



Technical Memorandum

Additional Analytes for the Fourth Quarter 2006 Groundwater Monitoring Event

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Pasadena, California

Final

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This technical memorandum identifies additional analytes that will be sampled for during the fourth quarter 2006 groundwater monitoring event as part of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) program at the National Aeronautics and Space Administration (NASA) Jet Propulsion Laboratory (JPL) in Pasadena, California. These additional analytes will be included in the fourth quarter groundwater monitoring event to improve the understanding of chemical concentrations that may impact design and/or operation of the City of Pasadena Monk Hill Subarea treatment system and to address comments from the Department of Health Services (DHS) associated with Policy Memorandum 97-005.

Background

A long-term quarterly groundwater monitoring program was initiated by NASA at JPL in August 1996. The analytical parameter list for the long-term quarterly monitoring program was derived based on findings of the OU-1/OU-3 and OU-2 Remedial Investigations (RIs), which included regulatory agency approval to eliminate particular analytical parameters from the RI sampling program. Since completion of the RI, the long-term monitoring program includes analyses for VOCs [carbon tetrachloride, TCE, PCE, and 1,2-DCA in particular because these chemicals have been previously detected at concentrations exceeding state or federal maximum contaminant levels (MCLs)], perchlorate, select metals [chromium (total and hexavalent), arsenic, and lead], nitrate and nitrite, and Title 22 general minerals on a quarterly, semiannual, or annual basis. Additionally, analyses for certain compounds [e.g., 1,4-dioxane and n-nitrosodimethylamine (NDMA)] have been included for select wells during various quarterly sampling events at the request of DHS.

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 DHS as part of Policy Memorandum 97-005 compliance. DHS Policy Memorandum 97-005 provides an evaluation framework for source water located in an "extremely impaired source," such as a CERCLA Operable Unit. The JPL monitoring wells (e.g., MW-3) and multi-level well screens (e.g., MW-3-3 refers to monitoring well 3 - Screen 3) selected for the comprehensive groundwater monitoring event included: MW-3-3, MW-3-5, MW-4-1, MW-4-2, MW-4-5, MW-7, MW-8, MW-10, MW-12-3, MW-12-5, MW-14-2, MW-14-4, MW-16, MW-17-3, MW-17-4, MW-18-3, MW-18-4, MW-19-3, MW-19-5, MW-21-3, MW-21-5, MW-24-2. These wells were selected to be representative spatially distributed locations within the capture zones for the four City of Pasadena production wells: Arroyo Well, Well 52, Ventura Well, and Windsor Well. Figure 1 is a site map that shows the locations of all monitoring wells at JPL and nearby production wells. For purposes of evaluating nature and extent of chemicals in groundwater, the JPL groundwater monitoring wells are grouped into four categories: on-facility source area wells (MW-7, MW-13, MW-16, and MW-24); other on-facility wells (MW-6, MW-8, MW-11, MW-22, and MW-23); perimeter off-facility wells (MW-1, MW-3, MW-4, MW-5, MW-9, MW-10, MW-12, MW-14, and MW-15); and off-facility wells (MW-17, MW-18, MW-19, MW-20, MW-21, MW-25, and MW-26).

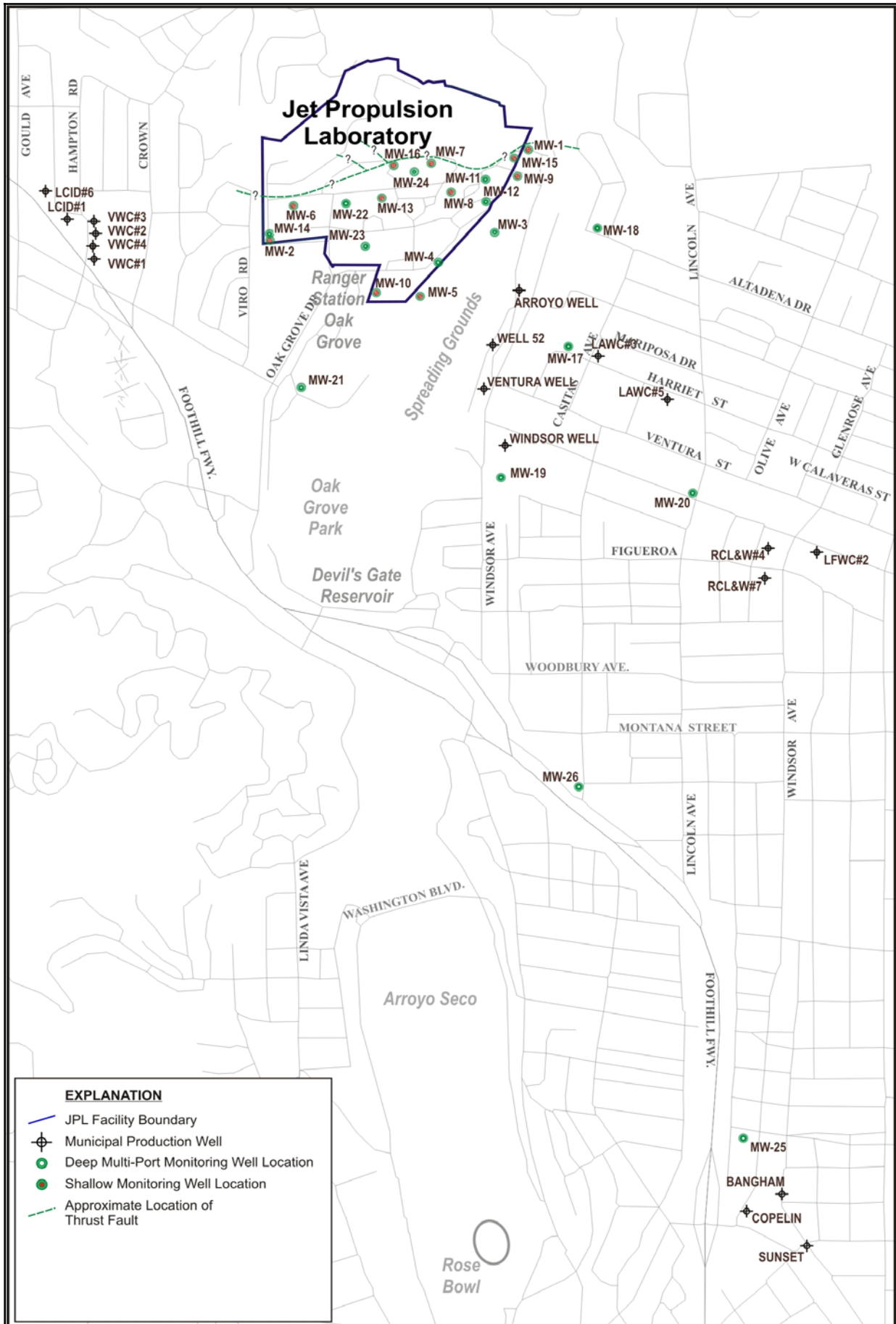


Figure 1. Locations of JPL Groundwater Monitoring Wells and Nearby Municipal Production Wells

Sampling results for the comprehensive groundwater monitoring event are reported in the revised draft *DHS Policy Memorandum 97-005 Documentation for the Raymond Basin, Monk Hill Subarea* (NASA, 2004). Chemical constituents detected in the comprehensive monitoring event that were not detected (or not analyzed for) in the historical JPL monitoring data include 2,4,6-trinitrotoluene (TNT), high-velocity military explosive (HMX); and royal demolition explosive (RDX); n-nitrosodiphenylamine (NDPHA); n-nitrosodi-n-propylamine (NDPA), NDMA, and total petroleum hydrocarbons quantified as diesel (TPH-D) and motor oil (TPH-MO). In addition, 1,2,3-trichloropropane (1,2,3-TCP), and 1,4-dioxane, which were detected in previous quarterly monitoring events, also were detected during the comprehensive monitoring event. Note that 1,2,3-TCP was detected one time in April 2002 at a concentration of 0.8 µg/L in MW-24-3 using Method 524.2; however, 1,2,3-TCP was not detected in previous or subsequent samples collected from this well. The comprehensive groundwater monitoring event was the first time the more sensitive analytical method, 504.1, was used to determine the presence of 1,2,3-TCP in groundwater at JPL.

Table 1 provides a summary of the locations where each emergent constituent was detected during the comprehensive monitoring event, and the range of detections compared to California State Notification Levels (NLs). As shown on Table 1, detections for all of the emergent constituents were more prevalent in the perimeter off-facility wells, MW-3, MW-4 and MW-12. Off-facility wells (MW-17, MW-18, MW-19, and MW-21) indicated the presence of 1,2,3-TCP, 1,4-dioxane, and nitrosamines. Concentrations of 1,2,3-TCP, NDPA, RDX, and TNT were detected above their respective NLs.

At the request of DHS, select samples from MW-3, MW-12, and MW-18 were analyzed for NDMA, NDPA, and 1,2,3-TCP during the third quarter 2005 sampling event based on the results from the comprehensive groundwater monitoring event conducted in December 2002/January 2003. Sensitive analytical methods (*i.e.*, Method 504.1 for 1,2,3-TCP and Method 1625 C for the nitrosamines) were used for these analyses. Sampling locations and analytical results for these additional analyses are summarized in Table 2.

Comments received in May 2006 from the DHS regarding the revised draft *DHS Policy Memorandum 97-005 Documentation for the Raymond Basin, Monk Hill Subarea* (Battelle, 2004) stated that analysis for these emergent constituents should be incorporated into the quarterly groundwater monitoring program at JPL. In addition, DHS requested in their review comments that tentatively identified compounds (TICs) and unknown scans be routinely reported by the laboratory so that these compounds can be evaluated and investigated as necessary. DHS further pointed out that various other chemicals were detected in soils or underlying groundwater based on the results of the OU-1/OU-3 and OU-2 remedial investigations (RI) and that these other chemicals need to be further evaluated with regard to their presence in groundwater.

To address DHS' comments, Battelle conducted a review of all soil and groundwater data collected during the RIs, as well as reviewed the results of a records search that identified chemicals used at or generated by JPL. Based on this review, chemicals were selected for a more in-depth evaluation in order to determine whether they should be included in future groundwater monitoring events at JPL. The results of the historical data review are summarized on Table A-1 in Attachment A.

To more thoroughly evaluate those constituents identified in the initial data review, a matrix was developed (see Attachment A, Table A-2) to provide a step-wise process of evaluation that indicates if the constituent was detected in soil or groundwater, where it was detected, if it would be expected to travel through the environmental media based on its chemical properties (*i.e.*, fate and transport), and whether it could be treated with the ion exchange or activated carbon systems proposed for the Monk Hill well treatment system. The group identification column in the matrix designates the analyte in one of three groups: 1, 2, or 3. A "1" indicates that the parameter is already included in the long-term monitoring plan, either as a chemical known to be present in groundwater or as an additional target parameter included in the analytical method. A "2" indicates that the analyte will undergo additional investigation and will be included in the fourth quarter 2006 groundwater monitoring event.

Table 1. Locations where Emergent Constituents Detected and Range of Detections

Analyte	Wells/Screens Where Analyte Detected During the CGWME ⁽¹⁾				Range of Detections (µg/L)	California State Notification Level (µg/L) ⁽⁴⁾
	On-facility Source Area Wells	Other On-facility Wells	Perimeter Off-facility Wells	Off-facility Wells		
1,2,3-TCP ⁽²⁾			MW-12-3	MW-18-4	0.024 - 0.071	0.005
1,4-Dioxane ⁽³⁾	MW-7, MW-16		MW-3-3, MW-4-1, MW-4-2, MW-10, MW-12-3, MW-14-2	MW-18-4	0.6 - 3	3
TPH-D ⁽²⁾	MW-24-2		MW-3-3	MW-17-4	10 - 20	N/A
TPH-MO ⁽²⁾			MW-3-3 and MW-4-2		30 - 90	N/A
NDPHA ⁽³⁾	MW-7, MW-16	MW-8	MW-3-5, MW-4-1, MW-4-5, MW-10, MW-14-2, MW-14-4	MW-17-3, MW-17-4, MW-19-3, MW-19-5, MW-21-5	0.001 - 0.02	N/A
NDMA ⁽³⁾	MW-7		MW-3-3, MW-3-5	MW-21-5	0.0004 - 0.006	0.01
NDPA ⁽³⁾			MW-3-5		0.125	0.01
RDX ⁽³⁾	MW-16		MW-3-3, MW-4-1, MW-4-2, MW-12-3, MW-12-5		0.66 - 27	0.3
HMX ⁽³⁾			MW-3-3, MW-4-1		0.7 - 2.5	350
TNT ⁽³⁾	MW-16		MW-3-3, MW-4-1, MW-4-2, MW-12-5		2.2 - 26	1

CGWME - comprehensive groundwater monitoring event conducted December 2002/January 2003

N/A - not available

- (1) Bolded well screen indicates that the concentration detected in that well/screen was equal to or above the NL.
- (2) The JPL monitoring wells sampled for this constituent during the comprehensive groundwater monitoring event included: MW-3-3, MW-4-2, MW-7, MW-10, MW-12-3, MW-14-2, MW-16, MW-17-4, MW-18-4, MW-19-3, MW-21-5, MW-24-2.
- (3) The JPL monitoring wells sampled for this constituent during the comprehensive groundwater monitoring event included: MW-3-3, MW-3-5, MW-4-1, MW-4-2, MW-4-5, MW-7, MW-8, MW-10, MW-12-3, MW-12-5, MW-14-2, MW-14-4, MW-16, MW-17-3, MW-17-4, MW-18-3, MW-18-4, MW-19-3, MW-19-5, MW-21-3, MW-21-5, MW-24-2.
- (4) Notification Levels obtained from California Department of Health Services – Drinking Water Program at <http://www.dhs.ca.gov/ps/ddwem/>

Table 2. Sampling Locations and Analytical Results for NDMA, NDPA, and 1,2,3-TCP During Third Quarter 2005 Sampling Event

Well ID	Parameter	Analytical Method	Well Screen	Result (µg/L)
MW-3	NDMA	1625 C	1	0.005J
			2	0.0076
			3	<0.002
			4	0.002J
			5	<0.002
MW-3	NDPA	1625 C	1	<0.002
			2	<0.002
			3	<0.002
			4	<0.002
			5	<0.002
MW-12	1,2,3-TCP	504.1	1	<0.005
			2	<0.005
			3	0.018
			4	0.023
			5	0.014
MW-18	1,2,3-TCP	504.1	1	<0.005
			2	<0.005
			3	<0.005
			4	0.037
			5	<0.005

Bold analytical result indicates the constituent was detected above the NL.
 NA - not analyzed

A “3” indicates that the compound will not be included in future groundwater sampling based on the results of previous soil and groundwater investigations and its chemical-specific fate and transport properties.

New Analytes

Based on the results of the comprehensive groundwater monitoring event in conjunction with the matrix evaluation, the following constituents were given the Group identification of “2”, indicating that they will be included in the fourth quarter 2006 groundwater monitoring event:

- Explosive compounds (RDX, HMX, TNT);
- Nitrosamines (NDMA, NDPHA, NDPA, etc.)
- Tributyltin

Two analytes, 1,2,3-TCP and 1,4-dioxane, were assigned a Group Identification number of “1” because they have been analyzed for in select wells at least annually since the comprehensive groundwater monitoring event was completed (at times, the quarterly sampling events may have included additional analyses for various compounds like 1,2,3-TCP and 1,4-dioxane, which were not permanently included in the long-term groundwater monitoring program).

TICs/unknowns for volatile organic compounds (VOCs), although not evaluated in the matrix, will be requested from the laboratory during all groundwater monitoring events.

Because nitrosamines may be released from some resins used for drinking water treatment, all nitrosamine compounds included in the analytical method for NDMA, have also been identified for analysis. Other nitrosamine compounds that will be included for future analysis include n-nitrosodiethylamine (NDEA), n-nitrosodi-n-butylamine (NDBA), n-nitrosomethylethylamine (NMEA), n-nitrosopiperidine (NPIP), and n-nitrosopyrrolidine (NYPR).

Tributyltin has historically been used by industry in cooling towers as an anti-bacterial agent. Because cooling towers have been, and still are, used at JPL, tributyltin analyses were performed on samples from select wells during five RI sampling events at the request of the DTSC. The wells sampled included MW-4-1 and 2, MW-8, MW-12-1 and 2, and MW-13. Tributyltin was detected in one sample from MW-4-2 during the June/July, 1997 event, and in MW-12-1 during the August/September, 1996 and June/July, 1997 events at very low levels (not greater than 0.005 µg/L). Analysis for tributyltin was subsequently discontinued after the September/October, 1997 event, pursuant to approval from the EPA, DTSC, and the RWQCB. However, to address current concerns from DHS, tributyltin has been selected as a new analyte to include in the fourth quarter sampling event. The presence of tributyltin will be determined based on analyses for tin in groundwater.

Additionally, analytes that may impact design and/or operation of the City of Pasadena Monk Hill Subarea treatment system were identified by PWP and are summarized on Table 3. Some of these analytes are a concern because they could also be adsorbed by the ion exchange media, which could cause sooner than expected perchlorate breakthrough thereby increasing operating costs. Other analytes (*i.e.*, silica) may cause scaling or fouling of the media which will increase pressure drop across the beds and eventually require change out of the media. The other general water quality data (*e.g.*, bicarbonate and alkalinity) can be used to determine the need for pretreatment to eliminate scaling problems with the system. Disposal costs/options could also be impacted due to the accumulation of radionuclides or metals on the treatment media.

Except for silica, historical data for the water quality analytes exist which can be used to estimate impact on the design/operation of the treatment system. Therefore, silica has been identified as a new analyte to include in the fourth quarter monitoring event so that concentrations of silica present within the capture zone of the treatment system may be quantified and its impact on system design/operation determined.

Sampling Locations

Sampling locations selected for fourth quarter sampling of these additional analytes are monitoring wells MW-3, MW-4, MW-5, MW-10, MW-17, MW-18, and MW-19. This group of wells consists of both perimeter off-facility wells and off-facility wells, which were selected based on their location within the capture zone of the four Monk Hill wells (Arroyo, Well 52, Ventura, and Windsor). Samples will be collected from all screens within each of these wells and analyzed for the additional analytes.

As detailed in the draft DHS Policy Memorandum 97-005 Documentation (NASA, 2004), capture zones for each production well were identified using a steady-state flow simulation to generate the groundwater flow fields. Forward and backward particle-tracking were used to assess the advective flow paths of the groundwater. Capture zones for each of the production wells include the following JPL monitoring wells selected as sampling locations for the additional analytes:

- Arroyo: MW-3, MW-4, MW-5, MW-10, MW-17, and MW-18;
- Well 52: MW-3, MW-4, MW-5, MW-10, MW-17, and MW-18;
- Windsor: MW-19;
- Ventura: MW-19.

Table 3. Water Quality Information for Design/Operation of Treatment System

Analyte	Influent Concentration ⁽¹⁾
Chloroform	3.4 ug/L
Methylene chloride	0.33 ug/L
Bicarbonate (as CaCO ₃)	230 mg/L
Total alkalinity	188 mg/L
Arsenic	0.004 mg/L ⁽²⁾
Barium	0.11 mg/L
Chromium (total)	0.006 mg/L
Phosphorus	0.106 mg/L
Selenium	0.005 mg/L ⁽²⁾
Silica	ND ⁽³⁾
Vanadium	0.027 mg/L ⁽²⁾
Fluoride	0.629 mg/L
Lead	2.5 ug/L ⁽²⁾
Gross alpha	4.5 pCi/L
Gross beta	1.9 pCi/L
Natural uranium	4.6 pCi/L
Uranium	3.2 pCi/L
Combined Ra 226+228	1.5 pCi/L
Total alpha	5.6 pCi/L
Total beta	8.7 pCi/L

- (1) Unless otherwise indicated, the influent concentration was derived using historical concentration data from the Arroyo Well, Well 52, Windsor Well, and the Ventura Well. The 95% upper confidence limit of the mean was calculated for each well based on the distribution of the data and was used in conjunction with expected flowrate (2,200 gal/min for the Arroyo Well, 1,800 gal/min for Well 52 is 1,400 gal/min for the Windsor Well, and 1,600 gal/min for the Ventura Well). The final influent concentration assumes all four wells contribute proportionally to the total flow rate.
- (2) Historical production well data for these wells either do not exist or are insufficient (i.e., less than three data points); therefore, the influent concentration was derived using existing groundwater data from JPL monitoring wells that are located in the capture zone of the production well as determined in the 97-005 Policy Document (Battelle, 2004). Data from all of the well screens were included. JPL wells associated with each production well are as follows:
 Arroyo: MW-3, MW-4, MW-8, MW-12, and MW-18;
 Well 52: MW4, MW-10, MW-14, MW-17, and MW-18;
 Windsor: MW-19 and MW-21;
 Ventura: MW-19 and MW-21.
- (3) ND – data were not available for either the production wells or the JPL monitoring wells; thus, a representative concentration could not be determined.

Sampling Requirements and Analytical Methods

Sample collection procedures and analyses for groundwater samples will be conducted in accordance with the Work Plan for Performing a Remedial Investigation/Feasibility Study (Ebasco 1993a) and associated field sampling and analyses and quality assurance plans (Ebasco, 1993b, 1993c, and 1994).

Analytical methods and relevant sampling information are summarized in Table 4. Laboratory practical quantitation limits and method detection limits also are provided in Table 4. The analytical precision acceptability limits for each analyte are listed in Table 5. Accuracy ranges for each analyte also are listed in Table 5.

References

NASA. 2004. Revised Draft DHS Policy Memorandum 97-005 Documentation Raymond Basin, Monk Hill Subarea. Prepared for California Department of Health Services. November.

Ebasco. 1993a. Work Plan for Performing a Remedial Investigation/Feasibility Study, National Aeronautics and Space Administration Jet Propulsion Laboratory, Pasadena, California. December.

Ebasco. 1993b. Field Sampling and Analysis Plan for Performing a Remedial Investigation at Operable Unit 1: On-Site Groundwater. NASA-Jet Propulsion Laboratory. December, 1993.

Ebasco. 1993c. Quality Assurance Program for Performing a Remedial Investigation for the National Aeronautics and Space Administration Jet Propulsion Laboratory, Pasadena, California. December 1993.

Ebasco, 1994. Field Sampling and Analysis Plan for Performing a Remedial Investigation at Operable Unit 3: Off-Site Groundwater. NASA-Jet Propulsion Laboratory. May, 1994.

Foster Wheeler Environmental Corporation (FWEC). 1999b. Final Remedial Investigation Report for Operable Units 1 and 3: On-Site and Off-Site Groundwater. Prepared for National Aeronautics and Space Administration/Jet Propulsion Laboratory.

Foster Wheeler Environmental Corporation (FWEC). 2000. Draft Feasibility Study Report for Operable Units 1 and 3: On-Site and Off-Site Groundwater. Prepared for National Aeronautics and Space Administration/Jet Propulsion Laboratory.

FWEC, see Foster Wheeler Environmental Corporation.

Table 4. Summary of Sample Requirements and Analytical Methods for Additional Analytes

Analyte	Preparation and Analytical Method ⁽¹⁾	Containers (number, size, type)	Preservatives	Holding Times ⁽²⁾	Practical Quantitation Limit (ug/L) ⁽¹⁾	Method Detection Limit (ug/L) ⁽¹⁾	Notification Level (ug/L) ⁽³⁾
NDMA	EPA 521	2 x 1L amber glass	Chill to 4 °C	< 7/40 days	0.002	0.0014	0.01
NDPA	EPA 521	2 x 1L amber glass	Chill to 4 °C	< 7/40 days	0.002	0.00092	0.01
NDPHA	EPA 521	2 x 1L amber glass	Chill to 4 °C	< 7/40 days	NA ⁽⁴⁾	NA ⁽⁴⁾	NA ⁽⁴⁾
NDEA	EPA 521	2 x 1L amber glass	Chill to 4 °C	< 7/40 days	0.002	0.00089	0.01
NDBA	EPA 521	2 x 1L amber glass	Chill to 4 °C	< 7/40 days	0.002	0.00093	NA
NMEA	EPA 521	2 x 1L amber glass	Chill to 4 °C	< 7/40 days	0.002	0.00064	NA
NPIP	EPA 521	2 x 1L amber glass	Chill to 4 °C	< 7/40 days	0.002	0.00079	NA
NYPR	EPA 521	2 x 1L amber glass	Chill to 4 °C	< 7/40 days	0.002	0.00082	NA
1,4-Dioxane	EPA 8270	2 x 1L amber glass	Chill to 4 °C	< 7/40 days	1	0.27	3
1,2,3-TCP	EPA 504.1	2 x 1L amber glass	Chill to 4 °C No Headspace	< 14 days	NA ⁽⁴⁾	NA ⁽⁴⁾	NA ⁽⁴⁾
2,4,6-TNT	EPA 8330	2 x 1L amber glass	Chill to 4 °C	< 7/40 days	2.0	0.18	1
RDX	EPA 8330	2 x 1L amber glass	Chill to 4 °C	< 7/40 days	2.0	0.25	0.3
HMX	EPA 8330	2 x 1L amber glass	Chill to 4 °C	< 7/40 days	2.0	0.22	350
Tin	EPA 200.7	1 x 125 mL polyethylene	Add HNO ₃ to pH < 2 Chill to 4 °C	< 180/180 days	50	20	NA
Silica	EPA 200.7	1 x 500 ml polyethylene	Chill to 4 °C	< 28/28 days	400	30	NA

NA - not available.

(1) Source: Columbia Analytical Services.

(2) The first number indicates holding time to extraction; the second number indicates the holding time to analysis

(3) Notification Levels obtained from California Department of Health Services – Drinking Water Program at <http://www.dhs.ca.gov/ps/ddwem/>

(4) Waiting on data from the laboratory.

Table 5. Analyte List, Precision, and Accuracy for Groundwater Samples

Analytical Parameter	Precision (% RPD)	Accuracy MS/MSD (% Recovery)	Accuracy LCS/LCSD (% Recovery)
<i>U.S. EPA Method 8330</i>			
RDX	11	42-143	60-117
Trinitrotoluene (TNT)	12	57-134	73-111
HMX	13	47-128	66-109
<i>U.S. EPA Method 504.1</i>			
1, 2, 3- TCP	NA ⁽¹⁾	NA ⁽¹⁾	NA ⁽¹⁾
<i>U.S. EPA Method 8270</i>			
1,4 - Dioxane	30	39-96	46-97
<i>U.S. EPA Method 521</i>			
NDMA	30	70 -130	70 -130
NDPHA	NA ⁽¹⁾	NA ⁽¹⁾	NA ⁽¹⁾
NDPA	30	70 -130	70 -130
NDEA	30	70 -130	70 -130
NDBA	30	70 -130	70 -130
NPIP	30	70 -130	70 -130
NMEA	30	70 -130	70 -130
NYPR	30	70 -130	70 -130
<i>U.S. EPA Method 200.7</i>			
Tin	20	75-125	85-115
Silica	20	75-125	85-115

LCS: laboratory control spike; MSD: matrix spike duplicate; LCSD: laboratory control spike duplicate;
MS: matrix spike; RPD: relative percent difference

Source: Columbia Analytical Services Laboratory

(1) Waiting on information from the laboratory

ATTACHMENT A
SUPPORTING DATA EVALUATION TABLES

Table A-1. Summary of Chemicals/Chemical Groups Known to be Used at JPL, Identification of the Chemical of Interest, and Presence in Environmental Media

Chemical/Chemical Group Reportedly Used at JPL ⁽¹⁾	Chemical of Interest ⁽²⁾	Currently being monitored for in groundwater?	Analyzed in Soil ^{(3)?}	Detected in Soil ^{(3)?}	Analyzed in Groundwater?	Detected in Groundwater?	Notes
acetic acid	acetic acid	no	no	--	no	--	Not a health concern.
aluminum powder	aluminum	no	no	--	yes	yes	Aluminum historically analyzed in groundwater, but at low levels; regulatory agencies agreed it did not have to be sampled.
aniline	nitroanilines	no	yes	no	yes	no	Nitroanilines have been analyzed but not detected in soil and groundwater.
arsenic trioxide	arsenic	yes	yes	yes	yes	yes	Continues to be monitored in groundwater sampling events.
aluminum powder	aluminum	no	no	--	yes	yes	Aluminum historically analyzed in groundwater, but at low levels; regulatory agencies agreed it did not have to be sampled.
ammonia isotopes N14 an N15	nitrogen (nitrates)	yes	yes	yes	yes	yes	Continues to be monitored in groundwater sampling events.
ammonium perchlorate	perchlorate	yes	no	--	yes	yes	Continues to be monitored in groundwater sampling events.
calcium permanganate	manganese	no	no	--	no	--	Not a concern.
chlorine trifluoride	chloride, fluoride	yes (chloride only)	no	--	yes	yes	Chloride continues to be monitored in groundwater sampling events. Fluoride presence attributed to natural conditions and monitoring was discontinued with regulatory approval.
chromic acid	chromium (3+ and 6+)	yes	yes	yes	yes	yes	Continues to be monitored in groundwater sampling events.
cryolite (sodium aluminum fluoride)	fluoride	no	no	--	yes	yes	Fluoride monitoring was discontinued with regulatory approval.
ethylene diamine	amines, nitrogen (nitrates)	yes	no	--	no	--	Continues to be monitored in groundwater sampling events.
helium	helium	no	no	--	no	--	Not a concern.
hydrazine	NDMA (Amines are precursors to nitrosamines, thus why NDMA is significant)	yes	no	--	yes	yes	Requires additional evaluation; See Matrix.
hydrazine diperchlorate	NDMA, perchlorate	yes	yes (perchlorate)	yes	yes	yes	Continues to be monitored in groundwater sampling events.
hydrogen peroxide	hydrogen peroxide	no	no	--	no	--	Not a concern.
iron oxide	iron	yes	no	--	yes	yes	Continues to be monitored in groundwater sampling events.
liquid nitrogen	nitrogen (nitrates)	yes	yes	yes	yes	yes	Continues to be monitored in groundwater sampling events.
liquid oxygen		no	no		no	--	Not a concern.
magnesium fluoride	magnesium, fluoride	yes (magnesium)	no	--	yes	yes	Magnesium continues to be monitored in groundwater sampling events. Fluoride presence attributed to natural conditions and monitoring was discontinued with regulatory approval.

Table A-1. Summary of Chemicals/Chemical Groups Known to be Used at JPL, Identification of the Chemical of Interest, and Presence in Environmental Media

Chemical/Chemical Group Reportedly Used at JPL ⁽¹⁾	Chemical of Interest ⁽²⁾	Currently being monitored for in groundwater?	Analyzed in Soil ⁽³⁾ ?	Detected in Soil ⁽³⁾ ?	Analyzed in Groundwater?	Detected in Groundwater?	Notes
monomethyl hydrazine (MMH)	NDMA	yes	no	--	yes	yes	Requires additional evaluation; See Matrix.
nitrofluoride	nitrogen (nitrates), fluoride	yes (nitrates)	yes	yes	yes	yes	Nitrate continues to be monitored in groundwater sampling events. Fluoride presence attributed to natural conditions and monitoring was discontinued with regulatory approval.
nitrogen gas	nitrogen (nitrates)	yes	yes	yes	yes	yes	Continues to be monitored in groundwater sampling events.
nitrogen tetroxide	nitrogen (nitrates)	yes	yes	yes	yes	yes	Continues to be monitored in groundwater sampling events.
nitromethane	nitrogen (nitrates)	yes	yes	yes	yes	yes	Continues to be monitored in groundwater sampling events.
polybutadiene acrylic acid acrylonitrile terpolymer binder	acrylonitrile, hexachlorobutadiene	yes (hexachlorobutadiene)	yes	no	yes	no	Both constituents were analyzed in early 1990s and were nondetect. Hexachlorobutadiene is included as a target analyte with the VOC analysis during sampling events.
sodium hydroxide	sodium	yes	no	--	yes	yes	Continues to be monitored in groundwater sampling events.
1,1-dimethyl-hydrazine	NDMA	yes	no	--	yes	yes	Requires additional evaluation; See Matrix.
aluminum alloys	aluminum	no	no	--	yes	yes	Aluminum not analyzed for in soil. Was analyzed for in groundwater during the OU-1/OU-3 RI. Aluminum was eliminated from the groundwater sampling program with regulatory approval because it was not considered to be a concern.
heavy metals	arsenic, chromium, cadmium, mercury, lead, antimony, thallium, strontium, vanadium, molybdenum, copper, cobalt	yes (arsenic, lead, chromium)	yes	yes	yes	yes	As, Cr, Cd, Hg, Pb, Sb, Tl, Sr, Va, Mo, Cu, Co analyzed for in soil. Where detected, metal concentrations were reasonably well correlated within the range of typical soil background levels. The majority of metals were eliminated from the groundwater sampling program (except arsenic, lead, and chromium 3+ and 6+) with regulatory approval because they were either not detected or were present at such low levels, well below regulatory limits, that they were not considered a concern.
magnesium alloy	magnesium	yes	no	--	yes	yes	Magnesium not analyzed for in soil. Magnesium was included in the analyses for the OU-1/OU-3 RI in order to identify water type.
metal alloys	metals	yes (arsenic, lead, chromium)	yes	yes	yes	yes	All metals included in the suite of analyses for Title 26 Metals, plus strontium and hexavalent chromium, were detected in JPL soils with the exception of selenium. Where detected, metal concentrations were reasonably well correlated within the range of typical soil background levels.
polyurethane	nitrogen (nitrates), amines	yes	no	--	yes	yes	Continues to be monitored in groundwater sampling events.

Table A-1. Summary of Chemicals/Chemical Groups Known to be Used at JPL, Identification of the Chemical of Interest, and Presence in Environmental Media

Chemical/Chemical Group Reportedly Used at JPL ⁽¹⁾	Chemical of Interest ⁽²⁾	Currently being monitored for in groundwater?	Analyzed in Soil ⁽³⁾ ?	Detected in Soil ⁽³⁾ ?	Analyzed in Groundwater?	Detected in Groundwater?	Notes
ballastite (nitrocellulose and nitroglycerin blended with diphenylamine)	nitrogen (nitrates), amines	yes	yes	yes	yes	yes	Continues to be monitored in groundwater sampling events.
batteries/ battery acid	lead	yes	yes	yes	yes	yes	Continues to be monitored in groundwater sampling events.
coolants	freon 113 and freon 11	yes	yes	yes	yes	yes	Requires additional evaluation; See Matrix.
cooling tower chemicals	tributyltin and hexavalent chromium	yes (chromium)	yes	yes	yes	yes	See Matrix for tributyltin; Requires additional evaluation. Hexavalent chromium continues to be analyzed for during the quarterly sampling events.
fluorescent lights	mercury	no	yes	yes	yes	yes	Where detected, metal concentrations were reasonably well correlated within the range of typical soil background levels. Eliminated from the groundwater sampling program with regulatory approval.
fuming nitric acid	nitrates	yes	yes	yes	yes	yes	Continues to be monitored in groundwater sampling events.
gasoline	BTEX, TPH	yes (BTEX)	yes	yes	yes	yes	BTEX are included as target analytes for the VOC analysis during sampling events.
propane	propane	no	no		no		Not a concern
solid rocket fuel propellant	perchlorate	yes	no	--	yes	yes	Continues to be monitored in groundwater sampling events.
chemical lab waste	unknown	--	--	--	--	--	unknown
corrosives	unknown	--	--	--	--	--	unknown
paints	unknown	--	--	--	--	--	unknown
solvents	unknown	--	--	--	--	--	unknown
T17-E2 propellant (polysulfide fuel with ammonium perchlorate)	perchlorate	yes	no	--	yes	yes	Continues to be monitored in groundwater sampling events.
antimony	antimony	no	yes	yes	yes	no	Detected at background soil levels ^(a) .
barium	barium	no	yes	yes	yes	yes	Detected at background soil levels ^(a) , detected well below MCLs in groundwater.
beryllium	beryllium	no	yes	yes	yes	yes	Detected at background soil levels ^(a) , detected well below MCLs in groundwater.
cadmium	cadmium	no	yes	yes	yes	yes	Detected at background soil levels ^(a) , detected well below MCLs in groundwater.
cobalt	cobalt	no	yes	yes	yes	yes	Detected at background soil levels ^(a) , detected well below MCLs in groundwater.
copper	copper	no	yes	yes	yes	yes	Detected at background soil levels ^(a) , detected well below MCLs in groundwater.
mercury	mercury	no	yes	yes	yes	yes	Detected at background soil levels ^(a) , detected well below MCLs in groundwater.
molybdenum	molybdenum	no	yes	yes	yes	yes	Detected at background soil levels ^(a) , detected well below MCLs in groundwater.

Table A-1. Summary of Chemicals/Chemical Groups Known to be Used at JPL, Identification of the Chemical of Interest, and Presence in Environmental Media

Chemical/Chemical Group Reportedly Used at JPL ⁽¹⁾	Chemical of Interest ⁽²⁾	Currently being monitored for in groundwater?	Analyzed in Soil ⁽³⁾ ?	Detected in Soil ⁽³⁾ ?	Analyzed in Groundwater?	Detected in Groundwater?	Notes
nickel	nickel	no	yes	yes	yes	yes	Detected at background soil levels ^(a) , detected well below MCLs in groundwater.
selenium	selenium	no	yes	no	yes	yes	Detected below MCLs in groundwater.
silver	silver	no	yes	yes	yes	yes	Detected at background soil levels ^(a) , detected well below MCLs in groundwater.
strontium	strontium	no	yes	yes	yes	yes	Detected at background soil levels ^(a) , detected well below MCLs in groundwater.
thallium	thallium	no	yes	yes	yes	yes	Detected at background soil levels ^(a) , detected well below MCLs in groundwater.
zinc	zinc	no	yes	yes	yes	yes	Detected at background soil levels ^(a) , detected well below MCLs in groundwater.
arsenic	arsenic	yes	yes	yes	yes	yes	Appears to be naturally occurring in soil, but continues to be analyzed for during quarterly sampling events.
chromium (total)	chromium (total)	yes	yes	yes	yes	yes	Continues to be analyzed for during quarterly sampling events.
cyanide	cyanide	no	yes	yes	yes	yes	Where detected, metal concentrations were reasonably well correlated within the range of typical soil background levels ^(a) . Eliminated from the groundwater sampling program with regulatory approval.
hexavalent chromium	hexavalent chromium	yes	yes	yes	yes	yes	Continues to be analyzed for during quarterly sampling events.
lead	lead	yes	yes	yes	yes	yes	Continues to be analyzed for during quarterly sampling events.
fluoride	fluoride	no	no	--	yes	yes	Fluoride presence attributed to natural conditions and monitoring was discontinued with regulatory approval.
magnesium	magnesium	yes	no	--	yes	no	Continues to be analyzed for during quarterly sampling events.
nitrates	nitrates	yes	yes	yes	yes	yes	Continues to be analyzed for during quarterly sampling events.
potassium perchlorate	perchlorate	yes	no	--	yes	yes	Continues to be analyzed for during quarterly sampling events.
sulfuric acid - use sulfate ion	sulfate	yes	no	--	yes	yes	Continues to be analyzed for during quarterly sampling events.
1,1,2-trichloro-1,2,2-trifluoroethane (Freon 113)	1,1,2-trichloro-1,2,2-trifluoroethane (Freon 113)	yes	yes	yes	yes	yes	Requires additional evaluation; See Matrix.
1,1-dichloroethane	1,1-dichloroethane	yes	yes	yes	yes	yes	Requires additional evaluation; See Matrix.
1,1-dichloroethene	1,1-dichloroethene	yes	yes	yes	yes	yes	Requires additional evaluation; See Matrix.
1,2,3,4,6,7,8,9-octachlorodibenzo-p-dioxin	1,2,3,4,6,7,8,9-octachlorodibenzo-p-dioxin	no	yes	yes	yes	no	Requires additional evaluation; See Matrix.
1,2-dichloroethane	1,2-dichloroethane	yes	yes	yes	yes	yes	Requires additional evaluation; See Matrix.
arochlor-1242	arochlor-1242	no	yes	yes	yes	no	Requires additional evaluation; See Matrix.
arochlor-1254	arochlor-1254	no	yes	yes	yes	no	Requires additional evaluation; See Matrix.
arochlor-1260	arochlor-1260	no	yes	yes	yes	no	Requires additional evaluation; See Matrix.

Table A-1. Summary of Chemicals/Chemical Groups Known to be Used at JPL, Identification of the Chemical of Interest, and Presence in Environmental Media

Chemical/Chemical Group Reportedly Used at JPL ⁽¹⁾	Chemical of Interest ⁽²⁾	Currently being monitored for in groundwater?	Analyzed in Soil ^{(3)?}	Detected in Soil ^{(3)?}	Analyzed in Groundwater?	Detected in Groundwater?	Notes
benzene	benzene	yes	yes	yes	yes	no	Requires additional evaluation; See Matrix.
benzo(a)anthracene	benzo(a)anthracene	no	yes	yes	yes	yes	Requires additional evaluation; See Matrix.
benzo(a)pyrene	benzo(a)pyrene	no	yes	yes	yes	yes	Requires additional evaluation; See Matrix.
benzo(a)fluoranthene	benzo(a)fluoranthene	no	yes	yes	yes	yes	Requires additional evaluation; See Matrix.
benzo(g,h,i)perylene	benzo(g,h,i)perylene	no	yes	yes	yes	yes	Requires additional evaluation; See Matrix.
bis(2-ethylhexyl)phthalate	bis(2-ethylhexyl)phthalate	no	yes	yes	yes	yes	Requires additional evaluation; See Matrix.
butylbenzylphthalate	butylbenzylphthalate	no	yes	no	yes	no	Requires additional evaluation; See Matrix.
carbon tetrachloride	carbon tetrachloride	yes	yes	yes	yes	yes	Requires additional evaluation; See Matrix.
di-n-butylphthalate	di-n-butylphthalate	no	yes	yes	yes	yes	Requires additional evaluation; See Matrix.
fluoranthene	fluoranthene	no	yes	yes	yes	yes	Requires additional evaluation; See Matrix.
fluorotrichloromethane (Freon 11, trichlorofluoromethane)	fluorotrichloromethane (Freon 11, trichlorofluoromethane)	yes	yes	yes	yes	yes	Requires additional evaluation; See Matrix.
indeno(1,2,3-cd)pyrene	indeno(1,2,3-cd)pyrene	no	yes	yes	yes	yes	Requires additional evaluation; See Matrix.
n-nitroso-dipropylamine	n-nitroso-dipropylamine	yes	yes	yes	yes	yes	Requires additional evaluation; See Matrix.
phenanthrene	phenanthrene	no	yes	yes	yes	yes	Requires additional evaluation; See Matrix.
pyrene	pyrene	no	yes	yes	yes	yes	Requires additional evaluation; See Matrix.
tetrachloroethene (PCE)	tetrachloroethene (PCE)	yes	yes	yes	yes	yes	Requires additional evaluation; See Matrix.
total petroleum hydrocarbons	total petroleum hydrocarbons	no	yes	yes	yes	yes	Requires additional evaluation; See Matrix.
tributyltin	tributyltin	no	yes	yes	yes	yes	Requires additional evaluation; See Matrix.
trichloroethene	trichloroethene	yes	yes	yes	yes	yes	Requires additional evaluation; See Matrix.
xylenes	xylenes	no	yes	yes	yes	yes	Requires additional evaluation; See Matrix.
1,2-dichlorobenzene	1,2-dichlorobenzene	yes	yes	no	yes	no	Included as target analytes for the VOC analysis during sampling events.
1,4-dichlorobenzene	1,4-dichlorobenzene	yes	yes	no	yes	yes	Included as target analytes for the VOC analysis during sampling events.
bromodichloromethane	bromodichloromethane	yes	yes	yes	yes	yes	Included as target analytes for the VOC analysis during sampling events.
bromoform	bromoform	yes	yes	no	yes	yes	Included as target analytes for the VOC analysis during sampling events.
carbon disulfide	carbon disulfide	no	yes	no	yes	yes	Detections likely due to lab contamination. Identified as a TIC in RI sampling events (refer to TIC Memo included as separate file).
chlorobenzene	chlorobenzene	yes	yes	no	yes	no	Included as target analytes for the VOC analysis during sampling events.
chloroform	chloroform	yes	yes	yes	yes	yes	Included as target analytes for the VOC analysis during sampling events.
chrysene	chrysene	no	yes	yes	yes	no	Requires additional evaluation; See Matrix.
cis-1,2-dichloroethylene	cis-1,2-dichloroethylene	yes	yes	yes	yes	yes	Included as target analytes for the VOC analysis during sampling events.
fluorene	fluorene	no	yes	no	yes	no	Requires additional evaluation; See Matrix.
gross alpha	gross alpha	no	no	--	yes	yes	Detected below MCLs and comparable to upgradient sampling points.
gross beta	gross beta	no	no	--	yes	yes	Detected below MCLs and comparable to upgradient sampling points.
naphthalene	naphthalene	yes	yes	no	yes	no	Included as target analytes for the VOC analysis during sampling events.

Table A-1. Summary of Chemicals/Chemical Groups Known to be Used at JPL, Identification of the Chemical of Interest, and Presence in Environmental Media

Chemical/Chemical Group Reportedly Used at JPL ⁽¹⁾	Chemical of Interest ⁽²⁾	Currently being monitored for in groundwater?	Analyzed in Soil ⁽³⁾ ?	Detected in Soil ⁽³⁾ ?	Analyzed in Groundwater?	Detected in Groundwater?	Notes
toluene	toluene	yes	yes	yes	yes	no	Requires additional evaluation; See Matrix.
1,1,1-trichloroethane	1,1,1-trichloroethane	yes	yes	yes	yes	no	Included as target analytes for the VOC analysis during sampling events.
acetone	acetone	no	yes	yes	no	yes as a TIC	Detections in soil were likely due to laboratory contamination. For groundwater, subsequent groundwater samples collected from wells exhibiting the TIC did not indicate the presence of acetone when acetone was a target analyte.
dibromochloromethane	dibromochloromethane	yes	yes	no	yes	no	Included as target analytes for the VOC analysis during sampling events.
styrene	styrene	yes	no	--	yes	no	Included as target analytes for the VOC analysis during sampling events.
hexane	hexane	no	no	--	no	yes as a TIC	Not detected during comprehensive groundwater monitoring event.
Sulfur dioxide	Sulfur dioxide	no	no	--	no	yes as a TIC	Not detected during comprehensive groundwater monitoring event.
2-methylpropane	2-methylpropane	no	no	--	no	yes as a TIC	Not detected during comprehensive groundwater monitoring event.
1,1-difluoroethane	1,1-difluoroethane	no	no	--	no	yes as a TIC	Not detected during comprehensive groundwater monitoring event.
2-methyl-1-propene	2-methyl-1-propene	no	no	--	no	yes as a TIC	Not detected during comprehensive groundwater monitoring event.
1,2,3-trichlorobenzene	1,2,3-trichlorobenzene	yes	no	--	yes	yes	Included as target analytes for the VOC analysis during sampling events.
1,1,2,2-tetrachloroethane	1,1,2,2-tetrachloroethane	yes	yes	no	yes	yes	Included as target analytes for the VOC analysis during sampling events.

TIC - tentatively identified compound

BTEX - benzene, toluene, ethylbenzene, xylenes

TPH - total petroleum hydrocarbons

MCL - maximum contaminant level

VOC - volatile organic compound

(1) Chemical/chemical group identified as being used at JPL

(2) Specific chemical of interest for monitoring based on the chemical/chemical group.

(3) Includes analyses for samples of soil gas and soil.

(a) Where detected, metal concentrations were reasonably well correlated within the range of typical soil background levels. The majority of metals were eliminated from the groundwater sampling program (except arsenic, lead, and chromium 3+ and 6+) with regulatory approval because they were either not detected or were present at such low levels, well below regulatory limits, that they were not considered a concern.

Table A-2. Matrix for Determining Chemical Constituents for Groundwater Analysis During Future Groundwater Monitoring at JPL

Analyte	Detected in Soil Gas during OU2 RI?	Detected in Soil During OU2 RI?	Detected in GW during the OU1 RI (1994-1998)?	Currently Included as Parameter in Long-Term Monitoring Program?	Analyte Detected in Comprehensive Groundwater Monitoring Event?	Wells Where Detected in CGWME	Supporting Information Based on the Results of the OU-1 and OU-2 RI and other Soil and Groundwater Investigations	Range of Concentrations Detected (mg/L) for the Years 2000 - 2005				California State MCL or Notification Level	Fate and Transport ^(5,6,7)	Treatability	Recommendation for Future GW Sampling	Group Identification ⁽⁸⁾
								Detected Minimum	Detected Maximum	Arithmetic Mean ⁽⁴⁾	Standard Deviation ⁽⁴⁾					
Solvents/Chlorinated Compounds																
1,1,2-Trichloro-1,2,2-trifluoroethane (Freon 113)	Yes	NA	Yes	Yes ⁽¹⁾	Yes	MW-7, MW-8	Has been consistently detected in groundwater since the OU-1/OU-3 RI at concentrations below the MCL.	0.0005	0.0092	0.00031	0.0006	1.2 (MCL)	Freon 113 is considered to be <i>insoluble</i> (i.e. solubility = 0.17 mg/L), however, its chemical retardation factor of 1.84 indicates that it is <i>moderately mobile</i> in groundwater.	Amenable to treatment with GAC.	Recommend keeping analyte for future groundwater sampling due to its mobility properties and because concentrations continue to be detected in groundwater.	1
1,2,3-Trichloropropane	NA	NA	No	Yes ⁽²⁾	Yes	MW-12-3, MW-18-4	Had not been detected until the CGWME when more sensitive analytical methods were used. Since the CGWME, has been detected in MW-18, MW-12, MW-25 using the more sensitive analytical method (EPA 504.1). Note that not all wells have been analyzed using EPA 504.1.	0.00001	0.0008	0.00025	0.00008	0.000005 (NL)	1,2,3-TCP is <i>highly soluble</i> (1,750 mg/L) and has a chemical retardation factor of 1.23, indicating that it is <i>highly mobile</i> in groundwater.	Amenable to treatment with GAC.	Recommend keeping analyte for future groundwater sampling due to its solubility and mobility properties and because concentrations continue to be detected in groundwater.	1
1,1-Dichloroethane	Yes	NA	Yes	Yes ⁽¹⁾	Yes	MW-4-2, MW-10, MW-7	Has been consistently detected in groundwater since the OU-1/OU-3 RI at concentrations below the MCL.	0.0003	0.0013	0.0003	0.00015	0.005 (MCL)	1,1-DCA has a solubility of 8,520 mg/L (<i>highly soluble</i>) and with a chemical retardation factor of 1.12 it is <i>extremely mobile</i> in groundwater.	Amenable to treatment with GAC.	Recommend keeping analyte for future groundwater sampling due to its solubility and mobility properties and because concentrations continue to be detected in groundwater.	1
1,1-Dichloroethene	Yes	NA	Yes	Yes ⁽¹⁾	Yes	MW-7	Has been consistently detected in groundwater since the OU-1/OU-3 RI at concentrations below the MCL.	0.0003	0.012	0.0003	0.0007	0.006 (MCL)	1,1-DCE is <i>highly soluble</i> (2,250 mg/L) and with a chemical retardation factor of 1.58, it is <i>moderately mobile</i> in groundwater.	Amenable to treatment with GAC.	Recommend keeping analyte for future groundwater sampling due to its solubility and mobility properties and because concentrations continue to be detected in groundwater.	1
1,2-Dichloroethane	Yes	NA	Yes	Yes ⁽¹⁾	No	N/A	Has been consistently detected in groundwater above the MCL in select wells since the OU-1/OU-3 RI.	0.0004	0.0009	0.0003	0.00008	0.0005 (MCL)	1,2-DCA is <i>highly soluble</i> (8,520 mg/L) and has a chemical retardation factor of 1.1, indicating that it is <i>extremely mobile</i> in groundwater.	Amenable to treatment with GAC.	Recommend keeping analyte for future groundwater sampling due to its solubility and mobility properties and because concentrations continue to be detected in groundwater.	1
1,4-Dioxane	NA	NA	NA	Yes ⁽³⁾	Yes	MW-3-3, MW-4-1, MW-4-2, MW-7, MW-10, MW-12-3, MW-14-2, MW-16, MW-18-4	Detected in the CGWME and then in select wells since then. Some concentrations are above the NL.	0.004	0.01	0.002	0.002	0.003 (NL)	1,4-Dioxane is <i>miscible</i> in water and has a chemical retardation factor of 1.0, indicating that it is <i>extremely mobile</i> in groundwater.	Not treatable with GAC or ion exchange. This constituent can be treated using UV chemical oxidation.	Recommend including this constituent for future groundwater sampling on an interim basis to begin with in order to confirm presence based on the detections in the CGWME and to determine extent because based on the fate and transport properties this compound is highly mobile in groundwater.	1
Carbon tetrachloride	Yes	NA	Yes	Yes ⁽¹⁾	Yes	MW-7, MW-8, MW-12-3, MW-16, MW-17-3, MW-18-4, MW-24-2	Based on the OU-2 RI, this compound is present in the soil. This compound was detected at levels above the MCL during the groundwater RI. Continues to be detected in on-site and off-site wells above the MCL during the long-term groundwater monitoring program.	0.0002	0.208	0.002	0.011	0.0005 (MCL)	Carbon tetrachloride is <i>moderately soluble</i> (154 mg/L) and with a chemical retardation factor of 1.62, it is <i>moderately mobile</i> in groundwater.	Amenable to treatment with GAC.	Recommend keeping analyte for future groundwater sampling due to its solubility and mobility properties and because concentrations continue to be detected in groundwater.	1
Methylene chloride	Yes	NA	Yes	Yes ⁽¹⁾	Yes	MW-3-5, MW-4-2, MW-4-5, MW-12-3	Was detected in groundwater above the MCL in select wells in the CGWME; however, these same wells were nondetect the following sampling event and have remained nondetect since then. Several wells continue to indicate the presence of methylene chloride at levels below the MCL.	0.0003	11.3	0.014	0.37	0.005 (MCL)	With a solubility of 13,200 mg/L and a chemical retardation factor of 1.07, methylene chloride is <i>extremely soluble</i> and <i>extremely mobile</i> in groundwater.	Amenable to treatment with GAC.	Recommend keeping analyte for future groundwater sampling due to its solubility and mobility properties and because concentrations continue to be detected in groundwater.	1
Styrene	No	NA	No	Yes ⁽¹⁾	Yes	MW-3-5	Sporadically detected in select wells at low levels below the MCL.	0.0003	0.0008	0.0003	0.00008	0.1 (MCL)	Styrene is <i>moderately soluble</i> (310 mg/L) and with a chemical retardation factor of 2.01, it is <i>moderately mobile</i> in groundwater.	Amenable to treatment with GAC.	Recommend keeping analyte for future groundwater sampling due to its solubility and mobility properties and because concentrations continue to be detected in groundwater.	1
Tetrachloroethene (PCE)	Yes	NA	Yes	Yes ⁽¹⁾	Yes	MW-4-2, MW-7, MW-10, MW-14-2, MW-17-3, MW-18-3, MW-18-4, MW-19-3, MW-19-5, MW-21-3, MW-21-5, MW-24-2	Has been consistently detected in groundwater. Concentrations above the MCL in select on-site and off-site wells.	0.0003	0.035	0.001	0.003	0.005 (MCL)	PCE is <i>moderately soluble</i> (200 mg/L) and with a chemical retardation factor of 1.81, it is <i>moderately mobile</i> in groundwater.	Amenable to treatment with GAC.	Recommend keeping analyte for future groundwater sampling due to its solubility and mobility properties and because concentrations continue to be detected in groundwater.	1
Trichloroethene (TCE)	Yes	NA	Yes	Yes ⁽¹⁾	Yes	MW-4-1, MW-4-2, MW-7, MW-8, MW-10, MW-12-3, MW-14-2, MW-17-3, MW-17-4, MW-18-4, MW-19-3, MW-19-5, MW-21-3, MW-21-5, MW-24-2	Has been consistently detected in groundwater. Concentrations above the MCL in select on-site and off-site wells.	0.0003	0.03	0.001	0.003	0.005 (MCL)	TCE is <i>highly soluble</i> (1,100 mg/L) and has a chemical retardation factor of 1.41, indicating that it is <i>moderately mobile</i> in groundwater.	Amenable to treatment with GAC.	Recommend keeping analyte for future groundwater sampling due to its solubility and mobility properties and because concentrations continue to be detected in groundwater.	1
Trichlorofluoromethane (Freon 11)	Yes	NA	Yes	Yes ⁽¹⁾	Yes	MW-8	Has been consistently detected in groundwater since the OU-1/OU-3 RI at concentrations below the MCL.	0.0003	0.002	0.0003	0.0001	0.15 (MCL)	Trifluoromethane is <i>highly soluble</i> (1,100 mg/L) and has a chemical retardation factor of 2.27, indicating that it is <i>moderately mobile</i> in groundwater.	Amenable to treatment with GAC.	Recommend keeping analyte for future groundwater sampling due to its solubility and mobility properties and because concentrations continue to be detected in groundwater.	1
Aromatic Hydrocarbons																

Table A-2. Matrix for Determining Chemical Constituents for Groundwater Analysis During Future Groundwater Monitoring at JPL

Analyte	Detected in Soil Gas during OU2 RI?	Detected in Soil During OU2 RI?	Detected in GW during the OU1 RI (1994-1998)?	Currently Included as Parameter in Long-Term Monitoring Program?	Analyte Detected in Comprehensive Groundwater Monitoring Event?	Wells Where Detected in CGWME	Supporting Information Based on the Results of the OU-1 and OU-2 RI and other Soil and Groundwater Investigations	Range of Concentrations Detected (mg/L) for the Years 2000 - 2005				California State MCL or Notification Level	Fate and Transport ^(5,6,7)	Treatability	Recommendation for Future GW Sampling	Group Identification ⁽⁸⁾	
								Detected Minimum	Detected Maximum	Arithmetic Mean ⁽⁴⁾	Standard Deviation ⁽⁴⁾						
Benzene	Yes	NA	Yes	Yes ⁽¹⁾	No	N/A	Detected once in MW-19-1 in July 2005, MW-1 in January 2001, and MW-23-4 in July 1997 at concentrations much less than the MCL.	0.0005	0.0006	0.0003	0.00007	0.001 (MCL)	With a solubility of 1,750 mg/L and a chemical retardation factor of 1.26, benzene is <i>highly soluble</i> and <i>highly mobile</i> in groundwater.	Amenable to treatment with GAC, used in conjunction with aeration.	Do not recommend keeping analyte as a parameter of interest based on the historical data; however, this compound will be included in standard VOC method analysis.	1	
Ethylbenzene	Yes	NA	Yes	Yes ⁽¹⁾	Yes	MW-3-5	Detected sporadically in MW-3, MW-4, MW-14, MW-8, MW-18, MW-21, MW-25 at concentrations much lower than the MCL.	0.0003	0.005	0.0003	0.0003	0.3 (MCL)	Ethylbenzene is <i>moderately soluble</i> (169 mg/L) and with a chemical retardation factor of 2.66, it displays <i>low mobility</i> in groundwater.	Amenable to treatment with GAC, used in conjunction with aeration.	Do not recommend keeping analyte as a parameter of interest based on the historical data and fate and transport properties; however, this compound will be included in standard VOC method analysis.	1	
Xylenes	Yes	NA	Yes	Yes ⁽¹⁾	No	N/A	Detected a few times in several wells at concentrations less than the MCL.	0.0004	0.0004	0.0003	0.00003	1.75 (MCL)	Xylenes are considered to be <i>insoluble</i> and with a chemical retardation factor of 2.34, this chemical shows <i>low mobility</i> in groundwater.	Amenable to treatment with GAC, used in conjunction with aeration.	Do not recommend keeping analyte as a parameter of interest based on the historical data and fate and transport properties; however, this compound will be included in standard VOC method analysis.	1	
Methyl-tert-butyl ether (MTBE)	No	NA	Yes	Yes ⁽¹⁾	No	N/A	Primarily detected in 2001 and 2002 at very low levels across the site. Detected once in MW-19-1 at an estimated concentration in July 2005, but was not detected at any other event in 2005.	0.0003	0.006	0.0005	0.0003	0.013 (MCL) 0.005 (Secondary MCL)	With a solubility of 51,000 mg/L and a chemical retardation factor of 1.02, MTBE is <i>extremely soluble</i> and <i>extremely mobile</i> in groundwater.	Can be treated with GAC, but usually requires multiple treatments.	Recommend keeping analyte for future groundwater sampling due to its solubility and mobility properties and because concentrations continue to be detected in groundwater.	1	
Toluene	Yes	NA	Yes	Yes ⁽¹⁾	No	N/A	Detected sporadically across the site in various wells at levels much lower than the MCL.	0.0003	0.0135	0.0003	0.0004	0.15 (MCL)	Toluene is <i>moderately soluble</i> (526 mg/L) and with a chemical retardation factor of 1.65, it is <i>moderately mobile</i> in groundwater.	Amenable to treatment with GAC, used in conjunction with aeration.	Do not recommend keeping analyte as a parameter of interest based on the historical data and fate and transport properties; however, this compound will be included in standard VOC method analysis.	1	
Total Petroleum Hydrocarbons																	
TPH (hydrocarbons greater than C10)	No	Yes	No	No	NA	N/A	In 1991, during excavation activities for the foundation of JPL Building 306, a layer of soil was encountered that appeared to be impacted with petroleum hydrocarbons. Soil samples were collected and indicated the presence of TPH up to 5,500 mg/kg at an average depth of 5 feet below ground surface.	N/A	N/A	N/A	N/A	N/A	According to the Toxicological Profile for TPH (ATSDR, 1999), solubility generally decreases with increasing molecular weight of the hydrocarbon compounds. For compounds having similar molecular weights, the aromatic hydrocarbons are more water soluble and mobile in water than the aliphatic hydrocarbons ⁽⁸⁾ and branched aliphatics are less water-soluble than straight-chained aliphatics. Lighter petroleum products such as gasoline contain constituents with higher water solubility and volatility and lower sorption potential than heavier petroleum products such as fuel oil. Data compiled from gasoline spills and laboratory studies indicate that these light-fraction hydrocarbons tend to migrate readily through soil, potentially threatening or affecting groundwater supplies. In contrast, petroleum products with heavier molecular weight constituents, such as fuel oil, are generally more persistent in soils, due to their relatively low water solubility and volatility and high sorption capacity.				
Total Petroleum Hydrocarbons (TPH) as Diesel Fuel (TPHD)	NA	NA	NA	No	Yes	MW-3-3; MW-17-4; MW-24-2 (range of 0.01 J mg/L to 0.02 J mg/L)	Approximately 19,000 tons of soil were subsequently excavated and properly disposed off-site. To evaluate whether TPH was detectable in the groundwater, groundwater samples from all five screens from MW-4 located immediately downgradient from Building 306, were analyzed for TPH during the first two RI sampling events (June 1994 and November 1994). TPH was not detected in well MW-4 during either sampling event. It was subsequently dropped as a constituent of concern pursuant to regulatory agency approval. TPHD and TPH Oil were detected at low levels during the CGWME in select wells; however individual constituents of TPH were not detected in these same wells during the CGWME.	0.01	0.02	0.365	0.2	N/A					
Total Petroleum Hydrocarbons (TPH) as Motor Oil	NA	NA	NA	No	Yes	MW-3-3 and MW-4-2 (0.03 J mg/L and 0.09 J mg/L)		0.03	0.09	0.411	0.2	N/A					
Total Petroleum Hydrocarbons (TPH) as Gasoline (TPHG)	NA	NA	NA	No	No	N/A		ND	ND	N/A	N/A	N/A		Individual constituents comprising TPH are amenable with GAC.	Do not recommend any future groundwater sampling for these compounds based on the historical groundwater results that indicate very low levels of TPH, but no detections of individual constituents. Because the TPH detected is comprised of the higher molecular weight compounds, the solubility and mobility are expected to be low. If, however, there are low levels in groundwater not being detected, the proposed treatment system design containing GAC would address their presence.	3	

Table A-2. Matrix for Determining Chemical Constituents for Groundwater Analysis During Future Groundwater Monitoring at JPL

Analyte	Detected in Soil Gas during OU2 RI?	Detected in Soil During OU2 RI?	Detected in GW during the OU1 RI (1994-1998)?	Currently Included as Parameter in Long-Term Monitoring Program?	Analyte Detected in Comprehensive Groundwater Monitoring Event?	Wells Where Detected in CGWME	Supporting Information Based on the Results of the OU-1 and OU-2 RI and other Soil and Groundwater Investigations	Range of Concentrations Detected (mg/L) for the Years 2000 - 2005				California State MCL or Notification Level	Fate and Transport ^(5,6,7)	Treatability	Recommendation for Future GW Sampling	Group Identification ⁽⁸⁾
								Detected Minimum	Detected Maximum	Arithmetic Mean ⁽⁴⁾	Standard Deviation ⁽⁴⁾					
Nitrosamines																
n-Nitrosodiphenylamine (NDPHA)	NA	NA	NA	No	Yes	MW-3-5, MW-4-1, MW-4-5, MW-7, MW-8, MW-10, MW-14-2, MW-14-4, MW-16, MW-17-3, MW-17-4, MW-19-3, MW-19-5, MW-21-5	Not included as a parameter of interest in either of the RI reports. Was included as a parameter in the CGWME where it was detected in several wells at estimated concentrations below the method detection limit. Has not been analyzed for since the CGWME.	0.000001	0.00002	0.000003	0.000005	N/A	NDPHA is considered <i>insoluble</i> (0.102 mg/L) and with a chemical retardation factor of 3.62, it has <i>low mobility</i> in groundwater.	Not treatable with GAC or ion exchange. This constituent can be treated using UV chemical oxidation.	Recommend including this constituent for future groundwater sampling in select wells on an interim basis to begin with in order to confirm the presence based on the detections in the CGWME. Based on the fate and transport properties of this compound, NDPHA is not expected to be present as the results of the CGWME indicated; however, as noted by DHS, the analysis of NDPHA is tricky since it must be extracted under acidic conditions to prevent the di-phenyl amine group breaking off and become subject to laboratory cross contamination by such groups and maybe that is the reason for the previous detections.	2
n-Nitrosodimethylamine (NDMA)	NA	NA	NA	Yes ⁽³⁾	Yes	MW-3-3, MW-3-5, MW-7, MW-21-5	Not included as a parameter of interest in either of the RI reports. Was included as a parameter in the CGWME where it was detected in several wells at levels below the NL. Also detected in MW-3-1, MW-3-2, MW-3-4 in July 2005 below the NL.	0.000002	0.000008	0.000002	0.000002	0.00001 (NL)	NDMA is <i>miscible</i> in water and has a chemical retardation factor of 1.03, indicating that it is <i>extremely mobile</i> in groundwater.	Not treatable with GAC or ion exchange. This constituent can be treated using UV chemical oxidation.	Recommend including this constituent for future groundwater sampling in select wells on an interim basis to begin with in order to confirm presence based on the detections in the CGWME and to monitor concentrations in MW-3 and determine extent because based on its fate and transport properties, this compound is highly mobile in water.	2
n-Nitrosodi-n-propylamine (NDPA)	NA	Yes	Yes	Yes ⁽³⁾	Yes	MW-3-5	NDPA was detected at 30 ft bgs in waste pit 4 located in the southeast portion of the site at a concentration of 0.5 mg/kg. Was detected in groundwater once in MW-3-5 in February 2003 at 0.125 ug/L, but was nondetect in MW-3 (all screens) in July 2005 (<0.0004 ug/L)	0.000125	0.000125	0.000009	0.00002	0.00001 (NL)	NDPA has a <i>low solubility</i> (9.9 mg/L), however, with a chemical retardation factor of 1.35, it is <i>highly mobile</i> in groundwater.	Not treatable with GAC or ion exchange. This constituent can be treated using UV chemical oxidation.	Recommend including this constituent for future groundwater sampling in select wells on an interim basis to begin with in order to confirm its presence in MW-3-5 and determine extent because based on its fate and transport properties, this compound is highly mobile in water.	2
Organotin																
Tributyltin	NA	Yes	Yes	No	NA	N/A	Analyses for tributyltin were performed on samples from select wells during five RI sampling events at the request of the DTSC. Tributyltin has historically been used by industry in cooling towers as an anti-bacterial agent. Since cooling towers have, and still are, being used at JPL, tributyltin analyses were performed. The wells to be sampled and the number of samples to be collected were recommended and agreed upon by the regulatory agencies (EPA, DTSC, and RWQCB) prior to sampling. Wells sampled included MW-4-1 and 2, MW-8, MW-12-1 and 2, and MW-13. Tributyltin was detected in one sample from MW-4-2 during the June/July, 1997 event, and in MW-12-1 during the August/September, 1996 and June/July, 1997 events at very low levels (not greater than 0.005 µg/L). Analysis for tributyltin was subsequently discontinued after the September/October, 1997 event, pursuant to approval from the EPA, DTSC, and the RWQCB.	NA	NA	N/A	N/A	N/A	According to the Toxicological Profile for Tin and Tin Compounds (ATSDR, 2005), organotin compounds are generally <i>only sparingly soluble</i> in water and are likely to partition to soils and sediments. Most commercially used organotin compounds are relatively immobile in environmental media due to their low vapor pressures, <i>low water solubilities</i> , and <i>high affinities for soil and organic sediments</i> . Tributyltin that is associated with particles in the water column may settle out, which is an important process in its removal from the water column. Tributyltin sorption coefficients to sediments can range from 100 to 10,000.	???	Do not recommend any future groundwater sampling for this compound based on the historical groundwater results, the low solubility, and the high affinity for soil.	2 (in order to address concerns from DHS)

Table A-2. Matrix for Determining Chemical Constituents for Groundwater Analysis During Future Groundwater Monitoring at JPL

Analyte	Detected in Soil Gas during OU2 RI?	Detected in Soil During OU2 RI?	Detected in GW during the OU1 RI (1994-1998)?	Currently Included as Parameter in Long-Term Monitoring Program?	Analyte Detected in Comprehensive Groundwater Monitoring Event?	Wells Where Detected in CGWME	Supporting Information Based on the Results of the OU-1 and OU-2 RI and other Soil and Groundwater Investigations	Range of Concentrations Detected (mg/L) for the Years 2000 - 2005				California State MCL or Notification Level	Fate and Transport ^(5,6,7)	Treatability	Recommendation for Future GW Sampling	Group Identification ⁽⁸⁾
								Detected Minimum	Detected Maximum	Arithmetic Mean ⁽⁴⁾	Standard Deviation ⁽⁴⁾					
Explosive Compounds																
RDX	NA	NA	NA	Yes ⁽³⁾	Yes	MW-3-3, MW-4-1, MW-4-2, MW-12-3, MW-12-4, MW-16	Included in the CGWME at the request of DHS. Some concentrations detected above the NL.	0.0007	0.027	0.002	0.006	0.0003 (NL)	RDX has a <i>low solubility</i> (60 mg/L), however, with a chemical retardation factor of 1.28, it is <i>highly mobile</i> in groundwater.	Amenable to treatment with GAC.	Recommend including this constituent for future groundwater sampling on an interim basis to begin with in order to confirm presence based on the detections in the CGWME and to determine extent because based on the fate and transport properties this compound is highly mobile in groundwater.	2
HMX	NA	NA	NA	Yes ⁽³⁾	Yes	MW-3-3, MW-4-1	Included in the CGWME at the request of DHS. All concentrations detected were below the NL.	0.0007	0.0025	0.0006	0.001	0.35 (NL)	HMX is <i>moderately soluble</i> (140 mg/L) and with a chemical retardation factor of 1.56, it is <i>moderately mobile</i> in groundwater.	Amenable to treatment with GAC.	Recommend including this constituent for future groundwater sampling on an interim basis to begin with in order to confirm presence based on the detections in the CGWME and to determine extent because based on the fate and transport properties this compound is fairly mobile in groundwater.	2
2,4-Dinitrotoluene	NA	No	Yes	No	No	N/A	This compound was not detected in soil during the OU-2 investigation. Compounds were detected in the June 1994 groundwater sampling event but not detected in a previous event (October 1993) or a subsequent event (December 1994). Note that the June data appear to be results for matrix spikes/duplicates rather than normal samples. Verification of these results cannot be made because the data are not available. It was analyzed for, but not detected in the CGWME.	ND	ND	N/A	N/A	N/A	2,4-DNT is <i>moderately soluble</i> (270 mg/L) and with a chemical retardation factor of 1.96, it is <i>moderately mobile</i> in groundwater.	Amenable to treatment with GAC.	Do not recommend any future groundwater sampling for this compound based on the historical groundwater results; however, this constituent is included in the analytical method for other explosive compounds that will be recommended for analysis. If, however, there are low levels in groundwater not being detected, the proposed treatment system design containing GAC would address their presence.	3 (This constituent was not detected in the CGWME, but will be analyzed for as part of the analytical method used for the other explosive compounds)
2,4,6-Trinitrotoluene	NA	NA	NA	Yes ⁽³⁾	Yes	MW-3-3, MW-4-1, MW-4-2, MW-12-5, MW-16	Included in the CGWME at the request of DHS. Some concentrations detected above the NL.	0.002	0.026	0.002	0.006	0.001 (NL)	2,4,6-TNT is <i>moderately soluble</i> (130 mg/L) and with a chemical retardation factor of 5.27, it displays <i>low mobility</i> in groundwater.	Amenable to treatment with GAC.	Recommend including this constituent for future groundwater sampling on an interim basis to begin with in order to confirm presence based on the detections in the CGWME.	2
PAHs																
Benzo(b)fluoranthene Benzo(a)pyrene Benzo(g,h,i)perylene Fluoranthene Indeno(1,2,3-cd)pyrene Phenanthrene Pyrene Benzo(a)anthracene Chrysene	NA	Yes	Yes	No	No	N/A	PAHs were detected only in one on-site well (MW-12-2) in June/July, 1994. A duplicate sample from MW-12-2 also was collected and analyzed during the June/July 1994 event, and no PAHs were detected. In addition, no PAHs were detected in MW-12-2 during the subsequent November/December, 1994 event. Thus, evidence suggested that the initial detects were anomalous. To further investigate, an additional sample and duplicate sample from MW-12-2 was analyzed for PAHs that had been previously detected during the August/September, 1996 event, and again, no PAHs were detected. It was therefore concluded that the initial detects were anomalous. Based on the results of these initial sampling events, and with the approval of the regulating agencies, SVOCs were excluded from the sampling program for subsequent events.	ND	ND	N/A	N/A	N/A	The solubility of these PAHs range from 0.00026 to 0.265, which is considered <i>insoluble</i> . The chemical retardation factors for PAHs ranges from 4.47 to 5,390, which corresponds to an <i>extremely low mobility to immobile</i> in groundwater. Given these properties, it is extremely unlikely that PAHs in soil could adversely affect the deep groundwater at JPL.	Amenable to treatment with GAC.	Do not recommend any future groundwater sampling for these compounds based on the historical groundwater results, the low solubility, and high affinity for soil. If, however, there are low levels in groundwater not being detected, the proposed treatment system design containing GAC would address their presence.	3

Table A-2. Matrix for Determining Chemical Constituents for Groundwater Analysis During Future Groundwater Monitoring at JPL

Analyte	Detected in Soil Gas during OU2 RI?	Detected in Soil During OU2 RI?	Detected in GW during the OU1 RI (1994-1998)?	Currently Included as Parameter in Long-Term Monitoring Program?	Analyte Detected in Comprehensive Groundwater Monitoring Event?	Wells Where Detected in CGWME	Supporting Information Based on the Results of the OU-1 and OU-2 RI and other Soil and Groundwater Investigations	Range of Concentrations Detected (mg/L) for the Years 2000 - 2005				California State MCL or Notification Level	Fate and Transport ^(5,6,7)	Treatability	Recommendation for Future GW Sampling	Group Identification ⁽⁸⁾
								Detected Minimum	Detected Maximum	Arithmetic Mean ⁽⁴⁾	Standard Deviation ⁽⁴⁾					
Dioxins/Furans																
1,2,3,4,6,7,8,9-OCDD	NA	Yes	NA	No	No	N/A	During the OU-2 RI, one dioxin congener was detected in soil at one location at a depth of 1 foot near an outfall south of Building 103. The closest downgradient monitoring well, MW-3, was analyzed for dioxins in October 1991 during the JPL Groundwater Sampling Program 1990-1993. Groundwater samples were nondetect. Groundwater samples collected from monitoring wells MW-1 through MW-7 in October 1991 were nondetect for dioxins as well. Furans were not detected in any of the soil or groundwater samples collected at JPL during the OU-1 and OU-2 RI.	ND	ND	N/A	N/A	N/A	Dioxins are <i>insoluble</i> and <i>immobile</i> and are therefore not considered a threat to groundwater at JPL.	Amenable to treatment with GAC.	Do not recommend any future groundwater sampling for this compound based on the historical groundwater results, the low solubility, and high affinity for soil. If, however, there are low levels in groundwater not being detected, the proposed treatment system design containing GAC would address their presence.	3
PCBs																
Aroclor-1232 Aroclor-1254 Aroclor-1260	NA	Yes	No	No	No	N/A	During the OU-2 RI, PCBs were detected at three locations within the top 6 feet of soil near an outfall just north of the southeastern corner of Building 103 and near another outfall south of Building 103. The closest downgradient monitoring well, MW-3, was analyzed for PCBs in March 1990 and October 1991. Groundwater samples from each event were nondetect for PCBs. In fact, groundwater samples collected from monitoring wells MW-1 through MW-7 have been nondetect for PCBs based on the results of these two sampling events.	ND	ND	N/A	N/A	N/A	PCBs are considered <i>insoluble</i> , and with a chemical retardation factor of 171, PCBs are considered <i>immobile</i> . Therefore, it is extremely improbable that concentrations of PCBs in soil could impact the deep groundwater at JPL.	Amenable to treatment with GAC.	Do not recommend any future analyses for PCBs in groundwater based on the results of the historical groundwater sampling events, and the insoluble nature and low mobility of these compound in soil. If, however, there are low levels in groundwater not being detected, the proposed treatment system design containing GAC would address their presence.	3
Bis(2-ethylhexyl)phthalate Di-n-butyl phthalate Butyl benzyl phthalate	NA	Yes	Yes	No	No	N/A	Compounds were detected in associated blank samples during groundwater RI and were therefore determined not to be present in groundwater.	ND	ND	N/A	N/A	N/A	The solubility of these phthalate compounds range from 0.285 to 13.0 mg/L, which is considered to be <i>low solubility to insoluble</i> . The chemical retardation factors for phthalates range from 4.68 to 234, which corresponds to an <i>extremely low mobility to immobile</i> in groundwater. Given these properties, it is extremely unlikely that phthalates in soil could adversely affect the deep groundwater at JPL.	Amenable to treatment with GAC.	Do not recommend any future groundwater sampling for these compounds based on the historical groundwater results, the low solubility, and high affinity for soil. If, however, there are low levels in groundwater not being detected, the proposed treatment system design containing GAC would address their presence.	3
Phenols																
Phenol, Chlorophenols (2-chlorophenol, 4-chloro-3-methylphenol, pentachlorophenol)	NA	No	No	No	No	N/A	The 97-005 Policy Document (Table 2-16) erroneously reported these compounds as detected in groundwater. Closer examination of the data indicated that the detections actually were results for matrix spikes/duplicates rather than normal samples for MW-6 in June 1994. Data obtained for MW-6 during the previous event (October 1993) and subsequent event (December 1994) were nondetect.	ND	ND	N/A	N/A	N/A	The solubility of these chlorophenols compounds range from 100 to 27,000 mg/L, which is considered to be <i>moderate to high solubility</i> . The chemical retardation factors for chlorophenols ranges from 1.04 to 44.25, indicating that chlorophenols can be <i>extremely mobile</i> in groundwater. Given these properties, it is possible that chlorophenols in soil could adversely affect the deep groundwater at JPL.	Amenable to treatment with chemical oxidation.	Do not recommend any future groundwater sampling for these compounds based on the results of the RI for soil and groundwater which support these compounds are not present in soil or groundwater.	3
Nitrophenols (4-nitrophenol)	NA	No	No	No	No	N/A	The 97-005 Policy Document (Table 2-16) erroneously reported these compounds as detected in groundwater. Closer examination of the data indicated that the detections actually were results for matrix spikes/duplicates rather than normal samples for MW-6 in June 1994. Data obtained for MW-6 during the previous event (October 1993) and subsequent event (December 1994) were nondetect.	ND	ND	N/A	N/A	N/A	The solubility of nitrophenols range from 1,400 to 16,000 mg/L, which is considered to be <i>highly to extremely soluble</i> . The chemical retardation factors for nitrophenols range from 1.31 to 1.7, which corresponds to <i>moderate to high mobility</i> in groundwater. Given these properties, it is possible that nitrophenols in soil could adversely affect the deep groundwater at JPL.	Amenable to treatment with chemical oxidation.	Do not recommend any future groundwater sampling for these compounds based on the results of the RI for soil and groundwater which support these compounds are not present in soil or groundwater.	3

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Analyte	Detected in Soil Gas during OU2 RI?	Detected in Soil During OU2 RI?	Detected in GW during the OU1 RI (1994-1998)?	Currently Included as Parameter in Long-Term Monitoring Program?	Analyte Detected in Comprehensive Groundwater Monitoring Event?	Wells Where Detected in CGWME	Supporting Information Based on the Results of the OU-1 and OU-2 RI and other Soil and Groundwater Investigations	Range of Concentrations Detected (mg/L) for the Years 2000 - 2005				California State MCL or Notification Level	Fate and Transport ^(5,6,7)	Treatability	Recommendation for Future GW Sampling	Group Identification ⁽⁹⁾
								Detected Minimum	Detected Maximum	Arithmetic Mean ⁽⁴⁾	Standard Deviation ⁽⁴⁾					

(1) All VOCs under EPA Method 524.2 are analyzed for on a quarterly or semi-annual basis for all wells.

(2) 1,2,3-TCP is included under Method 524.2, but detection limits are higher than the NL; More sensitive analytical methods are used for analysis at select wells on a quarterly basis

(3) Analyzed for quarterly in select wells.

(4) The arithmetic mean and standard deviation are based on both detects and nondetects for the 2000-2005 sampling events. One-half the detection limit was used for nondetects.

GAC - granulated activated carbon
 NA - not analyzed
 N/A - not applicable

CGWME - Comprehensive Groundwater Monitoring Event

(5) Solubility is expressed in terms of the number of milligrams of pure chemical that can be dissolved in one liter of water under standard conditions of 25 °C and one atmosphere of pressure. The solubility of an organic compound determines its propensity to dissolve into water. The greater the solubility, the greater the likelihood that the chemical will dissolve into infiltrating rainwater or groundwater and migrate away from release area. Solubility generally decreases with increasing molecular weight of the hydrocarbon compounds.

(6) The fate and transport properties of each chemical was characterized using chemical-specific properties and site-specific geotechnical data. Solubility is an important chemical property which defines the maximum amount of mass that is soluble in a given volume of water. The chemical retardation factor is a function of the organic carbon partitioning coefficient, K_{oc} and can be used to characterize the rate of contaminant transport relative to the groundwater velocity. A retardation factor of 1 corresponds to a chemical that is not retarded in groundwater, and thus travels at the same velocity as groundwater flow. The retardation factor can be used to calculate the velocity of contaminant transport in groundwater by dividing the groundwater flow velocity by the chemical retardation factor. The assumptions used to calculate the chemical retardation factor are shown below:

$$R = 1 + \rho_b (f_{oc} + k_{oc}) / \theta$$

$\rho_b = 1.6 \text{ g/cm}^3$
 $f_{oc} = 0.0005$
 $\theta = 0.30$
 k_{oc} = Chemical-specific property obtained from the Hazardous Substance Database.

(7) The fate and transport characteristics of each chemical have been characterized using the following scales:

Solubility Classification Scale:

insoluble ≤ 1.0 mg/L < *low* ≤ 100 mg/L < *moderate* ≤ 1,000 mg/L < *high* ≤ 10,000 mg/L < *extremely soluble*

Mobility Classification Scale:

extremely mobile ≤ $\frac{R = 1.13}{(K_{oc} = 50)}$ < *high* ≤ $\frac{R = 1.40}{(K_{oc} = 150)}$ < *moderate* ≤ $\frac{R = 2.33}{(K_{oc} = 500)}$ < *low* ≤ $\frac{R = 6.33}{(K_{oc} = 2,000)}$ < *slight* ≤ $\frac{R = 54.33}{(K_{oc} = 20,000)}$ < *immobile*

(8) **Table 5-7. Representative Physical Parameters for TPH Fractions, Based on Correlation to Relative Boiling Point Index**

Fraction	Solubility, mg/L	Vapor pressure, atm	Henry's law, cm ³ /cm ³	Log K _{oc}
Aliphatics				
EC ₇ -EC ₉	36	0.35	47	2.9
EC ₁₀ -EC ₁₁	5.4	0.063	50	3.6
EC ₁₂ -EC ₁₃	0.43	0.0063	55	4.5
EC ₁₄ -EC ₁₅	0.034	0.00063	60	5.4
EC ₁₆ -EC ₁₈	0.00076	0.000076	69	6.7
EC ₁₉ -EC ₂₅	0.0000025	0.0000011	85	8.8
Aromatics				
EC ₇ -EC ₇ ^a	220	0.11	1.5	3.0
EC ₇ -EC ₈ ^b	130	0.035	0.86	3.1
EC ₉ -EC ₁₀	65	0.0063	0.39	3.2
EC ₁₂ -EC ₁₂	25	0.00063	0.13	3.4
EC ₁₂ -EC ₁₆	5.8	0.000048	0.028	3.7
EC ₁₉ -EC ₂₁	0.65	0.0000011	0.0025	4.2
EC ₂₁ -EC ₂₅	0.0066	0.0000000044	0.000017	5.1

^a The only compound contained in this fraction is benzene.
^b The only compound contained in this fraction is toluene.

Source: TPHCWG 1997b

(9) Group identification is as follows: 1 - indicates that the parameter is already included in the long-term monitoring program; 2 - indicates that this parameter needs additional investigation to determine whether it should be included in the groundwater monitoring program; 3 - indicates that the compound will not be included in future groundwater sampling based on the results of previous investigations and chemicals properties.