alternative 2 is effective over the long term because the process permanently removes VOCs and perchlorate from the groundwater and restores the groundwater for drinking water use by the local community (LAWC and the City of Pasadena). After remediation is complete, groundwater chemical concentrations will be below the cleanup goals, thus making the groundwater suitable for drinking water without additional treatment for VOCs and perchlorate.

Alternative 1 (No Action) is not a treatment technology and does not reduce the toxicity, mobility, or volume of VOCs or perchlorate in the groundwater at OU1. Alternative 2, active treatment, is a remedy that permanently and irreversibly removes VOCs and perchlorate from groundwater. Thus, Alternative 2 reduces the volume and mobility of VOCs and perchlorate in the groundwater.

Table 13-2. Comparison of Costs and Effectiveness of Alternatives for OU1 and OU3

Alternative	Present-Worth Cost	Long-Term Effectiveness and Permanence	Reduction of Toxicity, Mobility, or Volume Through Treatment	Short-Term Effectiveness
Alternative 1 (No Action)	$0	• Not effective over the long term • VOCs and perchlorate can continue to migrate into unaffected	• Not a treatment technology • Does not reduce toxicity, mobility, or volume of VOCs and	• No short-term effects on workers, public, or the environment

Alternative	Present-Worth Cost	Long-Term Effectiveness and Permanence	Reduction of Toxicity, Mobility, or Volume Through Treatment	Short-Term Effectiveness
		groundwater • Groundwater is not restored for drinking water use	perchlorate in groundwater	
Alternative 2 (Active Treatment)	$175,000	• Effective over the long term • VOCs and perchlorate permanently removed from groundwater • Groundwater restored for drinking water use	• Presumptive remedy • Permanently removes VOCs and perchlorate from groundwater	• Insignificant short-term effects on workers, the public, and the environment

Alternative 1 does not include remedial action. Because this alternative does not require construction or installation of equipment on facility, potential short-term effects to workers, the public, and the environment are minimal. Alternative 2 presents minimal risk to workers, the public, and the environment. Groundwater extraction, treatment and re-injection systems are designed so that extraction, injection wells, and associated piping are under constant monitoring. The VOCs and perchlorate in the extracted groundwater are removed by an aboveground treatment system, in accordance with state and local regulations. The potential short-term effects to workers, the public, and the environment are expected to be minimal during continued operation of treatment systems.

The estimated present-worth cost of Alternative 1 is $0. Because Alternative 1 does not reduce the toxicity, mobility, or volume of VOCs and perchlorate at OU1, it is not effective in the long term, and, therefore, is not a cost-effective alternative.

The estimated present-worth cost of Alternative 2 is $175,000, representing additional costs associated with this Final ROD. Costs for O&M of all three systems and groundwater monitoring were accounted for and authorized as part of the Interim RODs for OU1 and OU3. Because Alternative 2 permanently reduces the volume of VOCs and perchlorate at OU1 and OU3, and restores the use of groundwater at OU3, it is cost-effective in the long term.

NASA and the regulatory authorities agree that the costs associated with continued operation of the treatment systems are justified because the response action reduces and removes VOCs and perchlorate from groundwater at JPL OU1 and reduces the potential for continued migration of untreated groundwater to off-facility areas. In addition, groundwater in OU3 is restored as a drinking water source for the local community (City of Pasadena and LAWC).

13.4 Use of Permanent Solutions and Alternative Treatment Technologies

Alternative 1 (No Action) cannot meet the RAOs because, under this alternative, further migration of VOCs and perchlorate from the JPL site is not prevented, and beneficial use of groundwater containing VOCs and perchlorate originating from JPL is not restored. In addition, Alternative 1 is not a treatment technology, does not reduce the toxicity, mobility, or volume of chemicals of concern at OU1, and is not effective over the long term because VOCs and perchlorate are left in place.

Alternative 2 (active treatment), the selected remedy, is a remedy that permanently removes VOCs and perchlorate from the groundwater, thus reducing the volume of chemicals of concern at OU1 and restoring unrestricted beneficial use of groundwater containing VOCs and perchlorate originating from JPL. This alternative is effective over the long term, is protective of human health and the environment, and can meet all ARARs.

13.5 Preference for Treatment as a Principal Element

The selected remedy will continue to permanently remove VOCs and perchlorate from the groundwater at OU1 and OU3, and thus reduce volume and mobility of the chemicals. In addition, centralized treatment provides for immediate restoration of the OU3 groundwater as a drinking water source. The selected remedy meets the CERCLA preference for treatment as a principal element.

13.6 Five-Year Review Requirements

NASA intends to remove VOCs and perchlorate in the groundwater at JPL to prevent further migration of VOCs and perchlorate to unaffected groundwater used for drinking water, and will reduce the concentrations of hazardous substances, pollutants, or contaminants remaining in the groundwater to levels that allow for unlimited use and unrestricted exposure. Therefore, a statutory review will not be required pursuant to CERCLA Section 121(c) after the remedy is complete. However, because it will take more than five years to complete the remedial actions, as a matter of policy, a review shall be conducted within five years after initiation of remedial action and every five years thereafter until the remedial action is complete, pursuant to EPA’s Comprehensive Five-Year Review Guidance, OSWER No. 9355.7-03 B-P (June 2001), to ensure that the remedy is, or will be, protective of human health and the environment.

14.0 Documentation of Significant Changes

The Proposed Plan (NASA, 2014b) identified Alternative 2, active treatment, as the preferred alternative for remediation of groundwater chemicals of concern at JPL (OU1) and the off-facility areas (OU3). NASA reviewed and considered all written and verbal comments submitted during the public comment period. Responses to all comments received during the public comment period are provided in Part III Responsiveness Summary. It was determined by NASA, U.S. EPA, DTSC, and RWQCB that no significant changes to the remedy, as originally identified in the Proposed Plan, were necessary or appropriate.

It should be noted that this ROD includes a clarification related to cost that was not made in the Proposed Plan. Costs for O&M of all three systems and groundwater monitoring were accounted for and authorized as part of the Interim RODs for OU1 and OU3 (NASA, 2007b and 2007c). Only costs for additional actions are authorized in this Final ROD. Additional actions include implementation of ICs, which are estimated at a total cost of $175,000.

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PART III: RESPONSIVENESS SUMMARY

The purpose of the Responsiveness Summary is to provide an opportunity for the National Aeronautics and Space Administration (NASA) to review and respond to the public's comments, concerns, and questions about the remedial approach selected to clean up groundwater at the Jet Propulsion Laboratory (JPL). This summary also includes an overview of the selected remedy and a background on the community involvement program at the JPL site.

1.0 Overview

NASA performed a thorough review of all comments received during the public comment period associated with the remedial approach selected to clean up groundwater at JPL. This responsiveness summary describes NASA's analyses and response to comments. Based on this analysis, NASA has decided to proceed with the preferred alternative described in the Proposed Plan for groundwater remediation (NASA, 2014a), which includes:

(i) Continuing to fund and operate the three existing treatment systems in Operable Units 1 and 3 (OU1 and OU3). The three systems have proven effective and will continue to remove COCs from groundwater including perchlorate and volatile organic compounds (VOCs). The three systems include the 300 gallon per minute (gpm) OU1 source area treatment system, the 2,000 gpm Lincoln Avenue Water Company (LAWC) treatment system located at the leading edge of the chemical plume, and the 7,000 gpm Monk Hill Treatment System (MHTS) located mid-plume.

(ii) Addition of various institutional controls (ICs) to ensure impacted groundwater within the JPL site is not utilized without appropriate evaluation and/or treatment. ICs will be implemented as part of the preferred alternative via a legal agreement with the Raymond Basin Management Board (RBMB) and/or the State of California. The agreements include commitments that require the agency to notify NASA of any proposed new extraction wells in the Monk Hill Subarea, and that NASA evaluate the impact of any proposed extraction wells within/near the capture zones on the remedies for OU1 and OU3. In addition, NASA will conduct annual reviews of new well permits in the Monk Hill Subarea as an additional control to prevent exposure to chemicals.

(iii) Continuing the routine groundwater monitoring program to monitor remedy performance and effectiveness.

Continuation of the current systems is preferred by NASA because historical operating data demonstrate that there has been a decreasing trend in perchlorate and VOC concentrations in the extracted groundwater over the duration of operation, and the systems have consistently treated chemicals to below cleanup levels for OU1 and established drinking water criteria for OU3, including maximum contaminant levels (MCLs). Based on this information, the existing OU1 and OU3 treatment systems are considered protective of human health and the environment and are effectively working to remove site-related chemicals from the groundwater in an aquifer. In addition, groundwater monitoring data show that these systems have been effective in containing chemicals originating from JPL. Lastly, the OU3 systems have restored use of a valuable groundwater resource for Altadena and Pasadena.

2.0 Background on Community Involvement

For more than a decade, NASA has engaged in outreach to residents of the communities surrounding JPL, updating them on the status of the cleanup efforts for the JPL CERCLA site by holding public meetings, mailing newsletters, maintaining a website (http://jplwater.nasa.gov), preparing annual summaries of investigation and cleanup efforts, and meeting with and listening to community groups, individuals, health care and local government representatives, and water purveyors. A *Community Involvement Plan Update* was finalized in June 2014 (NASA, 2014b).

In January 2004, public meetings were held to inform the public and JPL employees about the progress of cleanup activities that included describing several possible treatment technologies and alternatives to treat perchlorate and VOCs beneath the JPL facility. A newsletter on the project was also mailed to more than 15,000 residents of communities surrounding JPL.

In April 2004, a public meeting was held to discuss questions about potential public health effects associated with chemicals in the groundwater near JPL. Newsletters were distributed to more than 15,000 local residents in August 2004 and March 2005 describing cleanup actions funded by NASA at the two LAWC wells. In addition, numerous fact sheets were prepared to address specific questions from the community. All newsletters and fact sheets are available at the JPL CERCLA Program website (http://jplwater.nasa.gov).

A community information session (CIS) was held in March 2005, providing an opportunity for attendees to speak with NASA project staff and contractors involved in the cleanup. The CIS included a series of displays describing the site background and treatment options among other topics. The OU3 systems (the existing treatment plant for LAWC and the then-proposed MHTS) also were discussed at this session.

On November 16, 2005, a public meeting was held to provide information, and receive public comments on a Proposed Plan for the OU1 source area groundwater treatment system as an interim remedy. On May 3, 2006, a public meeting was held to provide information, and receive public comments on a Proposed Plan for the off-facility OU3 treatment systems as an interim remedy. Responsiveness summaries were prepared following the public comment period for each Proposed Plan and included with the respective Interim RODs for OU1 and OU3.

Since 2006, progress of the OU1 system, LAWC plant, and MHTS has continued to be communicated to the community via newsletters, annual year-in-reviews, site tours, and the JPL CERCLA Program website. NASA also worked closely with the City of Pasadena prior to and during construction of the MHTS (2008 through 2011) to obtain community feedback on the treatment system location, landscaping, and construction mitigation measures (e.g., noise, dust).

On October 29, 2014, NASA issued the Proposed Plan for Groundwater Remediation at NASA JPL, which presented the preferred alternative for cleanup of OU1 and OU3 groundwater. A public meeting was held on November 12, 2014 to present the Proposed Plan and to allow the public to comment or ask questions about the preferred alternative. Residents were informed of the public meeting and the public comment period through newspaper ads, flyers in the community, and by postcard mailings to more than 5,000 local residents on NASA's mailing list.

Based on requests from the public, NASA extended the public comment period from December 3, 2014 to January 30, 2015 and then again to March 3, 2015. Residents were informed of the public comment period extensions via a newspaper ad (first extension only), a mailing to over 5,000 local residents on NASA's mailing list (first extension only), e-mail notifications, and website postings.

NASA continues to regularly update its website (http://jplwater.nasa.gov) with news and information about the cleanup program. Official documents related to the cleanup can be found in the Administrative Record section of the website and via the computers found at these Information Repositories:

La Cañada Flintridge Public Library
4545 Oakwood Ave.
La Cañada Flintridge, CA 91011
(818) 790-3330

Altadena Public Library
600 East Mariposa Ave.
Altadena, CA 91001
(626) 798-0833

Pasadena Central Library
285 East Walnut St.
Pasadena, CA 91101
(626) 744-4052

JPL Library
(JPL Employees Only)
Building 111, Room 112
(818) 354-4200

3.0 Summary of Public Comments Received during the Public Comment Period and Responses from NASA

This section summarizes key issues expressed by the public during the public comment period (November 3, 2014 through March 3, 2015) and NASA's responses. Sections 3.1 through 3.7 categorize the questions and comments received that were shared by three or more members of the community and Sections 3.8 and 3.9 address comments that were expressed by only one or two individuals in the community.

NASA received comments on the Proposed Plan from a total of 11 individuals/organizations, several of whom had comments on multiple aspects of the Proposed Plan. Three commenters submitted a comment card provided at the public meeting, or provided comments as part of the public meeting transcript. Another four commenters sent their comments by letter via the U.S. Mail. A remaining four commenters provided comments via e-mail directly to NASA.

Appendix F provides a table with each comment provided during the public comment period and NASA's response. The meeting transcript from the November 12 public meeting and copies of each of the letters and comment cards that were submitted during the public comment period are provided in Appendix G.

3.1 Extension to the Public Comment Period on NASA's Preferred Alternative

Three comments were received by NASA requesting an extension to the public comment period.

NASA Response: NASA extended the public comment period from December 3, 2014 to January 30, 2015. NASA later further extended the public comment period to March 3, 2015.

3.2 Cleanup Levels for Perchlorate and Other Compounds

Eight comments were received by NASA related to the cleanup levels identified in the Proposed Plan.

NASA Response: NASA appreciates that people have concerns as to whether exposure to perchlorate and other chemicals could have resulted in health concerns. As soon as levels of chemicals above State of California notification levels were discovered in drinking water wells, the wells were immediately removed from service, and NASA has since been taking steps to remove chemicals from the groundwater using three treatment systems.

NASA has established cleanup goals that meet all applicable laws and regulations and are fully protective of public health and the environment. Drinking water quality is overseen by California State Water Resources Control Board Division of Drinking Water (DDW). NASA has worked closely with DDW, LAWC, and PWP to obtain drinking water permits for the LAWC system and the MHTS. The OU3 treatment systems have and will continue to be operated in accordance with DDW permitting requirements.

NASA is committed to cleaning up groundwater. The selected alternative will effectively do that, and ensure a continued source of groundwater to LAWC and PWP that meets state and federal drinking water standards.

3.3 Support for NASA's Cleanup Approach

Four comments were received by NASA expressing support for the preferred alternative.

NASA Response: NASA appreciates the support associated with the remedial approach presented in the Proposed Plan.

3.4 Sunset Reservoir Area Wells

Five comments were received by NASA regarding the inclusion of the Sunset Reservoir Area wells as part of the JPL site.

NASA Response: The City of Pasadena's concerns with chemicals detected in the Sunset Reservoir wells, located approximately 3 to 4 miles downgradient of the JPL site, have been thoroughly evaluated by NASA, the U.S. EPA, and the state regulators (DTSC and RWQCB). Prior to proceeding with the Proposed Plan, NASA thoroughly investigated the extent of chemicals from the JPL CERCLA site and defined the boundaries of chemicals in groundwater. A summary of the *History and Status of NASA's Additional Investigation Associated with Perchlorate in PWP's Sunset Reservoir Wells* is provided on the JPL CERCLA website homepage (http://jplwater.nasa.gov/) under News Updates. Below is an abbreviated summary.

In 2005, NASA conducted an additional investigation to determine if the occurrence of perchlorate in the Sunset Reservoir wells was associated with chemical migration from the JPL facility. Upon completion of the investigation and subsequent technical interactions with PWP and the regulators, NASA concluded that (1) the chemicals from the JPL facility are captured within the Monk Hill Subarea, and (2) the perchlorate detected at the Sunset Reservoir wells is of a different origin than that used at, and originating from, JPL (NASA, 2007a; 2008). All NASA documentation and reviews provided by PWP, the regulators, and others were made available at the CERCLA program website.

In 2012, PWP prepared additional technical memoranda concerning perchlorate in the Sunset Reservoir wells. NASA thoroughly evaluated these memoranda and again concluded (1) the chemicals from the JPL facility are captured within the Monk Hill Subarea, and (2) the perchlorate detected at the Sunset Reservoir wells is of a different origin than that used at, and originating from, JPL.

The Sunset Reservoir wells were discussed at the April 30, 2013 project meeting, and additional meetings and technical discussions were conducted by PWP, U.S. EPA, DTSC, and RWQCB representatives regarding perchlorate in the Sunset Reservoir wells. Subsequently, U.S. EPA issued a letter on November 19, 2013 to Ms. Phyllis Currie, PWP General Manager, which stated that U.S. EPA, DTSC, and RWQCB agreed that based on currently available information, the Sunset Reservoir well area is not part of the NASA JPL CERCLA site.

The White Paper provided by PWP on December 1, 2014 does not present any new information or additional analysis that would change the conclusions reached by NASA.

NASA will continue to monitor groundwater between the JPL site and the Sunset Reservoir wells. Data from this monitoring will be evaluated, at a minimum, as part of the five-year reviews for JPL.

3.5 Additional ARARs

Four comments were received by NASA requesting the inclusion of additional ARARs, including the National Environmental Policy Act (NEPA).

NASA Response: The NASA JPL Site is regulated under CERCLA. CERCLA includes a rigorous process for the investigation of sites, as well as the analysis of alternatives to address contamination and achieve cleanup. This includes addressing the potential for impacts and developing mitigation measures to address potential impacts of cleanup alternatives. CERCLA actions do not require a separate NEPA or CEQA review because the CERCLA process is essentially equivalent to the NEPA process. Courts consistently have recognized that U.S. EPA procedures or environmental reviews under enabling legislation (including CERCLA) are functionally equivalent to the NEPA process and thus exempt from the procedural requirements in NEPA (http://www.epa.gov/compliance/nepa/epacompliance/).

A NEPA values assessment was completed as part of the Interim Records of Decision for OU-1 and OU-3 (NASA, 2006a). In addition, during implementation of the LAWC treatment system and MHTS, CEQA evaluations were performed by LAWC and the State Water Resources Control Board, and Pasadena Water and Power.

3.6 Additional Remedial Alternatives

Three comments were received by NASA requesting evaluation of additional remedial alternatives.

NASA Response: NASA appreciates the questions regarding what cleanup and scientific methods are available to address chemicals in groundwater. Information has been added to Parts II of this ROD to summarize the thorough evaluation of technologies and alternatives performed at the site, including those described in the Interim RODs for OU1 and OU3 (NASA, 2007b; NASA, 2007c). Those analyses formed the basis for selection of the interim remedies and that information was also considered for the Proposed Plan. The technologies and alternatives identified in the Proposed Plan are the most appropriate for cleanup of groundwater at the JPL Site.

In January 2000, NASA completed a draft Feasibility Study that identified and evaluated various groundwater cleanup alternatives for both the source area and in off-facility areas adjacent to the JPL facility (Foster Wheeler Environmental Corporation [FWEC], 2000). In addition, a literature review was conducted to assess the development status of various biological, physical, chemical, and thermal treatment technologies used for the removal of perchlorate from groundwater (NASA, 2006b). As part of this effort, NASA also conducted a number of different pilot tests to see which technologies might be the most promising for use at the JPL site. The technologies tested included reverse osmosis, fluidized bed reactor (FBR), packed bed reactors, in situ bioremediation, and ion exchange.

Due to the depth and extent of the chemicals in groundwater as well as the location and density of buildings at JPL, in situ bioremediation is not practical, nor cost-effective, at JPL. Therefore, groundwater must be pumped from the ground and treated aboveground. The best aboveground perchlorate treatment depends on several factors including the perchlorate concentrations that exist, specific site conditions, and other considerations. Two perchlorate treatment processes have been proven at full-scale application at JPL and other sites: FBR and ion exchange.

FBR is cost effective for relatively high concentrations of perchlorate and at locations where continuous operation can be achieved, such as the source area beneath JPL. The FBR contains carbon particles covered with a coating of bacteria that destroy perchlorate. The primary advantages of this system are the destruction of perchlorate and relatively low operational cost.

Ion exchange consists of small plastic beads, or resin, in a tank. As the water passes through the tank, perchlorate attaches to the resin. After enough perchlorate attaches to the resin, the resin is removed and sent to a licensed disposal facility, and new resin is added. Ion exchange is the only perchlorate removal technology that has been used for drinking water systems in California. Ion exchange is more cost-effective at low perchlorate levels, such as those found in groundwater off-facility, and it is more appropriate for operations where the flowrate is varied, such as the MHTS and the LAWC treatment system.

The U.S. EPA has identified air stripping and LGAC as the best technologies to use for aboveground treatment of groundwater containing VOCs, referring to these as “presumptive technologies” (U.S. EPA, 1996). U.S. EPA expects these technologies to be used for removal of VOCs at “all appropriate sites.” LGAC treatment is currently in place at JPL and is working effectively as part of all three treatment systems.

3.7 Health Concerns Associated with Exposure to Chemicals

Fifteen comments were received by NASA with health concerns regarding exposure to chemicals originating from JPL, including those in soil, surface water, groundwater, and drinking water.

NASA Response: NASA recognizes that some members of the public have concerns about the potential for health effects as a result chemicals originating from JPL and has always taken such concerns seriously. NASA’s chemicals are located in the deep groundwater beneath JPL (more than 300 feet below the surface). Chemicals originating at JPL are not found in off-site soils or surface water. The only exposure pathway that exists for humans and animals is ingestion of groundwater pumped from deep below the ground surface. Groundwater pumped from nearby drinking water production wells is treated to remove NASA’s chemicals prior to distribution to consumers. Perchlorate is removed from the pumped water using a proven and approved technology called ion exchange. Volatile organic compounds (VOCs) are removed from the pumped water using a proven and approved technology called liquid-phase granular activated carbon (LGAC). After treatment, the concentrations of chemicals are well below federal and state drinking water MCLs, which are levels considered safe for human consumption. The State of California establishes safe levels for drinking water consumption.

Chemicals from the JPL Site are not present in soil or surface water present in the Arroyo Seco. Information has been added to Part II of this ROD regarding investigation results of soil and surface water in the Arroyo.

NASA recognizes there have been concerns about the potential for health impacts and has provided health experts and agencies responsible for protecting public health to respond to such questions. NASA brought in Dr. Thomas Mack, a prominent area epidemiologist, to evaluate the data and NASA hosted a public meeting to understand community concerns. Dr. Mack is the Director of the Division of Epidemiology at the University of Southern California Norris Cancer Center and the Department of Preventive Medicine in the USC Keck School of Medicine, Los Angeles.

Dr. Mack conducted extensive research on the incidence of cancers in Southern California. He looked at 84 types of cancers and how they are distributed in 1600 census tracts in Los Angeles County. Dr. Mack found that none of the cancers was shown to be at a higher-than-expected incidence-level in the census tracts near JPL, with the exception of prostate cancer which is not associated with perchlorate.

Dr. Mack's research may be examined in his book *Cancers in the Urban Environment* (June 2004), available at the Altadena Public Library, the La Cañada Flintridge Public Library and the Pasadena Central Library.

A link to a summary of a NASA-facilitated Community Meeting on Health, at which Dr. Mack and other experts spoke, may be found on the NASA groundwater cleanup website at http://jplwater.nasa.gov. The State of California agencies responsible for ensuring public safety, DDW and DTSC, were also at the meeting. NASA has coordinated closely with these agencies on investigation and cleanup action at the JPL Site.

In addition, the Agency for Toxic Substances and Disease Registry (ATSDR) conducted site visits in 1997 to assess the potential for public health hazards associated with groundwater adjacent to the JPL facility (ATSDR, 1999). ATSDR determined that the VOCs in groundwater do not present a past, present, or future public health concern to JPL employees or nearby residents. On-facility groundwater has never been used as a source for drinking water and area water purveyors regularly monitor to ensure that the water meets the federal and state water quality standards. Based on an analysis performed by the ATSDR, it was determined unlikely that chemicals in groundwater posed a past public health hazard.

NASA is committed to cleaning up the aquifer containing chemicals originating from JPL. The three systems that are in place and operating provide the best approach for achieving the cleanup objectives.

3.8 Other Technical Clarifications and Requests

Ten comments received by NASA were specific technical requests or clarifications. These included a request for a seismic and energy study, concern about the current drought in California, a request for better maps, a request for new monitoring wells, inclusion of website references, as well as clarifications about plume movement and monitoring, the 2012 five-year review, reinjection at the OU1 system, OU2 cleanup, sediment removal required for the Devil's Gate Reservoir, and landfill disposal.

NASA Response: Responses to these technical clarifications and requests are provided in the responses to comments table provided in Appendix F.

3.9 Other Administrative Clarifications and Requests

Seven comments received by NASA were specific administrative requests or clarifications. These included requests to continue communication and update the Community Involvement Plan, a request to make available and update the Federal Facilities Agreement (FFA), a request to be added to the mailing list, clarification on the impact of the cleanup approach on local taxes and fees, and concern about potential conflict of interest between NASA and PWP regarding the East Parking Lot lease.

NASA Response: Responses to these administrative clarifications and requests are provided in the responses to comments table provided in Appendix F.

3.10 Data Sources Identified by Project Soliton

Project Soliton requested that "all the data found in the internet url addresses" referenced in their comment letter be made available to the public and as part of the Administrative Record. Project Soliton's letter can be found in Appendix G.

4.0 REFERENCES

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