Technical Memorandum

Lincoln Avenue Water Company Treatment System
National Aeronautics and Space Administration
Jet Propulsion Laboratory, Pasadena, California

Final April 2015

This technical memorandum documents the performance of the Lincoln Avenue Water Company (LAWC) groundwater treatment system through March 2015. The treatment system was originally implemented as a removal action 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). The Action Memorandum for this removal action was signed on August 23, 2004.[1] Operation of the treatment system is now part of the remedial action for Operable Unit 3 (OU-3), documented in the Final Interim Record of Decision (ROD).[2] Table 1 provides an overview of the system operations to date, which began on July 28, 2004.

Table 1. LAWC System Operational Summary (July 2004 through March 2015)

Parameter	Units	LAWC#3	LAWC#5	Total
Total Volume of Groundwater Extracted	Acre-ft	11,455	9,969	21,424
Mass of Perchlorate Removed	lb	703	399	1,102
Mass of Carbon Tetrachloride (CCl_4) Removed	lb	59	41	100
Mass of Trichloroethene (TCE) Removed	lb	68	73	141

BACKGROUND

Liquid wastes (such as cleaning solvents, solid and liquid rocket propellants, cooling tower chemicals, and analytical laboratory chemicals) generated at JPL in the 1940s and 1950s were disposed of in seepage pits, a common and acceptable practice at the time. Some of these wastes contained chemicals (e.g., perchlorate and chlorinated solvents containing volatile organic compounds [VOCs]) that have been found in groundwater beneath and adjacent to JPL, including groundwater extracted from two drinking water wells operated by LAWC (LAWC#3 and LAWC#5). Figure 1 is a location map showing JPL and the LAWC production wells.

VOCs were first detected in LAWC#3 and LAWC#5 in 1981. By 1984, VOC concentrations were increasing and both wells were shut down. With NASA funding, LAWC installed a VOC treatment facility for the wells in the early 1990s. NASA also funded the ongoing operations of the plant. The existing VOC treatment facility consists of four 12-ft-diameter treatment vessels (Calgon Carbon Model 12 adsorption systems), each containing 20,000 lb of liquid-phase granular activated carbon (LGAC). The LGAC treatment facility was operated in accordance with requirements of the State Water Resources Control Board (SWRCB) Division of Drinking Water (DDW).

[1] NASA. 2004. *Action Memorandum for the Lincoln Avenue Water Company (LAWC), Altadena, California Associated with Groundwater Cleanup at the National Aeronautics and Space Administration, Jet Propulsion Laboratory, Pasadena, California*. August.
[2] NASA. 2007. *Final Interim Record of Decision for Operable Unit 3 Off-Facility Groundwater, National Aeronautics and Space Administration, Jet Propulsion Laboratory, Pasadena, California.* August.

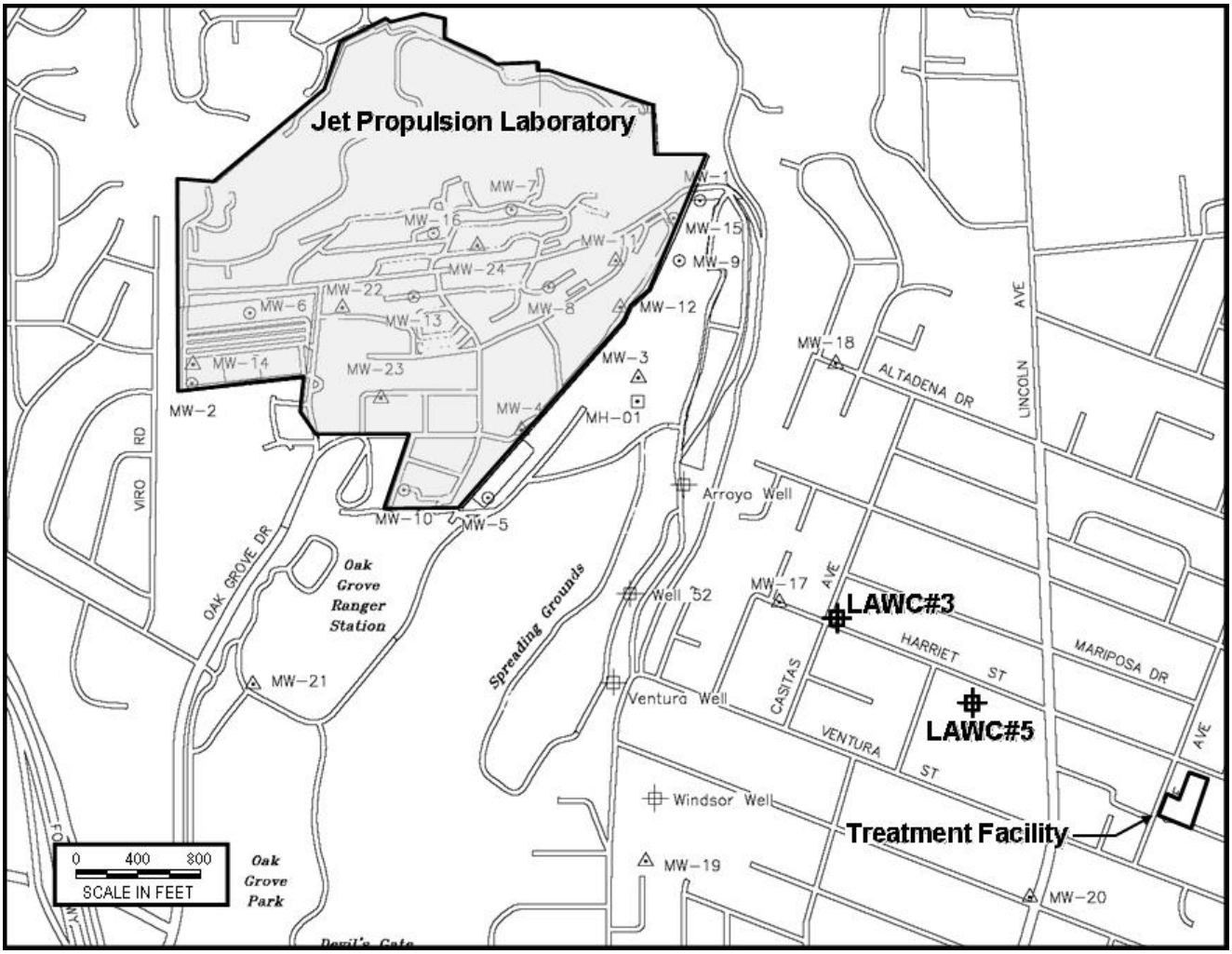


Figure 1. Location Map

Perchlorate concentrations were first detected in samples collected from the LAWC wells in 1997, when an improved analytical method using ion chromatography was developed to detect low levels of perchlorate. Since 1997, perchlorate concentrations in samples from the LAWC wells have ranged from less than 4 micrograms per liter (µg/L) to 46 µg/L. In July 2004, an ion exchange (IX) system was incorporated into the treatment train at LAWC, consisting of LGAC, chlorination, and blending with Foothill Municipal Water District (FMWD) water in the Olive Sump. Water in the Olive Sump is pumped into the distribution system for potable use by LAWC customers. A process flow diagram for this entire treatment system is provided as Figure 2.

IX treatment consists of a US Filter Model HP1220DS Hi-Flow System. The HP1220DS system has two 12-ft-diameter IX vessels, with a nominal treatment capacity of 2,000 gallons per minute (gpm). Each IX unit contains approximately 300 cubic feet of perchlorate-selective resin. DDW issued a permit amendment on July 26, 2004 for the LAWC system, a copy of which was provided in the Technical Memorandum submitted in 2005.[3] In late 2007, LAWC contracted Calgon Carbon Corporation for IX resin replacement and management associated with the treatment system. Calgon continued these services throughout this reporting period.

[3] NASA. 2005. *Technical Memorandum, Lincoln Avenue Water Company (LAWC) Treatment System, National Aeronautics and Space Administration, Jet Propulsion Laboratory, Pasadena, California*. May.

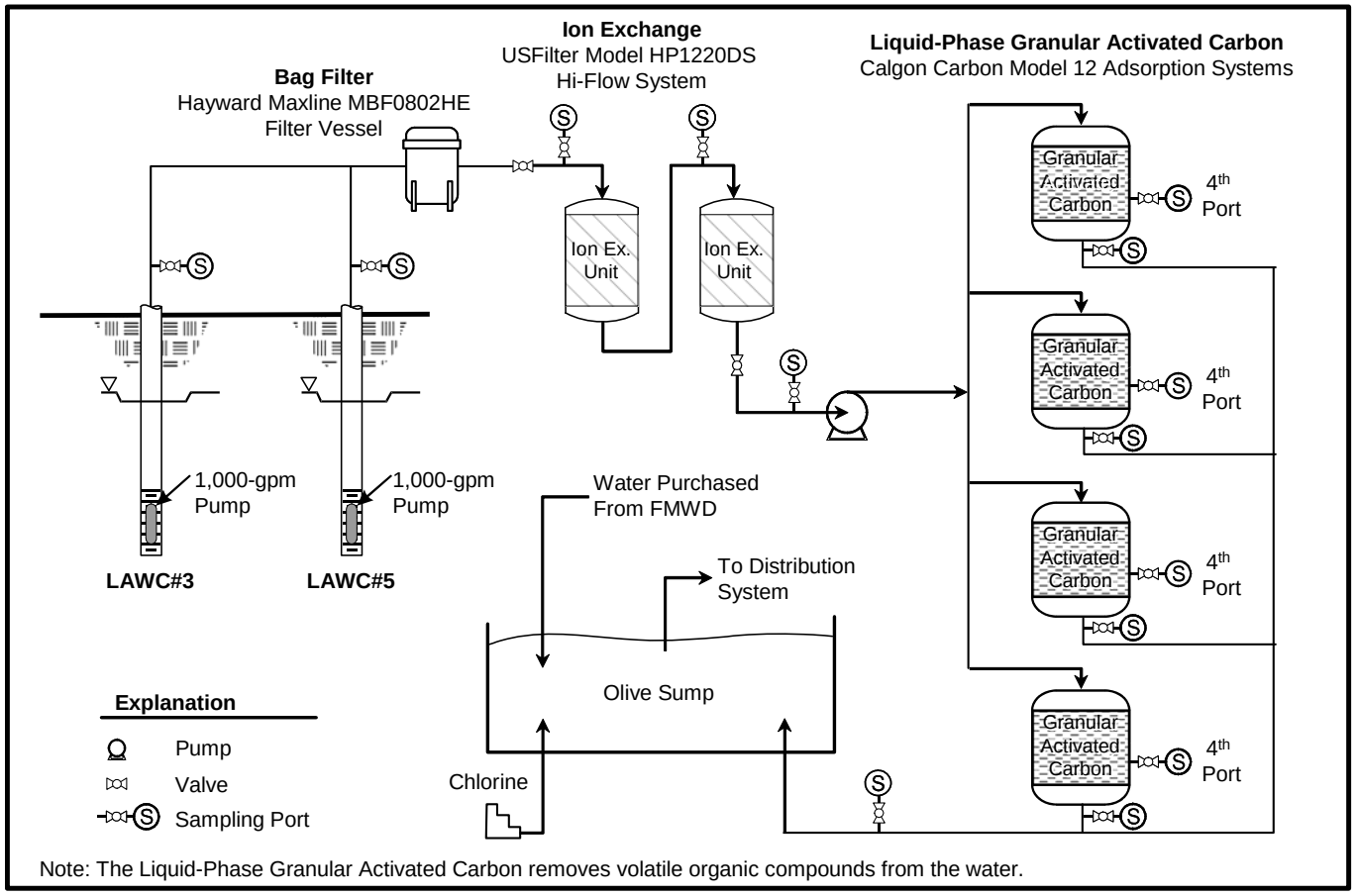


Figure 2. Process Flow Diagram

LAWC#3, LAWC#5, AND MW-17

Table 2 summarizes the maximum and average (during reporting period) carbon tetrachloride (CCl_4), trichloroethene (TCE), and perchlorate concentrations detected in LAWC#3 and LAWC#5, and maximum concentrations in MW-17 located less than 500 feet upgradient of LAWC#3. Figures 3 and 4 are graphs of the concentrations in extracted groundwater samples collected from LAWC#3 and LAWC#5.

LAWC#3 and LAWC#5 were operated consistently over the past 12 months. Perchlorate concentrations in LAWC#3 ranged from 18 to 26 µg/L, with an average of 22.3 µg/L, during this reporting period. Concentrations of CCl_4 and TCE increased slightly in LAWC#3 throughout the reporting period, averaging 2.5 µg/L and 2.2 µg/L, respectively.

Table 2. Summary of Highest Chemical Concentrations Historically Detected

		LAWC#3		LAWC#5		MW-17 (Maximum Levels)					
Analyte	Units	Avg. (Current Reporting Period)	Max	Avg. (Current Reporting Period)	Max	S1	S2	S3	S4	S5	MCL
CCl_4	µg/L	1.7	4	1.2	4.1	30	1.6	14.9	0.9	1.0	0.5
TCE	µg/L	1.9	20.8	2.3	57.4	3.5	6.2	23	15.5	16	5
Perchlorate	µg/L	21.0	46	11.6	44.0	1,230^	90.1	209	18	22	6

Note: MW-17 is a multiport monitoring well containing five separate sampling screens, denoted S1 through S5.
^ All other historic results were < 6 µg/L
MCL – maximum contaminant level

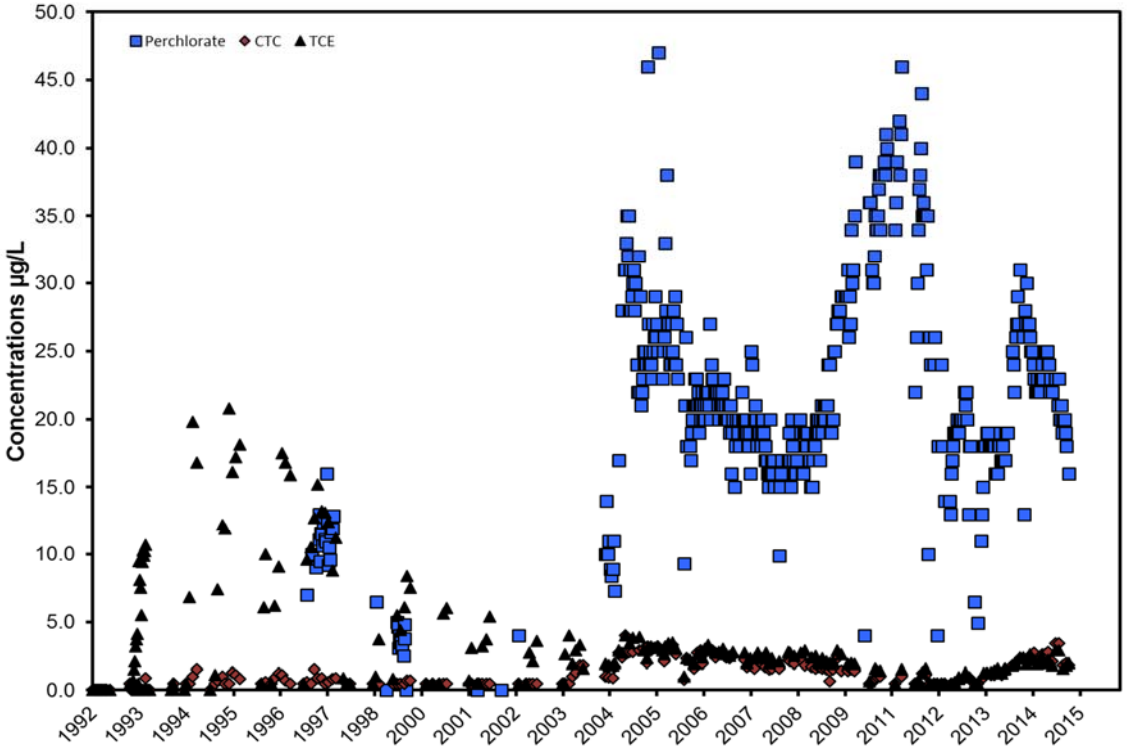


Figure 3. Historical Concentrations of CCl_4, TCE, and Perchlorate in LAWC#3

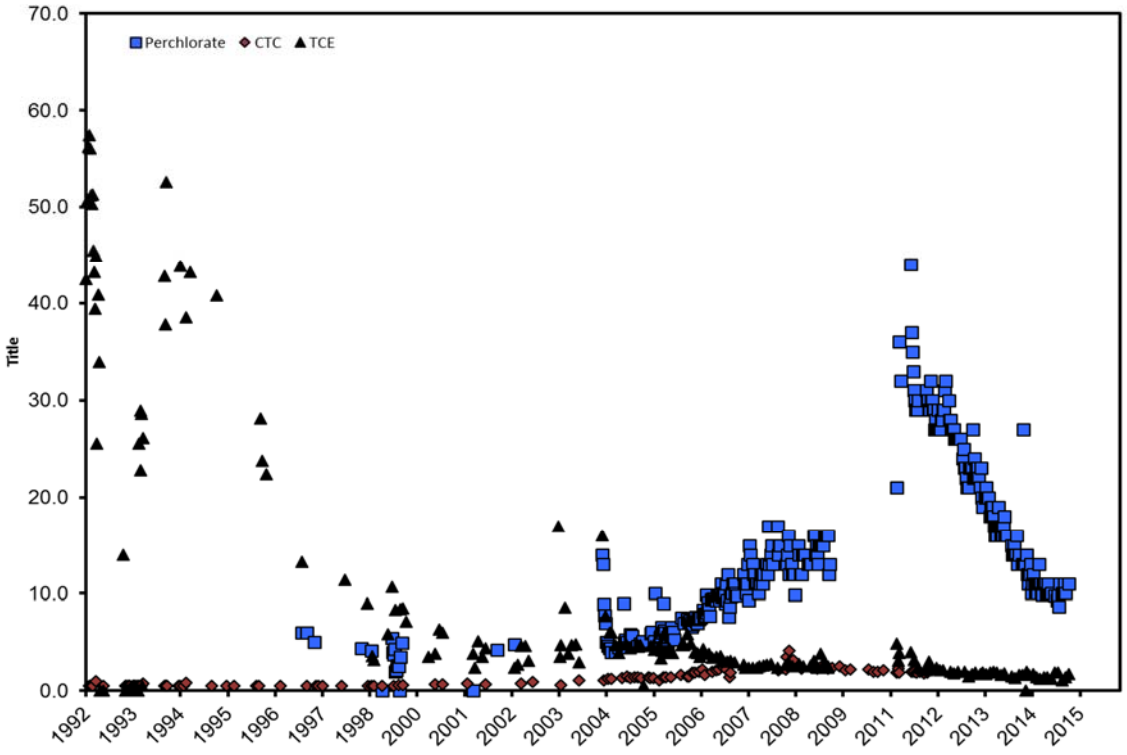


Figure 4. Historical Concentrations of CCl_4, TCE, and Perchlorate in LAWC#5

As shown in Figure 4, the July and August 2011 samples represent the highest levels of perchlorate measured in LAWC#5 since 1997 (44 µg/L). The perchlorate concentrations have since decreased to the current level of approximately 10 µg/L. The changes in perchlorate concentrations at LAWC#5 are believed to be associated with operation of NASA's mid-plume treatment system, which began operation in 2011.[4] Perchlorate concentrations in LAWC#5 during this reporting period ranged from 9.8 to 12 µg/L, with an average of 10.6 µg/L. Average concentrations of CCl_4 and TCE in LAWC#5 were measured at 1.3 µg/L and 1.5 µg/L, respectively, during this reporting period.

NASA JPL has a multiport monitoring well, MW-17, located upgradient of LAWC#3 (see Figure 1). Table 2 presents a summary of the maximum CCl_4, TCE, and perchlorate levels detected in samples collected from the five sampling screens (discrete sampling intervals) of MW-17. This monitoring well serves as the best available indicator of near-future (1-2 years) concentrations that may be observed in LAWC wells. Results of sampling conducted at MW-17, support continued operation of the LAWC treatment system in its current configuration. Figures 5, 6, and 7 provide the historical concentrations of CCl_4, TCE, and perchlorate in MW-17.

Perchlorate concentrations in MW-17 (Screen 2) began trending upward from 24.1 µg/L (February/March 2011) to 90.1J µg/L (January/February 2012), but decreased to non-detect by July 2013 where it has remained ever since. Perchlorate concentrations in MW-17 (Screen 3) have remained relatively stable since 2011 with concentrations ranging from 5.1 µg/L to 8.5 µg/L .

From the third quarter 2002 to the fourth quarter 2012, the perchlorate concentrations in MW-17 (Screen 4) had been either non-detect or below the state MCL (6.0 µg/L) with only one detection that exceeded the state MCL (second quarter 2003 [6.5 µg/L]). During the period from first quarter 2013 through fourth quarter 2014, the perchlorate concentrations exceeded the state MCL (6.0 µg/L) in seven of eight sampling events with concentrations ranging between 6.8 µg/L (October 2014) to 18.0 µg/L (January/February 2014 and July/August 2014). During the first quarter 2015 sampling event, perchlorate was detected in MW-17 (Screen 4) at an estimated value of 3.0J µg/L (January/February 2015). The changes in perchlorate concentrations at MW-17 (Screen 4) are believed to be associated with changes in groundwater flow associated with operation of NASA's mid-plume treatment system, which began operation in 2011.[4]

Perchlorate concentrations in MW-17 (Screen 5) were non-detect or below the state MCL (6.0 µg/L) from April/May 2002 to October 2014 with the exception of two detections that exceeded the state MCL (fourth quarter 2013 [9.9 µg/L] and second quarter 2014 [15.0]). CCl_4 and TCE concentrations in MW-17 continued to be low and relatively stable.

[4] NASA. 2015. Technical Memorandum Pasadena Water & Power Monk Hill Treatment System, National Aeronautics and Space Administration Jet Propulsion Laboratory, Pasadena, California. April.

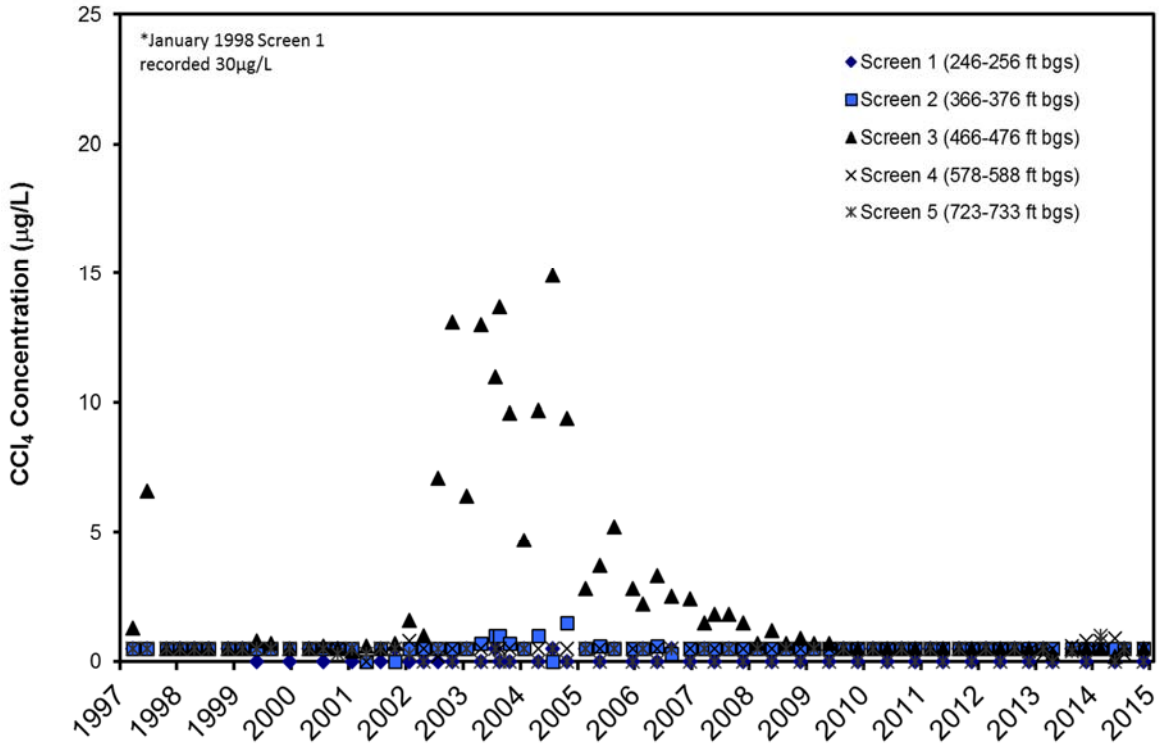


Figure 5. Historical Concentrations of CCl_4 in MW-17

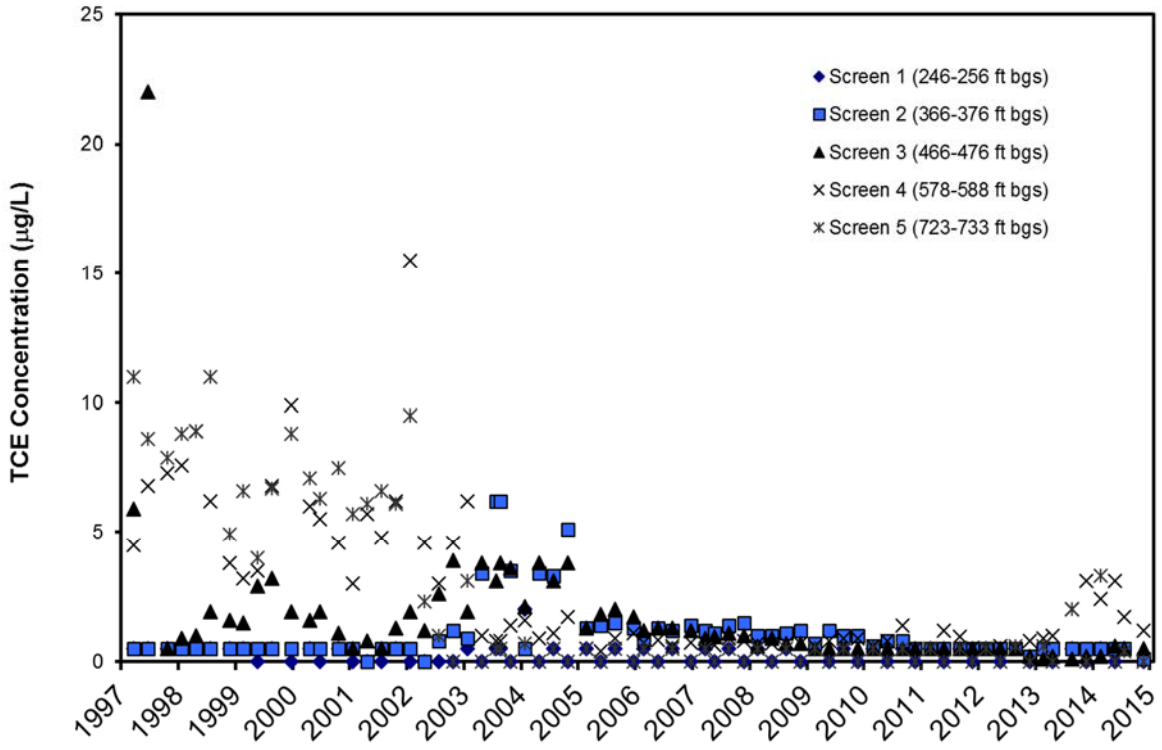


Figure 6. Historical Concentrations of TCE in MW-17

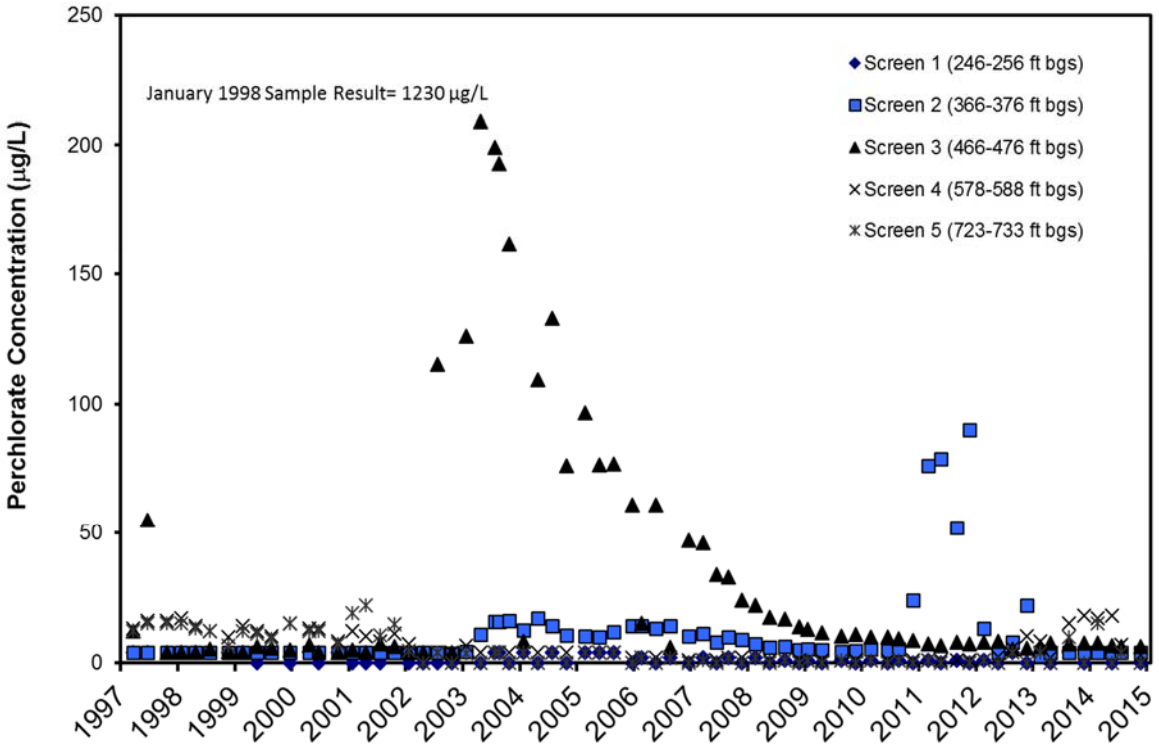


Figure 7. Historical Concentrations of Perchlorate in MW-17

ROUTINE MONITORING AND DISCHARGES

Table 3 summarizes the routine monitoring schedule for the IX and LGAC system. LAWC provides monthly reports to DDW summarizing analytical and performance data from the system. Perchlorate, TCE, and CCl_4 analytical results from samples collected from LAWC#3 and LAWC#5 are presented in Figures 3 and 4, respectively.

Table 3. Sampling Locations and Routine Monitoring Schedule

Analyte	Method	LAWC#3	LAWC#5	IX Influent	Lead IX Effluent	Lag IX Effluent	LGAC- 4th Port [a]	LGAC-Effluent [a]	Combined Effluent
CCl_4	EPA 524.2	M	M	-	-	-	W	M	M
TCE	EPA 524.2	M	M	-	-	-	W	M	M
PCE	EPA 524.2	M	M	-	-	-	W	M	M
Perchlorate	EPA 314.0	M	M	W	W	W	-	-	M
Nitrate	EPA 300.0	-	-	M	M	M	-	M	-
Total Coliform	EPA 1604	M	M	-	-	-	-	M	W
Heterotrophic Plate Count	9215B	-	-	-	-	-	-	M	W

(a) Samples collected from each of the four LGAC vessels.
M = Monthly; W = Weekly; EPA = Environmental Protection Agency

Figure 8 shows perchlorate analytical results associated with the IX system. Influent concentrations decreased during this reporting period with both LAWC#3 and LAWC#5 in operation, associated with the decreasing levels of perchlorate in groundwater extracted from LAWC#5. The system operated effectively, removing perchlorate to below detectable levels at the effluent of the second ("lag") IX vessel. Perchlorate breakthrough in the lead IX vessel occurred twice, in June 2014 and March 2015, triggering IX resin change-out events. A total of 2,003 acre-feet of water was treated during this reporting period.

In addition to routine monitoring summarized in Table 3, samples were collected quarterly, per the drinking water permit, during this reporting period from LAWC#3 and LAWC#5 (7 samples total) and analyzed for low-level 1,2,3-trichloropropane (TCP). Concentrations in all samples were non-detect.

Table 4 summarizes the LGAC change-out dates and frequency based on the fourth port analytical results. CCl_4 consistently broke through prior to other VOCs.

LGAC change-outs require approximately 20,000 gallons of water to backwash each carbon vessel. LAWC received a discharge permit from the Regional Water Quality Control Board (RWQCB) on July 30, 2009, regulating backwash water associated with carbon change-outs. Seven backwash water discharge events were performed during this reporting period. Analytical results were provided to RWQCB, in accordance with LAWC's discharge permit.

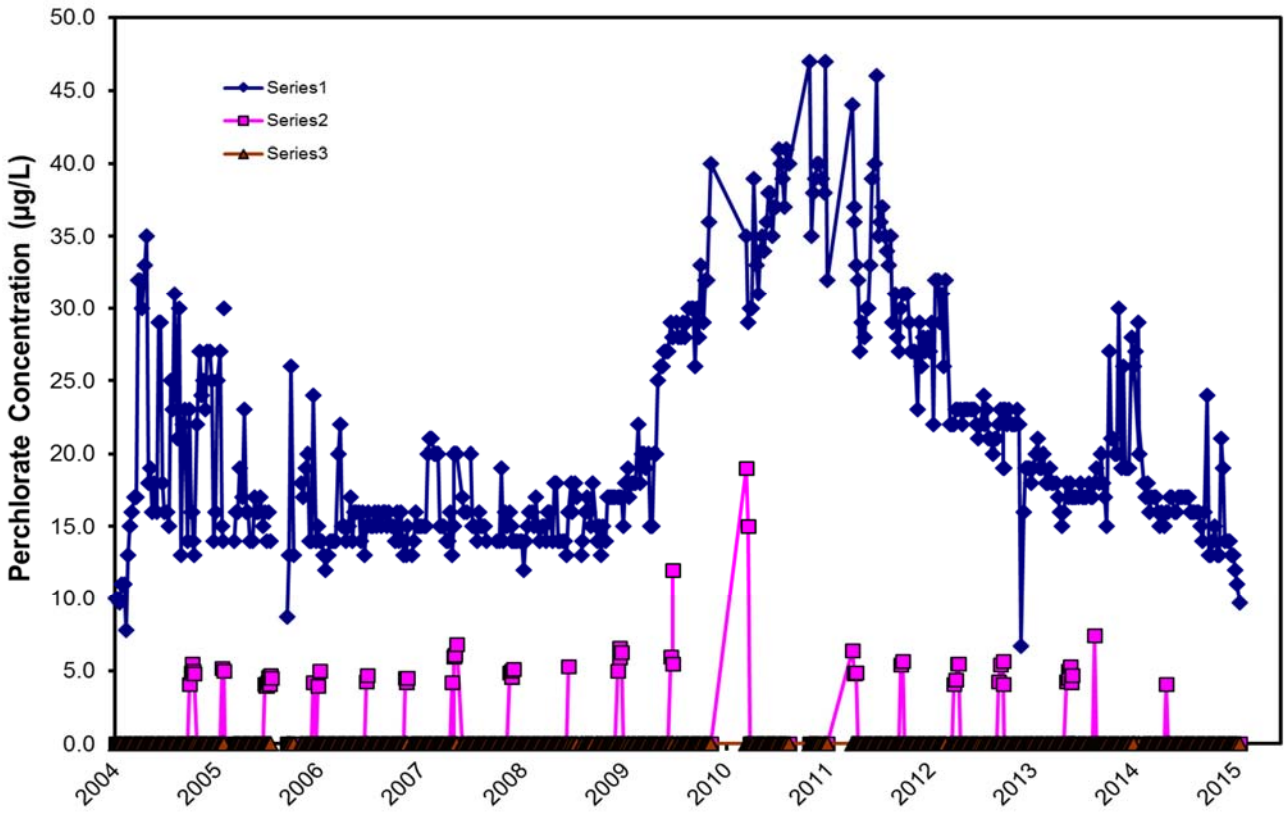


Figure 8. Ion Exchange System Performance

The LGAC effluent and combined effluent sampling locations have not contained detectable CCl_4, TCE, PCE, or perchlorate concentrations at any time since startup in July 2004. This demonstrates that the plant is operating effectively. Also, samples are collected at influent and effluent locations of the plant on a monthly basis to analyze for nitrate concentrations. During this reporting period, concentrations of nitrate were relatively stable, ranging from 15 to 19 mg/L. Lastly, total coliform and heterotrophic plate count sampling is conducted weekly to evaluate biological activity in the system. Results indicated that biological activity was effectively controlled.

Table 4. Carbon Change-Out Frequency Based on LGAC Fourth Port VOC Sampling (past 5 years)

Note: Changeout triggered after detection of VOCs, typically CCl_4, at the LGAC fourth port.

Description	1st Vessel	2nd Vessel	3rd Vessel	4th Vessel
Date of 16th Change-out	9/2/2010	6/23/2009	10/16/2010	6/16/2009
Days between change-outs	380	133	424	196
Date of 17th Change-out	7/28/2011	11/17/2009	8/9/2011	3/10/2011
Days between change-outs	329	147	297	632
Date of 18th Change-out	1/5/2012	7/8/2010	4/19/2012	8/9/2011
Days between change-outs	161	233	254	152
Date of 19th Change-out	6/1/2012	7/20/2011	2/22/2013	2/7/2012
Days between change-outs	148	377	309	182
Date of 20th Change-out	11/20/2012	12/6/2011	5/23/2014	7/25/2012
Days between change-outs	172	139	455	169
Date of 21st Change-out	5/10/2013	4/26/2012	12/23/2014	3/1/2013
Days between change-outs	171	142	214	219
Date of 22nd Change-out	11/8/2013	9/11/2012		9/13/2013
Days between change-outs	182	138		196
Date of 23rd Change-out	7/15/2014	4/12/2013		8/28/2014
Days between change-outs	249	213		349
Date of 24th Change-out	12/10/2014	8/23/2013		1/22/2015
Days between change-outs	148	133		147
Date of 25th Change-out		7/6/2014		
Days between change-outs		317		
Date of 26th Change-out		11/14/2014		
Days between change-outs		131		
Average days between change-outs	**216**	**203**	**326**	**249**
Minimum days between change-outs	**148**	**133**	**214**	**147**
Maximum days between change-outs	**380**	**377**	**455**	**632**

FIVE-YEAR REVIEW

In February 2012, NASA completed its first Five-Year Review of the JPL CERCLA program.[5] The review concluded that the interim remedy at LAWC was protective of human health and the environment in the short term. Potential exposure pathways that could result in unacceptable risk (i.e., ingestion and contact with chemicals in groundwater) are being controlled through groundwater extraction and treatment by the LAWC treatment system. Treated water from the LAWC system is in compliance with all water quality requirements specified by Federal and state regulations, with concentrations below Federal and California MCLs.

One recommendation related to the LAWC system was made in the Five-Year Review Report. The recommendation was to evaluate future sampling results at LAWC#5 to monitor the perchlorate concentration trend at this well. The evaluation over the current reporting period is provided as follows:

- Concentrations of perchlorate in LAWC#5 have steadily decreased since 2011. As shown in Figure 4, the July and August 2011 samples represent the highest levels of perchlorate measured in LAWC#5 since 1997. The highest recorded concentration of perchlorate in LAWC#5 is 44 µg/L. Since August 2011, the perchlorate concentrations in LAWC#5 have decreased to the current level of 10 µg/L (March 2015); this result is approximately 29% lower than the March 2014 sample of 14 µg/L.
- Since Pasadena's Monk Hill Treatment System (MHTS) began operation in July 2011, concentrations of perchlorate in the LAWC wells have been decreasing. Two MHTS wells, Arroyo Well and Well 52, are located upgradient of the LAWC wells. This trend is expected to continue.
- Trends in the perchlorate data from LAWC#5 will continue to be evaluated and reported annually as part of the JPL CERCLA Program.

PLUME CONTAINMENT

The LAWC treatment system provides leading edge containment of the chemical plumes originating from JPL. Groundwater monitoring levels are measured quarterly as part of the JPL groundwater monitoring program and are used to develop groundwater contour maps. The contour map from the fourth quarter 2014 groundwater monitoring event is shown as Attachment A The contour map shows that pumping at the LAWC wells and the MHTS wells has a significant effect on the groundwater flow near JPL.

Three-dimensional plume containment is demonstrated by chemical data from NASA's multi-port monitoring wells. In particular, MW-20 is deep multi-port well located near and down gradient of LAWC#5. MW-20 is also located near, but up gradient of Rubio Cañon Land and Water Association production wells, No. 4 and No. 7 (RCLWA#4 and RCLWA#7). The RCLWA wells are the next downgradient production wells from LAWC, and would be the next set of wells impacted by chemicals originating from JPL if containment is lost.

Due to sporadic detections of perchlorate in MW-20 (Screens 4 and 5) in 2008 and 2009, RCLWA, in consultation with NASA, modified the sampling protocol for RCLWA#4 and RCLWA#7 to include weekly low-level perchlorate sampling and analysis at RCLWA#4 and RCLWA#7. From May 2009 to

[5] NASA. 2012. *Final First Five-Year Review Report, National Aeronautics and Space Administration, Jet Propulsion Laboratory, Pasadena, California*. Final.

present, 318 and 343 samples have been analyzed from RCLWA#4 and RCLWA#7, respectively. During this period, perchlorate concentrations in RCLWA#4 have averaged 1.5J µg/L with a maximum detection of 2.8J µg/L (June 22, 2009 and April 9, 2012) and the average perchlorate concentration in RCLWA#7 has been 1.7 µg/L, with a maximum detection of 3.1 µg/L (May 7, 2009). Weekly samples collected at RCLWA#4 and RCLWA#7 during the current reporting period indicated perchlorate levels below 2.0 µg/L. These low levels of perchlorate are consistent with regional background conditions and are below the state MCL of 6.0 µg/L. The results show that perchlorate originating from NASA has not impacted the RCLWA wells.

Between April/May 2009 and January/February 2012, perchlorate concentrations in MW-20 (Screen 4) were detected above the state MCL five of the twelve quarters with detections ranging from 15.1 µg/L to 123.0J µg/L. During the other seven quarters, perchlorate concentrations were non-detect. During the same period, perchlorate concentrations in MW-20 (Screen 5) were detected above the state MCL in three of twelve quarters with detections exceeding the state MCL ranging from 11.5 µg/L to 56.5 µg/L. During the other nine quarters, perchlorate concentrations were non-detect with the exception of one detection of 4.2 µg/L. Perchlorate concentrations in MW-20 continue to be closely monitored and have not been detected in Screens 4 and 5 from April/May 2012 to January/February 2015.

With regards to VOC concentrations, it should be noted that CCl_4 has not been detected in MW-20 (Screens 1 to 5) or in the RCLWA wells. In addition, TCE and PCE detections in MW-20 (all screens) have been low and sporadic. In contrast, CCl_4 and TCE have been detected above the respective MCLs at MW-17, which is located upgradient and within the capture zone of LAWC#3 and LAWC#5 (Figures 5 and 6).

Samples collected from MW-20 during the four quarters (i.e., January/February, April/May, July, and October/November) of 2014 did not contain VOC or perchlorate concentrations exceeding the respective MCLs. During the four quarters of 2014, CCl_4 was not detected in MW-20 (all screens). TCE was detected in MW-20 (Screens 2 and 3) with detections ranging from 0.1J to 0.3J µg/L; however, all detections were below the state MCL of 5 µg/L. TCE was not detected during the four quarters of 2014 in MW-20 (Screens 1, 4, and 5). PCE was detected in MW-20 (Screen 2 and 3) with detections ranging from 0.2J µg/L to 0.3J µg/L, but was not detected in MW-20 (Screens 1, 4, and 5). Perchlorate was detected in MW-20 (Screen 2) with concentrations ranging from 1.6J to 4.0 µg/L, but was not detected in MW-20 (Screens 1, 3, 4, and 5).

Based on groundwater monitoring data collected at MW-17, LAWC#3, LAWC#5, MW-20, RCLWA#4 and RCLWA#7, these data demonstrate that the perchlorate and VOC plumes are contained and not migrating down gradient of LAWC's wells.

SYSTEM OPTIMIZATION

NASA submitted a final Optimization Work Plan[6] in June 2014. This new LAWC extraction well (LAWC#6) is considered a voluntary enhancement to NASA's overall treatment approach. Installation of LAWC#6 was completed in April 2015 and installed on the same property containing as LAWC#5 (installed in 1971) and the LAWC office building. LAWC#6 is currently being developed and tested, and is scheduled to be online in September 2015. The new drinking water production well will improve reliability, reduce risk of losing containment, and enhance capture and mass removal at the leading edge of the JPL contaminant plume.

[6] NASA, 2014. Final Optimization Work Plan, National Aeronautics and Space Administration, Jet Propulsion Laboratory, Pasadena, California. June.

COST SUMMARY

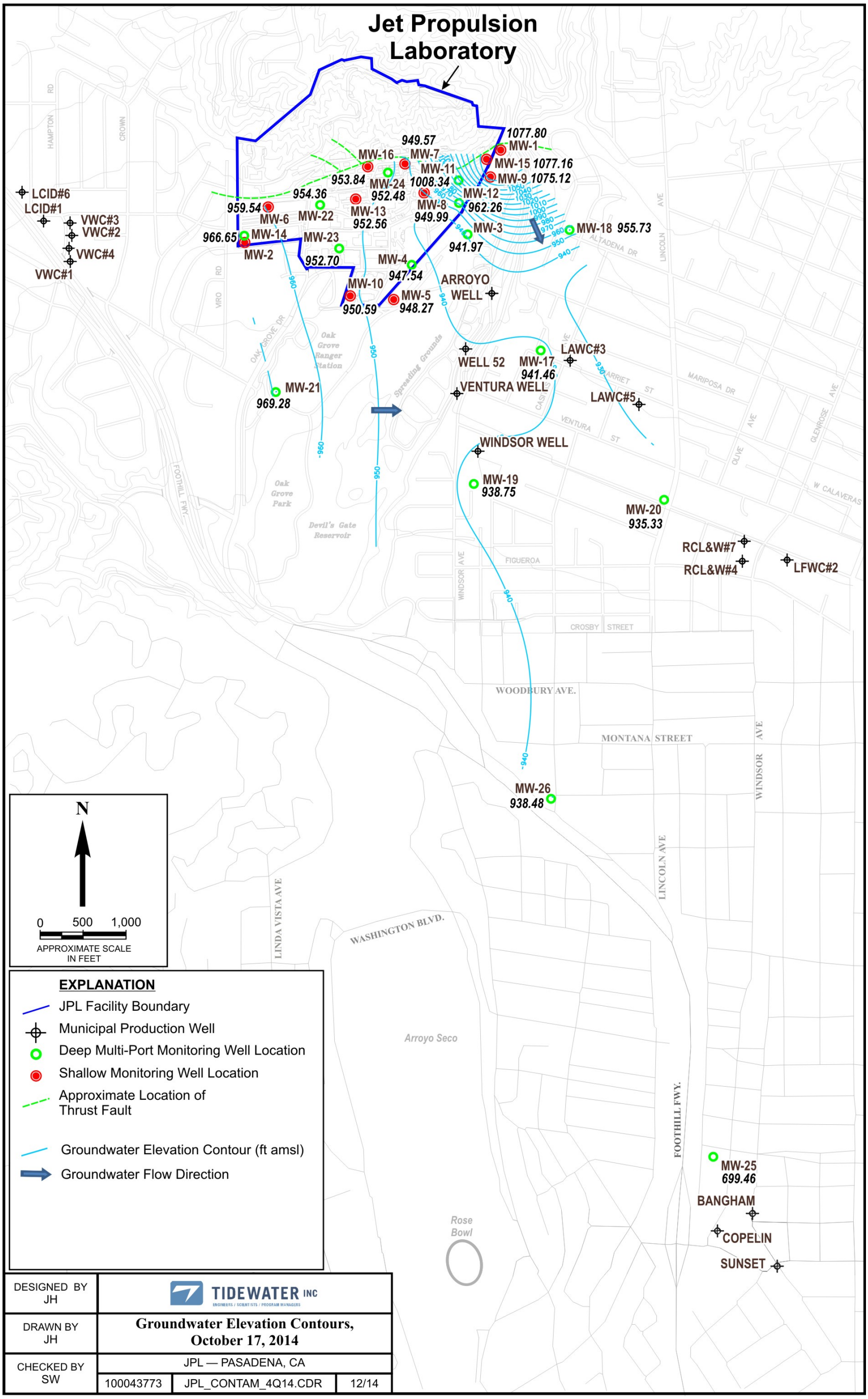
Table 5 summarizes the operational costs incurred between January and December 2014. These costs equate to $361.55 per acre-ft of treated water for a total of approximately 2,092 acre-ft in 2014.

Table 5. Operational Costs: January through December 2014

DESCRIPTION	IX Cost	GAC Cost	Subtotal
Facility Inspection	$25,421.20	$25,259.08	$50,680.28
Water Sampling Analysis	$20,220.50	$42,732.50	$62,953.00
Water Sampling Collection	$6,225.61	$8,722.34	$14,947.95
Maintenance	$19,390.16	$24,772.71	$44,162.87
Carbon Changeout	NA	$225,530.56	$225,530.56
IX Treatment Cost	$144,451.00	NA	$144,451.00
IX-GAC Associated Cost	Combined	Combined	$85,113.16
Chemical Cost	Combined	Combined	$22,119.18
Administration	$2,246.40	$2,246.40	$4,492.80
Excess Energy Costs (Combined)	Combined	Combined	$2,517.69
Auto Costs	Combined	Combined	$611.52
Incremental Costs	Combined	Combined	$113,291.20
CDPH Billing	Combined	Combined	$15,504.33
GRAND TOTAL			**$756,375.54**

NA = not applicable

Attachment A
Groundwater Elevation Contours- October 2014


Jet Propulsion Laboratory
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MW-4
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ARROYO WELL
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MW-5
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LCID#1
VWC#3
VWC#2
VWC#4
VWC#1
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LAWC#3
VENTURA WELL
LAWC#5
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WINDSOR WELL
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MW-20
935.33
RCL&W#7
RCL&W#4
LFWC#2
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938.48
MW-25
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BANGHAM
COPELIN
SUNSET
Oak Grove Park
Devil's Gate Reservoir
Spreading Grounds
Arroyo Seco
Rose Bowl
FOOTHILL FWY.
WINDSOR AVE
LINDA VISTA AVE
LINCOLN AVE
WOODBURY AVE.
MONTANA STREET
CROSBY STREET
FIGUEROA
WASHINGTON BLVD.
ALTADENA DR
MARIPOSA DR
W CALAVERAS
VENTURA ST
HARRIET ST
OAK GROVE DR
HAMPTON RD
CROWN
VIRO RD
FOOTHILL FWY.
LINCOLN AVE
OLIVE AVE
GLENROSE AVE
N
0 500 1,000
APPROXIMATE SCALE IN FEET
EXPLANATION
JPL Facility Boundary
Municipal Production Well
Deep Multi-Port Monitoring Well Location
Shallow Monitoring Well Location
Approximate Location of Thrust Fault
Groundwater Elevation Contour (ft amsl)
Groundwater Flow Direction
DESIGNED BY JH
DRAWN BY JH
CHECKED BY SW
TIDEWATER INC
ENGINEERS / SCIENTISTS / PROGRAM MANAGERS
Groundwater Elevation Contours, October 17, 2014
JPL — PASADENA, CA
100043773
JPL_CONTAM_4Q14.CDR
12/14

Figure 8.