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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX
75 Hawthorne Street
San Francisco, CA 94105

November 19, 2013

Ms. Phyllis E. Currie
General Manager
Pasadena Water and Power
150 S. Los Robles Ave., Suite 200
Pasadena, CA 91101

Re: Sunset Reservoir Drinking Water Wells Perchlorate Contamination

Dear Ms. Currie:

Thank you very much for your letters in follow-up to my September 19th meeting with your staff. You have requested our position regarding the perchlorate contamination at the Sunset Reservoir well area in relationship to the National Priorities List - NASA Jet Propulsion Laboratory (NASA JPL) Site. EPA has been working very hard to ensure that we consider all of the analysis provided by Pasadena Water and Power (PWP) in meeting your request.

We feel we have a thorough understanding of Pasadena's position and I have assigned Mr. Herb Levine as a technical reviewer to look at the problem with a fresh perspective. Mr. Levine is an EPA national expert in evaluating contaminated groundwater sites, with more than 30 years of technical experience.

Mr. Levine reviewed PWP's technical memoranda which reach the conclusion that NASA JPL is a source of the perchlorate in the Sunset Reservoir wells, NASA's responses to PWP's technical memoranda, EPA's contractor's comments on PWP's technical memoranda and NASA's responses, data PWP presented during our meeting, and other relevant background technical documents.

Based on multiple lines of evidence, Mr. Levine's professional opinion is that there is no evidence based on current data, to conclude that the perchlorate detected in the Sunset wells is related to the release of perchlorate at NASA JPL. The low level of perchlorate that is currently impacting Pasadena wells could be from a variety of known and unknown anthropogenic perchlorate sources, including injected Colorado River water and fertilizer-impacted surface water infiltration.

EPA recently consulted with the California Department of Toxic Substances Control and the Los Angeles Regional Water Quality Control Board as co-regulators of NASA. All three agencies agree that based on currently available information, the Sunset Reservoir well area is not part of the NASA JPL Superfund Site. We will require that the upcoming NASA Proposed Plan and subsequent Record of Decision for groundwater include monitoring in the Sunset Reservoir well

area to confirm the effectiveness of upgradient remediation systems. In addition, these monitoring wells could help clarify conditions immediately upgradient of the Sunset wells. We will periodically re-evaluate this data to determine if the remedy remains protective of the Sunset Reservoir well area.

We look forward to further technical discussions at our upcoming meeting on November 20th and will bring our detailed technical comments. Attached please find a proposed agenda. Please feel free to contact me at 415-972-3438 should you have any questions.

Sincerely,

Michael Montgomery
Assistant Director, Superfund Division

cc: Ms. Sayareh Amirebrahimi, California Department of Toxic Substances Control
Dr. Kwang-il Lee, Regional Water Quality Control Board, Los Angeles Region
Mr. Steve Slaten, NASA JPL
Mr. James E. Woolford, EPA OSRTI
Mr. Reggie Cheatham, EPA FFRRO

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Technical Opinion on Various Technical Memorandum, Comments and Response to Comments from NASA JPL, Pasadena Power and Water, US EPA, California DTSC, and the University of Illinois, Chicago

The purpose of this review is to provide a technical opinion about the assertion by Pasadena Water and Power (PWP) that synthetic perchlorate[1] found in the Sunset Area wells originated from releases at the NASA JPL facility, which NASA disputes.

As requested, this reviewer is providing a technical opinion of technical memoranda prepared by NASA for the Jet Propulsion Laboratory (JPL) facility, including the Additional Investigation report; technical memoranda and presentations prepared by PWP; as well as comments and response to comments raised by these parties and by the U.S. environmental protection Agency (EPA), the Department of Toxic Substances Control (DTSC), and the University of Illinois, Chicago.

Background

The NASA JPL facility began testing of liquid propellant rockets in the Arroyo Seco as early as 1936. Over time, various chemicals, including perchlorate, have been used and disposed in brick-lined seepage pits at JPL. The JPL facility is located in Los Angeles County, in the foothills of the San Gabriel Mountains adjacent to the cities of Pasadena and La Canada-Flintridge. The groundwater underlying the facility and the immediately surrounding area is the Monk Hill Subbasin, a part of the Raymond Basin, which is an important source of potable water for many communities around the JPL facility. Groundwater flow in the area is generally towards the pumping wells east of JPL.

[1] This review only addresses sources of synthetic perchlorate. Perchlorate from natural sources, such as Chilean nitrogen fertilizer, also exists in the groundwater at the Sunset Area wells, but the source of that perchlorate is not the subject of the current dispute. Throughout this memorandum, the term "perchlorate" will be used to mean synthetic perchlorate.

The Site was placed on the Superfund National Priorities List in 1992 because of releases of hazardous substances from the facility in the groundwater and vadose zone, for which interim remedial actions have been implemented. Perchlorate was identified as a contaminant in the groundwater in 1997, and the remedial actions modified to include treatment for perchlorate. The remedial actions include extraction of contaminated water and treatment at domestic water supply production wells operated by the Lincoln Avenue Water Company and PWP, located approximately 1 mile east of the JPL facility. In 2012, EPA deemed these interim remedial actions to be operating effectively.

In 2007 NASA prepared an Additional Investigation Report to fill data gaps and investigate whether JPL released contaminants have impacted Sunset Reservoir Area wells. PWP questioned whether the JPL facility is the source of elevated perchlorate concentrations in the groundwater in the Sunset Reservoir Area, located approximately 3 to 4 miles south of the JPL facility. The Additional Investigation Report concludes that the perchlorate in the Sunset wells is not from the JPL facility, because groundwater contaminated by releases from JPL is hydraulically contained within the Monk Hill Subbasin of the Raymond Basin. The Sunset Reservoir Area wells are outside of the Monk Hill Subbasin.

The PWP disputes this position, and prepared a technical memorandum in 2012 that presented a series of technical arguments that the JPL facility is a source of the perchlorate in the Sunset Area wells.[2] This review focuses on the data provided by PWP in support of its position, and on the question of whether evidence demonstrates that the perchlorate found in the Sunset wells originated at NASA JPL.

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[2] In PWP's 2012 memorandum, each argument utilized a single line of evidence for support. In contrast, NASA's technical commentary to the 2012 PWP memorandum included an approach utilizing multiple lines of evidence. Due to inherent uncertainty with subsurface investigations, it is a widely accepted practice in environmental forensics to rely upon multiple lines of evidence to reduce uncertainty. Rarely can a single line of evidence be relied upon on its own.

There are two separate inquiries that facilitate answering this question:

(1) Whether the Monk Hill pumping wells have captured the perchlorate released from the JPL facility within the Monk Hill subbasin; and
(2) Whether there is a chemical signature that can be used forensically to identify the sources of perchlorate in the Sunset Area wells.

Capture

Capture refers to the idea that groundwater contamination from releases at the JPL facility is contained within the Monk Hill Subbasin. The question of whether the Monk Hill wells are containing the groundwater contamination from JPL facility turns on whether the Monk Hill and Lincoln Avenue wells have consistently provided hydraulic control to prevent contamination from JPL from flowing south and out of the Monk Hill subbasin. The RI report evaluates water levels and pumping rates to answer this question.

In 2003, after the Remedial Investigation (RI) in 1999, NASA developed a groundwater flow model to further evaluate the capture zone of the Monk Hill and Lincoln Avenue wells. The RI used basic hydrogeologic concepts to evaluate flow paths based on water levels from multiple time periods, pumping rates and duration over multiple time periods, determination of extent of volatile organic compounds (VOCs) by aquifer zone as well as using anions and cations for water typing. The groundwater flow model was intended to evaluate capture.

Groundwater monitoring data demonstrate that a plume of groundwater contaminated with carbon tetrachloride[3], another hazardous substance released at the JPL site, is moving eastward - toward the Monk Hill and Lincoln Avenue wells, rather than southward - toward the Sunset Reservoir Area. Carbon tetrachloride behaves differently in groundwater than perchlorate – it is expected to degrade and be retarded during transport, while the perchlorate is non-reactive and is expected to be transported at similar rates as groundwater flow.

[3] This plume is defined by groundwater exceeding 5ppm of carbon tetrachloride.

Perchlorate should behave similar to dissolved carbon tetrachloride and move toward the Monk Hill and Lincoln Avenue wells. The RI presents plume maps of carbon tetrachloride and trichloroethene for each aquifer zone. The footprints of the VOCs indicate that these plumes are migrating towards the pumping wells to the east and not to the Sunset Area wells to the south. It is reasonable to conclude that the perchlorate released from JPL migrates in the same direction as the VOC plumes and is also captured by the Monk Hill and Lincoln Avenue wells.

Groundwater extraction wells in the Monk Hill area have been operated by the City of Pasadena since before JPL began operating, for the purpose of providing domestic water supplies to residents. Therefore these wells have likely been providing hydraulic containment since the releases at JPL occurred.

PWP disputes both the NASA groundwater model and its conclusions on flow and capture. PWP asserts that the particle tracking developed with NASA's model is not accurate and cannot be relied upon to determine the capture zone.

This reviewer did not have access to and did not review the model but does note that the use of particle tracking is consistent with EPA guidance on capture zone analysis (A Systematic Approach for Evaluation of Capture Zones at Pump and Treat Systems, US EPA/600/R-08/003, 2008). While models are inexact and models prepared by different parties with different assumptions can lead to differing results, the capture zone analysis is a relatively straightforward and appropriate use of a groundwater flow model. The EPA guidance on capture zone analysis recommends use of a model when groundwater flow is complex or multiple wells are pumping as is the case here.

EPA acknowledges that differences exist between the model developed by NASA JPL, the model developed by the Raymond Basin Management Board ("RBMB") and the model developed by PWP. In particular, the models use different approaches in releasing particles to evaluate groundwater flow. The NASA model released particles at the release area and followed those particles forward to the Monk Hill and Lincoln Avenue pumping wells while the PWP model released particles at the Sunset area and followed those particles backwards. The NASA model predicted capture of the particles and hence imply capture of VOCs and

perchlorate at the Monk Hill and Lincoln Avenue wells. The PWP modeled particles did not intersect the NASA JPL facility implying that contamination from the JPL facility is not in communication with the Sunset Area wells.

EPA offered to facilitate meetings to discuss and resolve model differences, and NASA offered to provide contractor support to PWP to run its model, but PWP declined these offers. Based upon the available data, this reviewer does not have evidence or reason to dispute the NASA's conclusion that the Monk Hill wells capture the perchlorate released at the JPL facility within the Monk Hill Subbasin. The NASA capture zone analysis is consistent with EPA guidance and industry accepted approaches.

Chemical Signature

Groundwater in the Raymond Basin has been contaminated with perchlorate from multiple sources, including widespread use of Chilean fertilizer containing a natural form of perchlorate, and synthetic perchlorate from several sources, including the JPL facility, fireworks, and groundwater recharge using water obtained from the Los Angeles Metropolitan Water District ("MWD"), which obtained some of its water from the Colorado River, which was contaminated with perchlorate from the former Kerr McGee rocket fuel plant in Henderson, Nevada.

Perchlorate from Chilean fertilizer has a chemical signature that is distinguishable from synthetic perchlorate. However, technology is not yet available to distinguish among sources of synthetic perchlorate.

PWPs' 2012 technical memorandum stated that the most compelling evidence that releases from the JPL facility are a source of the perchlorate in the Sunset Area wells is PWP's analysis of nitrate and perchlorate in the Raymond Basin. PWP tested the hypothesis that perchlorate is contained within the Monk Hill Subbasin and the hypothesis that it is not contained by plotting concentrations of nitrate and perchlorate in groundwater, using these data from monitoring and production wells. The data plotted by PWP shows that the groundwater from La Canada-Flintridge has high levels of nitrogen (26-64 ppm), the water from the JPL

facility and from the San Gabriel Mountains have low levels of nitrogen (1-6ppm), and the levels of nitrate in the groundwater in the Sunset Area is between these two (23-38ppm). PWP concludes that the groundwater in the Sunset Area is therefore a blend of groundwater from La Canada-Flintridge, JPL and the San Gabriel Mountains.

There are several problems with this analysis. First, it used median values of concentrations of nitrate and perchlorate. It is important to recognize that groundwater chemical data are not normally distributed and median values are not informative. For example, chemical data from monitoring wells with open screens at specific depth intervals are only comparable to production wells with open screens over long depths if chemical concentrations are not variable with depth. In addition, timing and frequency of groundwater monitoring can vary, so that the median of concentrations taken from sampling infrequently will cannot easily be compared to a median concentration from a well sampled more frequently. Further, some of the data were from wells sampled more frequently for a period of time following a potential release, pursuant to regulatory requirements, which would skew the results. Seasonal differences can also affect monitoring results. In order to compare these data in a statistically meaningful way, adjustments must be made to compensate for these differences. PWP's analysis did not include such adjustments.

Next, PWP compared the levels of nitrate and perchlorate in the Sunset Area wells with the levels of these chemicals in the La Candada-Flintridge area, which is cross-gradient from the JPL facility. PWP proposed that if Monk Hill wells provide containment of perchlorate released from the JPL facility, then the levels of nitrate and perchlorate in the groundwater at the Sunset Area wells should be identical to the levels of these chemicals in the groundwater in the La Canada-Flintridge area, which is not the case. This ignores the fact that the levels of these chemicals vary throughout the Raymond Basin as a result of recharge by MWD water from irrigation as well as direct. The levels of perchlorate from MWD water vary based on the amount of the MWD water, the method of recharge, and

timing, among other factors.[4] The analysis also ignores the fact that La Canada-Flintridge does not use septic sewers, but rather leachfields for its domestic sewage, which typically increases the levels of nitrate in groundwater. PWP's 2012 technical memo shows maps with arrows depicting 'low' versus 'high' levels of perchlorate and nitrate moving toward the Sunset Area wells from La Canada-Flintridge, JPL and the San Gabriel Mountains. But as explained above, these figures are not statistically meaningful. There is no explanation of what is low or high. The arrows depicted as overlays on figures suggest a statistical analysis was made and trends were calculated. This is misleading as data variability was masked by plotting median values and the arrows are subjective. Other than calculating median values no statistical analysis was performed.

A more informative analysis of MWD water impacting the Raymond Basin is that made in the NASA Additional Investigation report which documents levels of of sulfate concentrations in the Raymond basin before and after recharge by Colorado River water, which has higher levels of sulfate than that naturally occurring in the Raymond Basin. The Additional Investigation Report shows that groundwater sulfate concentrations in the Raymond Basin in 1999 were significantly higher than they had been in 1950, before the introduction of Colorado River water. This would lead to a conclusion that at least one source of the perchlorate in the Raymond Basin is from Colorado River Water. The well MW-19 which is outside the VOC and perchlorate NASA JPL plumes reflects the influence of imported water and not is dissimilar to JPL water type.

An analysis of groundwater chemistry provides for water typing using conventional hydrogeological principles. The Additional Investigation Report analyzes water chemistry utilizing anions and cations projected onto Piper diagrams and the Remedial Investigation Report utilizes anions and cations depicted on Stiff diagrams. These analyses reveal three water types, a shallow native groundwater, deeper native groundwater and groundwater mixed with Colorado River water. The Sunset Area wells contain groundwater that is a mixture or blend of native groundwater and Colorado River water.

[4] The Kerr McGee plant in Henderson, Nevada has been the subject of Superfund remedial actions, as a result of which levels of perchlorate in Colorado River water has decreased over time.

Data clearly indicate that the groundwater in the Sunset Area containes perchlorate from sources other than the JPL facility. For example, perchlorate has been detected in monitoring well 21 (MW21). This well is cross-gradient to the JPL facility and outside the capture influence of the Monk Hill wells; therefore the JPL facility is not likely the source of perchlorate in MW21. The source of perchlorate in MW21 is unknown. Additionally, the groundwater flow model constructed by the Raymond Basin Management District (RBMD) shows MW21 to be within the flow path of the Sunset wells, which indicates that the perchlorate in the groundwater at MW21 is likely impacting the Sunset Area wells. This demonstrates that there is at least one source of perchlorate in the Sunset Area wells that is not JPL. The Sunset Area also received MWD water by direct injection, which demonstrates another source of the perchlorate in these wells. Further, the well MW-19 has not reported elevated perchlorate levels and bounds the JPL contaminant release.

The PWP 2012 technical memorandum discussed the perchlorate isotope analysis and study performed by the University of Illinois at Chicago, and concluded that Chilean fertilizer cannot be a significant source of perchlorate in the Sunset Area groundwater. The PWP concluded that the use of Chilean fertilizer in Pasadena occurred too distant in the past to be reflected in perchlorate in the groundwater at the Sunset Area analyzed recently.

One flaw in this argument is the persistence of perchlorate from Chilean fertilizer found in other groundwater basins in California and the arid southwest. Most specifically, in the Chino basin in Southern California there have been recent detections of perchlorate from Chilean fertilizer found near several Superfund sites. The use of isotope analysis at these sites demonstrates a distinction between perchlorate found in Chilean fertilizer and naturally occurring perchlorate. The data at these Sites show the persistence of perchlorate in the unsaturated zone over time at these sites and others. Infiltration of precipitation and irrigation-derived water will eventually flush the perchlorate through the unsaturated zone. However, this process has been shown to have been occurring over decades and is predicted to require centuries of flushing due to the low

amount of precipitation and infiltration in theses basins. This is likely the case in the Raymond Basin as well.

Further, it is possible to distinguish among naturally occurring perchlorate such as Chilean fertilizer and synthetic perchlorate such as that produced at JPL and formerly at the Kerr McGee facility in Henderson, Nevada. The groundwater at the Sunset Area appears to be contaminated with a combination of naturally occurring and synthetic perchlorate. Because the JPL facility is not and has never been a source of naturally occurring perchlorate, this paper only addresses the question of whether it is a source of the synthetic perchlorate in the groundwater at the Sunset Area wells.

The NASA evaluation of perchlorate isotopes presents samples from Colorado River water, The BMI Complex[5], NASA JPL, MW-25, MW-19, LFWC-2, Sunset, Garfield and Bangham wells. With multiple likely sources including the releases from NASA JPL, Colorado River recharge water, Chilean fertilizer, firework displays and naturally occurring perchlorate, it is understandable that mixtures might exist. The analysis and interpretation of the isotope data by the University of Illinois at Chicago appears to document that both synthetic perchlorate and mixtures of synthetic and naturally occurring perchlorate exist in the groundwater at the Sunset Area wells. From Figure 4 of the evaluation provided by Neil Sturchio of the University of Illinois, it appears that the JPL perchlorate is synthetic and the perchlorate measured in the Sunset Area wells, including the Garfield, Bangham and MW-25 wells, is a mixture of synthetic perchlorate, perchlorate from Chilean fertilizer and indigenous perchlorate. The isotope anaylsis does not provide distinction between two or more synthetic sources. Importantly, the analysis shows that the perchlorate in MW-19 has a similar isotopic signature as the Sunset Area wells and is not similar to the perchlorate found on the JPL facility. If perchlorate from JPL was impacting the Sunset wells then MW-19 isotopes should be similar to those found at JPL.

[5] The BMI complex in Henderson, Nevada, originally developed as a magnesium plant during World War II, the area became a large industrial complex that included numerous chemical manufacturers.

To the extent that the use of isotope analysis of perchlorate appears to demonstrate any distinction between sources of synthetic perchlorate, it suggests that the perchlorate in the Sunset wells is more comparable to a mixture of fireworks and Colorado River water than a JPL source.[6]

For the reasons described above, the use of isotope analysis in this case is not, in this reviewer's opinion, definitive. Sufficient ambiguity exists to preclude the use of isotopes to distinguish multiple synthetic sources.

Conclusion

Based on available data it is this reviewer's opinion that the hydrogeologic evaluation from the RI and the Additional Investigation demonstrates that the perchlorate released at the JPL facility is captured by the Monk Hill and Lincoln Avenue wells. Further, currently available data does not provide a distinction among sources of synthetic perchlorate. Absent any release of perchlorate from the NASA JPL facility, there would be perchlorate in groundwater within the groundwater at the Sunset Area. Based on multiple lines of evidence, it is not possible to conclude that the perchlorate detected in the Sunset wells is related to the release of perchlorate from JPL. The technical arguments raised by PWP do not assist in determining contribution from the known sources of perchlorate, nor do they demonstrate that JPL is a source of any of the perchlorate in the Sunset Area groundwater.

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[6] In a review of the data by Neil Sturchio dated May 15, 2007, isotope ration tables show samples of perchlorate from JPL ranging from approximately -25 to approximately -18 on the σ^{18} O axis, whereas perchlorate from fireworks, road flares, and the BMI complex range from approximately -20 to -10. All of these sources, however, are between -5 and 5 on the σ^{37} Cl axis, whereas perchlorate from Chilean ferlizer sources range from -10 to -15 on the σ^{37} Cl axis _____