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FINAL

OPERABLE UNIT 3
REMEDIAL INVESTIGATION (RI) ADDENDUM WORK PLAN
(PASADENA SAMPLING PLAN [PSP]-2004-1)

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

November 2004

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Abbreviations and Acronyms

3-D	three-dimensional
bgs	below ground surface
Cal-EPA	California Environmental Protection Agency
CCl_4	carbon tetrachloride
CCR	California Code of Regulations
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFEST	Coupled Flow Energy and Solute Transport model
CFR	Code of Federal Regulations
DEH	(Los Angeles County) Department of Environmental Health
DHS	(California) Department of Health Services
DO	dissolved oxygen
DTSC	(California) Department of Toxic Substances Control
DWR	(California) Department of Water Resources
EM	electromagnetic imaging
FWEC	Foster Wheeler Environmental Corporation
FFA	Federal Facility Agreement
GPR	ground-penetrating radar
GSC	General Sciences Corporation
IDW	investigation-derived waste
JPL	Jet Propulsion Laboratory
K_d	distribution coefficient
LAWC	Lincoln Avenue Water Company
LCID	La Cañada Irrigation District
LCS	laboratory control sample
MCL	maximum contaminant level
MDL	method detection limit
MOA	Memorandum of Agreement
MS/MSD	matrix spike/matrix spike duplicate
MWD	Metropolitan Water District (of Southern California)
N/A	not analyzed
NA	not available
NASA	National Aeronautics and Space Administration
NAVFAC	Naval Facilities Engineering Command
ND	not detected
NDMA	*n*-nitrosodimethylamine
NPL	National Priorities List

O.D.	outside diameter
ORP	oxidation-reduction potential
OU	Operable Unit
PCE	tetrachloroethene
PVC	polyvinyl chloride
PUSD	Pasadena Unified School District
PWP	Pasadena Water and Power
QA/QC	quality assurance/quality control
RBMB	Raymond Basin Management Board
RCLWA	Rubio Canyon Land and Water Association
RI	Remedial Investigation
RWQCB	Regional Water Quality Control Board, Los Angeles Region
SAP	Sampling and Analysis Plan
SARA	Superfund Amendments and Reauthorization Act
SESOIL	Seasonal Soil Compartment model
SHSP	Site Health and Safety Plan
SVOC	semivolatile organic compound
TBD	to be determined
TCE	trichloroethene
TDS	total dissolved solids
TNRCC	Texas Natural Resources Conservation Council
TPH	total petroleum hydrocarbons
USA	Underground Services Alert
U.S. EPA	United States Environmental Protection Agency
USCS	Unified Soil Classification System
USGS	United States Geological Survey
VOC	volatile organic compound
VWC	Valley Water Company

1.0 INTRODUCTION

This Work Plan was prepared for the National Aeronautics and Space Administration (NASA). An additional investigation is proposed within Operable Unit 3 (OU-3), off-facility groundwater, to better determine the extent of chemicals in groundwater that originate from the Jet Propulsion Laboratory (JPL) facility. This document and the additional investigation described herein will serve as an addendum to the *Remedial Investigation (RI) for OU-1 and OU-3* (Foster Wheeler Environmental Corporation [FWEC], 1999). NASA-JPL, which is located in Pasadena, CA (Figure 1-1), is on the United States Environmental Protection Agency (U.S. EPA) National Priorities List (NPL) and subject to the provision of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) as amended by the Superfund Amendments and Reauthorization Act (SARA).

NASA and the City of Pasadena have executed a legal agreement that allows NASA to conduct CERCLA actions on certain properties owned by the City of Pasadena. This *Use Agreement and Right-of-Entry for Environmental Actions* requires that the scope and location of specific actions be documented by NASA and approved by the City of Pasadena as part of a Pasadena Sampling Plan (PSP). This Work Plan fulfills the PSP requirement of the legal agreement and has been given the subtitle of PSP-2004-1. Ongoing efforts described in any previous PSP remain in effect and are not superceded by this PSP.

NASA is the lead federal agency for selecting, implementing, and funding remedial activities at JPL; and Naval Facilities Engineering Command (NAVFAC) is providing technical services, including contracting, under a Memorandum of Agreement (MOA). In accordance with the Federal Facility Agreement (FFA), the U.S. EPA, California Environmental Protection Agency (Cal-EPA) Department of Toxic Substances Control (DTSC), and the Regional Water Quality Control Board (RWQCB) Los Angeles Region provide oversight and technical assistance. In addition, NASA is working in conjunction with the City of Pasadena, the California Department of Health Services (DHS), and the Raymond Basin Management Board (RBMB) to implement the activities associated with the additional OU-3 investigation.

This Work Plan is divided into five sections. This section discusses the objectives of the additional investigation and summarizes previous investigations. Section 2.0 summarizes background information on site conditions. Section 3.0 provides an evaluation of available data and identifies current uncertainties. Section 4.0 discusses the proposed methods by which the additional investigation will be implemented. Section 5.0 provides a listing of references.

1.1 Objective

The objectives of the additional investigation are (1) to evaluate the downgradient (southern) extent of chemicals that originate from the JPL facility, and (2) to determine if the occurrence of perchlorate in the Sunset Reservoir area is associated with migration from the JPL facility. This report outlines the strategy by which the additional investigation will be implemented. In addition, this report will serve to document the results of the evaluation of existing data in selected municipal production wells within the Raymond Basin.

1.2 Previous Investigations

Several documents and data sets associated with previous investigations were evaluated and utilized during preparation of this work plan. Some of these investigations were conducted as part of the NASA

JPL CERCLA program and some were sponsored by drinking water purveyors in the Raymond Basin. These investigations are briefly summarized in the following sections.

1.2.1 First Technical Assessment of the Devil's Gate Multi-Use Project. Phase 1 (CH2M-Hill, 1990) and Phase 2 (CH2M-Hill, 1992) of the *First Technical Assessment of the Devil's Gate Multi-Use Project* were designed to assess how much water could be stored in the Raymond Basin and the associated potential impacts on groundwater quality. These documents were not prepared as part of the NASA-JPL CERCLA Program. The primary objective of the assessment was to develop and evaluate a conjunctive use alternative that could be implemented within the basin to meet increasing potable water demands. As part of this assessment, general groundwater quality of the Raymond Basin was provided for the period July 1979 through June 1988 and represented by five parameters: total dissolved solids (TDS), nitrate, trichloroethene (TCE), tetrachloroethene (PCE), and carbon tetrachloride (CCl_4).

A three-dimensional (3-D) groundwater flow model of the Raymond Basin was developed during Phase 2 of the assessment to assist in the conjunctive use alternative evaluation. The Coupled Flow Energy and Solute Transport (CFEST) model was selected to simulate groundwater flow in the basin and potential groundwater migration pathways. Particle tracking from near the Arroyo Seco spreading grounds was performed for the period July 1989 through June 2023 to provide an estimate of the migration of nitrate and volatile organic compounds (VOCs). The results of the simulations projected a southerly groundwater flow path from the Arroyo Seco spreading basins and the unsewered areas in the La Cañada-Flintridge areas toward the City of Pasadena production wells located near the Sunset Reservoir. The City of Pasadena has referenced these modeling results as evidence that the perchlorate concentrations near the Sunset Reservoir are associated with a release from JPL. However, this preliminary modeling exercise only evaluated flow paths and did not consider sorption, dispersion, biodegradation of chemicals, nor did it evaluate fate and transport of chemicals originating from the JPL facility.

1.2.2 Remedial Investigation. The RI for on-facility (OU-1) and off-facility (OU-3) groundwater at JPL was conducted as part of the CERCLA program to identify the nature and extent of chemicals in groundwater (FWEC, 1999). The RI assessed the fate and transport of chemicals in the groundwater beneath and adjacent to the JPL facility and provided a baseline risk assessment to evaluate exposure to chemicals in groundwater to human health and the environment. During the RI, 13 additional wells (including shallow wells and deep multi-port wells) were added to 10 existing wells in the JPL monitoring network (Figure 1-2). Samples were collected from the 23 wells and analyzed for an extensive list of chemicals, including: VOCs, semivolatile organic compounds (SVOCs), Title 26 metals, chromium, lead, arsenic, hexavalent chromium, total petroleum hydrocarbons (TPH), perchlorate, and water chemistry parameters (i.e., TDS, anions, and cations). Additionally, groundwater levels were recorded in shallow and deep wells during the RI and hydraulic conductivities of the aquifer were estimated using slug/bail and rising head tests in individual wells.

Data collected during the RI indicated the pumping of the City of Pasadena and other municipal production wells appears to be an effective barrier to extensive downgradient chemical migration (FWEC, 1999). Conservative fate and transport simulations were subsequently conducted using the transport model SOLUTE to estimate potential migration of CCl_4, TCE, and perchlorate from monitoring well MW-17 if the City of Pasadena and other nearby production wells were not in operation. Results indicated that the production wells would need to be off-line for more than 20 years for migration of these chemicals at existing levels to be detected above action levels (ALs) in downgradient monitoring well MW-20. This finding contradicts some recent monitoring data, which has shown detections of perchlorate in MW-20 (Screen 4) that appear to originate from the JPL facility. Therefore, additional modeling and investigation are warranted.

1.2.3 Raymond Basin Database. The RBMB compiled a database containing information relating to the municipal production wells in the Raymond Basin (Geoscience, Inc., 2003). The database was not prepared as part of the NASA-JPL CERCLA Program. The Raymond Basin Database contains historical information on the following: production well construction details, groundwater chemical concentrations, groundwater quality data, well-specific production and injection volumes, spreading volumes, and groundwater-level elevations. These data were used extensively in the evaluation presented in Section 3.0 of this work plan.

1.2.4 NASA-JPL Groundwater Monitoring Program. The groundwater monitoring program at NASA JPL was initiated in 1996 and currently consists of a network of 23 monitoring wells, each of which is monitored on either a quarterly or annual basis. 18 wells are located on-facility and 5 wells are located off-facility (Figure 1-2). Of the 23 wells, ten are relatively shallow conventional wells with a single screened interval spanning the groundwater table. All of the shallow wells are located on the JPL facility. The other 13 wells, including all of the off-facility monitoring wells, are relatively deep, multi-port wells that contain five screened intervals each and a Westbay® multi-port casing system that allows for simultaneous or independent monitoring of different aquifer zones. Data from the NASA-JPL Groundwater Monitoring Program were used extensively in the evaluation presented in Section 3.0.

1.2.5 JPL Groundwater Modeling Report. A 3-D finite element groundwater model of the Monk Hill Subarea was developed using FEFLOW (Diersch, 2002) as part of the NASA-JPL: CERCLA Program. The groundwater model encompasses a 4,560-acre area and consists of four elemental layers that are bounded by five nodal slices. The extent of the model domain and the calibrated material properties for each of the four layers is discussed in detail in the *JPL Groundwater Modeling Report* (NASA, 2003). Particle tracking was used to confirm the appropriateness of the simulation results with regard to the flow directions and gradients in the JPL facility area. In addition, the report serves to document the results of a multiple well pumping test that was designed to estimate aquifer parameters within the Monk Hill Subarea. This groundwater model provides enhanced understanding of groundwater flow near the JPL facility and was used as part of the evaluation presented in Section 3.0.

The study area for the additional investigation described in this Work Plan includes the on-facility (OU-1) and off-facility (OU-3) groundwater that contains chemicals related to historical activities conducted at JPL. The term “on-facility” refers to locations within the JPL facility boundaries, and the term “off-facility” refers to locations outside JPL facility boundaries.

2.1 Municipal Extraction and Injection Wells

Several municipal production wells are located in the vicinity of the JPL facility and are of interest in the additional investigation. Municipal production wells owned by the City of Pasadena, Lincoln Avenue Water Company (LAWC), Rubio Canyon Land and Water Association (RCLWA), and Las Flores Water Company are located hydraulically downgradient of JPL, and municipal production wells operated by La Cañada Irrigation District (LCID) and Valley Water Company (VWC) are located hydraulically upgradient of JPL (Figure 2-1) (NASA, 2003). Table 2-1 provides a listing of the individual production wells along with information regarding dates of operation, well construction, and extraction volumes. Two City of Pasadena production wells (Bangham and Garfield) and two VWC production wells (VWC-2 and VWC-3) are constructed to serve as extraction and injection wells. Table 2-2 provides a summary of the dates of operation and historical injection volumes for these wells. Table 2-2 indicates that the two VWC wells injected over 5,600 acre-ft of water since 1992, and the Bangham and Garfield wells combined have injected nearly 2,200 acre-ft of water since 1992. During this time period, the four VWC wells have extracted nearly 12,000 acre-ft and the Bangham and Garfield wells have extracted over 15,000 acre-ft. Although the extracted volume significantly exceeds the injected volume, the injections primarily occurred during periods when the surrounding extraction wells were not in operation for several months prior to and after injection.

In the early 1980s, analyses of groundwater from the City of Pasadena water supply wells located in the Arroyo Seco, near JPL, revealed the presence of VOCs. VOCs also were detected in two LAWC water supply wells during this timeframe. To ensure the delivery of safe drinking water to its customers, the City of Pasadena installed a VOC treatment facility for its drinking water wells in the Arroyo Seco in 1990 (FWEC, 1999). By 1992, the LAWC also had installed a VOC treatment facility to ensure the delivery of safe drinking water to its customers. Agreements were made with the City of Pasadena and LAWC for NASA to pay for construction and operation of the VOC treatment systems. During the summer of 2004, NASA funded installation and operation of a perchlorate treatment system for LAWC. NASA is currently working with the City of Pasadena to install a perchlorate treatment system associated with the four production wells in the Monk Hill Subarea.

2.2 Historical Chemical Usage at JPL

Testing of aeronautical equipment at the JPL facility commenced in 1936. To meet its mission objectives, JPL used various chemicals and materials including a variety of solvents, solid and liquid propellants, cooling-tower chemicals, and analytical laboratory chemicals. Many buildings at JPL used seepage pits/cesspools during the 1940s and 1950s to dispose of liquid and solid materials via infiltration into surrounding soil. Some of these seepage pits may have received chlorinated solvents, solid fuel residue containing perchlorate, and other chemicals that currently are found in the groundwater. A sewer system was installed during the mid-1950s, and use of the seepage pits for waste disposal was discontinued between 1956 and 1961 as buildings were demolished or connected to the sanitary sewer line (Table 2-3) (Develle, 2003). The seepage pits were backfilled between 1961 and 1963 (Ebasco, 1990). In addition, an on-facility incinerator and a furnace were constructed in the mid-1950s and 1960s, respectively, for use in burning propellants (NASA, 1998). Therefore, it is believed that the VOCs and perchlorate observed in groundwater today are associated with releases that occurred in the 1940s and 1950s. Figure 2-2 presents a chronology of early activities at the site. Today, all chemical wastes are either recycled or sent off-facility for treatment and disposal at regulated facilities.

2.3 Hydrogeology

The Raymond Basin, where the JPL facility is located, is bordered on the north by the San Gabriel Mountains, on the west by the San Rafael Hills, and on the south and east by the Raymond Fault. The Raymond Basin is further divided into three subareas based on differences in groundwater elevations and flow directions: the Pasadena Subarea, the Santa Anita Subarea, and the Monk Hill Subarea. JPL is located in the Monk Hill Subarea, which provides an important source of potable groundwater for many communities in the area including Pasadena, La Cañada-Flintridge, and Altadena.

The aquifer in the Monk Hill Subarea and the Pasadena Subarea is generally considered to be an unconfined, or water table, aquifer. However, vertical hydraulic head differences with depth are observed between screens in deep JPL multi-port monitoring wells located near active production wells. This indicates that the aquifer does not exhibit truly unconfined conditions, due to the presence of relatively thin, silt-rich layers located throughout the alluvial aquifer that inhibit vertical flow of groundwater. The aquifer can be divided into four groundwater aquifer zones above the crystalline basement complex, based to a large extent on how these silt-rich intervals influence the hydraulic heads in the aquifer during pumping periods at the nearby municipal wells. The primary aquifer zones were identified based on geologic formation maps published by the California Division of Mines and Geology and the United States Geological Survey (USGS). The four aquifer zones in the study area include the upper and lower sections of the Older Fanglomerate Series (Aquifer Zones 1 and 2, respectively), the Pacoima Formation (Aquifer Zone 3), and the Saugus Formation (Aquifer Zone 4). A conceptual model of the aquifer zones and associated silt-rich intervals is shown in Figure 2-3. It should be noted that the amount of available information for delineating aquifer zones significantly decreases with distance from the JPL facility and Arroyo Seco area (where the JPL monitoring wells are located).

In the Raymond Basin, groundwater generally flows southerly from areas of recharge at the base of the San Gabriel Mountains to areas of discharge along the Raymond Fault. A confluence of groundwater flow regimes occurs within the Monk Hill Subarea where JPL is located. At the western end of the Monk Hill Subarea (west of JPL) the groundwater flow is predominantly to the southeast; and at the eastern end of the Monk Hill Subarea (east of JPL) the groundwater flow is predominantly to the south.

The groundwater flow direction and magnitude (hydraulic gradient) beneath the study area are dynamic. In general, natural groundwater flow is across the facility to the southeast. However, the aquifer is affected by various natural and anthropogenic influences that include: (1) pumping from nearby municipal production wells, (2) groundwater recharge from Arroyo Seco spreading basins, (3) seasonal and regional groundwater recharge from precipitation (primarily at the mouth of the Arroyo Seco), and (4) regional groundwater flow. The extraction of water from municipal production wells (see Figure 1-2) has the most significant effect on the natural groundwater flow.

The groundwater surface has been measured in the JPL monitoring wells at depths ranging from approximately 22 ft (groundwater mound near the mouth of the Arroyo Seco) to 270 ft below ground surface (bgs). This wide range of depths to groundwater can primarily be contributed to the relatively steep topography present at the JPL facility and local groundwater mounding. It also can be accounted for by seasonal groundwater recharge from nearby spreading grounds and the extraction of groundwater from nearby municipal production wells. Based on monitoring data collected since 1996, groundwater elevations have fluctuated up to 75 ft each year beneath JPL, primarily as a result of these influences.

Figures 2-4 and 2-5 show generalized groundwater elevation contour maps for January 1998 and January 2002 that were constructed using groundwater elevation data from JPL monitoring wells and selected municipal production wells within the Monk Hill Subarea. Groundwater elevation data from the uppermost screen in the JPL multi-port wells were used during construction of the maps. These dates were chosen because they coincide with comprehensive groundwater monitoring events at NASA JPL, during which groundwater chemistry parameters were collected. These maps indicate a southeast flow direction to the west of JPL and a southwest flow direction near the mouth of the Arroyo Seco. Groundwater flow to the south of JPL is heavily influenced by operation of the municipal pumping wells and recharge at the Arroyo Seco.

2.4 Groundwater Chemistry

During the RI (FWEC, 1999), groundwater samples collected from JPL monitoring wells and from municipal production wells were analyzed for major anions (including chloride, sulfate, nitrate, and alkalinity), major cations (including calcium, magnesium, sodium, potassium, and iron), and TDS. The results of these analyses were used to evaluate the general chemistry of groundwater. Data were compiled in Stiff diagrams for a visual categorization of each water sample. A review of these diagrams suggest that the majority of groundwater at JPL can be divided into three general types:

Type 1: Calcium-bicarbonate groundwater. Groundwater with calcium as the dominant cation and bicarbonate as the dominant anion. Type 1 water appears to originate as rainwater runoff from the San Gabriel Mountains and enters the study area through the Arroyo Seco and the spreading grounds.

Type 2: Sodium-bicarbonate groundwater. Groundwater with sodium as the dominant cation and bicarbonate as the dominant anion. Type 2 water is typically found in deeper portions of the aquifer.

Type 3: Calcium-bicarbonate/chloride/sulfate groundwater. Groundwater with calcium as the dominant cation and bicarbonate the dominant anion, but with relatively elevated chloride and sulfate concentrations. This water type consistently has higher levels of TDS than the other two general types.

In addition to the general water types listed above, the analytical data suggest that mixing, or blending of water types, creates “intermediate” water types.

The most common water type at JPL, Type 1 water (calcium-bicarbonate), was detected primarily in monitoring and production wells in and near the mouth of the Arroyo Seco. It appears that Type 1 water may originate as rainwater runoff from the San Gabriel Mountains and enter the study area via the Arroyo Seco and spreading grounds. Type 2 water (sodium bicarbonate) is typically is found in deeper portions of the aquifer. Type 2 water, although found deep in the aquifer, is similar to water Type 1 in that both have relatively low TDS levels. A significant difference between these water types is that sodium is the predominant cation found in Type 2 water, whereas calcium is the predominant cation in Type 1 water. Type 3 water (calcium-bicarbonate/chloride/sulfate) is most prevalent in wells located upgradient and to the west of the JPL facility and is indicative of a mixture of Type 1 water and Colorado River water imported by the Metropolitan Water District of Southern California (MWD) (FWEC, 1999). Some Type 3 water also is found downgradient to the south of JPL. This water type differs from Types 1 and 2 by having elevated levels of chloride, sulfate, and TDS. A piper diagram showing the distribution of the three water types is presented in Figure 2-6. Figures 2-7 and 2-8 graphically present groundwater quality at JPL in January 1998 and January 2001, respectively.

Perchlorate detections have been reported in municipal production wells located throughout the Raymond Basin, including the wells owned by the City of Pasadena, LAWC, RCWLA, Las Flores Water Company, VWC, and LCID. In addition, perchlorate detections in furthest downgradient JPL monitoring well, MW-20, indicate the leading edge of the chemical plume originating at JPL is not currently delineated. NASA is pursuing treatment of VOCs and perchlorate in four City of Pasadena wells (Arroyo, Well 52, Ventura, and Windsor) and the two LAWC wells (LAWC 3 and LAWC 5). In the early 1990s, agreements were made with the City of Pasadena and LAWC for NASA to pay for implementation of VOC treatment systems. Recently, NASA modified the agreement with LAWC to include perchlorate treatment and a similar modification is being pursued for the four City of Pasadena wells. An initial evaluation of available data was performed to better determine the extent of chemicals originating from the JPL facility and to identify uncertainties that need to be addressed as part of the additional investigation (described in Section 4.0 of this work plan).

3.1 Methods of Analysis

Several different methods were used to evaluate the occurrence of VOCs and perchlorate in municipal production wells, including groundwater chemical concentrations, groundwater quality parameters, vadose zone and groundwater modeling, and other methods. A brief explanation of each is provided in the following sections.

3.1.1 Groundwater Chemical Concentrations. Chemical concentrations reported in groundwater collected from JPL monitoring wells and municipal production wells were evaluated to determine trends and the spatial distribution of VOCs and perchlorate.

The VOCs chosen for evaluation include PCE, TCE, and CCl_4 (each of these VOCs have been primarily used as degreasing agents). CCl_4 appears to have a unique association to JPL in the Monk Hill Subarea, with consistent detections in on-facility monitoring wells (maximum concentration of 208 μg/L in MW-7 in April 2002) and consistent nondetections in upgradient production wells. Historical records indicate CCl_4 was used during early activities at the JPL facility, but was reportedly phased out by the end of the 1950s (NASA, 1998). Therefore, CCl_4 is considered a good tracer for chemicals originating from JPL.

TCE also has been linked to historical activities at JPL; however, it has also been detected in upgradient wells. Low levels of PCE have been detected in wells located on the JPL facility; although higher levels observed in upgradient and downgradient production wells appear to be associated with sources other than JPL, such as dry cleaning sites and unsewered areas in La Cañada-Flintridge (FWEC, 1999). Because these three VOCs have similar characteristics associated with fate and transport in groundwater (e.g., retardation factors), higher levels of PCE and/or TCE and the absence of CCl_4 in downgradient municipal production wells generally indicate a VOC source other than JPL (FWEC, 1999).

Perchlorate detections throughout the Raymond Basin have necessitated the additional investigation described in this Work Plan. Compared to the fate and transport characteristics of VOCs, perchlorate has a lower retardation factor, which may result in faster migration in groundwater. Perchlorate usage has been linked to the JPL facility, where testing of perchlorate as a component of solid rocket propellant began around 1942 (NASA, 1969). Concentrations of perchlorate as high as 13,300 μg/L (MW-7 in October/November 2002) have been detected in samples from wells located on the JPL facility. While no other study has been conducted to determine sources of perchlorate in the Raymond Basin, MWD water imported from the Colorado River has been linked with perchlorate detections in the upgradient VWC wells (FWEC, 1999). Colorado River water has higher chloride, sulfate, and TDS concentrations (i.e., Type 3 water quality, see Section 2.4) than local water sources (i.e., Types 1 and 2). Therefore, perchlorate concentrations detected in samples with influences of Type 3 groundwater quality may be associated with a source other than JPL.

3.1.2 Groundwater Quality. Similar to chemical concentrations, water quality data in groundwater samples collected from JPL monitoring wells and municipal production wells were evaluated to determine trends and the spatial distribution. Each set of data was assigned a water-quality type consistent with the criteria discussed in Section 2.4. These data were used to make evaluations of the source of water for the respective sample. Type 1 and 2 groundwater originate locally and are found below the JPL facility, whereas Type 3 groundwater is not associated with sources originating from JPL.

3.1.3 Vadose Zone and Groundwater Modeling. As part of this work plan a vadose zone model was developed to predict migration time for select JPL chemicals of interest through approximately 200 ft of unsaturated soil to the groundwater table (i.e., simulating travel from a seepage pit to the groundwater). The Seasonal Soil Compartment (SESOIL) model (General Sciences Corporation [GSC], 1998) was used to make the predictions, taking into account site-specific input parameters. The model incorporated sorption to allow for the differentiation of chemicals through the use of a chemical-specific retardation factor that is based on the distribution coefficient (K_d). The SESOIL vadose zone model predicted a minimum travel time through the vadose zone of 7.5 years using conservative estimates of site-specific and chemical-specific (i.e., perchlorate) input parameters. By incorporating less conservative estimates of sorption in the model for perchlorate (Battelle, in press; Texas Natural Resources Conservation Council [TNRCC], 2002; Batista, et al., 2003), the estimated travel time could increase by a factor of 2 or more (i.e., $\geq$ 15 years).

The JPL groundwater flow model (NASA, 2003), which was constructed using FEFLOW (Diersch, 2002), was designed to simulate groundwater flow in the Monk Hill Subarea. The model was used to conduct particle tracking simulations that illustrate flow paths and provide estimates of advective travel times from potential chemical release sites to downgradient locations. Additionally, the boundaries of the JPL groundwater flow model were expanded to create a basin-scale groundwater flow model that encompassed the Monk Hill Subarea and a large portion of the Pasadena Subarea, including the wells near the Sunset Reservoir. Results from the groundwater flow model developed and implemented as part of the *Phase 2 First Technical Assessment, Devil's Gate Multi-Use Project* (CH2M-Hill, 1992) also were evaluated during the analysis. Results from the vadose zone and groundwater flow models were combined to estimate chemical travel times from a release near the ground surface (e.g., seepage pit) to a downgradient receptor in groundwater. Groundwater modeling results are provided in Sections 3.2 through 3.4.

3.1.4 Additional Methods. Additional methods of analysis include evaluation of groundwater-level elevation data, groundwater flux in the basin, and historical data review, whereby federal, state, and local databases were searched in a comprehensive Environmental Data Resources (EDR) Area Study Report to identify other potential sources within the study area (see Attachment A).

3.2 Sunset Reservoir Wells

The City of Pasadena wells located near the Sunset Reservoir include the Sunset, Bangham, Copelin, Garfield, and Villa (Figure 2-1). Table 3-1 provides a summary of VOC and perchlorate concentrations that have been detected in the Sunset Reservoir wells and in the most southerly JPL monitoring wells (MW-19 and MW-20). The data were compiled using information from the Raymond Basin (Geoscience, 2003), the JPL CERCLA Program (NASA, 2003), and DHS (DHS, 2004). Figure 3-1 shows the concentrations of perchlorate that have been detected in the Sunset Reservoir wells.

In general, the data evaluated for the Sunset Reservoir wells are inconclusive regarding the source of perchlorate. As such, Section 4.0 describes installation of additional monitoring wells to better understand the extent of perchlorate that originated from JPL.

Chemical Concentrations and Water Quality. PCE and TCE concentrations detected in the Sunset, Bangham, and Copelin wells are not consistent with a source originating from JPL because the concentrations are significantly higher than those detected in NASA's furthest downgradient monitoring wells MW-19 and MW-20. The absence of CCl_4 in the Sunset Reservoir wells and in NASA's furthest downgradient monitoring wells MW-19 and MW-20, with the exception of an isolated detection in August/September 1996 (0.5 μg/L in MW-19), further support that VOCs from JPL have not migrated to the Sunset Reservoir wells. However, due to its chemical properties, perchlorate could migrate faster than VOCs.

Since 1997, perchlorate has consistently been detected in the Sunset Reservoir wells, with maximum concentrations of 12.8, 9.0, 17.4, 27.7, and 7.2 μg/L in the Sunset, Bangham, Copelin, Garfield, and Villa wells, respectively (see Table 3-1 and Figure 3-1). Figures 3-2 through 3-4 show water quality trends in Sunset Reservoir wells, and indicate increasing chloride, sulfate, and TDS values since the early 1960s. Classification of the water quality in these wells indicates a shift from a Type 1 (local source) to a Type 3 water (not associated with JPL). Given this water quality data, it is not possible to determine the source of perchlorate in the Sunset Reservoir wells.

Sporadic detections have been observed in samples collected from MW-20 (Screen 4) since 1998 associated with deeper portions of the aquifer and Type 1 or 2 water quality (consistent with a source originating from JPL). Specifically, samples collected from MW-20 (Screen 4) contained perchlorate concentrations of 20 μg/L, 30 μg/L, 58.5 μg/L, and 124 μg/L in October/November 1998, April/May 2002, October/November 2002, and April/May 2003. All other samples from Screen 4 have shown non-detect concentrations of perchlorate. Nevertheless, the presence of perchlorate in MW-20 (Screen 4) indicates that the leading edge of NASA's plume has traveled beyond this monitoring location and the extent of the plume is not fully known in this area and it is not possible to say whether or not it may have impacted the Sunset wells. As such, NASA is proposing additional wells (see Section 4.0) to help delineate the leading edge of the perchlorate plume.

Samples collected in Screen 1 of MW-20 (located approximately 2 miles north of the Sunset Reservoir) have shown low levels of perchlorate since 1997; however, these samples were collected from locations in the uppermost hydrostratigraphic layer and were associated with Type 3 water, indicating a source other than JPL. In MW-19 (Figure 2-1), perchlorate has not been detected above 8 μg/L. Figure 3-5 shows historical perchlorate concentrations in JPL monitoring wells MW-19 and MW-20.

Figures 3-6 through 3-11 show a vertical cross section (A-A′) extending from the JPL facility to the downgradient Sunset Reservoir municipal production wells. These figures include concentrations of PCE, CCl_4, and perchlorate and indicate water type in monitoring wells and production wells for years 1997 through 2002.

It should be noted that MWD water has been injected into two Sunset Reservoir wells (approximately 2,200 acre ft in Bangham and Garfield wells between 1992 and 1996); however, the quantities injected (see Table 2-2) do not appear to be large enough to account for the magnitude and duration of observed perchlorate concentrations.

Vadose Zone and Groundwater Modeling. The SESOIL vadose zone model predicted a minimum travel time through the vadose zone of 7.5 years using conservative estimates (i.e., most rapid transport) of site-specific and chemical-specific input parameters. The basin-scale groundwater model constructed using FEFLOW was used to simulate flow in the Raymond Basin from the JPL facility to the Sunset Reservoir wells. This model indicates the advective travel times (i.e., most conservative) for a particle originating on the JPL Facility near MW-7 and captured at the Sunset Reservoir wells is between 40 and 96 years, with an average travel time of 70 years. Using these travel times, the estimated release period ranges between 1899 and 1955 (i.e., 2002 minus [40 to 96 years] minus 7.5 [vadose zone travel time]), with the average starting prior to prior to 1924. As indicated earlier, the JPL facility did not start testing perchlorate as a solid rocket propellant until after 1942. It should be noted that simulations performed using the groundwater flow model assume steady state conditions; therefore, recent modifications in production well operation may result in slightly different travel time estimates.

While particle tracking can be used to estimate groundwater flow paths and conservative travel times, it does not necessarily indicate that enough perchlorate mass traveled to the Sunset Reservoir wells to result in the observed concentrations. As indicated in previous reports (FWEC, 1999; NASA, 2003), the production wells in the Monk Hill Subarea have been in operation since the early 1900s and provide effective hydraulic containment of the groundwater originating from the JPL facility. Therefore, the vadose zone and groundwater modeling efforts provide additional uncertainty regarding the source of perchlorate in the Sunset Reservoir.

Other Potential Sources. Although none of the potential sources of chemicals in groundwater identified in the EDR Study were associated with perchlorate, it should be noted that the study area only encompassed the area downgradient of the JPL facility. As stated above, the RI indicates that injection of Colorado River water (which has been shown to contain perchlorate) in upgradient production wells has been shown to influence groundwater quality in the Basin (FWEC, 1999). Other potential sources include system leakage at/near the Sunset Reservoir, which receives water from MWD, or other underdetermined sources.

3.3 RCLWA and Las Flores Water Company Wells

RCLWA 7, RCLWA 4, and Las Flores 2 wells (Figure 2-1) are located in the Monk Hill Subarea, downgradient and approximately 1,200 feet southeast of JPL monitoring well MW-20. A summary of PCE, TCE, CCl_4, and perchlorate concentration data for the RCLWA, Las Flores, and LAWC (provided for comparison) wells is presented in Table 3-2. Figure 3-12 shows the concentrations of perchlorate that have been detected in the RCLWA and Las Flores Water Company wells.

CCl_4 has not been detected at all and TCE has not been detected at concentrations above maximum contaminant levels (MCLs) in the RCLWA and Las Flores wells. PCE was detected above its MCL only in the Las Flores 2 well (the only well associated with a mixture of Type 3 water), at a maximum concentration 17.2 μg/L. PCE first exceeded its MCL in the Las Flores 2 well in May of 1998 and has continued to exceed the MCL through the most recent data set, with detections consistently near or above 10 μg/L. The absence of CCl_4 indicates that VOCs from the source area at JPL have not migrated to the RCLWA or Las Flores Water Company wells. For comparison, CCl_4 and TCE have been detected in the LAWC 3 and LAWC 5 wells at concentrations above their MCLs. During the summer of 2004, NASA funded installation and operation of a perchlorate treatment system for LAWC.

Perchlorate has been detected above at or above 6 μg/L in the RCLWA 4 and Las Flores 2 wells. Perchlorate has not been detected in the RCLWA 7 well. A summary of groundwater quality information for the RCLWA and Las Flores Water Company wells is presented in Table 3-3. Groundwater from the

RCLWA 4 well has an average TDS of 371 mg/L and is consistently classified as Type 1 water, which originates locally. Groundwater from the RCLWA 7 well has an average TDS of 276 mg/L and varies between Type 1 and Type 2, which originate locally. Groundwater from the Las Flores 2 well has an average TDS of 396 mg/L and exhibits a combination of Type 1 and Type 3 water, indicating that groundwater extracted from the well is a mixture of local and non-local sources.

Isolated perchlorate concentrations (as high as 124 μg/L in Screen 4) in JPL monitoring well MW-20 have been detected in the lower two screened intervals, characterized by Type 2 groundwater. Perchlorate concentrations in MW-20 in the upper-most screen have been detected as high as 7.8 μg/L and were associated with Type 3 or 1/3 waters. Because the RCLWA and Las Flores wells are screened across multiple aquifer zones, the contributions of perchlorate from different zones, represented by the different screened intervals in MW-20, is uncertain. Figure 3-5 shows the historical concentrations of perchlorate in MW-20.

Due to the low levels of perchlorate in the RCLWA and Las Flores Water Company wells, these purveyors have not needed to treat for perchlorate (although Las Flores Water Company does have a DHS approved blending plan for perchlorate). Therefore, installation of an additional monitoring well east of these production wells does not appear to be appropriate at this time due to the proximity of MW-20 and the southerly groundwater flow conditions in the area. The data will continue to be evaluated closely for increasing perchlorate concentrations, presence of VOCs (particularly CCl_4), and groundwater quality.

Figures 3-13 through 3-18 are vertical cross-sections along a transect (B-B′) extending from the JPL facility to the RCLWA and Las Flores Water Company wells. Figures 3-19 through 3-24 are cross-sections along transect (C-C′) extending from LCID and VWC wells to the RCLWA and Las Flores Water Company wells. Each of these cross sections shows CCl_4, PCE, and perchlorate concentrations in addition to water quality and groundwater level information.

3.4 VWC/LCID Wells

Six municipal production wells are located upgradient of the JPL Facility, including wells VWC 1 through VWC 4, LCID 1, and LCID 6 (Figure 2-1). In addition to their extraction capability, production wells VWC-2 and VWC-3 were constructed to function as injection wells and inject MWD water. A summary of PCE, TCE, CCl_4, and perchlorate concentration data for these wells is presented in Table 3-4, which also includes information from two JPL monitoring wells (MW-14 and MW-6) that are located between the NASA facility and the production wells, and JPL monitoring well MW-7, which is located in the suspected JPL source area. A summary of groundwater quality information for these wells is presented in Table 3-5.

Elevated PCE and TCE in the VWC production wells and the absence of CCl_4 (with the exception of an isolated detection of 0.6 μg/L in production well VWC 4), indicate a VOC source other than JPL. PCE detections have been attributed to unsewered areas in La Cañada-Flintridge, where PCE was evidentially used as a septic system cleaner, and several dry cleaner sites. Figures 3-25 through 3-30 show CCl_4, PCE, and perchlorate concentrations and water quality data along a transect (D-D′) from the NASA facility to the upgradient production wells VWC wells to the downgradient production wells for years 1997 through 2002.

Perchlorate concentrations in the VWC wells have been attributed to injection of MWD Colorado River water (FWEC, 1999). Groundwater samples from the VWC wells (two of which have historically injected Colorado River water) have an average TDS of over 600 mg/L and are consistently classified as Type 1/3 or Type 3, indicating that it does not originate locally. Groundwater from the LCID wells, which are upgradient of the VWC wells, has an average TDS of under 420 mg/L and varies between Type 1 and Type 1/3, which indicates that it is primarily rainwater runoff with minor contributions from Colorado River water. Figures 2-7 and 2-8 show water quality distribution throughout the northern portion of the Monk Hill Subarea, including the NASA facility, for January 1998 and January 2001, respectively. These figures illustrate the transition from Type 1 to Type 3 waters between the NASA facility and the VWC and LCID production wells.

Groundwater elevation data (Figures 2-4 and 2-5) and groundwater flow modeling also support a chemical source other than JPL in the VWC and LCID wells. The simulations indicate that groundwater flows to the southeast in accordance with the regional flow in the Monk Hill Subarea and that particles released in the vicinity of the suspected source area at JPL would not migrate to the VWC and LCID wells. Additionally, the width of the Monk Hill Subarea narrows and the base of the alluvial aquifer (i.e., top of bedrock) increases in elevation toward the northwest, as indicated in Figures 3-25 through 3-30. These two characteristics inhibit the ability of the groundwater to flow from the JPL Facility toward the VWC wells due to the reduction in aquifer storage capacity and further support a southeasterly flow direction.

3.5 Summary and Conclusions

Table 3-6 summarizes the results from the data evaluation as they relate to the Sunset Reservoir, RCLWA, Las Flores, VWC, and LCID wells. The data indicate the following:

- The VOCs and perchlorate in the VWC and LCID wells do not appear to originate from the JPL Facility. This conclusion is supported by elevated levels of PCE and TCE and the absence of CCl_4, groundwater-level elevation data, water quality data showing significant Type 3 characteristics, and groundwater modeling.
- The VOCs in the Las Flores Water Company well do not appear to originate from the JPL Facility due to elevated PCE and the absence of CCl_4. The origin of perchlorate concentrations in the Las Flores Water Company well is uncertain. Although there is Type 3 water characteristics present (indicating a source other than JPL), samples collected from the deeper screens of MW-20 (located 1,200 feet upgradient) have shown elevated perchlorate concentrations that appear to originate from JPL.
- The VOCs in the RCLWA wells do not appear to originate from the JPL Facility due to the absence of CCl_4. However, the perchlorate detections in RCLWA 4 appear to originate from the JPL facility due to the presence of Type 1 water quality characteristics and the proximity to MW-20, which has perchlorate concentrations in samples from deeper screens that appear to originate at JPL.
- The VOCs in the Sunset Reservoir wells do not appear to originate from the JPL Facility due to elevated PCE and TCE, and the absence of CCl_4. However, the origin of perchlorate concentrations in the Sunset Reservoir wells is uncertain. The presence of Type 3 water characteristics and the results of groundwater modeling indicate a source other than JPL. However, the leading edge of perchlorate plume is not delineated (i.e., samples collected from the deeper screens of the furthest downgradient monitoring well, MW-20, have shown elevated perchlorate concentrations that appear to originate from JPL) and the Sunset Reservoir wells are hydraulically downgradient of the JPL Facility. Even though these wells are hydraulically downgradient of JPL, it is not clear whether the source is JPL due to travel time estimates and hydraulic containment by production wells in the Monk Hill Subarea. Additional investigation is warranted.

3.6 Recommendations

Due to the uncertainty associated with the origin of perchlorate in the Las Flores Water Company well and the Sunset Reservoir wells, NASA recommends the following:

- Continued monitoring of the RCLWA and Las Flores Water Company wells. Installation of an additional monitoring well east of these production wells does not appear to be appropriate at this time due to the proximity of MW-20 and the southerly groundwater flow conditions in the area. The data should be evaluated closely for increasing perchlorate concentrations, presence of VOCs (particularly CCl_4), and groundwater quality.
- Installation of additional multi-port monitoring wells south of MW-20 and near the Sunset Reservoir wells. These wells are recommended to help define the leading edge of the perchlorate plume and to help understand the relationship between water quality and perchlorate concentrations near the Sunset Reservoir.
- Collection of soil samples to better define aquifer characteristics, including bulk density, effective porosity, hydraulic conductivity, and fraction organic carbon. Column tests on soil samples are recommended to determine site-specific sorption coefficient (K_ds) for perchlorate. Estimation of these parameters will provide a better understanding of site-specific and chemical-specific characteristics that can be incorporated into groundwater modeling simulations. A work plan is provided as Appendix C.

4.0 ADDITIONAL INVESTIGATION

Additional investigation is proposed to delineate the leading edge of the perchlorate plume originating from the JPL Facility and to improve the understanding of the relationship between water quality and perchlorate concentrations near the Sunset Reservoir. The additional investigation includes installation of two multi-port monitoring wells and collection of monitoring data from these wells.

Multi-port wells are recommended due to the thickness of the aquifer in the area of interest and the presence of stratification within the aquifer. Well locations were selected in coordination with the City of Pasadena. To the extent possible, well locations were sited within City of Pasadena property to facilitate ease of access and minimize impact to private property and public right-of-way (e.g., streets, etc). Upon installation and development of the proposed wells, an initial round of groundwater monitoring will be conducted to provide a baseline understanding of hydrogeologic conditions in the vicinity of these wells. Monitoring data will consist of chemical concentrations, water quality parameters, and groundwater-level elevations. Data from the multi-port screens will be used to develop a vertical profile of the groundwater conditions. Groundwater monitoring and data collection will be conducted in accordance with the Sampling and Analysis Plan (SAP) provided in Appendix A. Following the initial sampling event, subsequent sampling events will be conducted as part of the existing JPL groundwater monitoring program conducted by NASA. All field activities at the site will be conducted according to the procedures outlined in the Site Health and Safety Plan (SHSP) (Appendix B).

In addition, an attempt will be made to collect one saturated and one unsaturated soil sample from each location for analysis of several physical parameters, including bulk density, effective porosity, horizontal and vertical hydraulic conductivity, and fraction organic carbon. In addition, collection of samples for column tests will be performed in an effort to determine site-specific sorption coefficient (K_ds) for perchlorate. The sample collection efforts are described in this Work Plan; however, a separate Work Plan has been prepared to discuss the column tests to determine perchlorate sorption coefficient (Appendix C).

4.1 Schedule

A proposed schedule for installation of the additional monitoring wells is presented in Table 4-1, and includes a timeframe for logistic coordination and field work. The proposed start date and subsequent milestones will be contingent upon modification of the *Use Agreement and Right-of-Entry for Environmental Actions* between the City of Pasadena and NASA.

4.2 Logistics Coordination

To ensure the successful planning, installation, construction, and monitoring of the proposed multi-port wells, this project will require coordination with all parties to the FFA, including NASA, U.S. EPA, DTSC, and the RWQCB Los Angeles Region, as well as the City of Pasadena and the RBMB. NASA has already initiated coordination with the City of Pasadena associated with well location and property access. A brief description of specific coordination activities associated with the City of Pasadena and the RBMB is provided below.

4.2.1 City of Pasadena. Proposed well locations are within City of Pasadena property and were selected in coordination with City of Pasadena Pasadena Water and Power (PWP) personnel. Therefore, close coordination of well installation and sampling activities will be required between NASA and the City of Pasadena. Use of portions of some City of Pasadena roads will potentially be disrupted, but the traffic can likely be accommodated through usual traffic control methods. In general, coordination activities associated with the City of Pasadena for this project will include the following:

- Finalization of the *Use Agreement and Right-of-Entry for Environmental Actions* between the City of Pasadena and NASA for access to well sites for project personnel, equipment, and vehicles during field related activities.
- Completion of appropriate City of Pasadena Department of Public Works and Department of Planning boring and construction approvals (including public notification requirements and traffic control plans).
- Utility map review and underground utility locating and clearances.
- Selection of locations for placement of construction equipment and support facilities including a temporary storage area for supplies and investigation-derived waste (IDW) at each proposed well site.
- Coordination of drilling, well construction, waste disposal, surveying, and groundwater sampling field schedules.

Prior to and during monitoring well installation on City-owned land, NASA will comply with all of the requirements in the *Use Agreement and Right-of-Entry for Environmental Actions*. NASA will submit to PWP a firm schedule of commitment two weeks prior to commencing with the well construction to coordinate with PWP inspections and planning.

4.2.2 RBMB. The RBMB oversees implementation of the adjudication provisions of the Raymond Basin Judgment. NASA will obtain written authorization from the Raymond Basin Watermaster for constructing and operating the proposed monitoring wells. Because well construction and development require groundwater extraction, the RBMB will be notified of estimated and actual extracted groundwater quantities before and after well construction.

4.3 Well Locations

Selection of the proposed additional monitoring well locations was based on groundwater analytical data from existing wells, known groundwater flow patterns in the OU-3 area, and available property. Two proposed monitoring well locations have been identified, each of which is located on property owned by the City of Pasadena. The first proposed location is downgradient of JPL monitoring well MW-20 (NASA's furthest downgradient monitoring well) on Montana Street (see Figure 4-1). The well is located between NASA's two most downgradient monitoring wells and the Sunset Reservoir wells. An alternate location is proposed on Pasadena Unified School District (PUSD) property, just south of the Montana Street location (see Figure 4-1). The exact location of the proposed monitoring well has yet to be finalized, and will be based upon the results of meetings with the drillers, a subsurface utility survey, and discussions with the City of Pasadena and PUSD. Data collected from this well will serve primarily to evaluate the downgradient extent of chemical that originate from the JPL facility. The well will be completed with depth-discrete monitoring points (see Section 4.4), so that vertical profiling of the aquifer can be performed to correlate depth with water quality and chemical concentrations.

The second proposed location is slightly upgradient of the City of Pasadena Sunset Reservoir area Bangham and Copelin wells (see Figure 2-3), in the northwest corner of the City's Yards complex, which encompasses both the Sunset Reservoir and three production wells, and near the intersection of Hammond Street and the Foothill Freeway (Figure 4-1). This monitoring well will be located north of the Sunset Reservoir and south of the first proposed location. The Sunset Reservoir wells are currently inactive, but the proposed location is approximately 1,000 ft upgradient of the closest well. Data collected from this well will serve primarily to better understand the occurrence of perchlorate in the vicinity of the Sunset Reservoir area. The well will be completed with depth-discrete monitoring points (see Section 4.4), so that vertical profiling of the aquifer can be performed to correlate depth with water quality and chemical concentrations.

Additional locations in OU-3 may be necessary depending on the groundwater sampling results from the two proposed wells. If the monitoring results necessitate additional locations, a letter report will be submitted as an addendum to this document. The letter report will document the rationale behind additional monitoring wells and the proposed location of these wells.

4.4 Well Construction

The following sections describe the well installation activities that will be performed as part of this additional investigation. These activities include permitting, geophysical surveying, deep multi-port well installation, and IDW treatment and disposal. Additional assessment activities are similar in scope to those performed as part of NASA's regulator approved *Work Plan for Performing a Remedial Investigation/Feasibility Study at NASA JPL* (Ebasco, 1993).

4.4.1 Well Permit Requirements. The proposed monitoring wells are located within the OU-3. As a CERCLA site, the activities conducted as part of this additional assessment are only subject to substantive requirements and not procedural or administrative requirements such as permits. Under CERCLA § 121(e)(1) and 40 Code of Federal Regulations (CFR) § 300.400(e), no Federal, State, or local permit is required for this additional RI, provided that the action is selected and carried out in compliance with CERCLA. This applies to all permits, including environmental and building permits.

Although permits are not required, NASA will comply with the substantive permitting requirements associated with monitoring well installation. This includes permitting requirements associated with the Los Angeles County Department of Environmental Health (DEH), City of Pasadena Building Department, RWQCB Los Angeles region, and the California Department of Water Resources (DWR) Southern District. NASA will coordinate with each agency on installation of additional monitoring wells.

4.4.2 Pre-Drilling Activities. Prior to beginning drilling, all available utility maps will be reviewed. To the extent possible, well locations will be strategically sited in the vicinity of the proposed location to avoid existing utilities. In addition, prior to performing any subsurface activities, the well locations will be scanned for underground utilities using geophysical methods. The utility-locating contractor will employ several methods, including ground-penetrating radar (GPR), magnetometer, magnetic gradiometer, and/or electromagnetic imaging (EM). As required by California State law, Underground Services Alert (USA) will be notified of the planned drilling activities. USA is a communication center that provides notice to utility owners that may potentially have underground utilities within the proposed well sites. USA requires notification a minimum of 48 hours prior to conducting any underground excavation. Following map review, geophysical utility locating, and USA clearance, the surface of the ground will be clearly marked where underground utilities are discovered. Drilling locations will be selected to avoid impact to existing utilities. Prior to the initiation of drilling activities, the drilling contractor will attempt to hand auger a pilot hole to a depth of approximately 5 ft bgs at each proposed well location to ensure that no underground utilities or obstructions are present.

4.4.3 Deep Multi-Port Well Installation. Similar to the existing JPL multi-port monitoring wells, the proposed monitoring wells have been designed to include five depth discrete monitoring points within one well casing, and will be equipped with the Westbay Instruments Ltd. Multi-port casing monitoring system. Both new wells will be drilled to the top of the crystalline bedrock. Based on boring logs from nearby wells (e.g., Sunset Well and MW-20), it is anticipated that the proposed wells will extend to depths of approximately 700 to 1,000 ft. This design may be amended in the field if site-specific conditions warrant a modified construction.

The remainder of this section includes a brief description of the drilling method, well construction details, well development procedures, and the multi-port casing system installation procedures. A detailed description of these procedures can be found in NASA's regulator approved *Work Plan for Performing a Remedial Investigation/Feasibility Study at NASA JPL* (Ebasco, 1993).

4.4.3.1 Drilling Method. Each groundwater monitoring well will be drilled to the required depth below ground surface using a 12.25-inch outside diameter (O.D.) mud-rotary drilling bit. Approximately 20 ft of steel conductor casing will be set at the surface of each borehole to maintain the near surface integrity. The conductor casing will be removed after the well is constructed and all backfill materials have been placed. During drilling and well construction, drill cuttings will be separated from the drilling mud using a mud shaker. The separated mud is recycled into the drilling process and the cuttings are stored in a roll-off bin. Additional details regarding containerization and disposal of IDW are provided in Section 4.4.3.6.

All drilling equipment and materials including drilling bits and pipes, drilling mud, and backfill materials will be either new or cleaned in the field using a high pressure steam cleaner. Clean, imported water or water supplied from a nearby clean water source (e.g., water spigot) will be used during drilling and well construction activities. Prior to use, a water sample will be collected from each water source. The water sample will be analyzed for perchlorate and VOCs using U.S. EPA-approved methods.

During drilling, soil samples will be collected for lithologic logging purposes and then disposed of with the soil cuttings. Soil samples will be logged using the Unified Soil Classification System (USCS). Soil boring logs will be incorporated into a bound field notebook. The field notebook will be used to document all sampling activities. These notebooks will be maintained as permanent records. A minimum of one saturated and one unsaturated soil sample will be collected from each monitoring well for use in determining selected physical parameters, such as hydraulic conductivity, porosity, and bulk density. In order to collect these samples, the downhole drilling equipment will be tripped so that soil sampling equipment can be inserted down the well for sample collection. A modified split-spoon sampler attached to a 300-pound hammer will be used to collect undisturbed soil samples that will be used for analysis of physical parameters and in column studies for determining chemical-specific transport parameters. The drilling method described above is a standard method for installation of environmental monitoring wells. Cross-contamination between aquifer layers will be minimized because the drilling mud is of a different viscosity thereby restricting groundwater flow within the borehole during the drilling and well installation activities. Additionally, during well construction and development, to the extent possible, the drilling mud will eventually be completely removed from the well.

Detailed descriptions of the mud rotary drill process and field documentation procedure are provided in NASA's regulator approved *Work Plan for Performing a Remedial Investigation/Feasibility Study at NASA JPL* (Ebasco, 1993).

4.4.3.2 Well Construction. The total depth of each well will be determined by the on-site geologist based on the depth that crystalline bedrock is encountered. Based on the lithology defined by similar wells in the area, it is assumed that the wells will be advanced to approximately 700 to 1000 ft.

Well construction will satisfy the requirements of the California DWR, Water Well Standards, Bulletin 74-90, Supplement to Bulletin 74-81. The initial well design will be based on the design of other deep multi-port wells located in the vicinity (e.g., MW-19 and MW-20). The outer well casing will consist of sections of 4-inch-diameter low carbon steel blank casing and five, 10-ft-long, 4-inch-diameter, stainless steel wire-wrap screens with 0.010-inch slots welded together. Each section of screen and blank casing will be measured and steam cleaned before being lowered into the boring. The proposed screen depths will initially be chosen based on lithologic information from existing production and monitoring wells and existing groundwater level data. However, field changes to the proposed screen depths may occur as a result of information collected from lithologic logging during drilling and geophysical logging (see Section 4.4.3.3). All bentonite seals and sand packs will be tremied into place. The sand packs will consist of No. 2 silica sand. A grout pump will be used to circulate drilling fluid out of the hole and to pump backfill materials into the boring. The backfill materials will include sand, a bentonite sealing mixture consisting of sand and bentonite, and Volclay grout or equivalent. A locking monument cover or a traffic box will be installed at the well after the grout has set. Concrete will be used to secure the monument cover or traffic box in place. Well design may be modified in the field based on site-specific conditions.

Additional details regarding well construction can be found in NASA's regulator approved *Work Plan for Performing a Remedial Investigation/Feasibility Study at NASA JPL* (Ebasco, 1993).

4.4.3.3 Geophysical Logging. Upon completion of the drilling, the wells will be logged in the open borehole using geophysical methods to assist the identification of well screen depths, borehole lithologies, water-bearing intervals, and stratigraphic correlation with existing JPL monitoring wells. During the geophysical logging, the sides of the open borehole will be held in place by the viscosity of the drill mud, which will remain in place throughout the process. To accurately interpret results from the logging, the properties of the drilling mud will be subtracted out during analysis of the data. Proposed geophysical methods include natural gamma radiation, electrical resistivity (R/SP), guard resistivity, and caliper surveying.

4.4.3.4 Multi-Port Casing System Installation. The multi-port casing will be provided and installed by certified technical representatives of Westbay Instruments, Inc. The multi-port casing will arrive on-site, pre-cleaned in factory packaging and will be installed by hand within the previously installed well casing. The multi-port equipment consists of 1.5- inch-diameter schedule 80 polyvinyl chloride (PVC) blank casing, PVC couplings used to connect various casing components, PVC measurement-port couplings, PVC pumping-port couplings, and nitrile rubber inflatable packers. The measurement ports are installed to allow access to the aquifer for well purging and hydraulic conductivity testing. The pumping-ports are installed to allow access to the aquifer for pressure measurements and water sampling and the packers are used to seal the annulus between the measurement and pumping ports at each screened interval.

During well construction and casing installation, cross contamination will be minimized through the placement of a bentonite seal between each screened interval. Each screened interval will be developed independently. Once the development is complete, the outer casing will be purged free of water.

Additional details regarding the multi-port casing system installation, testing, and well development can be found in NASA's regulator approved Work *Plan for Performing a Remedial Investigation/Feasibility Study at NASA JPL* (Ebasco, 1993).

4.4.3.5 Well Development Procedures. Each monitoring well will be developed within 24 hours after being installed. Well development will include an initial period of surging followed by over-pumping. Development will be considered complete when the pH, conductivity, temperature, and turbidity measurements reach stability (when two successive measurements collected 3 minutes apart are within approximately 10% of each other). Following development the interior of the steel well casing will be video logged to evaluate the efficacy of the initial development. Based on the results of the video log additional development may be conducted. Field notes collected during well development will be recorded on a well development log. Well development activities will be conducted in accordance with NASA's regulator approved *Work Plan for Performing a Remedial Investigation/Feasibility Study at NASA JPL* (Ebasco, 1993).

4.4.3.6 IDW Generation, Treatment, and Disposal. The primary wastes generated from implementing this additional assessment Work Plan include drill cuttings/mud, well development water, monitoring well purge water, and decontamination rinse water. The amount of waste generated will vary based on actual field operations. Waste samples will be analyzed for the medium-specific parameters presented on Table 4-2. If possible, development water will be stored in approved containers at each site until IDW disposal activities can be coordinated. Otherwise, IDW will be moved onto the JPL site and stored until appropriate disposal is arranged. Based on the laboratory results, the waste will be classified as hazardous or nonhazardous waste in accordance with the Code of Federal Regulations (40 CFR 261.31 to 261.33 and 261.21 to 261.24) and the California Code of Regulations (22 CCR). Battelle will prepare all required waste profiles and manifests for the waste. An appropriate U.S. EPA-certified waste disposal facility will be selected and a licensed transporter will haul the waste off-site for disposal. All waste transported off-site will be accompanied by the appropriate hazardous or nonhazardous waste manifest, signed by a NASA authorized representative. The disposal of waste will be in accordance with federal, state, and local laws, regulations, and instructions.

4.5 Monitoring Frequency and Analyses

Following the installation and development of the steel well casing, each of the screened intervals will be isolated using K-packers then purged and sampled. These sample analytical results will be used as baseline data for comparison with subsequent analytical data collected following the multi-port casing installation (i.e., purge and sample versus no purge sampling). Additionally, to evaluate flow conditions in the well prior to the installation of the multi-port casing system, a spinner log will be run under static conditions.

Following the installation of the multi-port casing system, the newly installed monitoring wells will be initially sampled from each interval following the development of the multi-port casing system (Westbay). Following the initial well sampling, these wells will be added to the JPL monitoring program, and monitoring will occur on a quarterly schedule. During the initial monitoring events, groundwater samples will be collected and analyzed for VOCs (including 1,2,3-trichloropropane), SVOCs, perchlorate, water quality parameters, *n*-nitrosodimethylamine (NDMA), and 1,4-dioxane. The method detection limits (MDLs) for these analytes are listed in Appendix A. The analysis frequency for selected parameters (i.e., SVOCs and water quality parameters) may be reduced after the initial year of monitoring if warranted by the historical results. Groundwater samples will be transported under chain-of-custody to a California approved analytical laboratory.

A comprehensive quality assurance/quality control (QA/QC) plan for groundwater monitoring has been established and is described in detail in the SAP (Appendix A). QA can be described as an integrated system of activities in the area of quality planning, assessment, and improvement to provide the project with a measurable assurance that the established standards of quality are met. QC checks, including both field and laboratory, are the specific operational techniques and activities used to fulfill the QA requirements. Proper sample acquisition and handling procedures are necessary to ensure the integrity of the analytical results. All procedures will be followed in both the field and the laboratory. The types and quantities of field QC samples will be collected as follows: field duplicates (10%), equipment rinsate (1 per day), trip blank (1 per cooler), and field blank (1 per day). Laboratory QC, including laboratory blank samples, matrix spike/matrix spike duplicate (MS/MSD) samples, and laboratory control samples (LCSs), will be collected at a frequency of 5% of the total number of samples.

4.6 Reporting

The results of the multi-port monitoring well installation portion of the OU-3 additional investigation will be submitted in a technical memorandum following well completion and initial monitoring within 60 days after completion of the investigation. Results from subsequent monitoring will be included in deliverables associated with the JPL quarterly monitoring program. NASA will report sampling results to PWP in accordance with the *Use Agreement and Right-of-Entry for Environmental Actions*.

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