

**FINAL  
GROUNDWATER  
MONITORING REPORT  
OCTOBER - NOVEMBER 2003**



**NATIONAL AERONAUTICS AND SPACE ADMINISTRATION  
JET PROPULSION LABORATORY  
4800 Oak Grove Drive  
Pasadena, California 91109**

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**Naval Facilities Engineering Command  
1220 Pacific Highway  
San Diego, California 92132-5187**

Prepared by:

**GEOFON, Inc.**  
22632 Golden Springs Dr. #270  
Diamond Bar, California 91765

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For | Prepared by:  2/5/04  
Brad Shojaee Date  
Project Hydrogeologist

Reviewed by:  2-5-04  
Anthony G. Ford Date  
Senior Geologist

Approved by:  2/5/04  
Asrar Faheem, REA Date  
Senior Project Manager

Approved by:  2-5-2004  
Charles K. Duckworth, P.E. Date  
Program Manager

## TABLE OF CONTENTS

<b>Section</b>	<b>Page</b>
ACRONYMS/ABBREVIATIONS.....	vii
EXECUTIVE SUMMARY .....	viii
1.0 INTRODUCTION .....	1
2.0 FIELD SAMPLING PROCEDURES .....	3
2.1 Shallow Monitoring Wells.....	3
2.2 Deep Multi-Port Monitoring Wells.....	4
2.3 Field Quality Assurance/Quality Control Samples .....	5
3.0 ANALYTICAL RESULTS .....	6
3.1 Volatile Organic Compounds .....	6
3.2 Perchlorate .....	7
3.3 Metals.....	8
3.4 Quality Assurance/Quality Control.....	8
4.0 DATA VERIFICATION AND VALIDATION.....	10
4.1 Data Verification.....	10
4.2 Data Validation.....	10
4.3 Data Validation Qualifiers .....	10
5.0 WATER LEVEL MEASUREMENTS .....	11
6.0 CONCLUSIONS AND RECOMMENDATIONS .....	13
7.0 REFERENCES .....	14

## **LIST OF TABLES**

Table 1-1	Summary of Well Construction Details for JPL Groundwater Monitoring Wells
Table 3-1	Summary of Analyses Performed on Groundwater Samples Collected from JPL Monitoring Wells
Table 3-2	Location of JPL Wells and Well Screens in Aquifer Layers
Table 3-3	Summary of Volatile Organic Compounds and Perchlorate Detected in Groundwater Samples Collected from JPL Monitoring Wells
Table 3-4	Summary of Volatile Organic Compounds and Perchlorate Detected during the Long-term Quarterly Groundwater Sampling Program
Table 3-5	Summary of Volatile Organic Compounds and Perchlorate Reported in Municipal Production Wells near JPL during the Most Recent Sampling Events
Table 3-6	Summary of Metals Analyses of Groundwater Samples Collected from JPL Monitoring Wells
Table 3-7	Summary of Metals Detected during the Long-term Quarterly Groundwater Sampling Program
Table 3-8	Summary of Contaminants Detected in Quality Control Samples Collected during the October - November 2003 Sampling Event
Table 5-1	Groundwater Monitoring Well Water Level Measurements, October 21-22, 2003
Table 5-2	Groundwater Monitoring Well Water Level Measurements, November 11, 2003

## **LIST OF FIGURES**

Figure 1-1	Locations of JPL Groundwater Monitoring Wells and Nearby Municipal Production Wells
Figure 3-1	Contours of Carbon Tetrachloride Concentrations in Aquifer Layer 1
Figure 3-2	Contours of Carbon Tetrachloride Concentrations in Aquifer Layer 2
Figure 3-3	Contours of Carbon Tetrachloride Concentrations in Aquifer Layer 3
Figure 3-4	Contours of Trichloroethene Concentrations in Aquifer Layer 1
Figure 3-5	Contours of Trichloroethene Concentrations in Aquifer Layer 2
Figure 3-6	Contours of Trichloroethene Concentrations in Aquifer Layer 3
Figure 3-7	Contours of Tetrachloroethene Concentrations in Aquifer Layer 1
Figure 3-8	Contours of Tetrachloroethene Concentrations in Aquifer Layer 2
Figure 3-9	Contours of Tetrachloroethene Concentrations in Aquifer Layer 3

## LIST OF FIGURES (CONT'D)

- Figure 3-10 Contours of Perchlorate Concentrations in Aquifer Layer 1
- Figure 3-11 Contours of Perchlorate Concentrations in Aquifer Layer 2
- Figure 3-12 Contours of Perchlorate Concentrations in Aquifer Layer 3
- Figure 3-13 Carbon Tetrachloride Detected at MW-3
- Figure 3-14 Perchlorate Detected at MW-3
- Figure 3-15 Carbon Tetrachloride Detected at MW-4
- Figure 3-16 Trichloroethene Detected at MW-4
- Figure 3-17 1,2-DCA Detected at MW-4
- Figure 3-18 Perchlorate Detected at MW-4
- Figure 3-19 Carbon Tetrachloride Detected at MW-5
- Figure 3-20 Trichloroethene Detected at MW-5
- Figure 3-21 Perchlorate Detected at MW-5
- Figure 3-22 Carbon Tetrachloride Detected at MW-7
- Figure 3-23 Trichloroethene Detected at MW-7
- Figure 3-24 Tetrachloroethene Detected at MW-7
- Figure 3-25 1,2-DCA Detected at MW-7
- Figure 3-26 1,1-DCE Detected at MW-7
- Figure 3-27 Perchlorate Detected at MW-7
- Figure 3-28 Carbon Tetrachloride Detected at MW-8
- Figure 3-29 Perchlorate Detected at MW-8
- Figure 3-30 Carbon Tetrachloride Detected at MW-10
- Figure 3-31 Trichloroethene Detected at MW-10
- Figure 3-32 Perchlorate Detected at MW-10
- Figure 3-33 Carbon Tetrachloride Detected at MW-11
- Figure 3-34 Perchlorate Detected at MW-11
- Figure 3-35 Carbon Tetrachloride Detected at MW-12
- Figure 3-36 Perchlorate Detected at MW-12
- Figure 3-37 Carbon Tetrachloride Detected at MW-13
- Figure 3-38 Trichloroethene Detected at MW-13
- Figure 3-39 1,2-DCA Detected at MW-13
- Figure 3-40 Perchlorate Detected at MW-13

## LIST OF FIGURES (CONT'D)

- Figure 3-41 Trichloroethene Detected at MW-14
- Figure 3-42 Perchlorate Detected at MW-14
- Figure 3-43 Carbon Tetrachloride Detected at MW-16
- Figure 3-44 Trichloroethene Detected at MW-16
- Figure 3-45 1,2-DCA Detected at MW-16
- Figure 3-46 Perchlorate Detected at MW-16
- Figure 3-47 Carbon Tetrachloride Detected at MW-17
- Figure 3-48 Trichloroethene Detected at MW-17
- Figure 3-49 Perchlorate Detected at MW-17
- Figure 3-50 Carbon Tetrachloride Detected at MW-18
- Figure 3-51 Trichloroethene Detected at MW-18
- Figure 3-52 Perchlorate Detected at MW-18
- Figure 5-53 Perchlorate Detected at MW-19
- Figure 3-54 Perchlorate Detected at MW-20
- Figure 3-55 Trichloroethene Detected at MW-21
- Figure 3-56 Tetrachloroethene Detected at MW-21
- Figure 3-57 Perchlorate Detected at MW-21
- Figure 3-58 Carbon Tetrachloride Detected at MW-23
- Figure 3-59 Trichloroethene Detected at MW-23
- Figure 3-60 Perchlorate Detected at MW-23
- Figure 3-61 Carbon Tetrachloride Detected at MW-24
- Figure 3-62 Trichloroethene Detected at MW-24
- Figure 3-63 Perchlorate Detected at MW-24
- Figure 5-1 Water-Table Elevation Contour Map, October 21-22, 2003
- Figure 5-2 Water-Table Elevation Contour Map, November 11, 2003
- Figure 5-3 Hydraulic Head Elevations from Deep Multi-Port Wells, October-November 2003

## **LIST OF APPENDICES**

- Appendix A Well Development/Well Sampling Log Forms for Shallow Wells and Groundwater Sampling Field Data Sheets for Deep Multi-Port Wells
- Appendix B Piezometric Pressure Profile Records
- Appendix C Laboratory Analytical Reports and Chain-of-Custody Forms
- Appendix D Data Validation Reports
- Appendix E Summary of Volatile Organic Compounds and Perchlorate Detected During the Long-Term Groundwater Sampling Program from Aug/Sep 1996 to Oct/Nov 2002
- Appendix F Summary of Metals Detected During the Long-Term Groundwater Sampling Program from Aug/Sep 1996 to Oct/Nov 2002

## ACRONYMS/ABBREVIATIONS

1,1-DCA	1,1-dichloroethane
1,2-DCA	1,2-dichloroethane
1,1-DCE	1,1-dichloroethene
APCL	Applied Physics and Chemistry Laboratory
As	total arsenic
CCl <sub>4</sub>	carbon tetrachloride
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
ClO <sub>4</sub> <sup>-</sup>	perchlorate
Cr	total chromium
Cr(VI)	hexavalent chromium
DHS	California Department of Health Services
DLR	detection level for the purpose of reporting
DQOs	data quality objectives
DTSC	Department of Toxic Substance Control
EPA	United States Environmental Protection Agency
GEOFON	GEOFON Incorporated
IAL	State Interim Action Level
JPL	Jet Propulsion Laboratory
LAWC	Lincoln Avenue Water Company
LCID	La Canada Irrigation District
LDC	Laboratory Data Consultants, Inc.
LFWC	Las Flores Water Company
MCLs	Maximum Contaminant Levels
µg/L	micrograms per liter
mg/L	milligrams per liter
MIBK	4-methyl-2-pentanone
mL	milliliter
MS	matrix spikes
MSD	matrix spike duplicates
MW	monitoring well
NASA	National Aeronautics and Space Administration
NDMA	N-nitrosodimethylamine
OU	operable unit
Pb	total lead
PCE	tetrachloroethene
PQL	practical quantitation limit

## ACRONYMS/ABBREVIATIONS (CONT'D)

QA/QC	quality assurance/quality control
QAPP	Quality Assurance Project Plan
RCLWC	Rubio Canon Land & Water Company
RWQCB	California Regional Water Quality Control Board
SOTA	SOTA Environmental Technology, Inc.
TCE	trichloroethene
TDS	total dissolved solids
VOCs	volatile organic compounds
VWC	Valley Water Company
Westbay	Westbay Instruments, Inc.

## EXECUTIVE SUMMARY

Presented in this report are the results of the October - November 2003 groundwater sampling event completed as part of the groundwater monitoring program at the National Aeronautics and Space Administration (NASA) Jet Propulsion Laboratory (JPL) under contract with Naval Facilities Engineering Command. This sampling event was conducted from October 21 through November 11, 2003.

During the October - November 2003 sampling event (a semi-annual sampling event), groundwater samples were collected from 23 JPL monitoring wells, both on- and off-facility, and analyzed for volatile organic compounds (VOCs), metals (total chromium, and hexavalent chromium), and perchlorate. MW-2 has not been sampled since it was replaced with well MW-14 as a JPL sampling point.

All data collected were subject to data verification and all laboratory analytical data were validated pursuant to the Navy's Level IV quality assurance requirements. Some of the analytical data were qualified based on data validation reviews, in accordance with applicable United States Environmental Protection Agency (EPA) guidelines. No data were rejected for non-compliance with method requirements during the course of validation and no data were qualified as unusable. The analytical results are summarized below.

- Seven on-facility wells and three off-facility wells contained concentrations of one or more of three VOCs (carbon tetrachloride, trichloroethene, and tetrachloroethene) that exceeded State or Federal Maximum Contaminant Levels (MCLs) for drinking water. Concentration contour maps generally indicate slow migration of the contaminant plumes over the last year.
- Perchlorate was detected in twelve on-facility wells and five off-facility wells, with concentrations in ten on-facility and five off-facility wells that exceeded the State Interim Action Level (IAL).
- Total chromium was detected in 21 wells; however, no concentrations exceeded the State and Federal MCL of 50  $\mu\text{g/L}$ . Hexavalent chromium was detected in two wells (MW-8 and MW-13). As of January 6, 2004, hexavalent chromium is regulated under the 50-microgram per liter ( $\mu\text{g/L}$ ) MCL for total chromium. The California Department of Health Services (DHS) will be adopting an MCL that is specific for hexavalent chromium (DHS, 2004).

Groundwater gradients and flow directions before and after sampling activities were consistent with the results from the January – February 2003 sampling event observations. The natural seasonal fluctuation of the hydraulic head is believed to be the main factor contributing to the difference in water level elevations between each quarterly sampling event. Other factors that might influence the water level can be caused by several hydrologic phenomena operating simultaneously including, but not limited to pumpage, and/or artificial recharge.

## 1.0 INTRODUCTION

The locations of the JPL groundwater monitoring wells are shown in Figure 1-1. Monitoring wells MW-3, MW-4, MW-11, MW-12, MW-14, and MW-17 through MW-24 are deep multi-port wells, each containing five screened intervals equipped with a Westbay Instruments, Inc. (Westbay) multi-port casing system. Monitoring wells MW-1, MW-5 through MW-10, MW-13, MW-15, and MW-16 are relatively shallow standpipe wells, each containing a single screened interval located just below the water table. A summary of the well construction details for the JPL groundwater monitoring wells is included in Table 1-1.

During the October - November 2003 event, GEOFON personnel collected samples from all JPL monitoring wells except MW-2. Shallow well MW-2 has not been sampled since it was replaced with deep multi-port well MW-14 as a JPL sampling point. Groundwater samples were collected in accordance with the sampling program that was previously approved by the Environmental Protection Agency (EPA), Department of Toxic Substance Control (DTSC), and California Regional Water Quality Control Board (RWQCB).

In addition, the water-level elevation at each well was measured on October 21 and 22, 2003 (prior to sampling), and on November 11, 2003 (after sampling) to evaluate groundwater flow directions and gradients.

Samples from each well were collected and analyzed during this event in accordance with the sampling program that was approved by the EPA, DTSC, and RWQCB.

All of the JPL groundwater samples were shipped to Applied Physics and Chemistry Laboratory (APCL) in Chino, California, for chemical analysis. APCL is certified by the California Department of Health Services and approved for use by the Naval Facilities Engineering Command, Quality Assurance/Quality Control (QA/QC) program. Sample collection procedures and sample analysis were conducted by GEOFON in accordance with the Work Plan for Performing a Remedial Investigation/Feasibility Study (Ebasco, 1993a), which was approved by the regulatory agencies.

In addition to groundwater samples, field QA/QC samples, including trip blanks, equipment blanks, duplicate samples, and a field blank, were collected for laboratory analyses. Sampling records for each shallow well and field data sheets for deep multi-port wells are included in Appendix A. Piezometric pressure profiling records for each deep multi-port well are included in Appendix B. Laboratory analytical reports and associated chain-of-custody forms are included in Appendix C, and data validation reports are provided in Appendix D.

Appendices E and F present summaries of analytical results for volatile organic compounds (VOCs) and metals, respectively, that were reported by others prior to GEOFON's initiation of the Long-Term Groundwater Monitoring activities at the JPL facility in January of 2003. Due to Navy's request, the format of the tables summarizing the result of the groundwater sample parameters was modified by GEOFON to present the data qualifiers as reported by the data validation company.

## **2.0 FIELD SAMPLING PROCEDURES**

Two different procedures were used to collect groundwater samples at JPL, one designed for the shallow wells and the other for the deep multi-port wells. These procedures are outlined below.

### **2.1 Shallow Monitoring Wells**

The sampling procedure described below was applied to all the shallow JPL monitoring wells, including MW-5, MW-6, MW-7, MW-8, MW-10, MW-13, MW-15 and MW-16.

- The primary equipment used to sample the shallow wells included dedicated 2-inch diameter Grundfos Redi-Flo2® pumps, a pump controller, and a 220-volt generator. All of the dedicated Grundfos Redi-Flo2® pump systems were previously decontaminated prior to their permanent installation. Details of the decontamination procedures for the Grundfos Redi-Flo2® pump systems are outlined in the Operable Unit (OU) OU-1 Field Sampling and Analysis Plan (Ebasco, 1993b).
- Prior to sample collection, the water in each shallow well casing was purged (by pumping at about 2.5 gallons per minute) to remove groundwater that may have been exposed to the atmosphere and thus may not be representative of undisturbed aquifer conditions. This purged groundwater was discharged into 500 or 1,000-gallon polyethylene storage tanks for subsequent disposal by GEOFON in accordance with Federal, State, and local regulations.
- Temperature, pH, electrical conductivity, and turbidity of the water removed from each well were monitored during purging. Pursuant to the approved work plan (Ebasco, 1993b), a minimum of three casing volumes of water was purged and temperature, pH, electrical conductivity and turbidity were monitored for stabilization. When two successive measurements, made approximately 5 minutes apart, were within 10 percent of each other, groundwater samples were collected using the dedicated pump. During sampling for VOCs, the pumping rate was reduced to minimize sample agitation and volatilization. All information concerning sampling was noted on the Well Development/Well Sampling Log forms included in Appendix A.
- All sample bottles were filled completely without overflowing, capped, labeled, and immediately placed in a cooler with ice. Samples collected for VOCs had zero headspace.

- Calibration, or standardization of the field instruments used to measure temperature, pH, electrical conductivity, and turbidity, was performed according to the manufacturer's specifications at the beginning of each sampling day.

## **2.2 Deep Multi-Port Monitoring Wells**

Sampling of the deep multi-port monitoring wells at JPL required specialized sampling equipment manufactured by Westbay Instruments, Inc. (Westbay). This equipment included a pressure profiling/sampling probe with a surface control unit. To ensure proper use, field personnel using this equipment were trained by Westbay personnel. Copies of the detailed operations manuals for the Westbay pressure profiling/sampling probe are included in the OU-1 and OU-3 Field Sampling and Analysis Plans (Ebasco, 1993b; 1994).

The Westbay sampling probe and sample-collection bottles were decontaminated prior to sampling each screened interval in the deep multi-port wells according to the following procedures:

- Each 250-mL stainless-steel sample-collection bottle was washed in a solution of non-phosphate detergent (Liquinox<sup>®</sup>) and distilled water, followed by a solution of an acidic detergent (Citranox<sup>®</sup>) and distilled water.
- Each bottle was rinsed with distilled water.
- The interior surfaces of the Westbay sampling probe, and the hoses and valves associated with the Westbay sample bottles were decontaminated by forcing several volumes of a solution of Liquinox<sup>®</sup> and distilled water through them, followed by forcing several volumes of a solution of Citranox<sup>®</sup> and distilled water. A final rinse with distilled water was carried out. Each of these decontamination procedures was completed using clean plastic spray bottles used only for this purpose.

Purging before sampling is not required in the deep multi-port monitoring wells because the groundwater samples were collected directly from the aquifer, thus ensuring that the groundwater samples were not exposed to the atmosphere. However, at each screened interval, an initial sample was collected in order to check temperature, pH, electrical conductivity, and turbidity in the field. Samples for laboratory analysis were then collected and transferred to sample containers as described in Section 2.1. Results of the field analyses were recorded on groundwater sampling field data sheets (Appendix A). Calibration of field instruments was carried out according to procedures described previously.

### 2.3 Field Quality Assurance/Quality Control Samples

Field QA/QC samples were collected to verify the quality of sampling procedures. The field QA/QC program included the collection of duplicate samples, equipment blanks, trip blanks, and source blanks. Laboratory QA/QC samples were used by the laboratory according to analytical method requirements.

Duplicate samples for VOCs, hexavalent chromium [Cr(VI)], total chromium (Cr), and perchlorate ( $\text{ClO}_4^-$ ) analyses were collected from deep multi-port monitoring wells MW-4 (Screen 5), MW-12 (Screen 1), MW-17 (Screen 3), MW-20 (Screen 2), and MW-24 (Screen 4). Two duplicate samples were also collected from shallow monitoring wells MW-8 and MW-15.

Matrix-Spike (MS) and Matrix-Spike Duplicate (MSD) samples were collected for 10% of samples that were analyzed for VOCs,  $\text{ClO}_4^-$ , Cr(VI), and Cr. These samples were used for laboratory QA/QC requirements.

One equipment blank was collected from the Westbay sample-collection bottles during each day of sampling the deep multi-port wells. Equipment blanks consisted of distilled water that was passed through the sampling equipment after the equipment was decontaminated. Equipment blanks were analyzed for the same constituents as the groundwater samples, except for cations and anions, total dissolved solids, and pH, to identify potential cross contamination due to inadequate decontamination. Because only dedicated sampling equipment was used, equipment blanks were not collected during sampling of the shallow wells.

A trip blank, consisting of American Society for Testing Materials Type II water placed in two 40-mL glass vials by the laboratory, was transported with the empty sample bottles to the field and back to the laboratory with the groundwater samples. One trip blank was submitted for VOC analysis with each shipment of groundwater samples to the laboratory. Trip blanks were used to identify potential cross contamination of groundwater samples during transport.

### 3.0 ANALYTICAL RESULTS

The groundwater samples collected during this sampling event were analyzed for the following:

- Volatile Organic Compounds (VOCs)
- Total Chromium (Cr)
- Hexavalent Chromium [Cr(VI)]
- Perchlorate ( $\text{ClO}_4^-$ )

A summary of the samples collected and the analyses performed on each sample is presented in Table 3-1. Analytical laboratory reports and associated chain-of-custody forms are included in Appendix C.

The aquifer beneath JPL was divided into four aquifer layers based primarily on correlations interpreted from lithologic cross sections (Foster Wheeler, 2000). Table 3-2 provides a list of the JPL Westbay monitoring well screens and their corresponding aquifer layers. Concentrations of carbon tetrachloride ( $\text{CCl}_4$ ), trichloroethene (TCE), tetrachloroethene (PCE), and perchlorate ( $\text{ClO}_4^-$ ) reported during this event are presented for each aquifer layer in Figures 3-1 through 3-12.

#### 3.1 Volatile Organic Compounds

Groundwater samples collected during the October - November 2003 sampling event were analyzed for over 60 different VOCs in accordance with EPA Method 524.2. Results of the analyses for VOCs are summarized in Table 3-3 along with the State and Federal Maximum Contaminant Levels (MCLs) for drinking water as listed in Title 22 of the California Code of Regulations and in the EPA Health Advisory Guidelines.

A small number of compounds were detected in the JPL samples, and three VOCs ( $\text{CCl}_4$ , TCE, and PCE) were found in one or more wells at concentrations that exceeded State and/or Federal MCLs. The concentrations of  $\text{CCl}_4$ , TCE, and PCE detected in each aquifer layer were contoured on site maps to show the spatial distribution of each constituent (Figures 3-1 through 3-9). The analytical results for compounds that exceeded MCLs are discussed below.

- Concentrations of  $\text{CCl}_4$  in excess of the State MCL [0.5 micrograms per liter ( $\mu\text{g/L}$ )] were reported in samples from six on-facility wells [MW-3 (Screen 2), MW-7, MW-12 (Screens 2 through 4), MW-13, MW-16, and MW-24 (Screens 1 and 2)] and two off-facility wells [MW-17 (Screens 2 and 3), and MW-18 (Screen 4)]. The Federal MCL (5.0  $\mu\text{g/L}$ ) was exceeded in MW-7 and MW-24. The highest concentration of  $\text{CCl}_4$  was reported in well MW-7 (42.0  $\mu\text{g/L}$ ).

- TCE was detected in eight on-facility wells and four off-facility wells. Reported TCE concentrations exceeded the State and Federal MCL (5.0 µg/L) in three on-facility wells (MW-7, MW-10, and MW-13) and two off-facility well [MW-17 (Screen 2) and MW-21 (Screen 1)]. The highest concentration of TCE was reported in on-facility well MW-10 (10.8 µg/L).
- PCE was detected in nine on-facility and four off-facility wells. The State and Federal MCL (5.0 µg/L) was exceeded in on-facility well MW-7 (7.2 µg/L) and off-facility well MW-21 Screen 4 (7.7 µg/L) and Screen 5 (8.8 µg/L).

A summary of the VOC results compiled from the long-term sampling events that have been completed to date is provided in Table 3-4. Nine chemicals have been most commonly reported with concentrations above the laboratory detection limits [ $\text{CCl}_4$ , TCE, PCE, 1,1-dichloroethane (1,1-DCA), 1,2-dichloroethane (1,2-DCA), 1,1-dichloroethene (1,1-DCE), Freon 113, chloroform, and  $\text{ClO}_4^-$ ]. The concentrations of these compounds versus time were plotted, if at any time they exceeded their respective MCL from August/September 1996 through October - November 2003. The plots are presented in Figures 3-13 through 3-63.

Additional data regarding VOC concentrations in samples collected from ten municipal production wells in the vicinity of JPL were obtained from the California Department of Health Services (DHS) Drinking Water Program (DHS, 2003). The most recently available analytical results were compiled for samples collected from municipal and private drinking water wells owned and operated by La Canada Irrigation District (LCID), Lincoln Avenue Water Company (LAWC), Valley Water Company (VWC), and Las Flores Water Company (LFWC).

The most recent samples from three drinking water wells exceeded the State MCLs for  $\text{CCL}_4$  and PCE.  $\text{CCL}_4$  was detected at LAWC Well #3 (1.8 µg/L), exceeding the State MCL (0.5 µg/L). PCE was detected at concentration above the MCL (5.0 µg/L) at LFWC Well #2 (maximum concentration of 18.0 µg/L) (DHS, 2004). TCE was detected in three municipal wells at concentrations below the State MCL (5.0 µg/L). The drinking water data from the municipal wells are summarized in Table 3-5.

### 3.2 Perchlorate

$\text{ClO}_4^-$  analyses were conducted on groundwater samples from the October - November 2003 event using ion chromatography modified EPA Method 314.0 and the results are summarized in Table 3-3.  $\text{ClO}_4^-$  is among the unregulated chemicals requiring monitoring (Title 22, California Code of Regulations §64450). Although, no MCL has been established for  $\text{ClO}_4^-$ , the DHS has implemented an interim action level (IAL) to protect the public from the adverse health effects of  $\text{ClO}_4^-$ . In January 2002, DHS reduced the  $\text{ClO}_4^-$  IAL to 4 µg/L (from the previous 18 µg/L).

DHS will be proposing an MCL for  $\text{ClO}_4^-$  in 2004. Until the MCL has been established, DHS will continue to using a 4  $\mu\text{g/L}$  AL.

Concentrations of perchlorate in excess of the State MCL [0.5 micrograms per liter ( $\mu\text{g/L}$ )] were reported in samples from ten on-facility wells [MW-3 (Screen 2), MW-7, MW-8, MW-10, MW-13, MW-14 (Screens 1 through 4), MW-16, MW-22 (Screen 2), MW-23 (Screen 2), and MW-24 (Screens 1 and 2)] and five off-facility wells [MW-17 (Screens 2 and 3), MW-18 (Screen 4), MW-19 (Screens 2 and 3), MW-20 (Screen 1), and MW-21 (Screen 1)].

The highest levels of  $\text{ClO}_4^-$  were reported in samples from MW-24 (2,760  $\mu\text{g/L}$ ), MW-16 (1,360  $\mu\text{g/L}$ ), and MW-7 (2,400  $\mu\text{g/L}$  in Screen 1).  $\text{ClO}_4^-$  concentrations have been contoured in Figures 3-10, 3-11, and 3-12 for aquifer layers 1, 2, and 3, respectively.

Additional data regarding  $\text{ClO}_4^-$  concentrations in samples collected from three municipal production wells in the vicinity of JPL were obtained from the DHS Drinking Water Program (DHS, 2003). The most recently available analytical results were compiled for samples collected from municipal and private drinking water wells owned and operated by LFWC and Rubio Canon Land & Water Company (RCLWC).  $\text{ClO}_4^-$  was detected and exceeded the IAL (4  $\mu\text{g/L}$ ) during several events at LFWC Well #2 and RCLWC Well #4 & 7 (DHS, 2003). The drinking water data for  $\text{ClO}_4^-$  are summarized in Table 3-5.

### **3.3 Metals**

Groundwater samples collected during the October - November 2003 event were analyzed for the following metals: Cr(VI) and Cr. The results of the metals analyses are presented in Table 3-6, and are summarized below.

- Cr(VI) was not detected in any of the wells sampled. At this time, neither State nor Federal regulatory agencies have established an MCL for Cr(VI). Cr(VI) is currently regulated by the State under the MCL for Cr (0.05  $\mu\text{g/L}$ ).
- Cr was detected in all 20 wells sampled during this monitoring event. None of the reported concentrations exceeded the State MCL (0.05 mg/L) or Federal MCL (0.10 mg/L).

Table 3-7 presents a summary of metals data from all quarterly sampling events completed to date during the long-term monitoring program.

### **3.4 Quality Assurance/Quality Control**

Review of the QA/QC data provided with the laboratory analytical results indicates that all of the analytical results obtained from October - November 2003 samples are acceptable for their intended use of characterizing aquifer quality. Surrogate compound, matrix and blank spike, and

method blank results were used by the laboratory to determine the accuracy and precision of the analytical techniques with respect to the JPL groundwater matrix, and to identify anomalous results due to laboratory contamination or instrument malfunction. In addition to laboratory QA/QC samples, GEOFON personnel collected QA/QC samples in the field in general accordance with the Quality Assurance Project Plan (QAPP) (Ebasco, 1993c). The field QA/QC samples included duplicate samples, equipment rinsate blanks, and trip blanks.

Duplicate samples were used to evaluate the precision of the laboratory analyses. Duplicate samples for VOCs, metals, and  $\text{ClO}_4^-$  analyses were collected from monitoring wells MW-4 (Screen 1), MW-14 (Screen 3), MW-15, MW-19 (Screen 4), MW-20 (Screen 3), and MW-22 (Screen 2). All of the analytical results for the duplicate samples were comparable to the results of the original groundwater samples (Tables 3-3 and 3-6).

Equipment rinsate blanks were collected each day non-dedicated sampling equipment was used. The equipment rinsate blanks, consisting of distilled water run through the sampling equipment after decontamination, were analyzed for all contaminants of concern to monitor possible cross-contamination of samples due to inadequate decontamination. No contaminants were detected in any equipment blank during the October – November 2003 sampling event.

A laboratory-prepared trip blank, consisting of reagent-grade water placed in a vial and transported with the sample bottles to the field, was submitted to the laboratory with each daily shipment of groundwater samples. Trip blanks were used to help identify cross-contamination of groundwater samples during transport and/or deficiencies in the laboratory bottle cleaning and sample handling procedures. 1,2,3-Trichloropropane, 2-Butanone, and/or methylene chloride were detected at estimated concentrations below the practical quantitation limit (PQL) of the laboratory in six trip blanks. Methylene chloride was detected in one trip blank (TB-13-11-10-03) above the PQL at a concentration of 0.6  $\mu\text{g/L}$ . Table 3-8 presents a summary of contaminants detected in quality control samples collected during the October - November 2003 sampling event.

## **4.0 DATA VERIFICATION AND VALIDATION**

The purpose of data verification and validation is to assure that the data collected meet the data quality objectives (DQOs) outlined in the Quality Assurance Project Plan of the Groundwater Monitoring Plan (Ebasco, 1993c). The process is intended to ensure that the data are of sufficient quality for use in meeting the objectives outlined in the Groundwater Monitoring Plan.

### **4.1 Data Verification**

All data collected were subjected to data verification. In general, verification identifies non-technical errors in the data package that can be corrected (e.g., typographical errors). Data verification included proofreading and editing hard-copy data reports to assure that data correctly represent the analytical measurement. Data verification also included verifying that the sample identifiers on laboratory reports (hard copy) matched those on the chain-of-custody record.

### **4.2 Data Validation**

Data validation is a systematic process that is used to interpret, define, and document analytical data quality and determine whether the data quality is sufficient to support the intended use(s) of the data. Validation of a data package includes reconstruction of sample preparation, analysis of the raw data, reconciliation of the raw data with the reduced results, identification of data anomalies, and qualification of data to identify data usability limitations.

Data validation was performed by an independent subcontractor, Laboratory Data Consultants, Inc. (LDC), Carlsbad, CA. One hundred percent of all data analyzed by a fixed-base analytical laboratory (APCL) were validated. Ten percent of the data were subjected to Level IV quality assurance requirements of the Navy (Navy, 1996 and Navy, 1999). The data were further evaluated to help ensure suitability and usability for the purpose of the groundwater monitoring report.

### **4.3 Data Validation Qualifiers**

Analytical data were qualified based on data validation reviews. For chemical data, qualifiers were assigned in accordance with the applicable EPA National Functional Guidelines for Data Validation (EPA, 1994a and 1994b). Individual laboratory data flags can be found in Appendix D. No data were rejected for non-compliance with method requirements during the course of validation.

## 5.0 WATER LEVEL MEASUREMENTS

Water level measurements were recorded before the sampling event on October 21-22, 2003, and after the sampling event on November 11, 2003, to evaluate groundwater flow directions and gradients beneath and adjacent to JPL. Water levels in the shallow wells were measured using a Solinst® water level meter. In the deep multi-port wells, the hydraulic head at each sampling port was measured with a Westbay pressure-transducer probe.

Water table elevation measurements taken before sampling are provided in Table 5-1 and have been contoured in Figure 5-1. Water table elevation measurements taken after sampling are provided in Table 5-2 and have been contoured in Figure 5-2. Piezometric pressure readings from the deep multi-port wells are generally recorded at the first screen interval. However, the recorded pressure readings from other screen intervals are used to validate the accuracy of the reading instrument or to screen for an erroneous field measurement at the first screen. Occasionally, the piezometric readings are determined to be out of range, when compared to the readings from the underlying screens. This could be attributed to several factors such as false readings or instrument errors. In either case, the piezometric pressure data that are deemed not usable are rejected and data from the underlying screens are used in the calculation of the water table elevation.

The hydraulic heads measured at each deep multi-port well screen before and after sampling are presented graphically in Figure 5-3. The piezometric pressure-profile records for the deep wells are included in Appendix B.

Water levels in the shallow wells decreased roughly 6.0 to 13.8 feet during the October - November 2003 event, decreasing an average of about 11.0 feet. This decrease was slightly larger than the decreases measured in Westbay wells screened in Aquifer Layer 1, which averaged about 8.6 feet and ranged from 4.2 to 51.6 feet. Water levels in all Aquifer Layers generally decreased during this event.

Water level fluctuations can result from a wide variety of hydrologic phenomena, some natural and some induced by man. It is likely that several of these phenomena are operating simultaneously including, but not limited to:

- Groundwater recharge/infiltration to the water table,
- Air entrapment during groundwater recharge,
- Groundwater pumpage, and/or
- Artificial recharge from the spreading grounds.

As depicted in Figures 5-1 and 5-2, the estimated groundwater flow direction both before and after sampling was generally consistent with previous observations. The flow was primarily to the south-southwest through the eastern portion of JPL and to the east-southeast in the southwest portion of JPL, Arroyo, and plain. The estimated groundwater gradients measured both at the beginning and end of the event ranged from about 0.21 feet per foot near MW-9, at the northern end of the Arroyo, to 0.005 feet per foot across the Arroyo and plain.

## 6.0 CONCLUSIONS AND RECOMMENDATIONS

The following conclusions are based upon interpretation of analytical data and field measurements collected during the October - November 2003 event and previous events of the JPL Monitoring Program:

- The chemical plumes beneath JPL are adequately defined and relatively stable. The concentration contour maps generally indicate slow migration of the contaminant plumes over the last year. Comparison of the results with the previous monitoring events did not reveal any significant increases or decreases in contaminant concentrations. In summary, the July – August 2003 analytical results indicate the following:
  - ◆ Three VOCs (CCl<sub>4</sub>, TCE, and PCE) were detected in one or more monitoring wells at concentrations above the State or Federal MCLs for drinking water.
  - ◆ ClO<sub>4</sub><sup>-</sup> concentrations exceeded the State IAL for drinking water in ten on-facility wells and five off-facility wells. The highest levels of perchlorate were reported in samples from MW-7, MW-13, MW-16, and MW-24. MW-13 and MW-24 (Screen 1) are showing an increasing trend in ClO<sub>4</sub><sup>-</sup> concentrations, however, the previously detected concentrations of ClO<sub>4</sub><sup>-</sup> at MW-20 (the farthest down gradient well) have been decreasing.
  - ◆ Cr was detected in all 21 wells sampled; however, no concentrations exceeded the State or Federal MCLs. Hexavalent chromium was not detected in any sample.
  - ◆ Moderate decreases in hydraulic head were measured during this event in shallow wells and Westbay well screens in all Aquifer Layers (1, 2, 3, and 4). The water level fluctuations are likely due to several hydrologic phenomena operating simultaneously including, but not limited to, groundwater recharge, pumpage, and/or artificial recharge.
  - ◆ Groundwater gradient maps prepared using the October - November 2003 water level measurements indicate that groundwater gradients and flow directions are generally consistent with previous observations (SOTA, 2002, 2001 and Foster Wheeler, 2000).

## 7.0 REFERENCES

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