

**NASA's Technical Response to Pasadena Water and Power's (PWP's) Memorandum Entitled,  
*Technical Memorandum on the Perchlorate Contamination of the Sunset Reservoir Wells*<sup>1</sup>**

Background:

NASA has been working collaboratively with Pasadena Water and Power (PWP) and its consultants since 2004 in an effort to collect data<sup>2</sup> and maintain an open technical discussion regarding the presence of perchlorate in PWP's Sunset Reservoir Wells. This effort has included installation of two new monitoring wells, groundwater sampling, groundwater modeling, analysis of groundwater monitoring well data dating back to the early 1990s, analysis of production well water quality data dating back to 1940, and a perchlorate isotope study. To be as comprehensive as possible, NASA's analysis used four distinct lines of scientific evidence, which were evaluated individually and collectively. The result of NASA's analysis completed in 2007 was the conclusion that the perchlorate in the Sunset Reservoir Wells had not originated from the Jet Propulsion Laboratory (JPL); rather, it was a mixture of one or more non-JPL, synthetic source(s) along with a substantial amount of naturally occurring perchlorate.<sup>3</sup>

Since finalizing these findings in January 2007, NASA has responded on an ongoing basis to comments from the PWP, U.S. Environmental Protection Agency (EPA), and the Department of Toxic Substances Control (DTSC). NASA submitted responses to all comments received on the January 2007 technical memorandum in December 2008.<sup>4</sup> After considering and responding to all comments, NASA again concluded that the perchlorate in the Sunset Reservoir Wells had not originated from JPL.

Some of the comments received on NASA's technical memorandum had to do with groundwater modeling, which is one of the four lines of scientific evidence used for this analysis. In 2009, Pasadena contracted Geoscience Support Services, Inc. to conduct additional modeling and evaluate the other lines of evidence presented by NASA in the Additional Investigation Technical Memorandum<sup>3</sup> and the associated responses to comments.<sup>4</sup> Geoscience's findings were documented in a technical memorandum,<sup>5</sup> dated October 28, 2009. NASA provided comments to PWP on Geoscience's memorandum on January 15, 2010. NASA had many questions regarding the assumptions used by Geoscience. Overall, the findings presented in the October 2009 technical memorandum from Geoscience were not substantiated by available data and did not consider all available data in an integrated manner. In a continued spirit of openness and collaboration, NASA participated in a teleconference with PWP, Geoscience, and the EPA on February 5, 2010. As a result of that teleconference, the parties concluded that Geoscience did not provide sufficient analysis in their

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<sup>1</sup> Pasadena Water and Power. 2012. Technical Memorandum on the Perchlorate Contamination of the Sunset Reservoir Wells. Submitted to Ms. Judy Huang, U.S Environmental Protection Agency. May.

<sup>2</sup> NASA. 2004. *Operable Unit 3 Remedial Investigation (RI) Addendum Work Plan (Pasadena Sampling Plan [PSP]-2004-1)*. Prepared by Battelle for the National Aeronautics and Space Administration. November.

<sup>3</sup> NASA. 2007. *Technical Memorandum, Additional Investigation Results, National Aeronautics and Space Administration, Jet Propulsion Laboratory, Pasadena, California*. Prepared by Battelle for the National Aeronautics and Space Administration. January.

<sup>4</sup> NASA. 2008. *Responses to Comments on the Additional Investigation Results, National Aeronautics and Space Administration, Jet Propulsion Laboratory, Pasadena, California*. Prepared by Battelle for the National Aeronautics and Space Administration. December.

<sup>5</sup> Geoscience Support Services, Inc. and Williams-McCaron, Inc. 2009. *NASA/JPL Perchlorate Contamination of Ground Water in the Raymond Basin*. Prepared for the City of Pasadena Water and Power. October 28.

modeling results to substantiate their interpretations. PWP decided not to pursue additional analysis, citing the expense.

NASA was surprised to receive a copy of PWP's May 2012 Technical Memorandum<sup>1</sup>, directed to the EPA and copied to numerous parties not part of any of the historical discussions on this topic over the last 8 years.

#### NASA's Review of PWP's May 2012 Technical Memorandum<sup>1</sup>:

This document provides NASA's detailed technical review of PWP's May 2012 Technical Memorandum. NASA's review is organized to correspond to the four "opinions" described in PWP's cover letter to Ms. Judy Huang and that are further expanded on in the May 2012 Technical Memorandum.<sup>1</sup> In addition, NASA prepared a matrix identifying all the instances where PWP misrepresented statements by NASA (and in one case the EPA), comparing the misrepresented statement to the actual statement(s). This matrix is provided as Attachment 1. In Attachment 2, NASA provides a matrix identifying erroneous statements/conclusions made by PWP and NASA's comments on the errors and omissions.

Dr. Neil Sturchio also reviewed PWP's May 2012 Technical Memorandum and his detailed comments are provided as Attachment 3. Dr. Sturchio is a recognized expert in the field of perchlorate isotopes and geochemistry. He has authored or co-authored more than 160 peer-reviewed scientific publications (including *Environmental Science and Technology* and *Analytical Chemistry*) and more than 200 presentations given at national and international scientific conferences in the areas of geochemistry, hydrology, and geology. He is currently serving as the Department Head and Professor of Geochemistry for the Department of Earth and Environmental Sciences at the University of Illinois at Chicago. In addition, he is the Founding Director of the Environmental Isotope Geochemistry Laboratory at the University of Illinois at Chicago, and has worked on numerous perchlorate-impacted sites in California.

Overall, NASA has many concerns over the interpretation of data and the misrepresentation of NASA's statements from the 2007 Technical Memorandum.<sup>3</sup> *The findings presented in the May 14, 2012 technical memorandum from PWP misrepresent NASA's statements, present opinions that are not substantiated by available data, and do not consider all available data in an integrated manner.*

#### **General Comments**

- Of utmost concern is that PWP's Technical Memorandum did not acknowledge NASA's December 2008 responses to all comments<sup>4</sup> received on the January 2007 technical memorandum. NASA's responses addressed all comments received from EPA, DTSC, and PWP. This is a significant oversight in several respects: (1) a reader of PWP's May 14, 2012 cover letter could conclude that the comments by EPA, DTSC, and PWP were unresolved and (2) the additional data analysis provided in NASA's 2008 responses is highly relevant to PWP's May 2012 Technical Memorandum. This latter omission does not reflect NASA's numerous offers of collaboration and openness to scientific resolution of the matter.
- The PWP evaluation did not evaluate all available data in an integrated manner. Rather, each of the analytical tools/lines of evidence was evaluated on an individual basis without consideration of all available data, which is required to understand the complex groundwater conditions and geochemistry of the Monk Hill Subarea. For example, PWP identifies JPL as the source of carbon tetrachloride in the Patton Well, located over 6 miles from the JPL facility, without consideration

of groundwater flow and chemical fate and transport data that would clearly indicate JPL is not the source of carbon tetrachloride in the Patton Well.<sup>6</sup>

- PWP's evaluation does not account for plume containment by the production wells operating in the Monk Hill Subarea over the past 75 years. Plume containment was discussed in detail as part of the Additional Investigation Technical Memorandum and NASA's 2008 responses to comments (RTCs). Both the JPL Groundwater Model and Raymond Basin Management Board (RBMB) Groundwater Model indicate that particles released from JPL would be captured by the production wells located in the Monk Hill Subarea and not migrate to the Sunset Reservoir Wells.
- PWP's evaluation does not account for groundwater chemical monitoring data that provide evidence that the leading edge of NASA's perchlorate plume has been established. This topic was discussed in detail as part of the Additional Investigation Technical Memorandum and NASA's 2008 RTCs.
- PWP does not properly interpret/consider the perchlorate isotope data, or the geochemical data collected as part of NASA's Additional Investigation. NASA sought a prominent expert (Dr. Neil Sturchio) in the field to interpret these data and subjected our findings to the normal scientific peer-review process, including a peer-reviewed publication<sup>7</sup>.

### Opinion 1

PWP attempts to connect groundwater age and the age of chemicals in groundwater. Specifically, PWP states that, "so unless the water in the Sunset Reservoir Wells is over 70 years old, it would be impossible for Chilean nitrate fertilizers to have contributed any perchlorate to those waters."

NASA has the following general comments:

- PWP's Opinion 1 fails to account for the fact that recent water can dissolve older salts/chemicals in situ. Dr. Sturchio's detailed comments (Attachment 3) state PWP's argument "falls apart in light of other recent scientific studies of the hydrologic transport of nitrate and perchlorate contamination from surface sources into aquifers...it is common for contaminants to reside in aquifer systems for much longer times than indicated by the apparent groundwater age."
- PWP's Opinion 1 fails to account for perchlorate isotope data from samples collected from MW-25, Garfield, and Bangham that provide strong evidence of mixing with up to about 25% natural perchlorate.

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<sup>6</sup> Throughout the process, NASA's approach to understanding groundwater conditions and the source of perchlorate in the Sunset Wells has been to evaluate all of the available data in an integrated manner. NASA evaluated four lines of evidence, representing all of the available data, to establish a conceptual site model for the study area and achieve the objectives of the study. The four lines of evidence included groundwater modeling data, groundwater geochemical data, chemical concentration data collected as part of the JPL groundwater monitoring program, and perchlorate isotope analysis data. Each of the four lines of evidence provide important information and need to be evaluated together to fully develop and understand the site conceptual model regarding the complexities of underground conditions and the presence of perchlorate in local groundwater.

<sup>7</sup> Steve Slaten, Keith A. Fields, Susan Santos, Andrew Barton, Heather V. Rectanus, and Mohit Bhargava. 2010. "Integrated Environmental Forensics Approach for Evaluating the Extent of Dissolved Perchlorate Originating from Multiple Sources." *Environmental Forensics*, 11:72-93. March.

## Opinion 2

PWP attempts to demonstrate that all perchlorate in the Raymond Basin, including perchlorate originating from JPL, is from the Basic Management Inc. (BMI) Complex in Henderson, Nevada.

NASA has the following general comments:

- PWP's Opinion 2 does not account for the evidence from the perchlorate isotope analysis conducted by NASA and presented in the Additional Investigation Technical Memorandum, which demonstrated that the perchlorate isotope signature associated with JPL was unique within the study area. In addition, PWP does not properly consider available records regarding perchlorate produced at the Los Angeles plant(s) of Western Electrochemical Company (WECCO) for JPL.
- PWP does not seem to be aware of the fact that large quantities of fireworks and road flares have been imported into the U.S., and the perchlorate in these imported items was not manufactured at the BMI Complex. Note also, Opinion 2 is partially based on PWP's misunderstanding of the use and transport of Chilean nitrate fertilizer (see NASA's input on Opinion 1).
- Dr. Sturchio's evaluation (Attachment 3) demonstrates that "a mixture of three sources of isotopically distinct perchlorate, all known to be present in the area, explains the isotopic variability of perchlorate in the Sunset Reservoir wells." Dr. Sturchio also demonstrates that "a single perchlorate source in the Raymond Basin is not consistent with the evidence presented by NASA" and that "no other perchlorate sources aside from Colorado River water, Chilean nitrate fertilizer, and indigenous natural perchlorate are required to explain the isotopic composition of perchlorate in all Raymond Basin groundwaters outside the zone of influence of JPL in the Monk Hill sub-basin."
- NASA provided a detailed response to questions associated with anaerobic biodegradation and the required oxidation-reduction conditions in the aquifer as part of the 2008 RTC. It does not appear PWP considered NASA's RTC as part of its technical memorandum. The presence of chloroform (trichloromethane [TCM]) was addressed in NASA's RTC:  
"The presence of chloroform, a daughter product of carbon tetrachloride degradation, cannot be used to indicate anaerobic degradation of carbon tetrachloride since chloroform was a compound used during historic laboratory operations at JPL (Reference OU-2 Remedial Investigation, 1999) and is a disinfection byproduct."

## Opinion 3

PWP attempts to show that all the perchlorate observed in the Sunset Reservoir wells originated from JPL, using concentrations of nitrate, perchlorate, and carbon tetrachloride observed in (1) groundwater representative of San Gabriel Mountain (SGM) run-off, (2) groundwater that flows beneath JPL, and (3) groundwater flow from the La Cañada Flintridge (LCF) area located northwest of JPL.

NASA has the following general comments:

- PWP's Opinion 3 fails to account for data demonstrating that the production wells in the Monk Hill Subarea contain the chemicals originating from JPL, as discussed extensively in NASA's 2008 RTCs. PWP also fails to account for the groundwater modeling data from the RBMB Groundwater Model (see Figure 1 of the 2012 PWP Technical Memorandum), which indicates that the majority of groundwater particles captured by the Sunset Reservoir Wells originates from the LCF area.

- PWP's Opinion 3 fails to account for available data demonstrating that the leading edge of NASA's perchlorate plume has been established, as discussed extensively in NASA's 2008 RTCs.
- PWP's Opinion 3 fails to consider historical data from MW-21 presented in NASA's Additional Investigation Technical Memorandum, indicating a more significant source of perchlorate in the LCF area.
- PWP's Opinion 3 does not account for the perchlorate isotope data, which do not support its conclusions.
- PWP does not account for other potential sources of perchlorate in the Sunset Reservoir wells, including Chilean nitrate fertilizers. PWP's underlying assumption is that there are only two sources of perchlorate in the basin (JPL and LCF). The perchlorate isotope data indicate that this is not true. PWP does not consider that perchlorate associated with imported water could have entered the aquifer near the Sunset Reservoir wells from areas other than LCF (e.g., the golf course near the Rose Bowl).
- Patton Well has isolated carbon tetrachloride hits, is located over 6 miles from the JPL facility (over 4 miles from the Monk Hill Subarea), and there is one isolated carbon tetrachloride detection of 0.1 µg/L (Villa Well, February 8, 1989) in between the Patton Well and the Lincoln Avenue Water Company (LAWC) wells. Clearly, carbon tetrachloride detections in the Villa Well and Patton Well are not from JPL, nor are they applicable to NASA's contention that carbon tetrachloride appears to be unique to the JPL facility within the Monk Hill Subarea. In addition, the RBMB Groundwater Model indicates that the capture zone for the Patton Well consists of groundwater to the west of the well toward the San Rafael Hills (see Figure 1 of the 2012 PWP Technical Memorandum). NASA statements with regard to carbon tetrachloride as a tracer for JPL chemicals were applicable to the Additional Investigation study area, not the entire Raymond Basin (as PWP has attempted to misrepresent), and must be considered in context of all available data (i.e., the groundwater flow paths represented by the JPL and RBMB Groundwater Models, and the available chemical data demonstrating that the extent of carbon tetrachloride originating from the JPL facility has been established).

#### Opinion 4

PWP attempts to use chemical and isotopic data for a variety of reactive solutes, such as strontium (Sr), nitrate, sulfate calcium, and sodium, along with <sup>87</sup>Sr/<sup>86</sup>Sr ratios and stable isotope ratios of water to demonstrate that the perchlorate in the Sunset Reservoir Wells is from JPL.

NASA has the following general comments:

- As discussed above, many of PWP's fundamental/underlying assumptions and assertions are shown to be incorrect (e.g., containment of chemicals originating from JPL, recent water dissolving older chemicals in situ, presence of natural perchlorate, etc.).
- PWP's Opinion 4 underestimates the importance of perchlorate in the Colorado River water. NASA's 2008 RTCs specifically address the volume of imported Colorado River water as well as the hypothetical perchlorate mass estimate that was used in the Additional Investigation Technical Memorandum (See Groundwater Chemical Concentrations Geoscience Comments No. 2 and 3 [pages 9-10]). In addition, pages 11-13 of the Additional Investigation Technical Memorandum define the Colorado River Water source.
- PWP water classification was different from the classification used by NASA and does not account for historical sulfate concentrations.

- Groundwater near the Sunset Reservoir Wells is a mixture of local water (which includes SGM runoff) and imported water. Historical data demonstrate that the Sunset Reservoir wells have been impacted by imported water (see Figures 7, 8, and 9 in the Additional Investigation Technical Memorandum).
- PWP's Opinion 4 fails to recognize that strontium is not effective as a conservative tracer in groundwater aquifers because of its high reactivity.
- PWP's analysis does not take into account the extreme annual variability in stable isotope composition of local meteoric water or Colorado River water.

## Conclusion

In summary, NASA concurs with Dr. Sturchio's evaluation (Attachment 3), which concludes, ***"The opinions of PWP are found to be based on flawed assumptions and incogent arguments leading to erroneous and unfounded conclusions regarding the origin of perchlorate in the Sunset Reservoir wells. The PWP (2012) opinions that there is a single source of perchlorate (BMI complex) in the Sunset Reservoir wells, that Chilean nitrate fertilizer could not have contributed perchlorate to the Sunset Reservoir wells, and that all of the perchlorate in the Sunset Reservoir wells is from JPL are inconsistent with the perchlorate isotopic data and other evidence presented by NASA (2007). The available data presented by NASA (2007) indicate clearly that at least three separate types of perchlorate must have contributed to the Sunset Reservoir wells, including mostly synthetic perchlorate (of which the majority is most likely from the BMI complex via imported Colorado River water) along with locally significant amounts of residual perchlorate from Chilean nitrate fertilizer and indigenous natural perchlorate from regional atmospheric deposition. The available data do not require the presence of any JPL-sourced perchlorate in the Sunset Reservoir wells, and the NASA (2007) report makes a reasonable case that all JPL sourced perchlorate is contained in the Monk Hill sub-basin."***

## **Attachment 1**

**Comparison of PWP Statement/Quote/Inference to NASA's Additional Investigation (AI)  
Technical Memorandum and NASA's Response to Comments (RTC)**

**Comparison of PWP Statement/Quote/Inference to NASA's Additional Investigation (AI) Technical Memorandum and NASA's Response to Comments (RTC)**

PWP Statement/Quote/Inference	NASA's AI <sup>1</sup> and/or RTC <sup>2</sup>	Comments
<b>NASA's Input on Pasadena Water and Power (PWP) August 2012 Cover Letter</b>		
<p><b>Opening paragraph:</b> "In June 2007 PWP submitted a review of the TM (prepared by our consultant Geoscience) 86 pages in length identifying where PWP believed that shortcomings and errors occurred in the TM. In October of 2007 Lewis Mitani of USEPA, the Remedial Project Manager at the time, wrote a five page memorandum identifying technical deficiencies of the TM. Similarly, in May 2008 Juli Osborne of DTSC submitted a 10 page memorandum identifying additional concerns about the soundness of the TM. Since then various exchanges between the above mentioned parties has occurred, but no resolution has been achieved. All three of the above mentioned memoranda (USEPA, PWP, and DTSC) concurred that the TM did not make a convincing case that the JPL could not have contributed contamination at the Sunset Reservoir Wells."</p>	<p>PWP does not acknowledge NASA's RTC submitted in December 2008. This RTC responded to all of the comments received on the 2007 AI Technical Memorandum (TM), including the ones referenced from the USEPA, PWP, and DTSC.</p> <p>It should be noted that one DTSC reviewer, Richard Coffman, Ph.D., P.G., concurred with NASA's conclusions. Dr. Coffman specific comment: <i>"I think that the JPL has made a compelling argument and has presented more supporting data than I have seen for any other site that their contaminant plume can be contained by the production wells in the Monk Hills subarea, and that the contamination present in the Sunset Reservoir wells is geochemically different from that released at the JPL. This contention is supported by the groundwater modeling that has been conducted, as well as by the various geochemical data that was presented. Based on what I read I would concur with their conclusions."</i></p>	<p>Failure to acknowledge NASA's RTC in PWP's May 2012 technical memorandum is inappropriate and of concern given the wide distribution, including Senator Dianne Feinstein, Senator Barbara Boxer, Representative Adam Schiff, Representative Judy Chu, Mic Stewart (MWDSC), and Jean-Lou Chameau (California Institute of Technology).</p> <p>It is also worth noting that in March 2010, NASA's AI study was published in the peer-reviewed journal <i>Environmental Forensics</i>.<sup>3</sup> The technical validity of NASA's findings was subject to a scientific peer-review process.</p>
<p><b>Concluding paragraph:</b> "PWP believes that the data in the NASA TM, when combined with a small amount of additional data, and the groundwater modeling information, conclusively demonstrates that JPL is the dominant source of perchlorate in the Sunset Reservoir Wells. PWP staff has prepared a TM documenting these assertions,</p>	<p>PWP does not acknowledge NASA's RTC submitted in December 2008.</p>	<p>PWP uses definitive language, (i.e., "conclusively demonstrates" and "thoroughly compelling case") that is not supported by their analysis of the data. In addition, PWP selectively targets individual elements of the AI Technical Memorandum, and does not consider all available data in an integrated manner.</p>

<sup>1</sup> NASA. 2007. *Technical Memorandum, Additional Investigation Results, National Aeronautics and Space Administration, Jet Propulsion Laboratory, Pasadena, California*. Prepared by Battelle for the National Aeronautics and Space Administration. January.

<sup>2</sup> NASA. 2008. *Responses to Comments on the Additional Investigation Results, National Aeronautics and Space Administration, Jet Propulsion Laboratory, Pasadena, California*. Prepared by Battelle for the National Aeronautics and Space Administration. December.

<sup>3</sup> Steve Slaten, Keith A. Fields, Susan Santos, Andrew Barton, Heather V. Rectanus, and Mohit Bhargava. 2010. "Integrated Environmental Forensics Approach for Evaluating the Extent of Dissolved Perchlorate Originating from Multiple Sources." *Environmental Forensics*, 11:72-93. March.



**Comparison of PWP Statement/Quote/Inference to NASA's Additional Investigation (AI) Technical Memorandum  
and NASA's Response to Comments (RTC)**

PWP Statement/Quote/Inference	NASA's AI <sup>1</sup> and/or RTC <sup>2</sup>	Comments
which when examined with previous memoranda from USEPA, DTSC, and Geoscience, make a thoroughly compelling case. PWP does not believe any further investigations are necessary to conclude that the Sunset Reservoir Wells should be included in the JPL Superfund site."		
<b>NASA's Input on the Synopsis of the August 2012 PWP Technical Memorandum</b>		
<b>Page 2, second paragraph:</b> "The document (NASA's 2007 TM) concluded that the perchlorate in Sunset Reservoir Wells does not come from Jet Propulsion Laboratory (JPL) in Pasadena, but is a mix from Chilean nitrate fertilizer and a man-made perchlorate manufactured at the Basic Management Inc. (BMI) Complex in Henderson, Nevada, which entered the Raymond Basin via the Colorado River Aqueduct."	<p>Consistent with the requirements of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) in performing remedial investigations, NASA's objective in the AI was to determine the extent of perchlorate originating from the JPL facility. We accomplished that objective. Direct statements on the sources of perchlorate in the Sunset Reservoir Wells were not made in the 2007 AI TM.</p> <p>NASA's conclusion was as follows: "The investigation employed use of four different analytic tools. Taken together, the results of the analysis lead to the conclusion that (1) the chemicals from the JPL facility are contained within the Monk Hill Subarea, and (2) the perchlorate detected at the Sunset area wells is of a different origin than that used at, and originating from, JPL. This conclusion is supported by (1) groundwater modeling; (2) groundwater geochemical data and supporting groundwater, strontium, and tritium/helium data; (3) groundwater carbon tetrachloride and perchlorate data collected as part of the JPL Groundwater Monitoring program and production well sampling; and (4) perchlorate isotope data." (AI, Pg. 5; paragraph: 3)</p>	This is the first of many examples where PWP misrepresents NASA's statements.
<b>Page 2, second paragraph:</b> "NASA has argued that groundwater from the base of the San Gabriel Mountains (SGMs), which includes JPL, is	NASA's statements were based on factual information and included:	<p>This misrepresents NASA's statements.</p> <p>NASA made no direct statements about</p>

**Comparison of PWP Statement/Quote/Inference to NASA's Additional Investigation (AI) Technical Memorandum and NASA's Response to Comments (RTC)**

PWP Statement/Quote/Inference	NASA's AI <sup>1</sup> and/or RTC <sup>2</sup>	Comments
hydraulically contained and cannot migrate south."	<p>"Groundwater modeling performed independently by NASA and RBMB indicate that dissolved chemicals originating from the JPL facility would be contained by production wells in the Monk Hill Subarea and not migrate to the Sunset Reservoir Wells." (AI, Pg. 3; paragraph: 3)</p> <p>"Results from the samples collected from JPL groundwater monitoring wells and from production wells indicate that carbon tetrachloride is unique to JPL within the Monk Hill Subarea. The extent of carbon tetrachloride is known, does not extend outside the Monk Hill Subarea, and correlates closely with groundwater modeling predictions." (AI, Pg. 22; text box)</p>	<p>groundwater from the base of the SGM.</p> <p>NASA's groundwater model (as well as the independently-developed Raymond Basin Management Board [RBMB] groundwater model), indicate that chemicals in groundwater originating from groundwater beneath JPL are contained within the Monk Hill Subarea.</p>
<p><b>Page 2, Opinion 1:</b> "According to NASA's TM there are four distinct sources of perchlorate in the Raymond Basin:</p> <ul style="list-style-type: none"> <li>• A source unique to JPL from a perchlorate facility in Los Angeles, California</li> <li>• Colorado River water, contaminated with perchlorate from the BMI Complex in Henderson, Nevada</li> <li>• Chilean nitrate fertilizers</li> <li>• Road flares"</li> </ul>	<p>NASA's statements included:</p> <p>"JPL perchlorate isotopic signature is distinct in the Monk Hill Subarea. The perchlorate in the wells near Sunset Reservoir appear to be influenced by at least two separate (non-JPL) sources, including a naturally occurring/fertilizer source and one or more synthetic sources." (AI, Pg. 30; text box)</p>	<p>This misrepresents NASA's statements. NASA did not make a definitive statement on four distinct sources of perchlorate in the Raymond Basin.</p>
<p><b>Page 2, Opinion 2:</b> "According to NASA's TM Stable Isotope Analysis (SIA) of perchlorate indicates that there were three industrial sources of perchlorate in the Raymond Basin, a "JPL" Source, the BMI Complex in Henderson Nevada, and road flares.</p>	<p>NASA's statement was:</p> <p>"The isotopic compositions of perchlorate in the MW-19, MW-25, Sunset, Bangham, and Garfield wells are all significantly different (higher <math>\delta^{18}\text{O}</math> values) from those of the JPL source area and MW-17-3 (downgradient near JPL). The isotopic compositions of perchlorate in MW-19, MW-25, Sunset, Garfield, and LFWC#2 are similar to those of fireworks, road flares, perchlorate manufactured at the BMI complex in southern</p>	<p>This misrepresents NASA's statements. NASA did not make a definitive statement on industrial sources of perchlorate in the Raymond Basin.</p>

**Comparison of PWP Statement/Quote/Inference to NASA's Additional Investigation (AI) Technical Memorandum  
and NASA's Response to Comments (RTC)**

PWP Statement/Quote/Inference	NASA's AI <sup>1</sup> and/or RTC <sup>2</sup>	Comments
	Nevada, and a surface water sample taken from the Las Vegas Wash as well as a groundwater sample taken near the BMI complex." (AI, Pg. 30; bullet: 3)	
<b>Page 4, Opinion 3:</b> "NASA has hypothesized that water flowing south from the SGMs, is contained by the pumping operations of various potable water operations and as a result entirely from the LCF area."	<p>Specific statements included:</p> <p>"Groundwater modeling performed independently by NASA and RBMB indicate that dissolved chemicals originating from the JPL facility would be contained by production wells in the Monk Hill Subarea and not migrate to the Sunset Reservoir Wells." (AI, Pg. 3; paragraph: 3)</p> <p>"The RBMB model also indicates that groundwater originating to the west of JPL in La Cañada Flintridge (LCF) flows south of the JPL facility and then towards the Sunset Reservoir Wells." (AI, Pg. 7; bullet: 2)</p> <p>"MW-21 is outside the capture zones of the Monk Hill Production wells and within the capture zone of the Sunset Reservoir wells according to the RBMB groundwater model...The elevated levels of perchlorate in MW-21, which were detected from when perchlorate sampling began in 1997 to 2000, provide evidence of a more significant source of perchlorate that did not originate from JPL." (AI, Pg. 26; paragraph: 1)</p>	Opinion 3 misrepresents NASA's statements. NASA did not make broad statements about water flowing south from the SGMs. NASA did make statements about containment of chemicals in the Monk Hill Subarea groundwater originating from the JPL facility.
<b>NASA's Input on the August 2012 PWP Technical Memorandum</b>		
<b>Page 11, first paragraph:</b> "NASA has contended that there are four distinct sources of perchlorate in the Raymond Basin; 1) A source unique to JPL from the Los Angeles WECCO facility, 2) the Basic Management Incorporated (BMI) Complex in Henderson, Nevada, 3) Road Flares, and 4) Chilean nitrate fertilizers. NASA has argued that the	"Historic waste disposal practices associated with research conducted in the 1940s and 1950s at the JPL facility are a known source of perchlorate in the Monk Hill Subarea of the Raymond Basin. While the highest concentrations of perchlorate in the Raymond Basin have been detected in groundwater beneath the JPL facility, sources of	NASA did not make a definitive statement on four distinct sources of perchlorate in the Raymond Basin, rather NASA established the presence of well-documented and widespread non-JPL sources.

**Comparison of PWP Statement/Quote/Inference to NASA's Additional Investigation (AI) Technical Memorandum  
and NASA's Response to Comments (RTC)**

PWP Statement/Quote/Inference	NASA's AI <sup>1</sup> and/or RTC <sup>2</sup>	Comments
<p>Sunset Reservoir Wells have perchlorate from the BMI Complex while Bangham Well has perchlorate from both Chilean nitrate fertilizer and BMI Complex. NASA based their argument upon ground water modeling, tritium and <sup>3</sup>He analysis, SIA of perchlorate, water, strontium as well as water typing to support this argument.”</p> <p><b>Page 12, third paragraph:</b> “In NASA TM, NASA argued that the perchlorate at the five Sunset wells does not originate from the JPL facility. NASA’s TM contends that there are other sources of perchlorate in the area. It was asserted in NASA’s TM that there are four different sources of perchlorate in all, impacting different wells:</p> <ol style="list-style-type: none"> <li>1) Los Angeles WECCO Facility (JPL, LAWC Wells, and the Monk Hill Wells)</li> <li>2) Chilean nitrate fertilizers (Bangham Well)</li> <li>3) Road Flares (LFWC Well #2)</li> <li>4) BMI Complex in Henderson Nevada via the Colorado River water and the MWDSC (Sunset Wells including Bangham)”</li> </ol>	<p>perchlorate in the environment other than those associated with solid rocket propellant are widespread and well documented, including road flares, fireworks, blasting operations, and naturally-occurring mineral deposits used in fertilizer production. Since analysis for perchlorate began in 1997, perchlorate detection in the Raymond Basin has been widespread. In the Raymond Basin, perchlorate has been detected beneath and adjacent to JPL, at locations hydraulically cross-gradient/upgradient of JPL (thus not associated with JPL), at the Sunset Reservoir Wells located approximately three miles hydraulically downgradient from JPL, and at wells even further from JPL (i.e., to the south and east of the Sunset Reservoir Wells).”</p> <p>(AI, Pg. 3; first paragraph)</p>	
<p><b>Page 11, second paragraph:</b> “Even the analysis of carbon tetrachloride, which NASA posits as the definitive marker of JPL contamination, is found both upgradient and downgradient from the Sunset Reservoir Wells.”</p>	<p>NASA made the following statements regarding carbon tetrachloride:</p> <p>“The VOC carbon tetrachloride is a reliable tracer for chemicals originating from JPL because significant quantities were disposed of at JPL during historical operations and because no other source of carbon tetrachloride is known to exist in the Monk Hill Subarea. Other VOCs, including trichloroethylene (TCE) and tetrachloroethylene (PCE), have been detected at relatively low levels in soil and groundwater beneath JPL. However, other sources of these VOCs exist in the Monk Hill Subarea, such as former dry cleaning sites and</p>	<p>NASA established that carbon tetrachloride is a reliable tracer for chemicals originating from JPL, as available data indicate that JPL is a unique source of carbon tetrachloride in the Monk Hill Subarea (not the entire basin). The extent of JPL’s carbon tetrachloride plume is established within the Monk Hill Subarea, extending approximately 1 mile from the JPL facility. Carbon tetrachloride in wells within the Pasadena Subarea of the Raymond Basin that are located three to five miles south of the JPL facility is clearly from another, non-JPL source.</p>

**Comparison of PWP Statement/Quote/Inference to NASA's Additional Investigation (AI) Technical Memorandum  
and NASA's Response to Comments (RTC)**

PWP Statement/Quote/Inference	NASA's AI <sup>1</sup> and/or RTC <sup>2</sup>	Comments
	<p>unsewered areas in La Cañada Flintridge so they cannot be used as tracers for chemicals originating from JPL. Analytical results of groundwater samples collected from JPL monitoring wells and production wells indicate that the carbon tetrachloride plume originating from JPL is fully delineated and contained with the Monk Hill Subarea...Groundwater monitoring data delineates the extent of carbon tetrachloride originating from the JPL facility as approximately one mile southeast of the JPL facility. Carbon tetrachloride has not been detected in the Sunset Reservoir Wells. Groundwater monitoring data on the extent of carbon tetrachloride correlates well with the aforementioned Raymond Basin Management Board (RBMB) and NASA groundwater modeling predictions.” (AI, Pg. 4; Paragraph 4)</p> <p>While carbon tetrachloride concentrations are lower than perchlorate concentrations by a factor of approximately 10, the detection limit for carbon tetrachloride is also lower than perchlorate by a factor of approximately 10. Therefore, the use of carbon tetrachloride as a tracer is not limited by the relative concentrations between it and perchlorate. In addition, we see a strong correlation between perchlorate and carbon tetrachloride in LAWC#5, located approximately 1 mile from the JPL source area (see Figure R4 in the general response). Therefore, NASA continues to believe that the use of carbon tetrachloride as a tracer is appropriate as one line of evidence to help understand the extent of JPL perchlorate.” (RTC, EPA Comment Pg. 13; Paragraph 2)</p>	
<b>Page 17, second paragraph:</b> “NASA’s TM argues	“Mixing of JPL perchlorate and another source	In addition to Bangham well data, perchlorate

**Comparison of PWP Statement/Quote/Inference to NASA's Additional Investigation (AI) Technical Memorandum  
and NASA's Response to Comments (RTC)**

PWP Statement/Quote/Inference	NASA's AI <sup>1</sup> and/or RTC <sup>2</sup>	Comments
<p>that Bangham Well has perchlorate that is a mixture of Chilean nitrate fertilizers and perchlorate from the Colorado River. NASA's hypothesis is that MWDSC water entered the Raymond Basin through return flow and injection for aquifer storage and recovery, and then blended with local waters influenced by Chilean nitrate fertilizers, but only at Bangham Well."</p>	<p>does not appear to be a viable explanation for the perchlorate signatures observed in the Sunset, Bangham, or Garfield wells." (AI, Pg. 30; paragraph: 2)</p> <p>"The isotopic compositions of perchlorate in the MW-19, MW-25, Sunset, Bangham and Garfield wells are all significantly different (higher <math>\delta^{18}\text{O}</math> values) from those of the JPL source area and MW-17-3 (downgradient near JPL). The isotopic compositions of perchlorate in wells MW-19, MW-25, Sunset, Garfield, and LFWC#2 are similar to those of fireworks, road flares, perchlorate manufactured at the BMI complex in southern Nevada, and a surface water sample taken from the Las Vegas Wash as well as a groundwater sample taken near the BMI complex." (AI, Pg. 30; paragraph: 3)</p> <p>"The <math>\Delta^{17}\text{O}</math> values of perchlorate in wells MW-25, Garfield, and Bangham show evidence of mixing with up to about 25% natural perchlorate (which is enriched in <math>^{17}\text{O}</math> relative to synthetic perchlorate). This natural perchlorate component could have been introduced by infiltration of agricultural fertilizers." (AI, Pg. 30; paragraph: 4)</p>	<p>isotope data from samples collected from MW-25 and Garfield show strong evidence of mixing, with up to about 25% natural perchlorate.</p>
<p><b>Page 19, second paragraph:</b> "NASA's TM suggests some influence of perchlorate from road flares on Las Flores Water Company (LCFW) Well #2; however, there is no evidence supplied to explain any possible link."</p>	<p>"The perchlorate isotope fingerprint at LFWC#2 is distinct from that of the JPL area. LFWC#2 appears to be synthetic perchlorate (<math>\Delta^{17}\text{O} \approx 0\text{‰}</math>) with heavier <math>\delta^{18}\text{O}</math> compared to the JPL facility. As seen in Figures 15 and 16, <math>\delta^{18}\text{O}</math> and <math>\delta^{37}\text{Cl}</math> values of perchlorate present in LFWC#2 are significantly different than those at JPL indicating a different source than JPL for the perchlorate present in the LFWC#2 well. The isotopic composition of</p>	<p>NASA used data collected as evidence to state that the isotopic composition of perchlorate in LFWC#2 "approaches that which is characteristic" of road flares.</p>

**Comparison of PWP Statement/Quote/Inference to NASA's Additional Investigation (AI) Technical Memorandum and NASA's Response to Comments (RTC)**

PWP Statement/Quote/Inference	NASA's AI <sup>1</sup> and/or RTC <sup>2</sup>	Comments
	perchlorate in LFWC#2 approaches that which is characteristic of perchlorate used in road flares." (Pg. 30; paragraph 7)	
<b>Page 23, first paragraph:</b> "Since trichloromethane (TCM) was not known to have been used or disposed of at JPL, its presence in wells that are well established to be influenced by JPL water demonstrates anaerobic biodegradation is occurring, irrespective of the DO and NO <sub>3</sub> concentrations."	TCM/chloroform was used during historic operations at JPL. The presence of TCM was addressed in NASA's RTC: "The presence of chloroform, a daughter product of carbon tetrachloride degradation, cannot be used to indicate anaerobic degradation of carbon tetrachloride since chloroform was a compound used during historic laboratory operations at JPL (Reference OU-2 Remedial Investigation, 1999) and is a disinfection byproduct." (RTC, Pg. 8; paragraph 3)	NASA provided a detailed response to questions associated with anaerobic biodegradation and the required oxidation-reduction conditions in the aquifer as part of the 2008 RTC. It does not appear PWP considered NASA's RTC as part of PWP's technical memorandum.
<b>Page 23, first paragraph:</b> "Further, Judy Huang of the USEPA, the current Remedial Project Manager, wrote in her 2010 memorandum: '...perchlorate degradation is qualitatively plausible...'"	Ms. Huang's full quote from February 4, 2010 letter: "EPA's review of the NASA/JPL responses and the 2009 Geosciences Report finds Geoscience's interpretation of the isotope data related to source attribution and perchlorate degradation is qualitatively plausible, <i>but it lacks any quantitative evidence that JPL is a major source of the perchlorate present in the PWP water supply wells. Importantly, the existence of geochemical conditions that indicate the potential for biotransformation of perchlorate does not necessarily demonstrate that biotransformation has indeed occurred. The isotopic information developed by JPL indicating other sources of perchlorate are also reasonably present in the basin further confounds Geoscience's conclusion that the JPL Superfund site is the only source of perchlorate in downgradient supply wells.</i> "	PWP omits text that puts the quoted comment in context.
<b>Page 24, fourth paragraph:</b> "It is the contention of NASA's TM that all of the water found in the Sunset Reservoir Wells comes from the LCF area	"Although the JPL Groundwater Model and the RBMB basin-scale model were created to satisfy different groundwater modeling objectives, the	NASA did not make statements about the transport of SGM water. All groundwater in the Basin contains SGM water. Both the JPL

**Comparison of PWP Statement/Quote/Inference to NASA's Additional Investigation (AI) Technical Memorandum  
and NASA's Response to Comments (RTC)**

PWP Statement/Quote/Inference	NASA's AI <sup>1</sup> and/or RTC <sup>2</sup>	Comments
<p>water course and that no water from the SGMs, either flowing parallel to or beneath JPL, has any influence on those five wells. This is based on the hypothesis that the production wells in the Monk Hill area, those belonging to PWP, LAWC, and RCLWA, extracted all SGM water flow and prevented any of the water from migrating south of those wells. Therefore, all of the perchlorate found in the Sunset Reservoir Wells must be from the LCF area."</p>	<p>flow fields predicted by both models in the Monk Hill Subarea are very similar. Particle tracking simulations performed using both the RBMB model and the JPL Groundwater Model indicate that particles released in the vicinity of JPL would not migrate downgradient to the Sunset Reservoir wells. Rather, they would be captured by extraction wells in the Monk Hill Subarea...The RBMB model also indicates that groundwater originating to the west of JPL in La Cañada Flintridge flows south of the JPL Facility and then towards the Sunset Reservoir Wells. (AI, Pg. 7, 11; Paragraphs: 1-3 [Pg. 7] and 1 [Pg. 11])</p>	<p>Groundwater Model and the RBMB Groundwater Model indicate chemicals originating from JPL would be captured by the extraction wells in the Monk Hill Subarea.</p>
<p><b>Page 25, first paragraph:</b> "The Patton Well has had perchlorate contamination for a number of years and is located approximately 8 km (5 miles) due south of the Sunset Reservoir Wells. In the summer of 2011, this well was found to have CTC as well as perchlorate and nitrate in concentrations comparable to the Sunset Reservoir Wells. If NASA's hypothesis that CTC is a conservative and a locally unique indicator of contamination from the JPL facility, then the water in this well must be influenced by water from JPL."</p>	<p>NASA stated that "The VOC carbon tetrachloride is a reliable tracer for chemicals originating from JPL because significant quantities were disposed of at JPL during historical operations and because no other source of carbon tetrachloride is known to exist in the Monk Hill Subarea... Analytical results of groundwater samples collected from JPL monitoring wells and production wells indicate that the carbon tetrachloride plume originating from JPL is fully delineated and contained with the Monk Hill Subarea...Groundwater monitoring data delineates the extent of carbon tetrachloride originating from the JPL facility as approximately one mile southeast of the JPL facility. Carbon tetrachloride has not been detected in the Sunset Reservoir Wells. " (AI, Pg. 4; Paragraph 4)</p>	<p>Patton Well has isolated carbon tetrachloride hits, is located over 6 miles from the JPL facility (over 4 miles from the Monk Hill Subarea), and there is only a single, very low carbon tetrachloride detection of 0.1 µg/L (Villa Well, February 8, 1989) in between the Patton Well and the LAWC wells. Clearly, carbon tetrachloride detections in the Villa Well and Patton Well are not related to JPL, nor are they applicable to NASA's contention that carbon tetrachloride appears to be unique to the JPL facility within the Monk Hill Subarea (Patton Well is located over four miles outside the Monk Hill Subarea). In addition, the RBMB Groundwater Model indicates that the capture zone for the Patton Well consists of groundwater to the west of the well toward the San Rafael Hills (see Figure 1 of the 2012 PWP Technical Memorandum). NASA statements with regard to carbon tetrachloride as a tracer for JPL chemicals were applicable to the AI study area, not the entire Raymond Basin (as PWP has attempted to misrepresent), and must be considered in context of all available data (i.e., the groundwater flow paths represented by the JPL</p>



**Comparison of PWP Statement/Quote/Inference to NASA's Additional Investigation (AI) Technical Memorandum  
and NASA's Response to Comments (RTC)**

PWP Statement/Quote/Inference	NASA's AI <sup>1</sup> and/or RTC <sup>2</sup>	Comments
		and RBMB groundwater models, and the available chemical data demonstrating that the extent of carbon tetrachloride originating from the JPL facility has been established).

## **Attachment 2**

**Erroneous Statements/Conclusions Made in the May 2012 PWP Technical Memorandum**

## Erroneous Statements/Conclusions Made In The May 2012 PWP Technical Memorandum

PWP Erroneous Statement/Conclusion	NASA's Comments
<b>NASA's Comments on the Pasadena Water and Power (PWP) Cover Letter</b>	
<p><b>Concluding paragraph:</b> "PWP believes that the data in the NASA TM, when combined with a small amount of additional data, and the groundwater modeling information, conclusively demonstrates that JPL is the dominant source of perchlorate in the Sunset Reservoir Wells. PWP staff has prepared a TM documenting these assertions, which when examined with previous memoranda from USEPA, DTSC, and Geoscience, make a thoroughly compelling case. PWP does not believe any further investigations are necessary to conclude that the Sunset Reservoir Wells should be included in the JPL Superfund site."</p>	<p>PWP does not acknowledge NASA's Responses to Comments (RTC) submitted in December 2008.<sup>1</sup> This RTC responded to all of the comments received on the 2007 AI Technical Memorandum, including the ones referenced from the USEPA, PWP, and DTSC.</p> <p>PWP uses definitive language, (i.e., "conclusively demonstrates" and "thoroughly compelling case") that is not supported by their analysis of the data.</p> <p>It is worth noting that in March 2010, NASA's AI study was published in the peer-reviewed journal <i>Environmental Forensics</i>,<sup>2</sup> as another means of reviewing the technical validity of NASA's findings.</p>
<b>NASA's Comments on the Synopsis of the August 2012 PWP Technical Memorandum</b>	
<p><b>Page 2, Opinion 1:</b> "Chilean nitrate fertilizer cannot be a source of perchlorate in the Sunset Reservoir because: There is no evidence that Chilean fertilizers were ever used in the recharge area of the wells and the recent origin of groundwater in the basin (tritium, helium, nitrate, etc.)"</p>	<p>According to the Altadena Historical Society website<sup>3</sup>, "Pasadena, beginning as a fruit growing colony, became part of a co-operative on December 14, 1893. Originally named the Pasadena Fruit Growers Association, in 1909 the name was changed to Pasadena Orange Growers Association...In 1917 the Association shipped 144,000 packed boxes worth \$200,000, over \$3 million in today's dollars."</p> <p>Dr. Sturchio's evaluation (Attachment 3), states PWP's argument "falls apart in light of other recent scientific studies of the hydrologic transport of nitrate and perchlorate contamination from surface sources into aquifers...it is common for contaminants to reside in aquifer systems for much longer times than indicated by the apparent groundwater age." Recent water can dissolve older salts/chemicals in-situ.</p> <p>PWP does not account for the <math>\Delta^{17}\text{O}</math> values of perchlorate in wells MW-25, Garfield, and Bangham that show evidence of mixing with up to about 25% natural perchlorate (which is enriched in <math>^{17}\text{O}</math> relative to synthetic perchlorate). This natural perchlorate component was likely introduced by infiltration of agricultural fertilizers and indigenous natural perchlorate.</p>

<sup>1</sup> NASA. 2008. *Responses to Comments on the Additional Investigation Results, National Aeronautics and Space Administration, Jet Propulsion Laboratory, Pasadena, California*. Prepared by Battelle for the National Aeronautics and Space Administration. December.

<sup>2</sup> Steve Slaten, Keith A. Fields, Susan Santos, Andrew Barton, Heather V. Rectanus, and Mohit Bhargava. 2010. "Integrated Environmental Forensics Approach for Evaluating the Extent of Dissolved Perchlorate Originating from Multiple Sources." *Environmental Forensics*, 11:72-93. March.

<sup>3</sup> <http://www.altadenahistoricalsociety.org/>

## Erroneous Statements/Conclusions Made In The May 2012 PWP Technical Memorandum

PWP Erroneous Statement/Conclusion	NASA's Comments
<b>Page 3, Opinion 1:</b> There is high variability in NASA's SIA results, particularly $\delta^{18}\text{O}$ that cannot be explained by blending different sources of perchlorate"	Dr. Sturchio's Expert Opinion (Attachment 3) shows that the results can be explained by blending.
<b>Page 4, first paragraph (Opinion 2):</b> "All of the industrial perchlorate in Raymond Basin comes from a single industrial source, WECCO. It is highly unlikely that all of the perchlorate found on the JPL facility was from the 2% of perchlorate manufactured at the Los Angeles facility between 1944 and 1946."	<p>The perchlorate isotopic data from the JPL source area and downgradient locations (MW-17, LAWC#3) whose source of perchlorate originates from the JPL facility are clearly distinguished from the WECCO (Henderson, NV) perchlorate source.</p> <p>Also, this statement does not consider perchlorate that could have been imported from outside the United States.</p>
<b>Page 4, Opinion 3:</b> Perchlorate measured in Sunset Reservoir Wells is from groundwater flowing north to south beneath the JPL facility.	This statement does not account for the groundwater modeling results from the JPL Groundwater Model and the RBMB Groundwater Model, which show that chemicals originating from the JPL facility are captured by production wells in the Monk Hill Subarea. The applicability of the two groundwater models to chemical fate and transport were addressed in detail as part of NASA's 2008 RTC on the Additional Investigation Results <sup>1</sup> .
<p><b>Page 4, Opinion 3:</b> Perchlorate measured in Sunset Reservoir Wells is from groundwater flowing north to south beneath the JPL facility. PWP's evaluation shows there are three water courses influencing groundwater in the Sunset Reservoir Wells:</p> <ol style="list-style-type: none"> <li>1. SGM run-off parallel to the Arroyo Seco that doesn't flow under JPL with very low concentrations of nitrate and no measurable perchlorate or carbon tetrachloride but very little nitrate</li> <li>2. SGM run-off that flows beneath JPL with high concentrations of perchlorate and CTC, but very little nitrate</li> <li>3. Groundwater flow below the LCF area with low concentration, intermittent detections of perchlorate, no CTC, and very high concentrations of nitrate</li> </ol>	<p>This opinion does not account for containment by production wells in Monk Hill Subarea and evidence that the leading edge of NASA's perchlorate plume has been established; both discussed extensively in NASA's 2008 RTC<sup>1</sup>.</p> <p>In addition, this opinion is not supported by perchlorate isotopic data, which suggests perchlorate originating from JPL has a unique signature, and oversimplifies the conceptual site model. There is a vertical profile to groundwater geochemistry, which is discussed in NASA's AI.</p>
<b>Page 4, Opinion 3:</b> "The amounts of perchlorate found in the Sunset Reservoir Wells are greater	Historical La Cañada-Flintridge (LCF) area perchlorate concentrations appear to be consistent with levels observed in the Sunset Reservoir Wells, as discussed in NASA's AI Technical Memorandum (Figure 15,

## Erroneous Statements/Conclusions Made In The May 2012 PWP Technical Memorandum

PWP Erroneous Statement/Conclusion	NASA's Comments
than those found in LCF area, but lower than those found at JPL."	page 26). Samples collected in 1997 from MW-21 showed perchlorate concentrations as high as 19 µg/L.
<p><b>Page 4, Opinion 3:</b> "Similar results for both nitrate and perchlorate are found in the Patton Well in Pasadena, which also has CTC as well as other VOCs found at both JPL and Sunset Reservoir Wells. CTC was historically detected in three wells between JPL and the Patton, including Villa Well.</p>	<p>Patton Well has isolated, low-level carbon tetrachloride hits, is located over 6 miles from the JPL facility (over 4 miles from the Monk Hill Subarea), and there is one isolated carbon tetrachloride detection of 0.1 µg/L (Villa Well, February 8, 1989) in between the Patton Well and the LAWC wells. Clearly, carbon tetrachloride detections in the Villa Well and Patton Well are not related to JPL, nor are they applicable to NASA's contention that carbon tetrachloride appears to be unique to the JPL facility within the Monk Hill Subarea. NASA statements with regard to carbon tetrachloride as a tracer for JPL chemicals were applicable to the AI study area, not the entire Raymond Basin, and must be considered in context of all available data (e.g., the groundwater flow paths represented by the JPL and RBMB groundwater models).</p> <p>PWP presented only four, isolated detections of carbon tetrachloride outside the Monk Hill Subarea (Appendix C in the PWP Technical Memorandum):</p> <ul style="list-style-type: none"> <li>• Woodbury Well – 0.8 µg/L (October 14, 1980)</li> <li>• Craig Well – 0.9 µg/L (September 14, 1988), 0.3 µg/L (February 8, 1989)</li> <li>• Villa Well – 0.1 µg/L (February 8, 1989)</li> </ul> <p>Woodbury Well and Craig Well are located approximately 1.5 to 2 miles east of the Sunset Reservoir Wells (4 to 5 miles from the JPL facility). According to the RBMB Groundwater Model, these wells are not along the groundwater flow path between JPL and the Patton Well. Patton Well is located approximately 2 to 3 miles south of the Sunset Reservoir Wells.</p>
<p><b>Page 4, Opinion 3:</b> "The nitrate, perchlorate, CTC, and other VOC data indicate that from the groundwater in the Sunset Reservoir Wells is influenced by water from the SGMs, the LCF area, and JPL, and that the dominant source of perchlorate and VOCs is JPL"</p>	<p>This opinion is not supported by the data. Specifically, it does not account for containment of chemicals originating from JPL by production wells in the Monk Hill Subarea, it misinterprets groundwater flow paths (documented by the RBMB Groundwater Model), chemical data do not support connection of carbon tetrachloride detected in the Monk Hill Subarea to carbon tetrachloride detected in Patton Well, and it does not account for historical data from MW-21 presented in NASA's AI Technical Memorandum indicating a more significant source of perchlorate in the LCF area.</p> <p>In addition, PWP does not point out the widespread occurrence of VOCs, nitrate, and perchlorate throughout the great Los Angeles Region,<sup>4,5</sup> weakening their opinion significantly.</p>
<p><b>Page 4, Opinion 4 (Introductory Statement):</b> "NASA's SIA and the available general mineral and physical data validate that the major source of</p>	<p>This opinion is not supported by PWP's analysis. The groundwater geochemistry data (in particular the dissolved sulfate data) show that groundwater in the Sunset Reservoir area has been impacted by imported water mixing with local waters (see Figures 7, 8, and 9 in the AI Technical Memorandum). In</p>

<sup>4</sup> Fram M. and Belitz K. 2011. Probability of detecting perchlorate under natural conditions in deep groundwater in California and the southwestern United States. *Environmental Science and Technology*. 45, 1271-1277.

<sup>5</sup> U.S. Geological Survey. 2012. *Groundwater Quality in the Upper Santa Ana Watershed Unit, California*. U.S. Department of Interior. July.

## Erroneous Statements/Conclusions Made In The May 2012 PWP Technical Memorandum

PWP Erroneous Statement/Conclusion	NASA's Comments
perchlorate in the Sunset Reservoir Wells originates from JPL"	addition, groundwater geochemistry data need to be evaluated in context of all available data, including chemical data, groundwater modeling data, and perchlorate isotopic data. This integrated evaluation of all available data was performed by NASA in both the AI Technical Memorandum and 2008 RTC. A thorough technical analysis requires integration and analysis of all available data and evidence.
<b>Page 4, Opinion 4 (Supporting Point 1):</b> "NASA's strontium SIA data shows that the water in the Sunset Reservoir Wells is chemically much more similar to SGMs water (MW-1 and MW-24) than to Colorado River water or rain water.	Water in the Raymond Basin is a mixture of local water (which includes SGM runoff) and imported water. Historical data demonstrates that the Sunset Reservoir wells have been impacted by imported water (see Figures 7, 8, and 9 in the AI Technical Memorandum).
<b>Page 4, Opinion 4 (Supporting Point 2):</b> "The water in Sunset Reservoir Wells of Type 1 while waters influenced by the Colorado River water are Type 3 waters."	PWP's interpretation of water types differed from that used by NASA and does not explain the historical sulfate concentrations. Water near the Sunset Reservoir Wells is a mixture of local water (which includes SGM runoff) and imported water. Historical data demonstrates that the Sunset Reservoir wells have been impacted by imported water (see Figures 7, 8, and 9 in the AI Technical Memorandum).
<b>Page 5, Opinion 4 (Supporting Point 3):</b> "Sulfate can be used as marker for the influence of Colorado River water, either alone or in conjunction with the strontium SIA. In both cases, the data indicates that there is little or no influence of Colorado River water on the Sunset Reservoir Wells.	This opinion is not supported by the analysis or available data. Historical data demonstrates that the Sunset Reservoir wells have been impacted by imported water (see Figures 7, 8, and 9 in the AI Technical Memorandum). Strontium is not effective as a conservative tracer in groundwater aquifers because of its high reactivity.
<b>Page 5, Opinion 4 (Supporting Point 4):</b> "When the perchlorate data is combined with the strontium SIA data, the influence of the three different water courses is made clear and that JPL is the dominant source of perchlorate"	Dr. Sturchio (Attachment 3) points out that, "PWP fails to recognize that Sr concentrations and isotope ratios in groundwater may be affected by alkaline earth and Sr isotope exchange with clay minerals (Johnson and DePaolo, 1997; Armstrong et al., 1998), and therefore Sr is not used effectively as a conservative tracer in groundwater aquifers."
<b>Page 5, Opinion 4 (Supporting Point 5):</b> "SIA of water indicates that the water from the SGMs (MW-1), JPL (MW-24), and the Sunset Reservoir Wells is located on the Global Meteoric Water Line (GMWL) indicating little or no blending with Colorado River water."	This opinion is not supported by PWP's analysis, nor does it attempt to perform an integrated analysis of all available data. Historical data demonstrates that the Sunset Reservoir wells have been impacted by imported water (see Figures 7, 8, and 9 in the AI Technical Memorandum). PWP's analysis does not take into account the extreme annual variability in stable isotope composition of local meteoric water or Colorado River water.
<b>Page 5, Opinion 4 (Supporting Point 6):</b> "The Type 1 waters are evenly distributed above and below the GMWL, while the Type 3 waters, those influenced by Colorado River water, are all below the GMWL. Type 3 waters are also at the lower	PWP water typing does not account for historical sulfate concentrations and the annual variability in isotopic compositions of the different end-member waters. Water near the Sunset Reservoir Wells is a mixture of local water (which includes SGM runoff) and imported water. Historical data demonstrates that the Sunset Reservoir wells have been impacted by imported water (see Figures 7, 8, and 9 in the AI Technical Memorandum).

## Erroneous Statements/Conclusions Made In The May 2012 PWP Technical Memorandum

PWP Erroneous Statement/Conclusion	NASA's Comments
left-hand side of the distribution of SIA data while the Type 1 waters are on the upper right-hand side of the distribution. The Sunset Reservoir wells are Type 1 and located in the upper right-hand side of the SIA distribution."	
<b>Page 5, Opinion 4 (Supporting Point 7):</b> "When the perchlorate data is combined with the water SIA data, the influence of the three different water courses is made clear and that JPL is the dominant source of perchlorate. This is even more clear with the CTC data is also included."	PWP Supporting Point 7 is not substantiated by available data. Rather, it is based on a misinterpretation of geochemical data (see NASA comments on Opinion 4 above and Dr. Sturchio's Comments [Attachment 3]), combined with a misinterpretation of the carbon tetrachloride data (see NASA's comments on Opinion 3 above).
<b>Page 5, Opinion 4 (Concluding Statement):</b> "All various markers: carbon tetrachloride, nitrate, perchlorate, chloride, sulfate, strontium, the Stable Isotope Analysis, and the water types indicate that groundwater in the wells is overwhelmingly local run-off from the SGMs."	NASA's demonstrated in the AI Technical Memorandum that local water, including groundwater near the Sunset Reservoir Wells, has been impacted by imported Colorado River Water.
<b>Page 5, Conclusions:</b> "Groundwater in the Sunset Reservoir Wells is recent age 20 to 30 years old and agricultural activities ceased 90 years ago so Chilean nitrate fertilizer, even if it had ever been used, could not be a source of perchlorate in these wells."	PWP's conclusion demonstrates a significant misunderstanding of chemical/compound dissolution, fate, and transport. Dr. Sturchio's Expert Opinion (Attachment 3), states PWP's argument "falls apart in light of other recent scientific studies of the hydrologic transport of nitrate and perchlorate contamination from surface sources into aquifers...it is common for contaminants to reside in aquifer systems for much longer times than indicated by the apparent groundwater age." Recent water can dissolve older salts/chemicals in-situ.
<b>Page 5, Conclusions:</b> "There are three waters courses that influence the Sunset Reservoir wells: (1) the flow from LCF area, northwest of JPL, influenced by infiltration and injection of substantial amounts of Colorado River water, with high concentrations of nitrate and low concentrations of perchlorate and no CTC, (2) the flow originating from the SGMs north of JPL with low concentrations of nitrate and no measurable amounts of perchlorate and CTC, and (3) the flow that passes under JPL and accumulates both high concentrations of perchlorate and CTC, but has low concentrations of nitrate.	Responding to each item: <ul style="list-style-type: none"> <li>Item 1 does not recognize historical elevated levels of perchlorate in the LCF area, demonstrated by historical data from MW-21.</li> <li>Item 2 – SGM water enters the Basin at the mouth of the Arroyo Seco, not north of JPL.</li> <li>Item 3 does not account for plume containment and the lack of perchlorate and carbon tetrachloride data to demonstrate a continuous plume between JPL and the Sunset Reservoir area.</li> </ul>

## Erroneous Statements/Conclusions Made In The May 2012 PWP Technical Memorandum

PWP Erroneous Statement/Conclusion	NASA's Comments
<b>Page 5, Conclusions:</b> "Both the JPL and LCF area water courses contain perchlorate that came from the same industrial source, military grade perchlorate manufactured by WECCO in Henderson, Nevada."	This statement is not substantiated by the available data. It does not account for the perchlorate isotope data and the fact that perchlorate manufactured in Los Angeles was used at the JPL facility. In addition, it does not account for other possible source of synthetic perchlorate such as imported fireworks and road flares.
<b>Page 5, Conclusions:</b> "SIA of strontium and water, general mineral and physical characteristics, and all available data clearly indicates the vast majority of perchlorate and VOCs found in the Sunset Reservoir Wells is from JPL"	This is an overly broad statement that is based on misinterpretations (identified above), and does not consider all of the available data in an integrated manner. This conclusion does not account for plume containment and groundwater modeling data, nor does it account for the data that demonstrate the leading edge of NASA's perchlorate plume has been established. This statement is not supported by all available data.
<b>NASA's Comments on the August 2012 PWP Technical Memorandum</b>	
<b>Page 15, First Paragraph:</b> "So unless the water in the Sunset Reservoir Wells is over 70 years old, it would be impossible for Chilean nitrate fertilizers to have contributed any perchlorate to those waters."	Dr. Sturchio's evaluation (Attachment 3), states PWP's argument "falls apart in light of other recent scientific studies of the hydrologic transport of nitrate and perchlorate contamination from surface sources into aquifers...it is common for contaminants to reside in aquifer systems for much longer times than indicated by the apparent groundwater age." Recent water can dissolve older salts/chemicals in-situ.
<b>Page 19, Second Paragraph:</b> "The industrial history of production of perchlorate strongly indicates that perchlorate used at the JPL facility was in fact produced at the facility that became known as the BMI Complex, just as the perchlorate released from the Colorado River was."	PWP opinion does not account for the evidence from the perchlorate isotope analysis conducted by NASA and presented in the AI Technical Memorandum which demonstrated that the perchlorate isotope signature associated with JPL was unique within the study area. In addition, PWP does not account for available records regarding perchlorate produced at the Los Angeles plant(s) of WECCO for JPL <sup>6</sup> .
<b>Page 20, First Paragraph:</b> "The most reasonable explanation is that all of the perchlorate in all of the local sources came from the same industrial source, WECCO."	PWP does not seem to be aware of the fact that large quantities of fireworks and road flares have been imported into the U.S., and the perchlorate in these imported items was not manufactured at the BMI Complex. Note also, this statement is partially based on PWP's misunderstanding of Chilean Nitrate fertilizer use, and fate and transport (discussed previously).
<b>Page 21, Second Paragraph:</b> "So there is a great deal more variability in the $\Delta^{17}\text{O}$ and $\delta^{37}\text{Cl}$ results among the Sunset Reservoir locations than among all of the other samples combined while the amount of $\delta^{18}\text{O}$ is about the same. This pattern of isotopic depletion cannot be explained by blending of different sources of perchlorate."	Dr. Sturchio's evaluation (Attachment 3) demonstrates that "a mixture of three sources of isotopically distinct perchlorate, all known to be present in the area, explains the isotopic variability of perchlorate in the Sunset Reservoir wells." Dr. Sturchio also demonstrates that "a single perchlorate source in the Raymond Basin is not consistent with the evidence presented by NASA" and that "no other perchlorate sources aside from Colorado River water, Chilean nitrate fertilizer, and indigenous natural perchlorate are required to explain the isotopic composition of perchlorate in all Raymond Basin groundwaters outside the zone of influence of JPL in the Monk Hill sub-basin."

<sup>6</sup> Schumacher, JC. 1999. *History of Establishing a Source of Potassium and Ammonium Perchlorates for Use in Solid Propellant Rockets*. 35<sup>th</sup> AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit, 20-24 June 1999, Los Angeles, California.



## Erroneous Statements/Conclusions Made In The May 2012 PWP Technical Memorandum

PWP Erroneous Statement/Conclusion	NASA's Comments
<p><b>Page 22, Second Paragraph:</b> "Consider the two samples collected from the same well, MW-16 and MW-16R (which are replicates). They show considerable differences in the degree of depletion of <math>\delta^{18}\text{O}</math>, approximately three <math>\delta^{18}\text{O}</math> units. That is about the difference between results from the OU1-IN sample and the Sunset Well sample and the MW-25 sample."</p>	<p>There are two significant inaccuracies with this statement: (1) samples MW-16 and MW-16R were not replicates, they were taken over nine months apart, and (2) their <math>\delta^{18}\text{O}</math> values vary by only about 1‰, not 3‰ as stated by PWP.</p>
<p><b>Page 23, First Paragraph:</b> "Since trichloromethane (TCM) was not known to have been used or disposed of at JPL, its presence in wells that are well established to be influenced by JPL water demonstrates anaerobic biodegradation is occurring, irrespective of the DO and <math>\text{NO}_3</math> concentrations."</p>	<p>NASA provided a detailed response to questions associated with anaerobic biodegradation and the required oxidation-reduction conditions in the aquifer as part of the 2008 RTC. It does not appear PWP considered NASA's RTC as part of their technical memorandum. The presence of TCM was addressed in NASA's RTC:</p> <p>"The presence of chloroform, a daughter product of carbon tetrachloride degradation, cannot be used to indicate anaerobic degradation of carbon tetrachloride since chloroform was a compound used during historic laboratory operations at JPL (Reference OU-2 Remedial Investigation, 1999) and is a disinfection byproduct." (RTC, Pg. 8; paragraph 3)</p>
<p><b>Page 25, First Paragraph:</b> "It is PWP's contention that there was no such containment and that the water in the Sunset Reservoir Wells is a mixture of all three water courses and that the vast majority of the perchlorate found in these wells comes from JPL. PWP's position is strongly supported by the fact that the concentrations of perchlorate found in the Sunset Reservoir Wells is higher than that found in the LCF area wells and lower than that found in the JPL wells while nitrate concentrations are lower than that found in the LCF area wells and higher than that found in the JPL wells. If there were containment by the Monk Hill Wells, this would not be possible."</p>	<p>There are several erroneous aspects of PWP's statement/conclusion:</p> <ol style="list-style-type: none"> <li>1. PWP does not account for containment by production wells in Monk Hill Subarea discussed extensively in NASA's 2008 RTC<sup>1</sup>.</li> <li>2. PWP does not consider evidence that the leading edge of NASA's perchlorate plume has been established, discussed extensively in NASA's 2008 RTC<sup>1</sup>.</li> <li>3. PWP does not account for historical data from MW-21 presented in NASA's AI Technical Memorandum, indicating a more significant source of perchlorate in the LCF area.</li> <li>4. PWP does not account for the perchlorate isotope data, which does not support this conclusion.</li> <li>5. PWP does not account for other potential sources of perchlorate in the Sunset Reservoir wells, including Chilean Nitrate fertilizers. PWP's underlying assumption is that there are only two sources of perchlorate in the basin (JPL and LCF). The perchlorate isotope data indicate that this is not true. PWP does not consider that perchlorate associated with imported water could have entered the aquifer near the Sunset Reservoir wells from areas other than LCF (e.g., the golf course near the Rose Bowl).</li> </ol>
<p><b>Page 25, Second Paragraph:</b> "Figure 12 presents a generalized summary of ground water movement and perchlorate pathways from JPL to the Sunset Reservoir Wells."</p>	<p>PWP has significantly misrepresented the nature and extent of perchlorate, site conditions and groundwater flow paths in formulating Figure 12. Specifically:</p> <ol style="list-style-type: none"> <li>1. Groundwater from the LCF area generally flows to the south of JPL based on the JPL and RBMB groundwater models (not directly into JPL as shown in Figure 12).</li> <li>2. The majority of SGM run-off water enters the aquifer to the east of the JPL Facility via the Arroyo Seco and Spreading Basins (not directly into JPL as shown in Figure 12).</li> </ol>

## Erroneous Statements/Conclusions Made In The May 2012 PWP Technical Memorandum

PWP Erroneous Statement/Conclusion	NASA's Comments
	<ol style="list-style-type: none"> <li>3. Groundwater beneath JPL is captured by Monk Hill Subarea production wells.</li> <li>4. The chemical plume depicted in Figure 12 is fictional and not supported by the available data, as it does not consider containment and evidence that the leading edge of NASA's perchlorate plume has been established. Chemical data from RCLWA-4 (shown in the figure) do not support the depicted plume.</li> </ol>
<p><b>Page 25, Last Paragraph:</b> "A review of laboratory reports from the 1980's and 1990's indicates a number of wells between JPL and Patton Well had low level CTC detections."</p>	<p>Patton Well has isolated, low-level carbon tetrachloride hits, is located over 6 miles from the JPL facility (over 4 miles from the Monk Hill Subarea), and there is only one isolated carbon tetrachloride detection of 0.1 µg/L (Villa Well, February 8, 1989) in between the Patton Well and the LAWC wells. Clearly, carbon tetrachloride detections in the Villa Well and Patton Well are not related to JPL, nor are they applicable to NASA's contention that carbon tetrachloride appears to be unique to the JPL facility within the Monk Hill Subarea. In addition, the RBMB Groundwater Model indicates that the capture zone for the Patton Well consists of groundwater to the west of the well toward the San Rafael Hills (see Figure 1 of the 2012 PWP Technical Memorandum). NASA statements with regard to carbon tetrachloride as a tracer for JPL chemicals were applicable to the AI study area, not the entire Raymond Basin (as misrepresented by PWP), and must be considered in context of all available data (i.e., the groundwater flow paths represented by the JPL and RBMB groundwater models, and the available chemical data demonstrating that the extent of carbon tetrachloride originating from the JPL facility has been established).</p> <p>PWP presented only four, isolated detections of carbon tetrachloride outside the Monk Hill Subarea (Appendix C in the PWP Technical Memorandum):</p> <ul style="list-style-type: none"> <li>• Woodbury Well – 0.8 µg/L (October 14, 1980)</li> <li>• Craig Well – 0.9 µg/L (September 14, 1988), 0.3 µg/L (February 8, 1989)</li> <li>• Villa Well – 0.1 µg/L (February 8, 1989)</li> </ul> <p>Woodbury Well and Craig Well are located approximately 1.5 to 2 miles east of the Sunset Reservoir Wells (4 to 5 miles from the JPL facility). According to the RBMB Groundwater Model, these wells are not along the groundwater flow path between JPL and the Patton Well. Patton Well is located approximately 2 to 3 miles south of the Sunset Reservoir Wells.</p>
<p><b>Page 27, Third Paragraph:</b> "PWP wells clearly have a mixture of water from the LCF area, JPL, and SGM courses. This data is incompatible with the hypothesis that there is containment of water from JPL by the Monk Hill area wells."</p> <p>Page 27, Last Paragraph: "This can only be explained by mixing between the three water courses and is inconsistent with the hypothesis</p>	<p>There are several erroneous aspects of PWP's statements/conclusions:</p> <ol style="list-style-type: none"> <li>1. PWP does not account for containment by production wells in Monk Hill Subarea discussed extensively in NASA's 2008 RTC<sup>1</sup>.</li> <li>2. PWP does not consider evidence that the leading edge of NASA's perchlorate plume has been established, discussed extensively in NASA's 2008 RTC<sup>1</sup>.</li> <li>3. PWP does not account for historical data from MW-21 presented in NASA's AI Technical Memorandum indicating a more significant source of perchlorate in the LCF area.</li> <li>4. PWP does not account for the perchlorate isotope data collected by NASA, which does not support this conclusion.</li> </ol>

## Erroneous Statements/Conclusions Made In The May 2012 PWP Technical Memorandum

PWP Erroneous Statement/Conclusion	NASA's Comments
that the water from JPL was contained by the Monk Hill area wells."	<p>5. PWP does not account for other potential sources of perchlorate in the Sunset Reservoir wells, including Chilean Nitrate fertilizers. PWP's underlying assumption is that there are only two sources of perchlorate in the basin (JPL and LCF). The perchlorate isotope data indicate that this is not true. PWP does not consider that perchlorate associated with imported water could have entered the aquifer near the Sunset Reservoir wells from areas other than LCF (e.g., the golf course near the Rose Bowl).</p>
<p><b>Pages 29-37:</b> Discussion of geochemical conditions.</p>	<p>PWP's geochemistry discussion is erroneous at multiple levels. Specifically:</p> <ol style="list-style-type: none"> <li>1. Many of PWP's fundamental assumptions and assertions are shown to be incorrect (as discussed above).</li> <li>2. PWP's interpretation of waters types differs from the classification used by NASA and does not account for historical sulfate concentrations.</li> <li>3. Water near the Sunset Reservoir Wells is a mixture of local water (which includes SGM runoff) and imported water. Historical data demonstrates that the Sunset Reservoir wells have been impacted by imported water (see Figures 7, 8, and 9 in the AI Technical Memorandum).</li> <li>4. PWP does not recognize that strontium is not effective as a conservative tracer in groundwater aquifers because of its high reactivity.</li> <li>5. PWP's analysis does not take into account the extreme annual variability in stable isotope composition of local meteoric water or Colorado River water.</li> </ol> <p>Dr. Sturchio's evaluation (Attachment 3) concluded, <b>"The opinions of PWP are found to be based on flawed assumptions and incogent arguments leading to erroneous and unfounded conclusions regarding the origin of perchlorate in the Sunset Reservoir wells.</b> The PWP (2012) opinions that there is a single source of perchlorate (BMI complex) in the Sunset Reservoir wells, that Chilean nitrate fertilizer could not have contributed perchlorate to the Sunset Reservoir wells, and that all of the perchlorate in the Sunset Reservoir wells is from JPL are inconsistent with the perchlorate isotopic data and other evidence presented by NASA (2007). The available data presented by NASA (2007) indicate clearly that at least three separate types of perchlorate must have contributed to the Sunset Reservoir wells, including mostly synthetic perchlorate (of which the majority is most likely from the BMI complex via imported Colorado River water) along with locally significant amounts of residual perchlorate from Chilean nitrate fertilizer and indigenous natural perchlorate from regional atmospheric deposition. The available data do not require the presence of any JPL-sourced perchlorate in the Sunset Reservoir wells, and the NASA (2007) report makes a reasonable case that all JPL sourced perchlorate is contained in the Monk Hill sub-basin."</p>

## **Attachment 3**

**Dr. Neil Sturchio's Comments on Pasadena Water and Power's "Technical Memorandum on  
Perchlorate Contamination of the Sunset Reservoir Wells"**

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COMMENTS ON PASADENA WATER AND POWER'S "TECHNICAL MEMORANDUM ON  
THE PERCHLORATE CONTAMINATION OF THE SUNSET RESERVOIR WELLS"

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NEIL C. STURCHIO, PH.D.

**Prepared for:** National Aeronautics and Space Administration (NASA)  
**Date:** August 15, 2012



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Neil C. Sturchio, Ph.D.

## 1.0 Introduction

The Pasadena Water and Power Company (PWP) produced a document in May 2012 titled “*Technical Memorandum on the Perchlorate Contamination of the Sunset Reservoir Wells*”. PWP argues against the conclusions of NASA as presented in the January 2007 document titled “*Technical Memorandum: Additional Investigation Results*” [hereafter referred to as NASA (2007)]. In this commentary, it is shown that PWP (2012) misrepresented some of the conclusions of NASA (2007), and reached erroneous and unfounded conclusions regarding the possible origins of perchlorate in the Sunset Reservoir wells. The following comments respond mainly, but not exclusively, to PWP’s opinions pertaining specifically to the interpretation of isotopic analyses of perchlorate that were presented in NASA (2007). These comments rely partly on new information published in the scientific literature since the release of NASA (2007), including Scanlon et al. (2008), Jackson et al. (2010), Fram and Belitz (2011), and Sturchio et al. (2012), as well as additional information obtained from older publications and online sources.

## 2.0 Responses to PWP (2012) Opinions

PWP (2012) organized its arguments into discussions of four separate opinions, as follows:

Opinion 1: The source of perchlorate found in groundwater of the Sunset Reservoir wells is of recent origin and not from the use of Chilean fertilizers for agriculture;

Opinion 2: Perchlorate found in the Raymond Basin is from a single industrial source;

Opinion 3: Perchlorate measured in the Sunset Reservoir wells is from groundwater flowing north to south beneath the JPL facility;

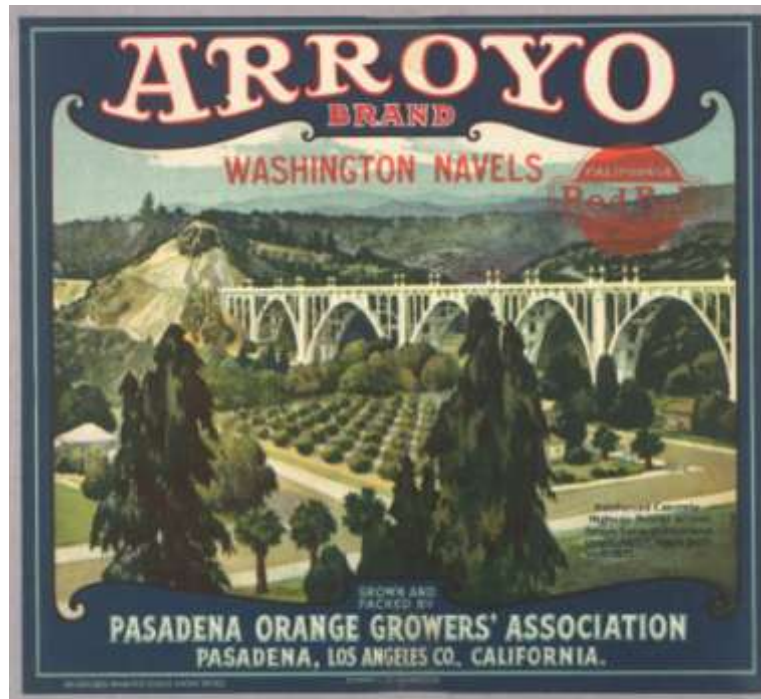
Opinion 4: Stable isotope analyses as well as general mineral and physical data validate that the source of perchlorate in the Sunset Reservoir wells originates from the JPL facility.

This commentary responds to these opinions in the following paragraphs, with special attention to arguments pertaining to the isotopic compositions of perchlorate.

### 2.1 Response to PWP Opinion #1

PWP argues against Chilean nitrate fertilizer use in the Pasadena area, because the land used for citrus cultivation by members of the Pasadena Orange Growers Association had been largely urbanized by the mid-1920s, and the only large plots of irrigated land remaining in the western Pasadena area today are golf courses. However, there was clearly a vigorous activity in citrus production in the Pasadena area in the period from 1893 through at least 1917. According to information on the Altadena Historical Society website (<http://www.altadenahistoricalsociety.org/>, accessed July 12, 2012), “*Pasadena, beginning as a fruit growing colony, became part of a co-operative on December 14, 1893. Originally named the Pasadena Fruit Growers Association, in 1909 the name was changed to Pasadena Orange Growers Association. Their first shipment was packed in a building south of California Street adjacent to the Santa Fe railroad tracks. In 1913 a permanent warehouse, employing about 100*

people, was built at 1097 South Marengo Avenue (near the current location of Blair High School just south of Glenarm). In 1917 the Association shipped 144,000 packed boxes worth \$200,000, over 3 million in today's dollars. (Source: Wood, J. W., *Pasadena, California, historical and personal*, p, 490, self published, 1917.)” An orange crate label from the Pasadena Orange Growers Association dated from the period 1920-1930 shows a picture of an apparent orange grove beneath the Arroyo Seco bridge in Pasadena (Fig. 1).



**Figure 1. Orange crate label from the Pasadena Orange Growers Association showing orange grove beneath the old Arroyo Seco bridge in Pasadena (from the Huntington Digital Library).**

In addition to such archived evidence for early citrus cultivation in the Pasadena area, which likely involved the use of substantial amounts of Chilean nitrate fertilizer (that may still be slowly leaching into the groundwater from soils and the underlying vadose zone), PWP does not consider the possibility of its use in fertilizing public and private lawns and gardens. Chilean nitrate fertilizer has been sold commercially by SQMNA under the brand names Champion and Bulldog Soda, and numerous other derivative fertilizer products containing Chilean nitrate have been sold commercially including Hoffman, Peters, Grow More, Hi-Yield, and North Country. Such products have been widely available and these products all contained substantial amounts of perchlorate up until about 2002 when SQM added a process to remove perchlorate from its nitrate products (Urbansky, 2001; Geosyntec, 2005).

PWP's principal argument against the presence of perchlorate from Chilean nitrate fertilizer is based on estimates of groundwater residence time from tritium-helium dating. It is asserted by PWP that *"unless the water in the Sunset wells is over 70 years old, it would be impossible for Chilean nitrate fertilizers to have contributed any perchlorate to those waters"* (PWP, 2012). PWP goes on to argue that, because apparent groundwater age in the Sunset Reservoir wells is only 20 to 30 years, therefore *"since there had been no agriculture of any significance since 1940 in the LCF area, and none in the Monk Hill area even earlier, Chilean fertilizers could not possibly have been the source of either nitrate or perchlorate for waters that entered the aquifer after 1952"*.

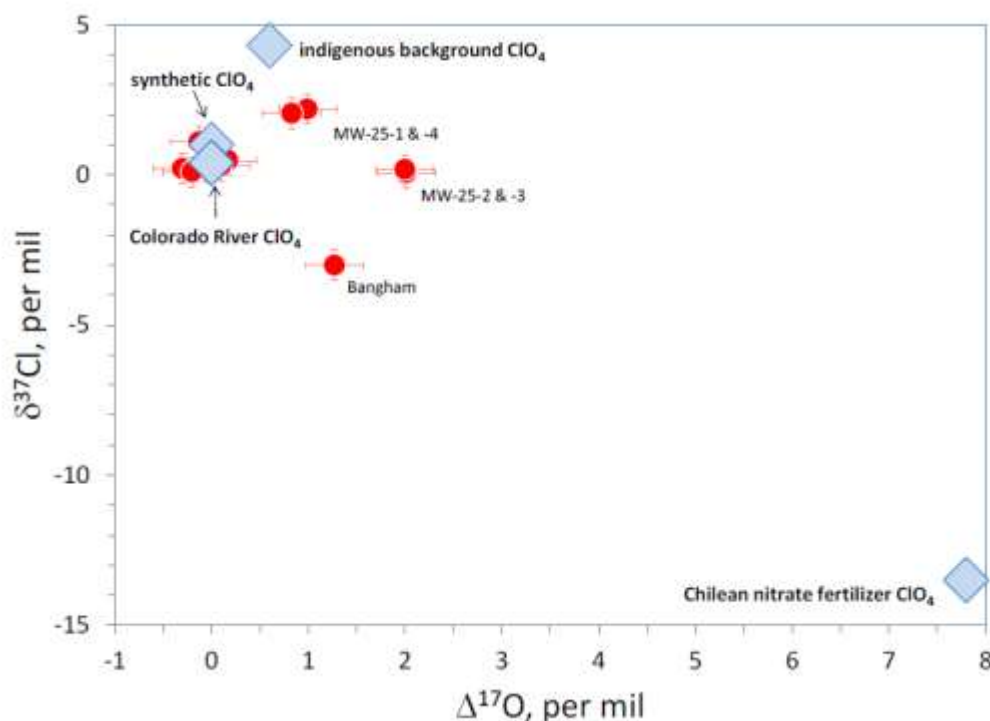
This argument of PWP (2012) falls apart in light of other recent scientific studies of the hydrologic transport of nitrate and perchlorate contamination from surface sources into aquifers. For example, Fogg et al. (1999) show that nitrate and other contamination from agricultural land use in the Salinas Valley area has a likely impact on groundwater for centuries following the time of fertilizer application because of the inherent time lag involved in contaminant transport. Weissman et al. (2002) performed extensive numerical simulations of groundwater age dispersion in an alluvial fan aquifer system near Fresno, CA and concluded *"simulated arithmetic mean groundwater ages do not correspond to mean ages estimated from simulated CFC concentrations. Results emphasize the potential ambiguity of "mean" groundwater ages estimated from environmental tracer concentrations in typically heterogeneous geologic systems. The significant dispersion of groundwater ages also implies that ultimate, maximum effects of nonpoint source, anthropogenic contamination of groundwater may not be reached until after many decades or centuries of gradual decline in groundwater quality."* A study of perchlorate contamination in the Southern High Plains of West Texas concluded that natural perchlorate in the vadose zone in this semiarid region, which accumulated at depths of a few meters over the past 30,000 years, has been mobilized by land-use change so that it is now reaching the underlying Ogallala Aquifer bringing perchlorate concentrations to increase up to about 60 ppb (Scanlon et al., 2008). Amounts of perchlorate stored in the vadose zone in this region are in the range 361-934 g/hectare (Scanlon et al., 2008). The above-cited studies, along with many others, indicate that it is common for contaminants to reside in aquifer systems for much longer times than indicated by the apparent groundwater age.

Considering that the typical application rate of Chilean nitrate fertilizer to citrus crops is about 1,000 pounds per acre per year (Collings, 1949), and typical Chilean nitrate fertilizer contains about 0.2 weight % perchlorate (Urbansky, 2001), then about 2 pounds per acre per year of perchlorate may have been applied to citrus groves in the Pasadena area for several decades. Even if citrus cultivation only lasted 30-40 years in Pasadena, such application of Chilean nitrate fertilizer could have added up to 80 pounds perchlorate per acre in citrus groves, and residual perchlorate could still be present in the soil and vadose zone beneath the former citrus groves. This is potentially a much larger amount of perchlorate (by a factor of 100 to 250) than the amount of natural indigenous perchlorate stored in the vadose zone of West Texas (Scanlon et al., 2008).

In addition to the scientific studies cited above, indicating that Chilean nitrate fertilizer could impact the groundwater long after its application at the surface, the isotopic data presented by NASA (2007) indicate that a substantial fraction of perchlorate (up to about 25%) in at least two



wells – MW-25 and Bangham – is likely derived from a Chilean nitrate source. Well MW-25 also may contain indigenous natural perchlorate (Jackson et al., 2010). This is illustrated by Figure 2, which shows data on the measured  $\delta^{37}\text{Cl}$  and  $\Delta^{17}\text{O}$  values of perchlorate extracted from wells sampled in the NASA (2007) investigation. This diagram is particularly useful for identifying the presence of natural perchlorate (either Chilean or indigenous) because of the distinctive  $\delta^{37}\text{Cl}$  and  $\Delta^{17}\text{O}$  values of these types of natural perchlorate, relative to those of synthetic perchlorate which has much narrower ranges of  $\delta^{37}\text{Cl}$  and  $\Delta^{17}\text{O}$  values.



**Figure 2.** Diagram showing  $\delta^{37}\text{Cl}$  vs.  $\Delta^{17}\text{O}$  values for perchlorate extracted from wells (red circles) in the vicinity of Pasadena, CA (NASA, 2007). Also shown are representative data (blue diamonds) for synthetic perchlorate (Sturchio et al., 2006), likely Colorado River perchlorate (based on analyses of perchlorate extracted from Las Vegas Wash surface water and Henderson, NV groundwater; Sturchio et al., 2006), Chilean nitrate fertilizer (Sturchio et al., 2006; Jackson et al., 2010; Sturchio et al., 2012), and indigenous background perchlorate from the southwestern U.S. (Jackson et al., 2010). Wells MW-25 (samples -2 and -3) and Bangham appear to contain perchlorate derived partly from Chilean nitrate fertilizer. MW-25 may also contain a significant contribution from indigenous perchlorate. On this diagram, sources of synthetic perchlorate are nearly indistinguishable, but there is simply no alternative source known for perchlorate having relatively high  $\Delta^{17}\text{O}$  values ( $\geq 1$  per mil) other than Chilean nitrate fertilizer or indigenous background perchlorate. Mixing fractions of Chilean nitrate fertilizer perchlorate and indigenous perchlorate for a particular sample can be estimated graphically on this diagram, as they are proportional to the linear distances between the perchlorate sample and the end-member sources.

The presence of perchlorate derived from Chilean nitrate fertilizer in the groundwater of the Raymond Basin is not unexpected, because of the historical citrus cultivation in the area, and considering that such perchlorate is the dominant non-point source of perchlorate contamination found in groundwater from both the Chino and Bunker Hill basins to the east of the Raymond Basin (Sturchio et al., 2012). The presence of a dilute component ( $\leq 1$  ppb) of indigenous natural perchlorate in the Raymond Basin is consistent with its continuous deposition in trace amounts from the atmosphere with precipitation and dry fallout (Rajagopalan et al., 2009), with a statistical analysis of perchlorate concentrations in California groundwater (Fram and Belitz, 2011), and with isotopic data on perchlorate from the Chino basin (Sturchio et al., 2008) and the Bunker Hill basin in Redlands, CA (Sturchio et al., 2012).

## 2.2 Response to PWP Opinion #2

PWP (2012) argues that all perchlorate in the Raymond Basin is from a single industrial source. They state that *“There does not appear to be any reason that all of the data collected could not have originated from the same source or that the SIA is capable of resolving one source or another or that there are even two sources at all”*. Following a lengthy description of the history of perchlorate production in the U.S., PWP (2012) concludes that *“the perchlorate used at the JPL facility was in fact produced at the facility that became known as the BMI Complex, just as the perchlorate released into the Colorado River was”*. PWP’s arguments ignore the evidence from the isotopic analyses of perchlorate, which show clearly that the perchlorate from the wells on the JPL site (MW-16, OU-1) and the Monk Hill capture zone (MW-17, LAWC-3) has a relatively narrow range in isotopic composition which is completely distinct from that of all other perchlorate analyzed for the NASA (2007) investigation. Furthermore, PWP (2012) ignores available records indicating that JPL’s source of perchlorate was, at least initially, from the Los Angeles plant(s) of WECCO, which were specifically developed to supply potassium perchlorate to JPL and others for development of solid rocket propellants (Schumacher, 1999). Therefore, PWP’s opinion that all of the perchlorate now present in the Raymond Basin is from a *“single source”*, produced at the BMI Complex in Henderson, NV, is not consistent with the factual evidence summarized by Schumacher (1999) for synthetic perchlorate used by JPL in the 1940s, as well as the evidence summarized above for the presence of Chilean nitrate fertilizer.

Furthermore, PWP (2012) states *“it seems unlikely that fireworks manufacturers and flare manufacturers had a different, unique source for their perchlorate. Is entirely possible that both of these sources were from the BMI Complex in Henderson, NV”*. PWP (2012) is apparently unaware of the fact that a huge quantity of fireworks are imported to the U.S. from China annually (e.g., \$223,600,000 worth in 2011, according to the Foreign Trade Division of the U. S. Census Bureau), and fireworks may contain a significant percentage of perchlorate which is known to contaminate the environment following their ignition (Geosyntec, 2005; Wilkin et al., 2007). Also, according to information on website of the Agency for Toxic Substances and Disease Registry (<http://www.atsdr.cdc.gov/ToxProfiles/tp162-c5.pdf>), about two to three million kg of road flares are imported to the U.S. annually, which implies that the perchlorate used in these flares is not produced at the BMI Complex. About 20-40 million road flares are sold annually in the U.S., and several g of perchlorate can be leached from each partially burned

flare (Geosyntec, 2005). Both fireworks and road flares are potential contributors of perchlorate to groundwater in the Raymond Basin.

Section 4.2.2 of the PWP (2012) report states that “NASA’s TM suggests some influence of perchlorate from road flares on Las Flores Water Company (LFWC) Well #2, however, there is no evidence supplied to explain any possible link”. This statement is typical of PWP’s misrepresentation of the content of the NASA (2007) report. The actual words used by NASA (2007) with respect to perchlorate isotopic composition in LFWC #2 are as follows: “The perchlorate isotope fingerprint at LFWC#2 is distinct from that of the JPL area. LFWC#2 appears to be synthetic perchlorate ( $\Delta^{17}\text{O} \approx 0\text{‰}$ ) with heavier  $\delta^{18}\text{O}$  compared to the JPL facility. As seen in Figures 15 and 16,  $\delta^{18}\text{O}$  and  $\delta^{37}\text{Cl}$  values of perchlorate present in LFWC#2 are significantly different than those at JPL indicating a different source than JPL for the perchlorate present in the LFWC#2 well. The isotopic composition of perchlorate in LFWC#2 approaches that which is characteristic of perchlorate used in road flares.” The NASA (2007) report does not state or imply any link with road flares other than a similarity in isotopic composition, to emphasize that the perchlorate in LFWC#2 is significantly different isotopically, thus indicating a different source, from that found on the JPL site or in the JPL plume capture zone within the Monk Hill subarea. In fact, perchlorate in the LFWC #2 well may contain a significant fraction of indigenous natural perchlorate, as discussed below. The particle-tracking models of the RBMB (Fig. 2 of NASA, 2007) show that groundwater and perchlorate in the LFWC #2 well comes from the north, which indicates that the perchlorate in LFWC #2 may have a different source than that in any of the other wells sampled by NASA (2007).

In section 4.2.3.2 of PWP (2012), it is stated that “there is a great deal more variability in the  $\Delta^{17}\text{O}$  and  $\delta^{37}\text{Cl}$  results among the Sunset Reservoir locations than among all of the other samples combined while the amount of  $\delta^{18}\text{O}$  is about the same. This pattern of isotopic depletion cannot be explained by blending of different sources of perchlorate”. This reasoning is shown to be incorrect, as demonstrated in Figure 2 above, which shows clearly that a mixture of three sources of isotopically distinct perchlorate, all known to be present in the area, explains the isotopic variability of perchlorate in the Sunset Reservoir wells. Interestingly, PWP (2012) also points out that “The Sunset Reservoir wells are scattered along three separate axes ( $\delta^{37}\text{Cl}$ ,  $\Delta^{17}\text{O}$ , and  $\delta^{18}\text{O}$ ) in such a way that it would require four different sources to account of it” [emphasis added]. They have reached essentially the same conclusion from the isotopic data as that reached by NASA (2007), namely that multiple sources in addition to JPL are required to explain the isotopic composition of perchlorate in the Sunset Reservoir wells, but PWP (2012) refuses to accept that any sources of perchlorate other than that manufactured at the BMI Complex could be present in the Raymond Basin. A single perchlorate source in the Raymond Basin is not consistent with the evidence presented by NASA (2007).

Quantitative estimates of the mixing proportions of different sources of perchlorate in the Raymond Basin groundwaters can be obtained graphically from diagrams showing  $\Delta^{17}\text{O}$  and  $\delta^{37}\text{Cl}$  values vs. the inverse perchlorate concentration,  $1/\text{ClO}_4$  (Figure 3). This simple algebraic procedure is commonly used in geochemical studies to understand isotopic mixing relationships in natural waters (Faure, 1998) as well as atmospheric trace gases. Data on perchlorate concentrations and isotopic compositions from NASA (2007) are shown in such diagrams in Figure 3, along with representative data for perchlorate end-member sources summarized from

Sturchio et al., 2006; Jackson et al., 2010; Sturchio et al., 2012). The end-member perchlorate sources all have relatively restricted ranges of  $\Delta^{17}\text{O}$  and  $\delta^{37}\text{Cl}$  values. These diagrams show clearly that four sources, all known to occur in the area, can explain the variability in isotopic composition seen in the Raymond Basin groundwaters. The four known sources are: (1) perchlorate used at the JPL facility, represented by MW-16, MW-17, LAWC #3, and OU-1 (which is partially biodegraded); (2) perchlorate imported with Colorado River water by the Metropolitan Water District; (3) perchlorate from use of Chilean nitrate fertilizer; and (4) indigenous natural perchlorate. The use of perchlorate concentration in these diagrams provides a strong constraint on possible mixing relationships. One of the important unknown parameters in evaluating the perchlorate occurrence in the Raymond Basin is the concentration of perchlorate in the imported Colorado River water. According to the Nevada Division of Environmental Protection (NDEP, 2012), the concentration of perchlorate in the Colorado River Aqueduct, which supplies river water to the Los Angeles area, was 9 ppb in 1999 and decreased to about 2 ppb in 2006. However, there is no information available on perchlorate concentration in the Colorado River Aqueduct prior to 1999. In Figure 3, I showed data for a range of 2 to 10 ppb perchlorate in the imported Colorado River water, and assumed a perchlorate isotopic composition similar to that measured in Las Vegas Wash (Sturchio et al., 2006). It is reasonable to assume that Colorado River water had a perchlorate concentration of at least 10 ppb or more prior to the available measurements from 1999, because the huge source of perchlorate contamination in Henderson, NV has been present since the 1940s. For example, water produced from MW-21, a well contained as much as 19 ppb perchlorate in 1997, indicating a substantial source of non-JPL perchlorate in the vicinity. PWP (2012) reviews the evidence that MW-21 contains a high proportion of imported Colorado River water. Using these assumptions, the top diagram in Figure 3 shows clearly that **no other perchlorate sources aside from Colorado River water, indigenous natural perchlorate, and Chilean nitrate fertilizer are required to explain the isotopic composition of perchlorate in all Raymond Basin groundwater outside the zone of influence of JPL in the Monk Hill sub-basin.**

PWP (2012) argues that the observed variations in perchlorate isotopic composition are best explained by “*inherent variability*” in manufacturing process and analytical method. PWP argues that all of the synthetic perchlorate in the Raymond Basin comes from a single industrial source, the BMI complex. While the BMI Complex has produced perchlorate having a wide range in  $\delta^{18}\text{O}$  values, ranging from -22 to -15 ‰ (Sturchio et al., 2006), the report of Schumacher (1999) indicates clearly that at least some of the perchlorate used at JPL was manufactured in Los Angeles in the 1940s. PWP uses two samples collected at well MW-16 on the JPL site as an example of the “*inherent variability*” in perchlorate isotopic composition, as follows: “*consider the two samples collected at the same well, MW-16 and MW-16R (which are replicates). They show considerable difference in the degree of depletion in the  $\delta^{18}\text{O}$ , approximately three  $\delta^{18}\text{O}$  units.*” There are two serious inaccuracies in this statement. First, MW-16 and MW-16R were collected over nine months apart, therefore they are not true replicates (which would have been collected at the same time). Second, their  $\delta^{18}\text{O}$  values are -21.8 ‰ and -20.7 ‰, which is a difference of only about 1 ‰, not 3 ‰ as stated by PWP.

The historic variability in isotopic composition of perchlorate manufactured at the BMI Complex is indicated by the data of Sturchio et al. (2006), and this is important with respect to the perchlorate isotopic composition of perchlorate delivered to the Raymond Basin groundwater

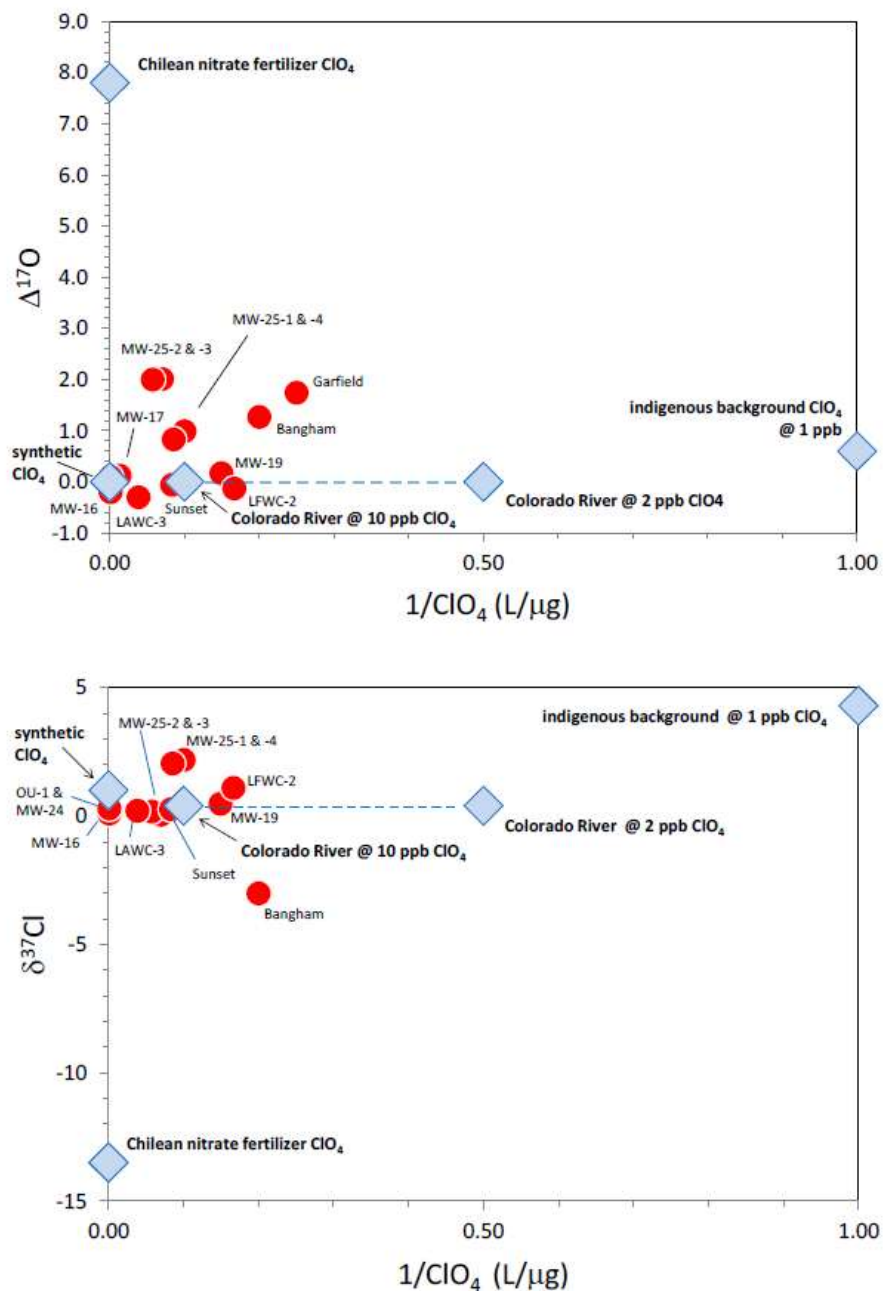
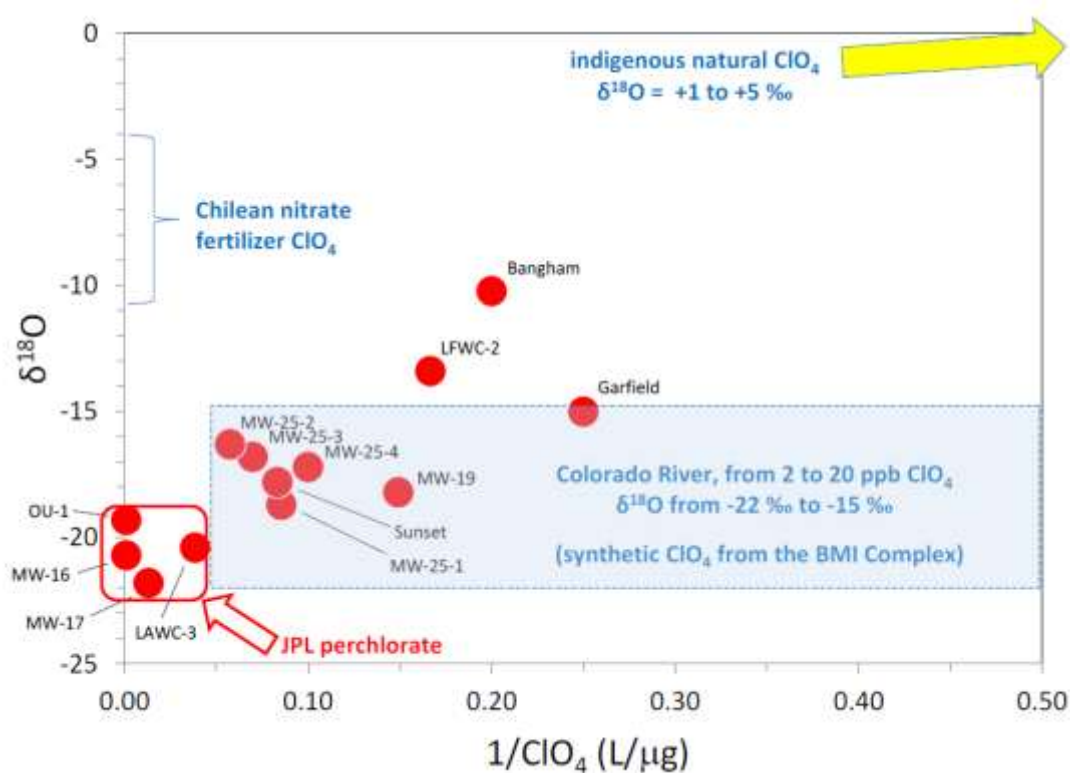


Figure 3.  $\Delta^{17}\text{O}$  (top) and  $\delta^{37}\text{Cl}$  (bottom) values vs. the inverse  $\text{ClO}_4$  concentration,  $1/\text{ClO}_4$  (L/ $\mu\text{g}$ ), for  $\text{ClO}_4$  extracted from wells (red circles) in the vicinity of Pasadena, CA (NASA, 2007). Also shown are representative data (blue diamonds) for the following sources of  $\text{ClO}_4$  (references cited in the caption to Fig. 2): synthetic; likely Colorado River water at  $\text{ClO}_4$  concentrations of 10 and 2 ppb (connected by dashed blue line); Chilean nitrate fertilizer; and indigenous background  $\text{ClO}_4$  from the southwestern U.S. (shown at a concentration of 1 ppb). These diagrams indicate that  $\text{ClO}_4$  isotopic compositions in Bangham, Garfield and MW-25 are best explained by a mixture of Colorado River water with a minor amount of Chilean nitrate fertilizer (with smaller amounts of indigenous natural  $\text{ClO}_4$ ), whereas Sunset could be explained entirely by a Colorado River water source of perchlorate.

with imported Colorado River water. The  $\delta^{18}\text{O}$  value of BMI Complex perchlorate has varied from about -22 to -15 ‰, so it is reasonable to expect that the isotopic composition of Lake Mead perchlorate also may have varied over this range, and consequently so may have that of the imported Colorado River water in Pasadena. The  $\delta^{18}\text{O}$  values of perchlorate in the Raymond Basin groundwaters are compared with the inverse perchlorate concentrations in Figure 4. The Colorado River water in this diagram is represented by perchlorate extracted from Las Vegas Wash, but it could also have been represented by perchlorate having any  $\delta^{18}\text{O}$  value from -22 to -15 ‰. In this case, the only observable difference between the synthetic perchlorate in the JPL-influenced wells (MW-16, OU-1, MW-17, LAWC #3) and the synthetic perchlorate in the other wells is that all the JPL-influenced wells have higher perchlorate concentrations.



**Figure 4.** Diagram showing  $\delta^{18}\text{O}$  values (‰) vs.  $1/\text{ClO}_4$  ( $\text{L}/\mu\text{g}$ ) for perchlorate extracted from wells (red circles) in the vicinity of Pasadena, CA (NASA, 2007). Also shown are possible ranges of perchlorate from imported Colorado River water for 2 to 20 ppb  $\text{ClO}_4$  (blue rectangle), the range in  $\delta^{18}\text{O}$  values of perchlorate from samples of Chilean nitrate fertilizer (Sturchio et al., 2006; 2012), and the approximate range in  $\delta^{18}\text{O}$  values of indigenous natural perchlorate at concentrations  $\leq 1$  ppb (i.e.  $1/\text{ClO}_4$  values  $> 1.0$   $\text{L}/\text{mg}$ ). Mixing fractions can be estimated graphically on this diagram, as they are proportional to the linear distances between the perchlorate samples and the end-member sources. The mixing relationships evident in this figure are consistent with those pointed out in Figs. 2 and 3.

PWP (2102) also argues that the presence of trichloromethane (TCM) is indicative of conditions conducive to biodegradation of perchlorate. They make the following statement in support of this argument: *“Since TCM was not known to have been used or disposed of at JPL, its presence in wells that are well established to be influenced by JPL water demonstrates anaerobic biodegradation is occurring, irrespective of the DO or NO<sub>3</sub> concentrations”*. In making this strong statement, PWP implies that the only source of TCM is from biodegradation of carbon tetrachloride, which is known to have been used at JPL; PWP ignores the well-known production of TCM as a byproduct of chlorination for disinfection, and it is possible that some of the water reaching the aquifer in the Raymond Basin has been contaminated by chlorination products such as bleach.

In reference to perchlorate, PWP states that *“Biodegradation can in fact also explain the wide variability in the <sup>18</sup>O results”*. This statement is incorrect. As shown by Sturchio et al. (2007), the characteristic fractionation factor ratio  $\epsilon^{18}\text{O}/\epsilon^{37}\text{Cl}$  for perchlorate biodegradation has a value of 2.5. It follows that if the ~10 per mil range in perchlorate  $\delta^{18}\text{O}$  values of the Sunset reservoir wells was caused by biodegradation of a single source, then it should be positively correlated with a 4 per mil range in  $\delta^{37}\text{Cl}$  values, which is not the case. The Sunset well having the highest  $\delta^{18}\text{O}$  value is Bangham, and this well also has the lowest  $\delta^{37}\text{Cl}$  value. As shown above, the range in perchlorate isotopic composition of the Sunset wells is caused mostly by mixing different perchlorate sources, including Chilean nitrate fertilizer and indigenous natural ClO<sub>4</sub>. PWP’s arguments that perchlorate has been affected by biodegradation, based on the presence of TCM and the wide range in perchlorate  $\delta^{18}\text{O}$  values, are therefore not valid.

### **2.3 Response to PWP Opinion #3**

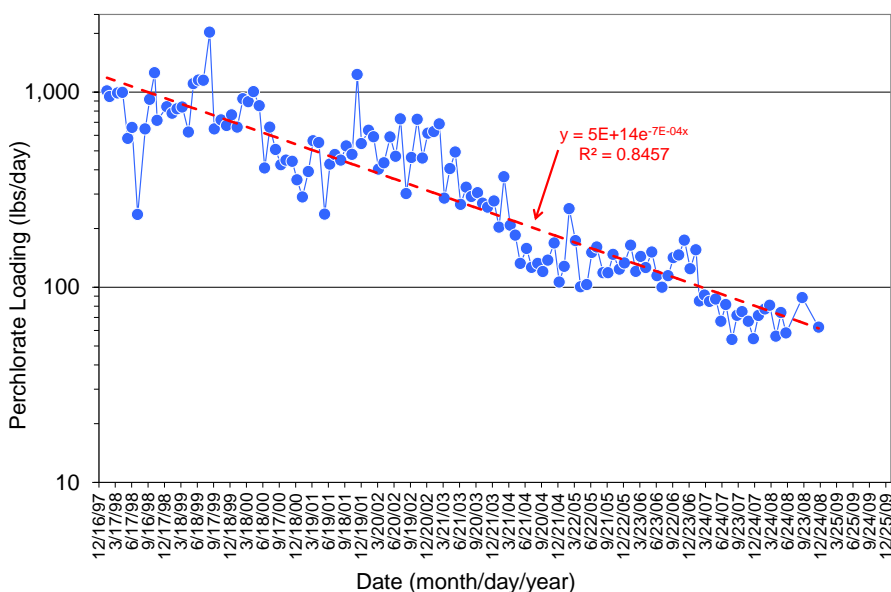
PWP’s opinion regarding the flow directions of water in the vicinity of Pasadena is inconsistent with the independent modeling results of the Raymond Basin Management Board as well as the JPL groundwater model. PWP relies on the presence and apparent mixing relationships implied by contaminants such as VOCs (CTC, PCE, TCE) and NO<sub>3</sub> to support their opinion. However, in developing their arguments, PWP neglects to point out the widespread occurrence and correlation of VOCs and NO<sub>3</sub> throughout the greater Los Angeles region (Fram and Belitz, 2011) which, when taken into account, severely weakens their arguments.

### **2.4 Response to PWP Opinion #4**

PWP (2012) compares concentrations of a variety of reactive solutes, such as Sr, NO<sub>3</sub>, Ca, and Na, with <sup>87</sup>Sr/<sup>86</sup>Sr ratios and stable isotope ratios of water. Through a series of assumptions and assertions, PWP concludes that all of the perchlorate in the Sunset Reservoir wells is from JPL and that no further investigations are necessary. However, PWP’s conclusions are invalid because many of their fundamental assumptions and assertions are incorrect.

In section 4.4.6, titled *“Colorado River Water is Only a Minor Source of Perchlorate”*, PWP (2012) neglects to consider the substantial temporal variations in perchlorate concentrations observed during the period from about 1997-2004 in many of the wells sampled for perchlorate

isotopes by NASA (2007). Water from MW-21-1 is cited by PWP (2012) as a good example of LCF water having strong Colorado River influence. MW-21 water had 14-16 ppb perchlorate in 1997 (NASA, 2007, Attachment 4), indicating that the imported Colorado River water contributing to MW-21 may have previously had much higher perchlorate concentration than the 8 ppb assumed by PWP (2012). The presence of higher perchlorate concentration in imported Colorado River water prior to 1997 is consistent with the exponentially decreasing trend in perchlorate loading from Las Vegas Wash to Lake Mead that has been measured since December 1997 (Figure 5). The routine monitoring at Willow Beach, AZ (11 miles downstream of Hoover Dam) that began in May, 1999, showed a high concentration of 9 ppb in the Colorado River, after on-site perchlorate remediation in the Henderson, NV area had already been initiated (NDEP, 2012). This concentration may have been much higher prior to 1999, and thus perchlorate concentrations in imported Colorado River water may have been much higher as well, contrary to PWP's (2012) stated assumption that imported water could not have contributed more than 3-4 ppb to Sunset Reservoir well waters. All else being equal, the high perchlorate loading prior to 1999 could have sustained a proportionally high perchlorate concentration in Colorado River water (i.e., higher by a factor of ten or more). **Given the mean groundwater travel times based on tritium data (i.e., 20-30 years), imported Colorado River water from the 1980s and 1970s, having much higher perchlorate concentrations than Colorado River water in 2005, could account for the high concentrations of perchlorate observed in the Sunset Reservoir groundwaters when they were sampled in 2005 (NASA, 2007).**



**Figure 5. Perchlorate loading (pounds/day) vs. calendar date at Northshore Road sampling point, positioned approximately one-half mile upstream from confluence of Las Vegas Wash and Lake Mead. Northshore Road sampling point should measure all perchlorate inputs entering the Colorado River System from the Las Vegas Valley via Las Vegas Wash. This plot indicates that the perchlorate loading from Las Vegas Wash to the Colorado River system decreased approximately exponentially by over 90%, from about 1,000 pounds/day to about 70 pounds per day, between December 1997 and January 2008 (data from NDEP, 2012).**



In section 4.4.7, titled “*Groundwater Types in the Raymond Basin*”, PWP (2012) discusses the NASA (2007) classification of groundwater into three types, and states that “NASA’s TM is not very explicit about how these types are defined”. The cause of PWP’s confusion on this point is difficult to understand, because the Piper diagrams (Figs. 5, 6, 7 and Attachment 2 presented in NASA, 2007), as explained at the top of p. 12 of NASA (2007), clearly show the divisions between groundwater types in terms of the equivalent cationic components Ca, Na+K, and Mg and the anionic components Cl, HCO<sub>3</sub>, and SO<sub>4</sub>. In section 4.4.7.1, PWP (2012) reclassifies the groundwaters in terms of only Ca/Na ratio and TDS, ignoring sulfate which is a key indicator of Colorado River (Type III) water. This clearly results in a much different classification than that defined by NASA (2007). After this reclassification exercise, PWP (2012) states “*it is not clear that the definitions used in this document are the same as those used in NASA’s TM*” and, in reference to NASA (2007), “*there is no table listing the sample locations with the corresponding concentrations of calcium, sodium, and TDS so that it can be known which samples correspond to which sample types*” despite the fact that Attachment I of NASA (2007) lists complete analytical data for each of the wells sampled for the perchlorate additional investigation. Piper diagrams are a standard tool in hydrogeochemical investigations. The unfamiliarity of PWP with such diagrams, and the poor quality of the arguments in this part of their Opinion #4, appears to indicate a generally careless and uninformed approach in the preparation of their technical response (PWP, 2012).

In their discussion of stable isotope data for H<sub>2</sub>O in section 4.4.8.4, PWP neglects to take into account the wide seasonal variations in stable isotopic composition of meteoric water that can be reflected in the isotopic compositions of shallow groundwater, in addition to the transient variations associated with artificial recharge. For example, the Los Angeles River, into which Arroyo Seco drains, has annual variations of about 50 ‰ in δD and 5 ‰ in δ<sup>18</sup>O which reflect seasonal variations in meteoric water composition (Coplen and Kendall, 2001), and the imported waters of the State Water Project and the Colorado River Aqueduct have comparably large annual variations (Williams and Rodoni, 1997). PWP (2012) incorrectly states that there are five isotopomers of water, when in fact water has nine stable isotopologues and no isotopomers. PWP presents an oversimplified concept of the causes of stable isotope variations of natural waters, and this invalidates their attempt at interpretation of the water isotope data. Furthermore, PWP (2012) interprets the stable isotope data of water samples in the context of their reclassification of water types, which differs from that of NASA (2007).

PWP also fails to recognize that Sr concentrations and isotope ratios in groundwater may be affected by alkaline earth and Sr isotope exchange with clay minerals (Johnson and DePaolo, 1997; Armstrong et al., 1998), and therefore Sr is not used effectively as a conservative tracer in groundwater aquifers.

### **3.0 Summary Remarks**

In summary, this commentary has reviewed the available data for perchlorate concentrations and isotopic compositions in groundwater in the vicinity of Pasadena, CA (NASA, 2007), along with other available data and the opinions expressed by PWP (2012). The opinions of PWP are found to be based on flawed assumptions and incogent arguments leading to erroneous and unfounded conclusions regarding the origin of perchlorate in the Sunset Reservoir wells. **The PWP (2012)**

**opinions that there is a single source of perchlorate (BMI complex) in the Sunset Reservoir wells, that Chilean nitrate fertilizer could not have contributed perchlorate to the Sunset Reservoir wells, and that all of the perchlorate in the Sunset Reservoir wells is from JPL are inconsistent with the perchlorate isotopic data and other evidence presented by NASA (2007).** The available data presented by NASA (2007) indicate clearly that at least three separate types of perchlorate must have contributed to the Sunset Reservoir wells, including mostly synthetic perchlorate (of which the majority is most likely from the BMI complex via imported Colorado River water) along with locally significant amounts of residual perchlorate from Chilean nitrate fertilizer and indigenous natural perchlorate from regional atmospheric deposition. The available data do not require the presence of any JPL-sourced perchlorate in the Sunset Reservoir wells, and the NASA (2007) report makes a reasonable case that all JPL-sourced perchlorate is contained in the Monk Hill sub-basin.

The isotopic composition of the perchlorate molecule provides the strongest and most direct evidence of the sources of perchlorate in the Sunset Reservoir wells. In the seven years since NASA (2007) sampled the wells for the additional investigations/perchlorate isotope study of the Sunset Reservoir wells, considerable progress has been made in analytical methodologies for perchlorate isotopes as well as the extent of the database for isotopic compositions of perchlorate sources (Hatzinger et al., 2009; Böhlke et al., 2009; Hatzinger et al., 2011). In particular, an additional isotope,  $^{36}\text{Cl}$ , has been added to the forensic toolbox for perchlorate investigations (Sturchio et al., 2009), and the capability for measuring isotopic compositions of perchlorate in groundwater having sub-ppb perchlorate concentrations has now been demonstrated (Jackson et al., 2010). Therefore, a new round of isotopic measurements on perchlorate from the wells sampled by NASA (2007), plus additional wells in the vicinity, could help to better resolve remaining uncertainties regarding the source of perchlorate in the Sunset Reservoir wells.

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## APPENDIX A: Statement of Qualifications and Experience In Perchlorate Research

I have over 30 years of experience in the chemical and isotopic analysis of natural materials, including rocks, minerals, waters, and gases, and in the interpretation of such analytical data in terms of geochemical, hydrological, and geological processes in a field-based context. I have authored or co-authored more than 160 peer-reviewed scientific publications and more than 200 presentations given at national and international scientific conferences in the areas of geochemistry, hydrology, and geology. I am active in research, teaching, and professional service. These accomplishments and activities are documented in my curriculum vitae (Appendix B).

I have pursued research with colleagues into the development and application of methods for the isotopic analysis of perchlorate since 1998. Our efforts in this area have resulted in 12 peer-reviewed publications since 2003 (listed below in Table A1). Most of these appear in high-impact journals published by the American Chemical Society, namely *Environmental Science and Technology* and *Analytical Chemistry* (ISI 5-year impact factors 5.4 and 5.9, respectively). In addition, I directed three M.S. thesis projects involving perchlorate isotope analysis, and I am currently advising a Ph.D. candidate in dissertation research on the isotopic composition of perchlorate in the environment. My work on perchlorate has been recognized within both the scientific community and the environmental industry by a number of invited talks beginning in 2004 (listed below in Table A2).

### Table A1. Peer-reviewed publications on the topic of perchlorate isotopic composition

Sturchio N. C., Hatzinger P., Arkins M., Suh C., and Heraty L. J., 2003. Chlorine isotope fractionation during microbial perchlorate reduction. *Environmental Science and Technology* **37**, 3859-3863.

Bohlke J.K., Sturchio N.C., Gu B., Horita J., Brown G.M., Jackson A., Batista J., Hatzinger P., 2005. Perchlorate isotope forensics. *Analytical Chemistry* **77**, 7838-7842.

Sturchio N.C., Bohlke J.K., Gu B., Horita J., Brown G.M., Beloso A., Hatzinger P., Jackson A., and Batista J., 2006. Stable isotopic compositions of chlorine and oxygen in synthetic and natural perchlorates. Ch. 5, p. 93-109. In: Gu B. and Coates J.D., Eds., *Perchlorate: Environmental Occurrence, Interactions and Treatment*. Springer, New York.

Sturchio N.C., Beloso A.D., Jr., Böhlke J.K., Streger S.H., Heraty L.J., and Hatzinger P.B., 2007. Oxygen and Chlorine Isotopic Fractionation During Perchlorate Biodegradation: Laboratory Results and Implications for Forensics and Natural Attenuation Studies. *Environmental Science and Technology* **41**, 2796-2802.

Seyfferth A.L., Sturchio N.C., and Parker D.R., 2008. Is perchlorate metabolized or retranslocated within lettuce leaves? A stable-isotope approach. *Environmental Science and Technology* **42**, 9437-9442.

Hatzinger, Paul; Bohlke, John Karl; Sturchio, Neil; Gu, Baohua; Heraty, Linnea; and Borden, Robert, 2009. Fractionation of stable isotopes in perchlorate and nitrate during in situ biodegradation in a sandy aquifer. *Environmental Chemistry* **6**, 44-52.

Böhlke J.K., Hatzinger P.B., Sturchio N.C., Gu B., Abbene I., and Mroczkowski S.J., 2009. Atacama perchlorate as an agricultural contaminant in groundwater: Isotopic and chronologic evidence from Long Island, New York, USA. *Environmental Science and Technology* **43**, 5619-5625.

Sturchio N.C., Caffee M.R., Beloso A. D., Heraty L.J., Böhlke J.K., Gu B., Jackson W.A., Hatzinger P.B., Heikoop J.R., and Dale M., 2009. Chlorine-36 as a tracer of perchlorate origin. *Environmental Science and Technology* **43**, 6934–6938.

Jackson, W.A., Böhlke J.K., Gu B., Hatzinger P.B., and Sturchio N.C., 2010. Isotopic Composition and Origin of Indigenous Natural Perchlorate and Co-Occurring Nitrate in the Southwestern United States. *Environmental Science and Technology* **44**, 4869-4876.

Gu B., Böhlke J.K., Sturchio N.C., Hatzinger P.B., Jackson W.A., Beloso A.D. Jr., Heraty L.J., Bian Y., and Brown G.M., 2011. Removal, Recovery and Fingerprinting of Perchlorate by Ion Exchange Processes. Chapter 3, p. 117-144. In: SenGupta, AK (Ed.), *Ion Exchange and Solvent Extraction: A Series of Advances*, vol. 20. CRC Press/Taylor & Francis, Boca Raton.

Sturchio N.C., Hoaglund J.R. III, Marroquin R.J., Beloso A.D. Jr., Heraty L.J., Bortz S.E., Patterson T.L., 2011. Isotopic Mapping of Groundwater Perchlorate Plumes. *Ground Water* (DOI: 10.1111/j.1745-6584.2011.00802.x).

Sturchio N.C., Böhlke J.K., Gu B., Hatzinger P.B., Jackson A.J., 2011. Isotopic tracing of perchlorate in the environment. Chapter 22, pp. 437-452. In: Baskaran M. (Ed.), *Handbook of Environmental Isotope Geochemistry*, Springer-Verlag.

## **Table A2. Invited talks on the topic of perchlorate isotopic composition**

Sturchio N.C., *Environmental Isotope Forensics of Perchlorate*. Perchlorate 2004: Perchlorate in California's Groundwater. Conference sponsored by Groundwater Resources Association of California, August 4, 2004, Glendale CA.

Sturchio N.C., *Stable Isotope Analysis in Environmental Forensic Investigations of Groundwater Contamination*. Environmental Forensics: Theory, Application, and Case Studies. Workshop sponsored by the International Society of Environmental Forensics, Charleston, SC, November 9-10, 2004.

Sturchio N.C., Böhlke J.K., Horita J., Gu B., Brown G.M., and Hatzinger P. *Environmental isotope forensics of perchlorate*. Goldschmidt 2005, Moscow, Idaho, May 2005.

Sturchio N.C., Beloso A.D., Jr., Böhlke J.K., Horita J., Gu B., Brown G.M., and Hatzinger P. *Environmental isotope forensics of perchlorate*. Eighth International In Situ and On-Site Bioremediation Symposium, Baltimore, MD, June 9, 2005.

Sturchio N.C., Böhlke J.K., Horita J., Gu B., Brown G.M., and Hatzinger P. *Environmental isotope forensics of perchlorate*. Argonne National Laboratory, Aug. 11, 2005.

Sturchio N.C., *Environmental Isotope Forensics of Perchlorate: Source Characteristics and Groundwater Case Studies*. Environmental Forensics: Focus on Perchlorate, Workshop sponsored by the International Society of Environmental Forensics, Santa Fe, NM, Sept. 21-22, 2005.

Sturchio N.C., *Environmental Isotope Forensics of Perchlorate*. University of Illinois at Chicago, Environmental Engineering Seminar Series, Oct. 7, 2005.

Sturchio, N.C., 2005. *Stable isotope diagnostics of common Cl-bearing environmental contaminants*. Annual Meeting of the Geological Society of America, Salt Lake City, UT, Oct. 15-19, 2005.

Sturchio N.C., *A Tale of Six Isotopes: Stable Isotopic Composition of Perchlorate in Groundwater*. Stockholm University, Sweden, May 11, 2006.

Sturchio N.C., LeClaire J., Beloso A., Heraty L., Manning K., Corsinita P. *Use of stable isotopes as a forensic tool to determine sources of perchlorate in groundwater in the Chino Basin, California*. Symposium on Applications of Isotope Tools to Groundwater Studies, Groundwater Resources Association of California, Concord, CA, Mar. 29, 2007.

Sturchio N.C., *Environmental Isotope Forensics of Perchlorate*. Laboratory Technical Information Work Group, U. S. EPA, Chicago, IL, May 1, 2007.

Sturchio N.C., *Update on Environmental Isotope Forensics of Perchlorate*. U. S. EPA Region V, Chicago, IL, Sept. 23, 2009.

Sturchio N.C., *Environmental Isotope Forensics of Perchlorate*. American Institute of Professional Geologists, Chicago Chapter Meeting, Lisle, IL, Oct. 15, 2008.

Sturchio N.C., *Isotopic Evidence for Perchlorate Sources in Groundwater of the Northern Santa Ana Watershed*. ESTCP Technical Advisory Committee for Rialto-Colton-Fontana Perchlorate Isotope Study, San Bernardino, CA, Feb. 23, 2010.

Sturchio N.C., Beloso Jr. A.D., Heraty L.J., LeClaire J., Rolfe T., Manning K.R. *Isotopic evidence for agricultural perchlorate in groundwater of the western Chino Basin, California*. Sixth International Conference on Remediation of Chlorinated and Recalcitrant Compounds: Monterey, California, May 18-22, 2008.

Sturchio N.C., *Environmental Isotope Forensics of Perchlorate*. University of Wisconsin at Milwaukee, Feb. 25, 2010.

Sturchio N.C., *Environmental Isotope Forensics of Perchlorate*. University of Texas at Arlington, April 15, 2010.

Sturchio N.C., Caffee M.R., Beloso Jr. A.D., Heraty L.J., Böhlke J.K., Gu B., Jackson W.A., Hatzinger P.B., Heikoop J.R., Dale M. *Chlorine-36 as a tracer of perchlorate origin*. Eighth International Conference on Remediation of Chlorinated and Recalcitrant Compounds: Monterey, California, May 24-28, 2010.

Sturchio N.C., Beloso Jr. A.D., Böhlke J.K., Caffee M., Gu B., Hatzinger P.B., Heraty L.J., Jackson W.A., *Tracing origins and transport of perchlorate using Cl and O isotopes* [KEYNOTE], Goldschmidt 2010, Knoxville, TN, June 2010.

Sturchio N.C., *Environmental Isotope Forensics of Perchlorate*, Purdue University, Nov. 11, 2011.

Sturchio N.C., *Environmental Isotope Forensics of Perchlorate*. Symposium on Environmental Forensics in an Era of Emerging Diagnostic Methods, Groundwater Resources Association of California, Irvine, CA, April 12, 2011.

## **APPENDIX B – Curriculum Vitae**

### **Neil C. Sturchio**

Department of Earth and Environmental Sciences  
University of Illinois at Chicago  
845 West Taylor Street, MC-186  
Chicago, IL 60607-7059  
312-355-1182 (voice); 312-413-2279 (fax)  
Sturchio@uic.edu

#### ***Education:***

*Ph.D., Earth and Planetary Sciences - Washington University, 1983*

*B.A. (Honors), Earth Sciences - Fairleigh Dickinson University, 1977*

#### **Awards and Honors:**

Project of the Year Award, U. S. Department of Defense, Environmental Security Technology Certification Program (ESTCP) (with P. Hatzinger, J.K. Böhlke, and B. Gu), 2008

Secretary of the Geochemical Society (elected position), 2008-2011

Visiting Professor, Ain Shams University (Cairo, Egypt), 2007

Marsden Visiting Fellow, Institute of Geological and Nuclear Sciences (New Zealand), 2000

Fellow, Geological Society of America (elected position), 1997

Pacesetter Award, Argonne National Laboratory, 1996

Outstanding Contributions to Geoscience Research Award,

U. S. Department of Energy, Office of Basic Energy Sciences (with R.P. Chiarello), 1995

Exceptional Performance Award, Argonne National Laboratory, 1995

Visiting Research Scholar, Kyoto University (Japan), 1994

Wheeler Fellow, Washington University, 1981-1982

McDonnell Fellow, Washington University, 1978-1981

#### **Professional Positions:**

University of Illinois at Chicago, Department of Earth and Environmental Sciences: 2000-present

Department Head, 2002-present; Acting Department Head, 2001-2002

Professor of Geochemistry, 2000-present

Founding Director, Environmental Isotope Geochemistry Laboratory, 2000-present

Argonne National Laboratory: 1983-2000

Scientist: 1989-2000; Assistant Scientist: 1985-1989; Postdoctoral Appointee: 1983-1985

Group Leader: 1986-2000

Special Term Appointee: 2000-2001; Guest Associate: 2001-present

#### **Professional Affiliations:**

American Association for the Advancement of Science (Member)

American Chemical Society (Member)

American Geophysical Union (Member)

Geochemical Society (Member; Secretary 2008-2011)

Geological Society of America (Fellow)

#### **Research Interests:**

Environmental geochemistry

Geochemical applications of radioactive and stable isotopes

Experimental studies of stable isotope fractionation

Experimental studies of mineral-fluid interface processes using synchrotron radiation techniques



## Neil C. Sturchio -- Additional Professional Activities

### Editorial

Editor in Chief: *The Geochemical News* (1997-2001)  
Editorial Boards: *Chemical Geology* (2001-)  
*Geochemical Journal* (2008-)  
*Environmental Forensics* (2001-)  
Guest Editor: *Geochimica et Cosmochimica Acta*, "Actinide-Series Disequilibria in Igneous and Geothermal Processes" (special issue, March, 1993)

### Reviews

Proposals: Department of Energy (BES, BER, SBIR)  
National Science Foundation (EAR)  
National Academy of Sciences/National Research Council  
NASA (Postdoctoral Program)  
Helmholtz Association (Germany)  
Institute of Geophysics and Planetary Physics (University of California)  
Israel Science Foundation  
Lise Meitner Postdoctoral Program (Austria-FWF)  
MacArthur Fellows Program  
Australian Research Council  
Natural Sciences and Engineering Research Council of Canada  
Canada Excellence Research Chairs Program  
Advanced Photon Source (beamtime proposals)  
Stanford Synchrotron Radiation Laboratory (beamtime proposals)  
Swiss National Science Foundation  
University of Wisconsin Water Resources Institute  
Romanian National Authority for Scientific Research  
National Geographic Society

### Journals:

<i>American Mineralogist</i>	<i>J. Chromatography A</i>
<i>Analytical Chemistry</i>	<i>J. Contaminant Hydrology</i>
<i>Analytica Chimica Acta</i>	<i>J. Environmental Quality</i>
<i>Atmospheric Chemistry and Physics</i>	<i>J. Forensic Science</i>
<i>Applied Geochemistry</i>	<i>J. Geology</i>
<i>Bulletin of Volcanology</i>	<i>J. Geophysical Research</i>
<i>Chemical Geology</i>	<i>J. Hydrology</i>
<i>Chemosphere</i>	<i>J. Materials Research</i>
<i>Earth &amp; Planetary Science Letters</i>	<i>J. South American Earth Sciences</i>
<i>Earth Science Reviews</i>	<i>J. Volcanology &amp; Geothermal Research</i>
<i>Economic Geology</i>	<i>Materials Research Society Proceedings</i>
<i>Environmental Forensics</i>	<i>Microbial Biotechnology</i>
<i>Environmental Pollution</i>	<i>Nature</i>
<i>Environmental Science and Technology</i>	<i>Nuclear &amp; Chemical Waste Management</i>
<i>European Journal of Mineralogy</i>	<i>Nuclear Instruments &amp; Methods Phys. Res. B</i>
<i>Geochemical Journal</i>	<i>Ore Geology</i>
<i>Geochimica et Cosmochimica Acta</i>	<i>Organic Geochemistry</i>
<i>Geological Society of America Bulletin</i>	<i>Pure and Applied Geophysics</i>
<i>Geology</i>	<i>Quaternary Geochronology</i>
<i>Geophysical Research Letters</i>	<i>Quaternary Research</i>
<i>Hydrogeology Journal</i>	<i>Rapid Comm. in Mass Spectrometry</i>
<i>Hydrological Processes</i>	<i>Reviews of Geophysics</i>
<i>Intl. J. Mass Spectrometry</i>	<i>Science</i>
<i>J. African Earth Sciences</i>	<i>Sedimentology</i>
<i>J. Archeological Science</i>	<i>Vadose Zone Journal</i>

## Review Panels

Member, DOE-BES Committee of Visitors, Chemical Sciences, Geosciences, and Biosciences Division, Apr. 5-8, 2011  
Member, DOE Review Committee for Stanford Synchrotron Radiation Laboratory, Feb. 9-11, 2011  
Member, DOE Review Team for Subsurface Focus Area, Lawrence Berkeley National Laboratory, May 20-21, 2010  
External Reviewer, Strategic Plan for Geosciences Department, Western Michigan University, December, 2009  
Member, DOE Proposal Review Panel for BES Early Career Research Program, November, 2009  
Member, Proposal Evaluation Panel for DOE Environmental Remediation Science Program, Apr. 9-10, 2008  
Member, DOE Review Committee for Stanford Synchrotron Radiation Laboratory, Jan. 29-31, 2008  
Member, NSF Proposal Review Panel for Geobiology and Environmental Geochemistry, Nov. 7-9, 2007  
Member, NSF Proposal Review Panel for Geobiology and Environmental Geochemistry, Apr. 25-27, 2007  
Member, NSF Proposal Review Panel for Geobiology and Environmental Geochemistry, Nov. 14-16, 2006  
Member, Proposal Evaluation Panel for DOE Environmental Remediation Science Program, Aug. 21-22, 2006  
Member, NSF Proposal Review Panel for Geobiology and Environmental Geochemistry, Apr. 18-19, 2006  
External Reviewer, U. S. State Dept, Environmental Hydrology Coalition Project (U.S.-Egypt), Dec. 2005  
Chair, Visiting Review Committee, Geological Sciences Department, University of Kentucky, Nov. 10-11, 2005  
Member, NSF Proposal Review Panel for Geobiology and Environmental Geochemistry, Nov. 3-4, 2005  
Member, NSF Proposal Review Panel for Geobiology and Environmental Geochemistry, May 9-10, 2005  
Member, DOE Proposal Review Panel for Office of Civilian Radioactive Waste Management, March 14-15, 2005  
External Member, Academic Program Planning Committee for Geosciences, Western Michigan University, January, 2005  
Member, NSF Proposal Review Panel for Geobiology and Environmental Geochemistry, October 20-21, 2004  
Member, NSF Site Visit Review Team for Environmental Molecular Science Institutes, July 2004  
Member, Proposal Evaluation Panel for DOE Environmental Management Science Program, Washington, DC July 14, 2004  
Member, Visiting Review Committee, Geosciences Department, U. Wisconsin-Milwaukee, April 2004.  
Member, Visiting Review Committee, Geology Department, Miami University, Oxford, Ohio, November, 2003  
Member, Visiting Review Committee, Geology Department, SUNY-Buffalo, Buffalo, New York, April, 2003  
Chair, Scattering Chem-Bio-Environ Beamtime Proposal Review Panel, Advanced Photon Source, Argonne IL, 2002-2005  
Member, Proposal Evaluation Panel for DOE Environmental Management Science Program, Washington D.C., May 2002

## Conference Organization

Co-organizer, *International Workshop on Tracer Applications of Noble Gas Radionuclides in the Earth Sciences*, Argonne National Laboratory, Argonne, IL, June 20-22, 2012.  
Session Co-organizer, *Formation Mechanisms, Stability, and Distribution of Oxyanions in the Environment*, Goldschmidt 2010, Knoxville, TN, June 2010.  
Session Chairman, *Geochemical and Isotopic Studies of Rocks, Minerals, and Fluids*, Geological Society of America, North-Central Section, Rockford, IL, April 2009.  
Session and Field Trip Co-organizer, *Travertines: Archives of archeology, neotectonics, and paleoclimate*. International Geological Congress, Florence, Italy, August 2004.  
Member, International Program Committee for *Goldschmidt 2003*, Kurashiki, Japan, September 2003  
Co-chair, *Applications of Synchrotron Radiation to Low Temperature Geochemistry and Environmental Science*, special session at the American Geophysical Union Annual Fall Meeting, San Francisco, CA, Dec. 6-10, 2002  
Session Chairman and Organizer, *Recent Highlights and New Directions in Environmental Science*, workshop at the 9<sup>th</sup> Annual Users Meeting of the Advanced Photon Source, May 2-4, 2000, Argonne, IL.  
Session Co-chair, *Mineral Growth Kinetics and Surface Reactivity*, V.M. Goldschmidt Conference, Tucson, AZ, June 1997.  
Session Chair, *Aqueous/Isotope Geochemistry*, Spring Meeting of the American Geophysical Union, Baltimore, MD (1996)  
Onsite organizer, DoE Symposium "Earth Materials: Theory, Simulation, and Experiment " held at Argonne National Laboratory, August, 1995.  
Session Organizer/Chairman, "Actinide Series Disequilibria in Igneous and Geothermal Processes", Annual Mtg. of the Geological Society of America, San Diego, CA (1991)  
Session Organizer/Chairman, "Radionuclide Migration in Natural Systems", International Symposium on the Scientific Basis for Nuclear Waste Management, Boston, MA (1990)

## Short Courses

Instructor, *Isotope Techniques for Assessment of Shallow Groundwater Systems and their Interactions with Surface Waters*, International Atomic Energy Agency, Advanced Regional Training Course, Argonne, IL, July 12-23, 2010  
Instructor, *Isotope Techniques for River Basin Management, Including River-Groundwater Interactions*, International Atomic Energy Agency, Advanced Regional Training Course, Argonne, IL, June 15-17, 2009  
Instructor, *Isotopic Age Determination Techniques for Water Resource Management*, International Atomic Energy Agency Workshop, Argonne, IL, June 16-18, 2008

Instructor, *Isotopes and Geochemistry Applied to Water Resource Evaluation*, Cairo University, Giza, Egypt, Dec. 7-8, 2003.  
 Organizer, *Applications of Synchrotron Radiation to Low Temperature Geochemistry and Environmental Science*,  
 Geochemical Society/Mineralogical Society of America Short Course, Monterey, CA, Dec. 3-5, 2002  
 Participant, MSA Short Course, *Geomicrobiology: Interactions Between Microbes and Minerals*, Salt Lake City, Oct. 1997.  
 Instructor, *Isotope Geochemistry and Hydrology*, Cairo University, Giza, Egypt, February 22-23, 1997.  
 Participant, MSA Short Course, *Chemical Weathering Rates of Silicate Minerals*, New Orleans, Louisiana (1995)  
 Participant, MSA Short Course, *Stable Isotopes in High Temperature Geological Processes*, San Antonio, Texas (1986)

### **Invited Talks at Conferences and Workshops**

Invited Keynote Speaker, *Environmental Isotope Forensics of Perchlorate*, Symposium on Environmental Forensics in an Era of Emerging Diagnostic Methods, Groundwater Resources Association of California, Irvine, CA, April 12, 2011  
 Invited Keynote Speaker, *A new approach to old water: atom-trap trace analysis of Krypton-81*, International Symposium on Isotopes in Hydrology, Marine Ecosystems, and Climate Change Studies, Monaco, Mar. 27-Apr. 1, 2011  
 Invited Keynote Speaker, *Tracing origins and transport of perchlorate using Cl and O isotopes*, Goldschmidt 2010, Knoxville, TN, June 2010  
 Invited Speaker, *Noble gas radionuclides and ATTA in hydrology: State of the art*. Goldschmidt 2009, Davos, Switzerland, June, 2009.  
 Invited Speaker, *Environmental Isotope Forensics of Perchlorate*, U. S. EPA, Chicago, IL, May 1-2, 2007.  
 Invited Speaker, *4th Mini-Conference on Noble Gases in the Hydrosphere and in Natural Gas Reservoirs*, Potsdam, Germany, March, 2007.  
 Invited Speaker, *Radiokrypton Analysis in the 21st Century*. Goldschmidt 2006, Melbourne, Australia, August, 2006.  
 Invited Speaker, *Synchrotron Radiation Research in the Pacific Rim and Emerging Techniques and Applications*, Pacificchem 2005, Honolulu, HI, Dec. 16-20, 2005.  
 Invited Speaker, *Workshop on Assessing Groundwater Development Potential in Arid and Hyperarid Regions*, Giza, Egypt, Dec. 11-12, 2005.  
 Invited Panelist, *Ground Water Age: Estimation, Modeling, and Water Quality Sustainability*, National Ground Water Association, Lake Tahoe, CA, Sept. 23-26, 2005.  
 Invited Speaker at *Environmental Forensics: Focus on Perchlorate*, Workshop sponsored by the International Society of Environmental Forensics, Santa Fe, NM, Sept. 21-22, 2005.  
 Invited Speaker, *Synchrotron Environmental Science-III*, Brookhaven National Lab., Upton, NY, Sept. 19-21, 2005.  
 Invited Speaker at *Interfacial Water Workshop*, sponsored by Sandia National Laboratory, Santa Fe, NM, April 25-26, 2005  
 Invited Speaker at *Environmental Forensics: Theory, Application, and Case Studies*, Workshop sponsored by the International Society of Environmental Forensics, Charleston, SC, November 9-10, 2004.  
 Invited Speaker at *Perchlorate 2004: Perchlorate in California's Groundwater*. Conference sponsored by Groundwater Resources Association of California, August 4, 2004, Glendale CA.  
 Invited Speaker, Symposium on *Application of Environmental Chemistry in Forensic Investigations*, Pittcon 2004, Chicago IL, March 7-12, 2004.  
 Invited Speaker, *International Workshop to Identify Water Resources/Environment-Related Research Needs for Egypt*, Cairo, Egypt, Dec. 3-6, 2003.  
 Organizer and Speaker, *New Views of Earth and the Environment*, Chicago Teachers as Scholars Workshop, Chicago, IL, April 7-8, 2003  
 Invited Speaker, Environmental Science Workshop, *Canadian Light Source Fifth Users Meeting*, Saskatoon (Nov. 2002)  
 Invited Speaker, *25<sup>th</sup> Midwest Environmental Chemistry Workshop*, Chicago, IL (Oct. 2002)  
 Invited Speaker, American Geophysical Union symposium on *Nanoparticles in the Environment and Technology*, San Francisco, CA, Dec. 9-15, 2001  
 Invited Speaker, NSF Workshop on *Future Directions in Solid State Chemistry*, Davis, CA, Oct. 12-14, 2001  
 Invited Speaker, *Eleventh Annual Goldschmidt Conference*, Roanoke, VA, May 20-24, 2001  
 Invited Participant, *Environmental Chemistry at the Clay-Water Interface*, Soil Science Society of America Bouyoucos Conference, Honolulu, HI, March 6-10, 2000.  
 Invited Speaker, Symposium on *Frontiers of Aqueous Physical Chemistry*, 13<sup>th</sup> International Conference on the Properties of Water and Steam, Toronto, Canada Sept. 12-16, 1999.  
 Invited Speaker, DOE/BES Geosciences Workshop on *Interfacial Processes in Geosciences*, Richland, WA, Feb. 1-2, 1999.  
 Invited Speaker, Workshop on *Environmental Molecular Science*, 8<sup>th</sup> Annual User's Meeting of the Advanced Photon Source, Argonne, IL, October 1998.  
 Invited Speaker, DOE/BES Earth Sciences Research Council Workshop, *Scaling in Geological Systems: Atomic to Field-Scale Processes*, Bodega Bay, CA, Sept. 27-30, 1997.  
 Invited Speaker, *Mineral Growth Kinetics and Surface Reactivity*, V.M. Goldschmidt Conference, Tucson, AZ, June 3-6, 1997.  
 Invited Speaker, Symposium on *Applications of Synchrotron X-rays in Earth and Environmental Sciences*, Fall Meeting of the American Chemical Society, Las Vegas, Nevada, Sept. 1997.

Invited Speaker, *X-ray Spectroscopies of Environmental Interfaces: Theory and Experiment* workshop, Richland, WA, September 1996.

### **Committees and Working Groups, National**

Member, 2012 Distinguished Geologic Career Award Committee, MPG Division, Geological Society of America  
Chair, External Advisory Board, Energy Frontier Research Center, Lawrence Berkeley National Lab., 2010-2014  
Member, External Advisory Board, Energy Frontier Research Center, Lawrence Berkeley National Lab., 2010-2014  
Member, Technical Advisory Committee, DOD-ESTCP Rialto-Colton-Fontana Perchlorate Isotope Study, 2010-  
Chair, Science Team for Advanced Photon Source Renewal Proposal (*Geological, Environmental, and Planetary Sciences*), June-October, 2008  
Invited Participant, DOE/NSF Workshop, *Assessing Synchrotron Radiation Capabilities and Future Needs for Molecular Environmental Science and Low-Temperature Geochemistry*, Rockville, MD, July 23-24, 2007  
Invited Participant, DOE/EM Subsurface Contaminants Focus Area, *Phytoremediation* Workshop, Argonne, IL, 11/30-12/2/99.  
Invited Participant, DoE Workshop on *Molecular Environmental Science*, Airlie, VA, July 1995.  
Member, DOE Interlaboratory Geosciences Coordinating Group (1989-2000)  
Member, "*Extraterrestrial Resource Utilization*" DOE Working Group for the Space Exploration Initiative (1990)  
Member, Illinois Basin Ultradeep Drillhole Consortium (1986)

### **Committees and Working Groups, Local and Regional**

Member, Search Committee for Dean of the College of Liberal Arts and Sciences, UIC, November 2011-April 2012  
Organizer, CIC Geoscience Department Heads and Chairs Workshop, Chicago, IL, October 2010  
Participant, CIC Geoscience Department Heads and Chairs Workshop, East Lansing, MI, September 2008  
Participant, CIC Geoscience Department Heads and Chairs Workshop, Ann Arbor, MI, September 2007  
Participant, CIC Geoscience Department Heads and Chairs Workshop, Evanston, IL, September 2006  
Chair, UIC Biological Sciences Department Head Search Committee (2004-2005)  
Participant, CIC Geoscience Department Heads and Chairs Workshop, Madison, WI, October 2004.  
Participant, CIC Geoscience Department Heads and Chairs Workshop, W. Lafayette, IN, October 2003.  
Member, UIC Institute of Environmental Science and Policy Steering Committee (2002-present)  
Chair, UIC Biological Sciences Department Head 5-Year Review Committee (2002-2003)  
Participant, CIC Geoscience Department Heads and Chairs Workshop, Iowa City, IA, October 18, 2002.  
Member, Board of Governors, Consortium for Advanced Radiation Sources (2001-present)  
Member, UIC Chemistry Department Review Committee (2001)  
Member, X15A Participating Research Team, National Synchrotron Light Source (1997-2000)  
Member, BES Synchrotron Radiation Center Collaborative Access Team, Advanced Photon Source (1992-2000)  
Member, BESSRC-CAT Users Committee (1995-1997)  
Member, BESSRC-CAT Executive Committee (1997-2000)  
Member, ANL Environmental Research Division Promotion and Hire Committee (1997-2000)

### **Miscellaneous International Activities**

Consultant, Kuwait Institute for Scientific Research, environmental assessments for power-desalination plants (2008-2009)  
Consultant, Cairo University Center for Environmental Hazard Mitigation, design of environmental laboratory (1994-1995)  
Consultant, British Geological Survey, Northern Kenya Rift geothermal exploration program (1991)  
Invited Panelist, Workshop on Nevado del Ruiz Volcano, Manizales, Colombia (1988)  
Participant, Fifth International Conference on Basement Tectonics, Cairo, Egypt (1986)  
Participant, IGCP Symposium, "*Crustal Evolution of the Arabian-Nubian Shield*", Jeddah, Saudi Arabia (1982)  
Member, Scientific Party, R/V *New Horizon* cruise to East Pacific Rise, 9°N (1979)

### **Invited Lectures Other Than Professional Meetings:**

1987-2000:

Associated Colleges of the Chicago Area - Nuclear  
Chemistry Seminar Series  
California Institute of Technology  
Carnegie Institution of Washington  
Egyptian Geological Survey & Mining Authority (Cairo)  
Geological Society of Washington  
Geological Survey of Japan  
Institute of Geological & Nuclear Sciences (New Zealand)  
Kyoto University (Japan), Kyushu University (Japan)

Los Alamos National Laboratory  
Miami University  
Northern Illinois University  
28th North Jersey Junior Science & Humanities Symp.  
Northwestern University  
Purdue University  
U.S. Geological Survey (Menlo Park, CA)  
U. S. Geological Survey (Reston, VA)  
Universite Blaise Pascal (France)

University of Chicago  
University of Grenoble (France)  
University of Illinois at Chicago  
University of Illinois at Urbana-Champaign  
University of Iowa  
University of Maryland

University of Oklahoma  
University of Paris (France)  
University of Southern California  
University of Wisconsin – Madison  
Washington University

Feb. 14, 2001	“Revelations at Mineral-Water Interfaces”	Miami University, Oxford, OH
Oct. 3, 2001	“Revelations at Mineral-Water Interfaces”	Rensselaer Polytechnic Institute, Troy, NY
Dec. 3, 2001	“Hot springs, isotopes, and X-rays”	University of Wisconsin, Madison, WI
Jan. 18, 2002	“Revelations at Mineral-Water Interfaces”	Northwestern University, Evanston, IL
Mar. 22, 2002	“Revelations at Mineral-Water Interfaces”	University of New Mexico, Albuquerque, NM
May 5, 2002	“Environmental Isotopes and the Hydrologic Cycle”	Ain Shams University, Cairo, Egypt
April 17, 2003	“Ancient Waters of the Sahara”	SUNY University at Buffalo, NY
May 20, 2003	“Environmental Forensics Using Stable Isotopes”	Association of Engineering Geologists, Chicago, IL
May 15, 2004	“Ancient Waters of the Sahara”	University of Chicago, Chicago, IL
Sept. 24, 2004	“Ancient Waters of the Sahara”	Washington University, St. Louis, MO
Dec. 20, 2004	“Ancient Waters of the Sahara”	Ain Shams University, Cairo, Egypt
Mar. 3, 2005	“Ancient Waters of the Sahara”	University of Kentucky, Lexington, KY
Apr. 4, 2005	“Ancient Waters of the Sahara”	Western Michigan University, Kalamazoo, MI
Oct. 7, 2005	“Environmental Isotope Forensics of Perchlorate”	University of Illinois at Chicago, Chicago, IL
Oct. 11, 2006	“Environmental Isotope Forensics of Perchlorate”	U. S. EPA Region V, Chicago, IL
May 1, 2007	“Environmental Isotope Forensics of Perchlorate”	U. S. EPA Region V, Chicago, IL
Oct. 15, 2008	“Environmental Isotope Forensics of Perchlorate”	American Inst. Prof. Geologists, Chicago Chapter
Feb. 25, 2010	“Environmental Isotope Forensics of Perchlorate”	University of Wisconsin at Milwaukee
Apr. 15, 2010	“Environmental Isotope Forensics of Perchlorate”	University of Texas at Arlington
Nov. 11, 2010	“Environmental Isotope Forensics of Perchlorate”	Purdue University

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K-12 Teachers:

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 (Argonne and UIC)

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 Dr. J.K. Bohlke (geochemist)  
 Dr. Evilene Bowley (environmental chemist)  
 Dr. Likwan Cheng (materials scientist)  
 Dr. Ron Chiarello (physicist)  
 Dr. John Hanchar (mineralogist)  
 Dr. Lin Huang (geochemist)  
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 Dr. Roy Wogelius (geochemist)  
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Dr. Ron Chiarello (physicist)  
 Dr. Paul Fenter (physicist)  
 Dr. Ben Holt (analytical chemist)

Technical Staff (UIC):

Ms. Linnea Heraty (environmental geochemist)  
 Ms. Leslie Patterson (geochemist)  
 Mr. Abe Beloso, Jr. (geochemist)

**Neil C. Sturchio: Research Funding History (as PI)**

Period of Grant: 10/1/1986-9/30/1987  
Amount: \$116,000  
Source: DOE Office of Basic Energy Sciences/Geosciences Research Program  
Project Title: *Trace Element Transport in Lithic Material by Fluid Flow at Elevated Temperature*

Period of Grant: 10/1/1987-9/30/1994  
Amount: \$1,494,000  
Source: DOE Office of Basic Energy Sciences/Geosciences Research Program  
Project Title: *Hydrothermal System Evolution*  
Supplemental Capital Equipment Funds: \$251,000 (1990)  
Justification: Purchase of VG Prism II Isotope Ratio Mass Spectrometer  
Supplemental Capital Equipment Funds: \$64,000 (1991)  
Justification: Purchase of HPGe Gamma Spectrometry System  
Supplemental Capital Equipment Funds: \$30,000 (1993)  
Construction of Laser/Fluorination Apparatus

Period of Grant: 10/1/1988-9/30/1990  
Amount: \$50,000  
Sources: U. S. Geological Survey/Water Resources Division  
Project Title: *Application of U, Ra, and Th Isotopes in Characterizing the Hydrogeology of Mammoth Hot Springs and the Adjacent Yellowstone Valley*

Period of Grant: 10/1/1990-9/30/1993  
Amount: \$255,000  
Source: DOE Office of Basic Energy Sciences/Geosciences Research Program  
Project Title: *Petroleum Maturation Processes*

Period of Grant: 10/1/1991-9/30/1996  
Amount: \$2,065,000  
Source: DOE Office of Basic Energy Sciences/Geosciences Research Program  
Project: *Mineral-Fluid Interactions*  
Supplemental Capital Equipment Funds: \$150,000 (1992)  
Justification: Purchase of Multielement X-ray Detector  
Supplemental Capital Equipment Funds: \$142,000 (1993)  
Justification: Purchase of X-ray Scattering Spectrometer  
Supplemental Capital Equipment Funds: \$112,000 (1994)  
Justification: Purchase of X-ray Scattering Spectrometer  
Supplemental Capital Equipment Funds: \$80,000 (1995)  
Justification: Equipment for X-ray Scattering Station at APS

Period of Grant: 10/1/1995-9/30/1996  
Amount: \$75,000  
Source: Argonne National Laboratory/Laboratory-Directed Research and Development Program  
Project: *Stable Isotopic Investigations of the Chemical and Biological Degradation of Chlorinated Organic Solvents*

Period of Grant: 10/1/1996-9/30/1999  
Amount: \$825,000  
Source: DOE Environmental Management Science Program  
Project: *Stable Isotopic Investigations of In Situ Bioremediation of Chlorinated Organic Solvents*

Period of Grant: 10/1/1996-9/30/1999  
Amount: \$1,860,000  
Source: DOE Office of Basic Energy Sciences



Project: *Mineral-Fluid Interactions: Synchrotron Radiation Studies at the Advanced Photon Source*  
           Supplemental Capital Equipment Funds: \$225,000 (1996)  
           Justification: Equipment for X-ray Scattering/Standing Wave Station at APS  
           Supplemental Capital Equipment Funds: \$197,000 (1997)  
           Justification: Equipment for X-ray Scattering/Standing Wave Station at APS  
           Supplemental Capital Equipment Funds: \$245,000 (1998)  
           Justification: Equipment for Beamline Construction at APS (\$115,000)  
                           Purchase of Atomic Force Microscope (\$130,000)

Period of Grant: 10/01/1999 – 09/30/2002  
 Amount: \$1,646,000  
 Source: DOE Office of Basic Energy Sciences/Geosciences Research Program  
 Project: *Mineral-Fluid Interactions: Synchrotron Radiation Studies at the Advanced Photon Source*  
           Supplemental Capital Equipment Funds: \$520,000  
           Justification: Equipment for Beamline Construction at APS

Period of Grant: 3/15/2002-4/14/2004  
 Amount: \$90,469  
 Source: NSF/Hydrological Sciences  
 Title: *Residence Time of Nubian Aquifer Determined Using Atom-Trap Trace Analysis of Krypton-81*

Period of Grant: 1/15/2003 – 1/14/2006  
 Amount: \$180,773  
 Source: DOE Office of Basic Energy Sciences/Geosciences Research Program  
 Project: *Mineral-Fluid Interactions: Synchrotron Radiation Studies at the Advanced Photon Source*  
 Effort: 2.0 months summer

Period of Grant: 11/24/2003 – 9/30/2004  
 Amount: \$10,000  
 Source: Oak Ridge National Laboratory  
 Project: *Environmental Isotope Forensics of Perchlorate Contamination*

Period of Grant: 7/1/2004-6/30/2007  
 Amount: \$197,399  
 Source: NSF/Hydrological Sciences  
 Title: *Krypton Isotope Hydrology*

Period of Grant: 1/1/2005-12/30/2006  
 Amount: \$63,500  
 Source: Metropolitan Water Reclamation District of Greater Chicago  
 Title: *Stable Isotope Study of Nitrate in the Illinois River Waterway*

Period of Grant: 11/1/2005-10/31/2007  
 Amount: \$120,000  
 Source: Henry and Camille Dreyfus Foundation Postdoctoral Fellowship in Environmental Chemistry  
 Title: *Exploring radiokrypton applications in environmental science: climate change, groundwater, and contaminant transport*

Period of Grant: 1/15/2006 – 1/14/2009  
 Amount: \$157,846  
 Source: DOE Office of Basic Energy Sciences/Geosciences Research Program  
 Project: *Mineral-Fluid Interactions: Synchrotron Radiation Studies at the Advanced Photon Source*  
 Effort: 2.0 months summer

Period of Grant: 1/1/2008-12/30/2008  
 Amount: \$29,200

Source: Metropolitan Water Reclamation District of Greater Chicago  
Title: *Stable Isotope Study of Nitrate in the Illinois River Waterway*

Period of Grant: 7/1/2008-12/31/2009  
Amount: \$102,000  
Source: Metropolitan Water Reclamation District of Greater Chicago  
Title: *Greenhouse Gas Emissions from the Stickney Water Reclamation Plant*

Period of Grant: 1/15/2009 – 1/14/2012  
Amount: \$185,729  
Source: DOE Office of Basic Energy Sciences/Geosciences Research Program  
Project: *Mineral-Fluid Interactions: Synchrotron Radiation Studies at the Advanced Photon Source*  
Effort: 2.0 months summer

Period of Grant: 1/1/2011 – 12/31/2012  
Amount: \$89,608  
Source: NSF/EAR-Instrumentation and Facilities  
Project: *Upgrade of Gamma Spectrometry Facility at the Environmental Isotope Geochemistry Laboratory of the University of Illinois at Chicago*

Period of Grant: 1/15/2012 – 1/14/2015  
Amount: \$341,035  
Source: DOE Office of Basic Energy Sciences/Geosciences Research Program  
Project: *Mineral-Fluid Interactions: Synchrotron Radiation Studies at the Advanced Photon Source*  
Effort: 2.0 months summer

Period of Grant: 4/1/2012 – 3/31/2013  
Amount: \$25,000  
Source: NSF Earth Sciences Division  
Project: *First International Workshop on Tracer Applications of Noble Gas Radionuclides in the Geosciences*

#### **Research Funding History as co-PI**

Period of Grant: 7/1/1994-6/30/1995  
Amount: \$10,180  
Source: NATO  
Project: *Applied Fluid Geochemistry to Hydrological, Environmental, and Volcanological Studies in the Canary Islands, Spain (with N. Perez)*

Period of Grant: 1/1/1995-12/30/1999  
Amount: \$3,000,000  
Source: U.S.D.A./Egyptian Ministry of International Cooperation  
Project: *Center for Environmental Hazard Mitigation, Cairo University, Giza, Egypt (with M. Sultan and others)*

Period of Grant: 7/01/2001 – 6/30/2004  
Amount: \$520,445 (\$75,000 to UIC)  
Source: NASA  
Project: *Assessment, Monitoring, and Modelling of Land-Cover, Land-Use Changes and Their Impacts on Groundwater Resources, Ecosystems, and Carbon Cycling in Saharan Africa: A Case Study, SW Egypt (with M. Sultan and R. M. Miller)*

Period of Grant: 1/01/2002-12/31/2004  
Amount: \$375,000 (\$80,000 to UIC)  
Source: NASA Astrobiology Program  
Project: *Biogeochemical Mars-like Environments (with J. Banfield, G. Luther, D. Emerson, and E. Roden)*

Period of Grant: 9/1/2002-8/31/2005  
 Amount: \$45,000 (21,000 to UIC)  
 Source: U.S.-Egypt Joint Science and Technology Fund (via USDA)  
 Title: *Environmental Assessment of Natural Radioactivity and Heavy Metal Pollution, El Fayoum area, Egypt* (with B. El Kaliouby, Y. Dawood, and M. Sultan)

Period of Grant: 4/15/03-9/14/05  
 Amount: \$540,000  
 Source: DOE Environmental Management Science Program  
 Project: *Reactivity of Primary Soil Minerals and Secondary Precipitates beneath Leaking Hanford Waste Tanks* (with K. L. Nagy)

Period of Grant: 3/1/05-9/30/07  
 Amount: \$1,142,500 total (\$165,000 to UIC)  
 Source: Environmental Science and Technology Certification Program (DoD)  
 Project: *Validation of Chlorine and Oxygen Isotope Ratio Analysis to Differentiate Perchlorate Sources and To Document Perchlorate Biodegradation* (with P. Hatzinger, J.K. Bohlke, and B. Gu)

Period of Grant: 4/1/2005-3/30/2008  
 Amount: \$107,941 to UIC  
 Source: DOE Atmospheric Sciences Program  
 Title: *Determining Aerosol Mean Residence Times and Black Carbon Washout Rates With Natural Radionuclides and Isotopic Signatures* (with J. Gaffney and T. Guilderson)

Period of Grant: 6/1/2005-5/30/2006  
 Amount: \$100,000 to UIC  
 Source: The Wetlands Initiative  
 Title: *Baseline Study of Carbon and Nitrogen Cycle in Goose Pond Engineered Wetland Project Area* (with M. Gonzalez-Meler)

Period of Grant: 03/01/2006 – 9/30/2008  
 Amount: \$732,613 (\$550,000 to UIC)  
 Source: DOE/Environmental Management Science Program  
 Title: *Nucleation and Precipitation Processes in the Vadose Zone during Contaminant Transport* (with K. L. Nagy, L. Soderholm, and C. Darnault)

Period of Grant: 4/1/2007 – 3/31/10  
 Amount: \$412,216  
 Source: NSF/EAR – Instrumentation and Facilities  
 Title: *Development of New Instrumentation for Laser Atom-Trap Analysis of Radiokrypton* (with Z.T. Lu and A.M. Davis)

Period of Grant: 9/7/2008-9/6/2012  
 Amount: \$170,000 to UIC  
 Source: DOD-SERDP  
 Title: *Formation mechanisms and isotopic characteristics of natural perchlorate* (with P. Hatzinger, Shaw Inc.; A. Jackson, Texas Tech; J.K. Bohlke, USGS; B. Gu, ORNL)

Period of Grant: 6/1/2009 – 5/31/11  
 Amount: \$231,812  
 Source: NSF/EAR – Petrology and Geochemistry  
 Title: *New Insights on Mantle Volatiles from Noble Gas Radionuclides* (with Reika Yokochi)

Period of Grant: 8/16/2009 – 8/15/12  
Amount: \$418,210  
Source: NSF/DEB – Ecosystem Science Cluster  
Title: *Effects of long-term elevated CO<sub>2</sub> on earthworm populations, bioturbation and carbon sequestration in soils* (with Y. Sanchez de Leon & M. Gonzalez-Meler)

Period of Grant: 10/1/2009 – 9/30/2012  
Amount: \$147,000 to UIC  
Source: DOD/SERDP  
Project: *Evaluation Of Perchlorate Sources In the Rialto-Colton-Fontana Area Using Chlorine And Oxygen Stable Isotope Ratio Analysis And Depth-dependent Water Quality Data* (with P. Hatzinger, Shaw Inc.; A. Jackson, Texas Tech; J.K. Bohlke and J. Izbicki, USGS)

Period of Grant: 8/1/2010 – 7/31/2015  
Amount: \$2,000,000 to UIC  
Source: EPA-Great Lakes National Program Office  
Project: *Great Lakes Sediment Surveillance Program (GLSSP)* (with A. Li, UIC; K. Rockne, UIC; and J.P. Giesy, University of Saskatchewan)

Period of Grant: 3/1/2011 – 1/31/2015  
Amount: \$180,000 to UIC  
Source: DOD/SERDP  
Project: *Tracking the Uptake, Translocation, Cycling, and Metabolism of Munitions Compounds in Coastal Marine Ecosystems Using Stable Isotope Tracers* (with C. Tobias and P. Vlahos, U. Connecticut; J.K. Böhlke, USGS; S. Fallis, Naval Air Warfare Center)

Period of Grant: 3/1/2012 – 2/28/2014  
Amount: \$595,000 (\$125,000 to UIC)  
Source: DOD/SERDP  
Project: *Validation of Stable Isotope Ratio Analysis to Document the Biodegradation and Natural Attenuation of RDX* (with P. Hatzinger and M. Fuller, Shaw Environmental; J.K. Böhlke, U.S. Geological Survey)

## **Neil C. Sturchio: Publications**

### **BOOKS EDITED:**

Fenter P., Rivers M. L., Sturchio N. C. and Sutton S. (Eds.), 2002. Applications of Synchrotron Radiation in Low-Temperature Geochemistry and Environmental Science. *Reviews in Geochemistry and Mineralogy*, Vol. 49. 579 p.

### **PATENTS:**

U.S. Patent # 5,942,439. Ben D. Holt and Neil C. Sturchio. Method for Isotopic Analysis of Chlorinated Organic Compounds (issued 8/28/1999).

### **PAPERS AND BOOK CHAPTERS (Chronological Order) [ISI h-index = 39; times cited = 4,001 as of 10.25.2011]**

1. Sturchio, N.C., M. Sultan, & R. Batiza, 1983. Geology and origin of Meatiq Dome, Egypt: A Precambrian metamorphic core complex? *Geology*, 11: 72-76.
2. Sturchio, N.C., M. Sultan, P. Sylvester, R. Batiza, C. Hedge, E. El Shazly, and A. Abdel Meguid, 1984. Geology, age, and origin of the Meatiq Dome: Implications for the Precambrian stratigraphy and tectonic evolution of the Eastern Desert of Egypt. In: A. Al Shanti (ed.), *Pan-African Crustal Evolution of the Arabian-Nubian Shield*,

3. Sturchio, N.C. & K. Muehlenbachs, 1985. Origin of low-<sup>18</sup>O metamorphic rocks from a Late Proterozoic shear zone in the Eastern Desert of Egypt. *Contributions to Mineralogy and Petrology*, 91: 188-195.
4. Sturchio, N.C. & M.G. Seitz, 1985. Behavior of nuclear waste elements during hydrothermal alteration of glassy rhyolite in an active geothermal system: Yellowstone National Park, Wyoming. In: C. Jantzen, J. Stone and R. Ewing (eds.), *Scientific Basis for Nuclear Waste Management*, VIII: 557-564. Materials Research Society.
5. Sturchio, N.C., K. Muehlenbachs, & M.G. Seitz, 1986. Element redistribution during hydrothermal alteration of rhyolite in an active geothermal system: Yellowstone drill cores Y-7 and Y-8. *Geochimica et Cosmochimica Acta*, 50: 1619-1631.
6. Sultan, M., R. Batiza, & N.C. Sturchio, 1986. The origin of small-scale geochemical and mineralogic variations in a granite intrusion. *Contributions to Mineralogy and Petrology*, 93: 513-523.
7. Tammemagi, H.Y., B. Haverslew, & N.C. Sturchio, 1986. Investigations of the Empire Creek Stock, Montana, as an analogue to a nuclear waste repository. *Chemical Geology*, 55: 375-385.
8. Sultan, M., R. Arvidson, & N.C. Sturchio, 1986. Mapping of serpentinites in the Eastern Desert of Egypt by using Landsat Thematic Mapper data. *Geology*, 14: 995-999.
9. Sturchio, N.C., C.M. Binz, & C.H. Lewis, III, 1987. Thorium-uranium disequilibrium in a geothermal discharge zone at Yellowstone. *Geochimica et Cosmochimica Acta*, 51: 2025-2034.
10. Sultan, M., R.E. Arvidson, N.C. Sturchio, & E.A. Guinness, 1987. Lithologic mapping in arid regions with Landsat Thematic Mapper data: Meatiq Dome, Egypt. *Geological Society of America Bulletin*, 99: 748-762.
11. Sultan, M., R.E. Arvidson, & N.C. Sturchio, 1987. Reply to Comment by Greiling and El Ramly on "Mapping of serpentinites in the Eastern Desert of Egypt by using Landsat Thematic Mapper data". *Geology*, 15: 874-875.
12. Abrajano, T.A., N.C. Sturchio, J.K. Bohlke, G.L. Lyon, R. Poreda, & C.M. Stevens, 1988. Methane-hydrogen gas seeps, Zambales ophiolite, Philippines: Deep or shallow origin? *Chemical Geology*, 71: 211-222.
13. Sturchio, N.C. & C.M. Binz, 1988. Uranium-series age determination of calcite veins, VC-1 drill core, Valles Caldera, New Mexico. *Journal of Geophysical Research*, 93: 6097-6102.
14. Sturchio, N.C., T.E.C. Keith, & K. Muehlenbachs, 1988. The dynamics of silica deposition in fractures: Oxygen isotope ratios in hydrothermal silica from Yellowstone drill core Y-13. *Geothermal Resources Council Trans.*, 12: 305-312.
15. Sturchio, N.C., S.N. Williams, N. Garcia P., & A. Londono C., 1988. The hydrothermal system of Nevado del Ruiz volcano, Colombia. *Bulletin of Volcanology*, 50: 399-412.
16. Sturchio, N.C., T.A. Abrajano, J. Murowchick, & K. Muehlenbachs, 1989. Serpentinization of the Acoje Massif, Zambales ophiolite, Philippines: Hydrogen and oxygen isotope geochemistry. *Tectonophysics*, 168: 101-107.
17. Sturchio, N.C., J.K. Bohlke, & C.M. Binz, 1989. Radium-thorium disequilibrium and zeolite-water ion exchange in a Yellowstone hydrothermal environment. *Geochimica et Cosmochimica Acta*, 53: 1025-1034.
18. Cifuentes, L., C. Corselli, T.C. Hoering, K.A. Kastens, G. DeLange, D. Muller, M. Perfit, N.C. Sturchio, & W.J. Ullman, 1989. Isotopic and chemical evidence on the origin of the "Gypsum Garden" gypsum crystals, Bacino Bannock, Eastern Mediterranean Sea. In: *Anoxic Basins of the Eastern Mediterranean* (M.B. Cita, A. Camerlenghi,

and C. Corselli, eds.), University Degli Studi di Milano, Ricerca Scientifica Supplemento, 72: 63-66.

19. Abrajano, T.A., Sturchio, N.C., Kennedy, B.M., Lyon, G. L., Muehlenbachs, K. & Bohlke, J.K., 1990. Geochemistry of reduced gas related to serpentinization of the Zambales ophiolite. *Applied Geochemistry*, 5: 625-630.
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