CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD
LAHONTAN REGION

MEETING OF JUNE 13-14, 2012
BARSTOW, CA

ITEM: **3**

SUBJECT: **STATISTICAL ANALYSIS OF BACKGROUND CHROMIUM GROUNDWATER SUBSET DATA, PACIFIC GAS AND ELECTRIC COMPANY'S HINKLEY COMPRESSOR STATION, SAN BERNARDINO COUNTY**

CHRONOLOGY: This chronology lists Water Board actions related to establishing background chromium concentrations in groundwater in the Hinkley area.

November 12, 2008	Amended Cleanup and Abatement Order No. R6V-2008-0002A1 established maximum and average background chromium concentrations in groundwater for total and hexavalent chromium based on results of PG&E's 2007 Groundwater Chromium Background Study Report. Maximum background concentrations for total and hexavalent chromium are adopted at 3.2 and 3.1 parts per billion, respectively.
March 9, 2011	At its regular meeting in Barstow, Water Board members heard public concerns about the validity of the PG&E's 2007 Background Study Report, related to deviations from the Water Board-approved study plan. Water Board members directed staff to obtain scientific peer review of PG&E's 2007 Background Study Report.
December 8, 2011	Water Board staff held a public meeting in Hinkley to present results of the peer review. Peer reviewers' comments were

primarily critical of the 2007 Background Study Report. The main criticisms are: 1) lack of aquifer-specific sampling; 2) questionable statistical methods and assumptions; 3) uncertainty regarding historic plume migration, and 4) unacceptable sample analysis quality control procedures.

March 12, 2012 — The Water Board, at its regular meeting in Barstow, discusses peer review comments on PG&E's 2007 Background Study Report. PG&E staff also presents a new February 2012 background study proposal, which they developed to address peer review comments.

In response to a letter petition signed by 25 Hinkley residents, Water Board members direct that background chromium levels be re-evaluated using subset(s) of the existing dataset generated from the 2007 Background Study Report. Staff is also directed to work with the Hinkley Community Advisory Committee and other experts to review the PG&E's February 2012 background study proposal.

DISCUSSION: University of California at Davis (UCD) Statistical Laboratory staff Dr. Neil Willits conducted analysis on two data subsets derived from PG&E's 2007 Background Study Report: 1) a subset of results from wells that sampled the upper aquifer only (the intended target aquifer for determining background concentrations); and, 2) a subset of results from wells that were sampled in either all four quarters of 2006, or were sampled only in the first two quarters of 2006 (this subset screened out 30 wells added after the second quarter sampling event that may have biased the sampling results).

The first data subset (wells from the upper aquifer only) did not contain enough sampling results from which to calculate statistically meaningful results. The second dataset contained a sufficient number of sampling results (n=66) so that UCD staff could calculate upper prediction limits of

maximum background values from those data. The upper prediction limits are:

- Total chromium: 2.74 parts per billion
- Hexavalent chromium: 2.53 parts per billion

ISSUE: At issue is whether the Water Board in the future should consider replacing the currently adopted maximum background values with the re-calculated values in existing orders and/or future orders of the Lahontan Water Board. The enclosed staff report provides additional context for this item, and considerations for future Water Board actions.

RECOMMENDATION: No formal Water Board action is recommended. The Water Board may provide direction to staff as appropriate.

ENCLOSURES

Enclosure	Item	Bates Number
1	Staff Report: Summary of Statistical Analysis of Background Chromium Groundwater Subset Data, Pacific Gas And Electric Company's Hinkley Compressor Station, San Bernardino County.	**3-7**

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ENCLOSURE 1

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CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD,
LAHONTAN REGION

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Staff Report

Summary and Discussion:
Statistical Analysis of Background Chromium Groundwater Subset Data
from
Pacific Gas & Electric Company's 2007 Groundwater Chromium Background Study Report

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Lahontan Regional Water Quality Control Board
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June 2012

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Appendices

I. Background

Site History

The Pacific Gas and Electric Company (PG&E) Compressor Station is located in the Hinkley Valley of San Bernardino County, just southeast of the town of Hinkley. The Compressor Station has operated since 1952. From 1952 to 1965, a hexavalent chromium-based corrosion inhibitor was added to water used in the cooling towers, and the untreated cooling tower water was discharged to unlined evaporation ponds. The unlined ponds have since been closed, covered, and replaced by lined evaporation ponds. In 1987, PG&E reported to the State total chromium and hexavalent chromium concentrations exceeding the California drinking water standard of 50 parts per billion (ppb) total chromium in groundwater beneath and down gradient of the site.

Groundwater in the Hinkley Valley occurs in two aquifers, known as the upper aquifer and the lower aquifer, which are separated by a layer of fine-grained clay and silts. This layer, the "blue clay", restricts groundwater flow between the two aquifers. The chromium plume (as currently defined) primarily exists in the upper aquifer, although in 2009 a limited area of the lower aquifer showed hexavalent chromium concentrations above background values where the blue clay is thin or absent. PG&E has determined the extent of this limited area of contamination in the lower aquifer, since the surrounding lower aquifer has no detectable chromium concentrations.

Currently, groundwater beneath the Compressor Station contains hexavalent chromium concentrations up to 4,300 ppb. There is no drinking water standard specific to hexavalent chromium; however, in July 2011 the state of California's Office of Environmental Health Hazard Assessment (OEHHA) adopted a Public Health Goal (PHG) for hexavalent chromium in drinking water of 0.02 ppb. A PHG is not an enforceable standard, but an estimate of the level of a contaminant in drinking water that would pose no significant health risk from consuming the water on a daily basis over a lifetime. Adoption of a PHG is the first step in setting an enforceable standard for a contaminant in drinking water.

PG&E's 2007 Background Study Report and Adopted Background Chromium Groundwater Levels

State Water Board Resolution No. 92-49 requires that dischargers clean up waste to either background water quality, or the best water quality which is reasonable if background levels of water quality cannot be restored, while protecting water quality for existing and future beneficial uses. In July 2002, PG&E submitted a study proposal for determining background levels of total and hexavalent chromium in groundwater in the Hinkley area, entitled *Scope of the Background Chromium Study* (the 2002 Background Study Plan). The 2002 Background Study Plan was peer reviewed through the

University of California, and revised in 2004 by PG&E to address peer review and Water Board staff comments.

In November 2004, Water Board staff conditionally approved the 2004 Revised Background Study Plan, including proposals to sample from fifteen to twenty wells over four consecutive quarters, and conduct depth-discrete sampling in five wells.

PG&E conducted groundwater sampling for the Background Study throughout 2006. In February 2007, PG&E submitted the *Groundwater Background Study Report, Hinkley Compressor Station, Hinkley, California*, dated February 28, 2007 (the 2007 Background Study Report). The 2007 Background Study Report presented the sampling data and the results of statistical analysis of the data.

At a public hearing in November 2008, the Lahontan Water Board adopted amended Cleanup Order No. R6V-2008-0002A1, establishing the following background chromium concentrations for the Hinkley area, based on data in the 2007 Background Study Report:

- Maximum background total/hexavalent chromium = 3.2/3.1 ppb
- Average background total/hexavalent chromium = 1.5/1.2 ppb

Peer Review of 2007 Background Study Report

At a meeting of the Lahontan Water Board in March 2011, several Hinkley residents expressed concerns about the validity of the PG&E's 2007 Background Study Report. Of particular concern were deviations from the 2004 Revised Background Study Plan, where PG&E added a significant number of wells concentrated in one area, without the specific locations or numbers accepted in advance by Water Board staff. The 2004 Revised Background Study Plan proposed sampling fifteen to twenty well locations during each sampling event. By the Study's end, a total of forty-eight well locations in the Hinkley area were sampled. Of these forty-eight wells, thirty were added after the first two sampling events, with twenty-three of those wells concentrated in one area near a well which showed the highest concentrations of chromium detected in the first two sampling events (well BGS-04). The explanation given in the 2007 Background Study Report was that the additional wells were added to compensate for not completing depth-discrete sampling at three well locations.

In addition, since the chromium plume had expanded beyond the previously delineated boundaries, concerns were expressed that the background study had incorporated wells that did not represent background chromium, but instead were affected by PG&E's waste chromium discharges.

In response to these issues, Lahontan Water Board members directed staff to obtain scientific peer review of the 2007 Background Study Report.

During summer 2011, three peer reviewers were identified through Cal/EPA's Scientific Peer Review Program. The reviewers were selected for their expertise in analytical chemistry, groundwater modeling, statistics, hydrogeology and chromium remediation, and underwent a rigorous conflict-of-interest disclosure process. Reviews were completed in October 2011, and in December 2011, Water Board staff held a public meeting in Hinkley to summarize the peer reviewers' comments. The peer reviewers identified several shortcomings in 2007 Background Study Report. Four primary criticisms were noted:

1) Ninety-two percent of the wells (44 out of 48) sampled were long-screened wells that sampled groundwater mixed from the upper and lower aquifers in the Hinkley Valley, rather than sampling only the upper aquifer. The upper aquifer was intended to be the target aquifer for the study. Sample results from mixed aquifer groundwater do not give specific information on water quality in the upper aquifer, and should not be used to calculate background values.
2) Laboratory quality control procedures were not properly followed for several sample groups, such that the results from those groups should not be used to calculate background values.
3) Assumptions regarding the statistical distribution of the data may have been incorrect since data from wells were averaged and the average values were used to calculate background values. Background values were calculated using parametric statistical methods, which require that the data be normally distributed, which is a questionable assumption. A further discussion on data distribution and statistical test choices is provided in Section II of this staff report.
4) Uncertainty regarding historical groundwater flow patterns. Groundwater pumping, irrigation, and climate events may have produced a different plume pattern than is observed now, leaving behind dispersed levels of waste chromium which could make background levels difficult to assess. The long period of time since the release of chromium from the cooling towers (between 1952 and 1965), and the lack of detailed information on the locations and rates of historical pumping make it difficult to accurately model localized plume migration patterns since the 1950s.

Water Board Actions on Peer Review Findings

At the March 2012 Water Board meeting in Barstow, Water Board staff presented the results of the peer review to Board members and the public (agenda item 12, heard on March 15, 2012). Agenda item 12 included a staff report which provided details of the peer review findings, regulatory and planning issues related to background levels, and options for the Water Board's consideration to address peer review comments. The March 2012 staff report is available at http://www.waterboards.ca.gov/lahontan/water_issues/projects/pge/index.shtml.

Also at the March 2012 Board meeting, PG&E staff presented their newly developed *Workplan for Evaluation of Background Chromium in the Groundwater of the Upper Aquifer of the Hinkley Valley,* dated February 22, 2012 (the February 2012 Workplan).

The February 2012 Workplan outlines a proposal to conduct a new groundwater sampling program to address the peer review comments on the 2007 Background Study Report, and includes PG&E's point-by-point responses to the peer reviewers' comments.

As part of agenda item 12, twenty-five Hinkley residents submitted a letter and signature petition to Water Board members. The letter requested that rather than start a new background study, the Water Board should use only the data in the 2007 Background Study that was compliant with the approved 2004 Revised Background Study Plan to re-calculate a new background number that could be used in the immediate future. A copy of the letter and petition is included in Appendix 1 to this report.

Following presentations, public comments and discussion, Water Board members directed its staff to move forward on two parallel tracks:

1) Work with University of California at Davis Statistical Laboratory to re-assess background values of chromium from subsets of the data generated during the 2006 sampling for the 2007 Background Study Report. The intent is to determine if statistically valid background values could be calculated from subsets of the original data after screening out sampling results which are not acceptable based on the peer reviewers' comments. This effort is discussed in Sections II and III of this report.

2) Work with the Hinkley Community Advisory Committee and its consultant, and other experts (such as the US Geological Survey, and the 2011 peer reviewers) to review the PG&E's February 2012 Workplan. This effort is discussed in Section IV.

II. Data Subsets and Statistical Methods

2007 Background Study Report Data Subsets

Data subsets were developed by first removing all results from the 2007 dataset for sample results that did not follow proper lab quality control procedures. Then, the remaining data were divided into 2 subsets: 1) a subset of results from wells that sampled the upper aquifer only (the intended target aquifer for determining background concentrations); and 2) a subset of results from wells that were sampled either in all four quarters of 2006, or were sampled only in the first two quarters of 2006 (this subset screened out 30 wells added after the second quarter sampling event that may have biased the sampling results). Data subsets are provided in Appendix 2.

Statistical Methods

Dr. Neil Willits of the University of California at Davis Statistical Laboratory used "non-parametric" statistics to estimate a 95 percent upper prediction limit for total and hexavalent chromium for the data subsets. According to Dr. Willits, a non-parametric statistical method is a more appropriate choice than the parametric method used in the 2007 Background Study Report. This is because parametric methods require that the data be "normally distributed", and this requirement was not met with strong enough evidence in the background data subsets.

Dr. Willits explained that under the best of circumstances, the most that can be shown is that the data are consistent with an assumption of normality (or if the log concentrations are being used, then log-normality), which falls short of demonstrating that the data are in fact normally distributed. Data that are normally distributed, when plotted on a histogram, look like a "bell-shaped curve", with the graph falling off evenly, or symmetrically, on either side of the average value of the data. When plotted on another type of common graph used in statistics called a quantile-quantile plot (Q-Q plot), the data will look like a roughly linear curve. When some of the values fall below the detection limit, then the portion of the Q-Q plot corresponding to values that are above the detection limit will plot as being roughly linear. That was not the case for the 2007 Background Study subset data. If the data are not normally distributed, applying a parametric statistical test which requires normally distributed data would result in errors when calculating values such as upper tolerance limits. Dr. Willits' report is included in Appendix 3.

III. Results of Statistical Analysis of Background Data Subsets

Dr. Willits considered two data subsets derived from PG&E's 2007 Background Study Report. The first data subset described above (wells from the upper aquifer only) did not contain enough sampling results from which to calculate statistically meaningful results. The second dataset contained a sufficient number of sampling results (n=66) so that 95 percent upper prediction limits of maximum background values could be determined from those data.

The 95 percent upper prediction limits are:

- Total chromium: 2.74 parts per billion
- Hexavalent chromium: 2.53 parts per billion

This analysis results in lower estimates of the maximum background chromium values than the currently adopted values. The currently adopted maximum background values for total chromium and hexavalent chromium are 3.2 and 3.1 parts per billion,

respectively. Groundwater contamination (or plume) maps are currently drawn using those adopted maximum background values.

Water Board staff looked at the most recent groundwater chromium plume map (Figure 3-1, Chromium Plume Map in the Upper Aquifer, from PG&E's First Quarter 2012 Groundwater Monitoring Report dated April 30, 2012) to assess changes to the plume boundary if the upper prediction limits bulleted above were used to draw the plume boundary. It appears that plume in the Hinkley Valley would have about four additional detached areas separated from the main plume. These detached areas are located to the west of the current plume boundary and appear similar in size and shape to those depicted in eastern portion of the current chromium plume map. Additionally, there would be perhaps four areas of minor plume bulging, with generally less than 1,000 feet of bulge. The general extent of the plume currently depicted on groundwater maps would not be substantially changed, except for the bulged and detached areas described above.

IV. Discussion

At issue is whether the Water Board should consider replacing the currently adopted maximum background values with the re-calculated values at some future time. Three points are relevant to this consideration:

1. *A Critical Issue from the 2011 Peer Review is Unresolved.*

Discussion: The data subset used to calculate the new values contains sampling data from wells screened across both the upper and lower aquifers. This was a major criticism from the 2011 peer review, because an assessment of water quality differences between two aquifers cannot be made with wells screened across both aquifers. This issue is unresolved by the data subset analysis, since the subset with results from wells screened in the upper aquifer only did not have a sufficient number of results to statistically analyze.

A new sampling effort using properly constructed monitoring wells, screened specifically in each aquifer, is the only way to overcome this issue, assuming acceptable background sampling locations can be determined.

2. *Technical Reviews of PG&E's February 2012 Workplan are Ongoing (and Slated).*

Discussion: Water Board staff is working with Dr. John Izbicki of the US Geological Survey, and the Hinkley Community Advisory Committee's consultant, Dr. Ian Webster, to review and provide comments on PG&E's February 2012 Workplan. Comments from both Dr. Izbicki and Dr. Webster are anticipated in mid-June 2012.

Concurrently, staff is working with the State Water Board's Peer Review Program Manager to develop a contract with the 2011 peer reviewers to provide additional technical advice and input to Water Board staff and the Hinkley Community Advisory Committee on PG&E's February 2012 Workplan. The contract with the 2011 peer reviewers is scheduled to be in place by summer 2012. The desired outcome is a background study design that is scientifically valid, addresses and overcomes as many of the shortcomings identified by the 2011 reviewers as possible, and is credible to the Hinkley community.

If these ongoing and upcoming technical reviews indicate that there are challenges in investigating new background values (such as determining appropriate sampling locations that represent background conditions) which cannot be addressed with a new sampling program, then the Water Board may wish to consider substituting Dr. Willet's May 2012 calculated upper prediction limits for the currently adopted values. However, until the technical reviews are completed, it would be premature to consider adopting new and potentially interim background values which do not overcome an important criticism from the 2011 peer review.

3. Whole-House Replacement Water CAO and PG&E's Proposed Expanded Replacement Water Program Lessens Concerns Regarding Current Maximum Background Levels.

Discussion: An important recent regulatory effort by the Water Board in Hinkley is amended Cleanup and Abatement Order (CAO) R6V-2011-00005A1, known as the "Whole-house Replacement Water" CAO. This CAO requires, in part, that PG&E provide whole-house replacement water to residents to whose wells exceed the current maximum background levels. It also requires PG&E to identify wells where chromium levels may be below the maximum background, but still attributable to PG&E's discharge. The CAO requires PG&E to determine whether such chromium is due to its discharge of waste, and if so, to provide whole-house replacement water.

In response to the CAO, PG&E has proposed an expanded program to provide whole-house replacement water to any household with detectable amounts of chromium in their well, within one mile of the plume. This program will alleviate many residents' health concerns about using household water with detectable amounts of chromium, and reduces the urgency for the Water Board to consider the new background values in the immediate term for the purposes of requiring replacement water. Instead, priority could be given to technical reviews of PG&E's February 2012 Workplan, along with the upcoming release of the draft Environmental Impact Report for comprehensive groundwater cleanup, and associated Waste Discharge Requirements, currently scheduled for release in July 2012. Water Board may consider a cleanup goal, including interim goals and/or a final goal, as part of a new cleanup and abatement order in 2013.

V. Recommendation

Water Board staff recommend that the upper prediction limits calculated by Dr. Willits for background chromium not be considered for adoption in the near term, while technical reviews of PG&E's February 2012 Workplan go forth. Water Board staff would instead focus on the following priorities for summer 2012:

1) Finalize the draft Environmental Impact Report for public and agency review by July 2012.
2) Develop new tentative Site-wide General Waste Discharge Requirements for comprehensive groundwater cleanup, to be circulated with the draft EIR.
3) Continue moving forward on the technical review of PG&E's February 2012 Workplan, including finalizing a contract request through the State Water Board for technical advice from the 2011 peer reviewers.

Water Board staff propose to provide a status update on the review of PG&E's February 2012 Workplan to the Board and public no later than September 2012.

Appendix 1: Letter and Petition from Hinkley Residents regarding 2007 Background Study Data, dated February 22, 2012

Concerned Hinkley Residents

Hinkley, California 92347

22 February 2012

Harold J. Singer, Executive Officer
California Regional Water Quality Control Board
2501 Lake Tahoe Boulevard
South Lake Tahoe, CA 96150

Dear Mr. Singer,

We, the people who live and/or work or own property in Hinkley, respectfully request the Water Board to conclude the 2007 Background Chromium Study by PG&E in accordance with the approved 2004 revised workplan. We want the range of naturally-occurring background chromium values in groundwater recalculated using just the wells, information, and statistics that had been approved by the Water Board. We also request that the Water Board adopt this range of background values for use in the investigation and cleanup of chromium in groundwater of the Hinkley Valley and for determining impacts to domestic, community, and agricultural wells. Further delay in concluding the study is detrimental to the Hinkley residents and the entire Hinkley Valley.

Chromium Background Values for the Hinkley Valley

The Hinkley residents shown on the enclosed lists request that the Lahontan Water Board revise the chromium background values in groundwater for the Hinkley Valley from those originally adopted in November 2008. This request is based upon the October 2011 peer review comments which criticized PG&E's 2007 Background Chromium Study.

Specifically, Hinkley residents respectfully request that the Water Board adopt non-detect levels as background values for hexavalent chromium (CrVI) and total chromium (CrT) based on depth-discrete water samples results in the 2007 Background Study. Or, that the Water Board recalculate background values using just the data obtained from the original wells approved in PG&E's 2004 revised workplan.

History

As the Water Board heard at its March 8, 2011, meeting in Barstow, Hinkley residents are concerned about the chromium background values that were adopted in November 2008. These values were 1.2 ppb average and 3.2 ppb maximum for hexavalent chromium (CrVI) and 1.5 ppb average and 3.2 ppb total chromium (CrT). The adopted values were from a background study conducted in 2006 by PG&E but significantly changed from the revised workplan approved by Board staff in 2004. After review, several residents suspected bias sample collection by PG&E during the 2006 field work and suggested that the Water Board revisit the background study.

During the summer of 2011, the Water Board contracted to have three outside parties provide peer review of the 2007 Background Study. As expected, the peer reviewers were critical of the Background Study, including the type and location of wells sampled, lab QA/QC practices, and statistical assumptions made. Based upon these comments, Hinkley residents have asked Board staff on numerous occasions what will be their recommendation to the Water Board. The answer we usually heard back was "we don't know."

Significance of Background Values

Hinkley residents are very concerned about the numbers representing the chromium background values in groundwater in the Hinkley Valley. Water Board staff have consistently told the public that background values will be used to set cleanup standards for PG&E's chromium plume. Yet, we all know that the background values are used in other applications, including those directly affecting Hinkley residents' daily lives.

As you know, the background values are used to draw the chromium plume boundaries in quarterly reports. PG&E uses these boundaries to decide who is offered bottled water and who isn't, beyond that listed in the Board's October 2011 cleanup and abatement order. PG&E also uses the plume boundaries and chromium values in domestic wells when deciding who to make offers of property purchase and the amount of purchase. Last, background values will be used in the near future for determining which residents will be offered whole house replacement water required in the Board's October 2011 cleanup and abatement order. Use of the chromium background values for the last three reasons listed is of more immediate concern to Hinkley residents than is the overall plume cleanup, which is projected to occur over many decades.

Therefore, the need to set un-biased, revised chromium background values in the Hinkley Valley is one that residents prefer happen sooner rather than later.

Residents' Recommendation

Hinkley residents are recommending that the Water Board use only those portions of the 2007 Background Study that follow PG&E's September 2004 revised workplan. This means that only data obtained from depth-discrete samples and wells sampled during all four quarters in 2006 are valid. As you will recall, the 2004 revised workplan was prepared based on the comments of three University of California peer reviewers. PG&E's deviation in implementing the workplan was not subject to peer review.

The revised workplan stated that PG&E would collect depth-discrete samples from a total of five wells. Since depth-discrete water samples were collected from only two wells, the Water Board should focus on the results from such wells, 36-01 and BGS-24 (located in the upgradient and cross directions of the plume), in which the lab reported non-detect concentrations (0.2 ppb CrVI and 1.0 ppb CrT). There appears to be no evidence in the Background Study that PG&E tried to collect samples from three more wells. This makes Hinkley residents question whether PG&E just abandoned the effort when it became obvious that all depth-discrete samples might end up being non-detect—the true natural chromium background levels in the Hinkley groundwater.

If depth-discrete well sample results are ignored, the Water Board should then focus on just wells that were sampled in all four quarters during 2006. In this case, only data from the original 14 wells would be used for calculating background values and the data from the 34 added wells would be ignored. It is obvious that PG&E included the latter wells to artificially raise the chromium background values, especially since 23 of the 34 wells were from one specific location west of the chromium plume. Using the data obtained from just the original 14 wells, we recommend that the Water Board arrange for someone from academia to apply the appropriate statistical analyses mentioned in the peer review for calculating background values. If these results should show a 5 percent or greater change from the 2008 adopted background values, the new numbers should be adopted by the Water Board as revised background chromium values.

In Conclusion

The results of the October 2011 peer review suggest that PG&E conducted a biased background study that yielded questionable data and statistical results. The unauthorized additions made by PG&E to the

2006 field work over that listed in the 2004 revised workplan were obviously done to promote biased background values greater than what was intended in the workplan approved by Water Board staff.

Given this history, PG&E and its easily-manipulated consultant, CH2MHill, cannot be trusted to conduct a supplemental background study. Furthermore, as one of the peer reviewers noted, extensive agricultural pumping in the Hinkley Valley and the length of time since chromium discharge (now over 50 years), makes it impossible to know what is background groundwater and what isn't. The Hinkley residents fear that PG&E will try to manipulate the Water Board with the suggestion that they will concoct another background study. This would be absurd as who in their right mind would actually believe the results of a new study conducted by PG&E? Most certainly not the Hinkley residents!

In conclusion, the only recourse that is fair to the Hinkley residents is to salvage as much of the 2007 Background Study as possible. This means using only data that was obtained from following the revised workplan approved by Board staff - and nothing else. This data would yield chromium background values which are more realistic and more likely to be accepted by the Hinkley residents. The apparent biases reflected in current background values from PG&E's flawed background study will never be accepted by the Hinkley residents. Using relevant data from the 2007 Background Study will provide revised background values that can be used in the *immediate* future as well as the long-term future.

Hinkley residents look forward to your decision on evaluating the adoption of revised chromium background values.

Sincerely,

Carmela Spasojevich, a Hinkley property owner
On behalf of the Hinkley Residents (Please see attached petitions)

Enclosure: Signed Petitions Listing Hinkley Residents Supporting this Letter (2 pages)

To: The California Regional Water Quality Control Board, Lahontan Region

We, the people who live and/or work in Hinkley, respectfully request the Water Board to conclude the 2007 Background Chromium Study by PG&E, in accordance with the approved 2004 revised workplan. We want the range of naturally-occurring background chromium values in ground water re-calculated using just the wells, information, and statistics that had been approved. And we want the Water Board to adopt this range of background values for use in the investigation and cleanup of chromium in ground waters of the Hinkley Valley and for determining impacts to domestic, community, and agricultural wells. Further delay in concluding the study is detrimental to Hinkley.

Printed Name	Signature	I Live in Hinkley (check here)	I work in Hinkley (check here)
1. Karen Dodd	Karen Dodd	✓	✓
2. JAMES DODD	James Dodd	✓	
3. Jackie Jones	Jackie Jones	✓	
4. NAZ AWAD	Naz Awad	✓	
5. Richard LEVEALY	Richard Levealy	✓	✓
6. Patricia Dickmann	Patricia Dickmann	✓	✓
7. Elaine Kearney	Elaine L Kearney	✓	
8. Barbara Groveau	Barbara Groveau	✓ part time	
9. Greg Kearney	Greg Kearney	✓	
10. PAUL GREENBERG	Paul Greenberg	✓	
11. Sandra K Wotherington	Sandra K Wotherington	✓	
12. ROGER SANDOZ	Roger Sandoz	✓	✓
13. JOYCE WHITE	Joyce White	✓	
14. YVONNE NETHERY	Yvonne Nethery	✓	
15. HERBERT NETHERY	Herbert Nethery	✓	
16. Scott Hasley	Scott Hasley	✓	
17 SHARON HASLIP	Sharon Haslip	✓	
18. Aaron Banks	Aaron Banks	✓	

To: The California Regional Water Quality Control Board, Lahontan Region

We, the people who live and/or work in Hinkley, respectfully request the Water Board to conclude the 2007 Background Chromium Study by PG&E, in accordance with the approved 2004 revised workplan. We want the range of naturally-occurring background chromium values in ground water re-calculated using just the wells, information, and statistics that had been approved. And we want the Water Board to adopt this range of background values for use in the investigation and cleanup of chromium in ground waters of the Hinkley Valley and for determining impacts to domestic, community, and agricultural wells. Further delay in concluding the study is detrimental to Hinkley.

Printed Name	Signature	I Live in Hinkley (check here)	I work in Hinkley (check here)
1. JAY POTTER	J Potter	X	X
2. McHENRY Cooke	McHenry Cooke	X	
3. Gina Romero	Gina Romero	X	
4. Gilbert Romero	Gilbert Romero	X	
5. Amber Dodd	Amber Dodd	X	X
6. IAN Frazier			
7. Virginia A. Davis	Virginia A. Davis	X	
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Appendix 2: Data Subsets from the 2007 Background Study

Data Subset 1: Upper Aquifer Wells

Well ID	Sample Date	2006 Calenday Year Quarter Sampled	Total Cr ppb (ND<1 ppb)	Hexavalent Cr ppb (ND<0.2 ppb)
BGS-04	2/1/2006	1st Q	2.39	2.5
	4/26/2006	2nd Q	2.74	2.4
	7/25/2006	3rd Q	2.65	2.53
	10/23/2006	4th Q	2.77	2.6
BGS-15	1/31/2006	1st Q	0.5	0.1
	4/26/2006	2nd Q	0.5	0.1
	7/25/2006	3rd Q	0.5	0.1
	10/23/2006	4th Q	0.5	0.1
BGS-01	1/31/2006	1st Q	0.5	0.32
	4/25/2006	2nd Q	0.5	0.495
	7/25/2006	3rd Q	0.5	0.1
	10/23/2006	4th Q	0.5	0.328
well 01-06	7/27/2006	3rd Q	2.68	0.1
		Number of Samples	**13**	**13**

Notes:

1. For duplicate samples, the lowest value measured was recorded.
2. These data are from wells screened in the upper aquifer only.
3. Non detects were converted to 1/2 of the detection limit on this spreadsheet tab, and highlighted in yellow.
4. All bad QC data are removed.

Data Subset 2: Wells sampled all 4 quarters or not added after second event.

Well ID	Sample Date	2006 Calenday Year Quarter Sampled	Total Cr ppb (ND<1 ppb)	Hexavalent Cr ppb (ND<0.2 ppb)
BGS-04	2/1/2006	1st Q	2.39	2.5
	4/26/2006	2nd Q	2.74	2.4
	7/25/2006	3rd Q	2.65	2.53
	10/23/2006	4th Q	2.77	2.6
BGS-16	1/31/2006	1st Q	1.36	1.35
	4/24/2006	2nd Q	2.05	1.77
	7/25/2006	3rd Q	1.77	1.45
	10/23/2006	4th Q	1.77	1.66
BGS-15	1/31/2006	1st Q	0.5	0.1
	4/26/2006	2nd Q	0.5	0.1
	7/25/2006	3rd Q	0.5	0.1
	10/23/2006	4th Q	0.5	0.1
BGS-01	1/31/2006	1st Q	0.5	0.32
	4/25/2006	2nd Q	0.5	0.495
	7/25/2006	3rd Q	0.5	0.1
	10/23/2006	4th Q	0.5	0.328
BGS-10	1/31/2006	1st Q	0.5	0.7
	4/26/2006	2nd Q	2.19	0.88
	7/26/2006	3rd Q	0.5	0.247
	10/24/2006	4th Q	2.44	1.37
BGS-23	1/31/2006	1st Q	1.3	1.4
	4/24/2006	2nd Q	1.48	1.48
	7/25/2006	3rd Q	1.21	1.22
	10/24/2006	4th Q	2.01	1.94
BGS-14	1/31/2006	1st Q	0.5	0.1
	4/26/2006	2nd Q	0.5	0.211
	Bad QC			
	10/23/2006	4th Q	0.5	0.216
BGS-25	1/30/2006	1st Q	0.5	0.477
	4/26/2006	2nd Q	1.2	0.767
	Bad QC	3rd Q		
	10/23/2006	4th Q	1.21	0.988
BGS-27	2/2/2006	1st Q	1.87	1.64
	4/25/2006	2nd Q	1.66	1.4
	Bad QC	3rd Q		
	10/24/2006	4th Q	1.38	1.28
BGS-22	1/30/2006	1st Q	0.5	1.08
	4/25/2006	2nd Q	1.23	1.36
	7/24/2006	3rd Q	0.5	0.813

Well ID	Sample Date	2006 Calenday Year Quarter Sampled	Total Cr ppb (ND<1 ppb)	Hexavalent Cr ppb (ND<0.2 ppb)
	10/24/2006	4th Q	0.5	0.608
BGS-12	1/30/2006	1st Q	0.5	0.224
	4/24/2006	2nd Q	0.5	0.457
	7/24/2006	3rd Q	0.5	0.445
	10/23/2006	4th Q	0.5	0.335
BGS-13	1/31/2006	1st Q	0.5	0.208
	4/27/2006	2nd Q	0.5	0.223
	7/25/2006	3rd Q	0.5	0.307
BGS-06	1/31/2006	1st Q	0.5	0.1
	4/26/2006	2nd Q	0.5	0.1
	7/24/2006	3rd Q	0.5	0.1
	10/23/2006	4th Q	0.5	0.1
BGS-09	1/30/2006	1st Q	0.5	0.1
	4/24/2006	2nd Q	0.5	0.1
	7/24/2006	3rd Q	0.5	0.1
	10/24/2006	4th Q	0.5	0.1
BGS-05	1/31/2006	1st Q	1.11	0.959
	4/25/2006	2nd Q	0.5	0.762
BGS-24	2/2/2006	1st Q	0.5	0.1
depth discrete @60	4/26/2006	2nd Q	0.5	0.1
depth discrete @100	4/26/2006	2nd Q	0.5	0.1
depth discrete @140	4/26/2006	2nd Q	0.5	0.1
	7/27/2006	3rd Q	0.5	0.1
BGS-18	2/1/2006	1st Q	1.53	1.75
	4/24/2006	2nd Q	1.91	1.61
	7/25/2006	3rd Q	0.5	0.27
	10/24/2006	4th Q	1.19	0.915
BGS-19	4/25/2006	2nd Q	0.5	0.658
	7/25/2006	3rd Q	1.08	1.03
	10/24/2006	4th Q	1.11	1.06
		Number of Samples	**66**	**66**

Notes:

1. For duplicate samples, the lowest value measured was recorded
2. Non detects were converted to 1/2 of the detection limit on this spreadsheet tab, and highlighted in yellow.
3. Data from Sample Delivery Groups 06G182, 06I248, 06K156, and 06K180 are screened out of this tab.

Appendix 3: Statistical Laboratory – Department of Statistics Statistical Consulting/Programming Report, dated May 22, 2012. Authored by Dr. Neil Willits, University of California at Davis

STATISTICAL LABORATORY – DEPARTMENT OF STATISTICS
STATISTICAL CONSULTING/PROGRAMMING REPORT

Client Name: *Anne Holden* Telephone: *542-5450*
Department: *O: Water Resources Control Board, Lahontan Region*
Status: *O*
Department Charge Number (Account/Fund or I.D.):
Major Professor: *Bill Ray* Consultant Name: *Neil Willits (NHW)*
Project Title: *Hexavalent chromium levels in the Hinkley Valley*

Nature of Consultation:
1. Statistical Consulting:
Appointment Date/Time: **(22May2012) (Tuesday)**
Task Description:
1. Advice 2. Modeling(chargeable) 3. Computations(Chargeable)-Computer/Analysis
Time with Client: Time on Follow-up: *(see attached)*

2. Programming:
Estimated Time: Date Started: Date Completed:
Task Description:
Language: Package Title:
Time with Client: Time on Follow-up:

Abstract of Problem:

Anne had sent me some revised data for the Hinkley Valley chromium values from 2006, so that I could provide revised critical values that could be used to decide whether subsequent values were significantly elevated relative to those baseline concentrations.

In past communications, I have recommended the use of a prediction limit with a discrete retest, which would allow for early detection of elevations in chromium concentrations, but would require that any such early detections be confirmed through subsequent sampling. It was (and still *is*) my opinion that this methodology provides earlier detection of possible problems, without the associated consequence of false positive detections, which generally require immediate and expensive forms of mitigation measures. Since this original suggestion was not met with much enthusiasm, the analysis of the new data subsets have been restricted to the use of parametric and nonparametric prediction limits, which *are* certainly valid methods but which lack the advantages that are afforded by a two-stage (re-sampling followed by mitigation) response to elevated values.

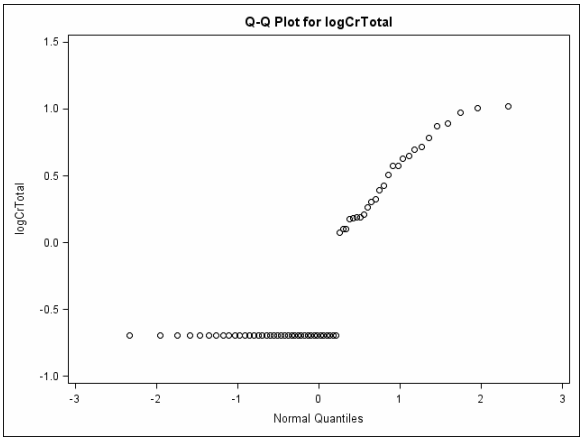
The difference between a parametric and nonparametric prediction limit is that the parametric limit assesses the likelihood of an extreme value relative to a normal (Gaussian) distribution with a mean and standard deviation that matches the baseline data. By contrast, the nonparametric prediction limit doesn't require the assumption that the data are normally distributed, at the cost that it makes somewhat less efficient use of the information in the data. Moreover, since the nonparametric limit doesn't attempt to draw inferences about the tails of the distribution based on what's observed in the middle, the sample size required to calculate a nonparametric prediction limit is greater than for a parametric limit. (Generally at least 20 valid observations are required to

estimate a 95% prediction limit.) If the data *are* normally distributed (or can be transformed to be normal), then a parametric limit would be preferable. If not, then the parametric limit is invalid, and the nonparametric limit would be preferable. The problem is that <u>*at best*</u> the baseline data can be shown to be *consistent with* an assumption of normality, which falls short of demonstrating that the data necessarily *is* in fact normal.

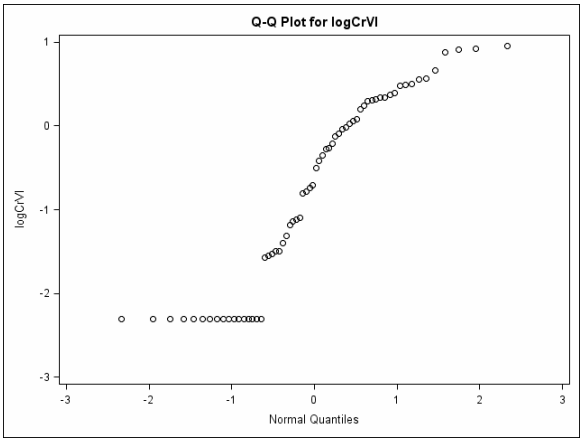
There were two data sets provided for re-analysis. The first contained data from only four wells, for a total of only 13 values. Moreover, around half of the values were below the detection limit (more than half for total Cr, and less than half for Cr VI). The upshot of this is that (1) the sample size is inadequate to provide an adequate assessment of the normality assumption, and (2) the sample size is inadequate for a nonparametric prediction limit. For these reasons, no additional calculations were completed for this data subset.

The second data subset contained data from 18 wells, most of which had valid observations for each of the four seasonal quarters of 2006. This sample *is* adequate for a nonparametric prediction limit, which would be defined in this case as the second largest of the observations. For total chromium, this value is 2.74. For hexavalent chromium, it is 2.53. These are the values that I would recommend using as upper prediction limits based on this subset of the 2006 baseline data.

I also calculated parametric prediction limits for total and hexavalent chromium for this subset of the data. As I mentioned, this method requires the data to be normally distributed. For most environmental monitoring data, the assumption of normality is more plausible for log-transformed observations than for the raw data. On some level, that's true here as well, though an additional feature of the data is that a fair number of values fall below the detection limit. If numerical values are assigned to these "non detect" values, then this will make the data fail a formal test of normality, due to the large number of observations that are all identical. A Wilk Shapiro test can be used to assess normality, which is equivalent to a correlation that's calculated from a Q-Q plot. This plot has the observed (ordered) values on one axis, and normal (ordered) values on the other axis. If the distribution is normal, then the plotted data should roughly follow a line. If the data were normal with a number of non-detect values, then the detected values should plot roughly as a line. The Q-Q plots for total and hexavalent chromium were:



For the



left-hand graph, the quantified data (the points on the right) are reasonably linear, though there's somewhat of a drop off for the last two or three points. This means that the tail weight of the residual distribution is somewhat lighter than you would expect for truly normal data. This will cause the parametric prediction limits to be somewhat too high relative to the residual distribution. For the right-hand graph, the drop off on the right is more dramatic, indicating that the tail weights here are *considerably* lighter than you would see in a normal distribution, which would make the prediction limits *substantially* higher than would be justified by the residual distribution. The parametric prediction limits corresponding to these two graphs are 2.81 for total chromium, and 4.57 for hexavalent chromium, which (as predicted) are slightly higher and substantially higher than the nonparametric prediction limits. I had mentioned previously that I would recommend the use of a nonparametric prediction limit in this case, and I would reiterate that here. The problem with the parametric prediction limits is that the residual distribution has lighter tails than for a normal distribution, which results in inappropriately inflated prediction limits when normality (or lognormality, in this case) is assumed.

I wanted to mention that I did some additional analysis on the 2006 data, looking for systematic seasonal or spatial trends in the data. These analyses demonstrated very week evidence of seasonality. These results were marginally insignificant at best ($p > .063$ in all cases) and empirically they're small as well. This would indicate that it ought to be possible to use a single prediction limit for all seasonal data, regardless of when a given observation was taken. By contrast the spatial differences are quite striking. For both total and hexavalent chromium, the *F*-test for well to well differences is highly significant ($p < .0001$ in both cases), and the significant differences among wells are as follows (for which wells with no letters in common are significantly different):
For total chromium:

Obs	Dependent	Well_ID	LSMean	Letter Group
1	logCrTotal	BGS-04	0.96816456	A
2	logCrTotal	BGS-16	0.54182090	AB
3	logCrTotal	BGS-27	0.44251628	B
4	logCrTotal	BGS-23	0.38579036	B
5	logCrTotal	BGS-18	0.13829428	BC
6	logCrTotal	BGS-10	0.07240131	BC
7	logCrTotal	BGS-25	-0.14916532	CD
8	logCrTotal	BGS-19	-0.19290245	CDE
9	logCrTotal	BGS-05	-0.30532403	CDE
10	logCrTotal	BGS-22	-0.46810684	DE
11	logCrTotal	BGS-13	-0.65800392	DE
12	logCrTotal	BGS-24	-0.65800392	DE
13	logCrTotal	BGS-01	-0.69314718	E
14	logCrTotal	BGS-06	-0.69314718	E
15	logCrTotal	BGS-09	-0.69314718	E
16	logCrTotal	BGS-12	-0.69314718	E
17	logCrTotal	BGS-15	-0.69314718	E
18	logCrTotal	BGS-14	-0.73557741	E

For hexavalent chromium:

Obs	Dependent	Well_ID	LSMean	Letter Group
1	logCrVI	BGS-04	0.91887255	A
2	logCrVI	BGS-16	0.43736632	AB
3	logCrVI	BGS-23	0.39751329	AB
4	logCrVI	BGS-27	0.28665729	B
5	logCrVI	BGS-22	-0.08003971	BC
6	logCrVI	BGS-18	-0.09057864	BC
7	logCrVI	BGS-19	-0.11507535	BC
8	logCrVI	BGS-05	-0.20969507	BC
9	logCrVI	BGS-10	-0.39201613	C
10	logCrVI	BGS-25	-0.41187884	C
11	logCrVI	BGS-12	-1.04562171	D
12	logCrVI	BGS-01	-1.31498964	DE
13	logCrVI	BGS-13	-1.37978960	DE
14	logCrVI	BGS-14	-1.86967193	EF
15	logCrVI	BGS-24	-2.26513861	F
16	logCrVI	BGS-15	-2.30258509	F
17	logCrVI	BGS-06	-2.30258509	F
18	logCrVI	BGS-09	-2.30258509	F

The least squares means here are in log units, indicating that the median hexavalent chromium value at well BGS-04 would be roughly 2.50 while well BGS-27 had the fourth highest median concentrations (equal to 1.33) and yet whose values were *significantly* lower than for BGS-04, as were the concentrations for *all* of these wells except for BGS-16 and BGS-23. This indicates that at least in 2006, there was substantial spatial variability in the values. This would mean that for a well with a high baseline value, the false positive error rate on subsequent values would be high, while for a well with a low baseline value, the false *negative* error rate (corresponding to failure to detect a genuine increase) would be high. The existence of these spatial trends limits the usefulness of overall prediction limits for detecting excessive values. In light of this, it makes good sense to combine the prediction limit methodology with intra-well comparisons (tests for trends), similar to the Spearman correlations (or Sen slopes) that were originally proposed for doing intra-well comparisons.