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December 22, 2011

Mr. Harold J. Singer
Executive Officer
California Regional Water Quality Control Board
Lahontan Region
2501 Lake Tahoe Boulevard
South Lake Tahoe, California 96150-7704

Re: Water Board December 7, 2011 Response to PG&E's November 23, 2011 Submittal Pursuant to Ordering Paragraph 3.a. Amended Cleanup and Abatement Order No. R6V-2011-0005A1

Dear Mr. Singer:

Pacific Gas and Electric Company (PG&E) submits the following in response to your December 7, 2011 letter requesting additional details of our statistical method evaluation pursuant to Ordering Paragraph 3.a. of Amended Cleanup and Abatement Order No. R6V-2011-0005A1 (the "Order") for the Hinkley Compressor Station.

PG&E is firmly committed to complying with the feasible provisions of the Order as evidenced by our provision of interim replacement water of demonstrated high quality to all residents who have impacted wells, our significant progress on the pilot study for the point-of-entry water treatment systems and the signing of a memorandum of agreement with the Hinkley Community Advisory Committee to fund an independent review panel. However, as discussed in our November 23, 2011 letter report, PG&E has found no technically sound statistical method to determine whether PG&E's plume has affected domestic wells with concentrations below the naturally occurring hexavalent chromium maximum background concentration of 3.1 parts per billion (ppb) as required by Ordering Paragraph 3a.

The challenges of finding an applicable statistical method were evident several months ago when the Board issued the draft Order. As you may recall, the statisticians from PG&E and the statistician used by the Board, Dr. Willits, discussed several possible statistical methods proposed in the draft Order during a September 22, 2011, conference call. At the time, Dr. Willits stated that the Board staff had requested he propose a statistical method that is commonly used to determine if a release has occurred from a hazardous waste landfill or impoundment; however he was uncertain whether that method was applicable to determining if the hexavalent chromium detected below the naturally occurring background value of 3.1 ppb is indicative of a release as

required by the Order. Dr. Willits also indicated that he was asked to also provide a trend test, and that he had done his best to create such a test. However, he acknowledged that his proposed test would create many false positive results. The final Order did not include the statistical methods initially proposed in the draft Order.

Despite these challenges, PG&E's experts continued to research possible statistical methods that could be used to achieve the objectives stated in the Order. We have summarized these efforts and conclusions below.

The Use of Established Background Levels to Determine Whether a Well is Impacted

The 2007 Background Study used a statistical method to establish an Upper Tolerance Limit (UTL) for hexavalent chromium of 3.1ppb for the study area. The goal of the UTL statistic is to establish whether sampled concentrations at a given well are higher than naturally occurring background concentrations. It is based upon a statistical test of the null hypothesis that concentrations at a tested well do not exceed the maximum average concentration among the background wells. The background study statistical approach produced the maximum background value for 95 percent of the population of background wells. Implicit in this UTL approach is that one background well in 20 (*i.e.*, 5 percent) will have natural concentrations above 3.1 ppb hexavalent chromium. Therefore, concentrations above the UTL are assumed to represent plume water with a potential error of this assumption (false positive) of 5 percent.

The background study represents an inter-well comparison, which compares wells to background wells outside of the area affected by the plume. Interwell comparisons are necessary when there are not sufficient historical (pre-release) measurements available for the affected wells to allow the establishment of naturally occurring background levels at a given site, as is the case here. It is important to note that historic data for hexavalent chromium at the very low level of 0.06 ppb set forth in the final Order cannot and does not exist for the domestic wells in Hinkley; until very recently, laboratory methods that could quantify hexavalent chromium at that level had not been developed..

The current directive to "determine if detectable levels of hexavalent chromium between the maximum background level and the PHG represent background conditions" is at odds with the existing UTL statistic, as it tests the same null hypothesis as the test using the UTL. Any test (inter-well or intra-well), which uses a lower threshold than 3.1ppb is therefore not consistent with the current testing procedure and would effectively invalidate and reset the UTL. This would lead to an inflation of the false positive rate under the currently accepted statistical distributional assumptions underlying the UTL.

PG&E appreciates the Water Board's recent peer review comments on the Hinkley background study. In January, 2012 we will propose an updated background study that takes into account those comments and the views of other experts, as well as builds on the significant advances in

our understanding of this site that have taken place since the original background study was initiated in 2005. We look forward to discussing this with the Water Board and developing a mutually agreed upon approach for an updated peer-reviewed background study.

September 22, 2011 Discussion

Any additional hypothesis tests need to be consistent with the hypothesis test currently in place (*i.e.*, the UTL statistical test) and should not lead to a significant inflation of the site-wide false positive rate. During our discussions with Dr. Willits on September 22, 2011, and in follow-up discussions, we established that:

- the Nonparametric Discrete Retest Procedure, which is another interwell testing method based on the distribution in the background wells; and,
- the Spearman Rank Correlation Test, which is an intra-well testing method based on a sequence of measurements at a given well,

lead to an excessive inflation of the overall false positive rate. Further, the Spearman Correlation method does not differentiate between statistically and environmentally significant trends.

PG&E's Analysis Pursuant to Ordering Paragraph 3.a. of the Order

As stated above, the current directive to "determine if detectable levels of hexavalent chromium between the maximum background level and the PHG represent background conditions" is at odds with the existing test as it tests the same null hypothesis as the test using the UTL statistic.

As directed by the final Order, our experts then turned to "a consideration of a number of factors, including, but not limited to: changes in hexavalent chromium levels over time", which are intra-well comparisons. The use of trend analysis is based on the scenario that a well originally outside the plume has been intercepted by the leading edge of the plume, as evidenced by a significant rise in chromium concentration. Because there are no pre-release monitoring data available, it is necessary to rule out any intra-well tests which rely on parameters estimated on data prior to release. We considered four different trend tests:

1. Sen Test: A simple non-parametric trend estimator, which calculates the median slope between any two data points at a given site. It requires a sample size of n>8 at the very minimum to estimate the variance to make statements of statistical significance.

2. Mann-Kendall Test: This test counts the number of overall increases and decreases in a time series, without taking into account the magnitude in the change. As this test does not distinguish between large and small increases in concentrations it is therefore conceptually similar to the Spearman test in the sense that it is able to detect a statistically significant test, yet does not distinguish between environmentally significant and

insignificant trends. It requires a sample size of at least 10 in order to make statements of statistical significance.

3. Univariate or Box-Jenkins regression: This method fits a trend line through observed monitoring data and provides an estimate of the environmental magnitude and statistical significance of the trend. The sample size requirements are large (n>10 at the very least). The slope estimate (environmental magnitude) of the trend can be biased by failure to properly account for confounders (*e.g.*, remediation activities). The estimate of statistical confidence is sensitive to distributional assumptions and the dependence structure of the residual terms (*e.g.*, temporal and spatial dependence).

4. Control Charts: The CUSUM or SHREWHART Control Charts provide a clear way to illustrate changes in a well over time, yet require the estimation of a mean and variance parameter, which requires n>8. Control charts require the samples to be statistically independent, which is impossible to establish with small sample sizes. Further they are only valid methods if the background mean is stationary over time, which is not the case at impacted wells.

All of these statistical methods require sample sizes of 8 or greater. Given the fact that less than 10 percent of wells have seven or more consistent measurements, none of the available methods are broadly applicable to test whether a trend is statistically *and* environmentally significant. The most suited technique to detect an environmentally and statistically significant trend, regression analysis, does have bad power properties at small sample sizes. In fact, research has shown that for proper application of Box-Jenkins methods, 50-100 measurements at equally spaced time intervals are required.[1]

The problem is more complex than this, as the Order recognizes. Even if a statistically significant trend was found at a given well, which is not possible given the current monitoring dataset, this significance needs to be evaluated in context of the hydrogeology. For example, are trends also detected at wells between the plume and the well with a detected trend? An isolated well with a statistically and environmentally significant trend that is reflected in none of the surrounding wells may be due to fluctuations in background. It is not clear how to define how many neighboring wells would also have to show a significant trend to determine that a well is impacted.

Further, remediation activities may affect background chromium levels, which are expected to lead to large fluctuations in background concentrations of chromium. These larger fluctuations

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[1] Robert D. Gibbons, Dulal Bhaumik, Subhash Aryal. 2009. Statistical Methods for Groundwater Monitoring. Second Edition. Wiley. ISBN-10:
0470164964

differ from fluctuations during a background sample due to remediation activities, not due to a change in the location of the plume, and again increase the site-wide false positive rate.

Finally, if there are seasonal swings in concentrations in the entire aquifer (background and non-background wells), a trend may be detected in all wells, which is simply due to fluctuations in background at all wells.

Conclusion

For the reasons described above, PG&E has concluded that there is no valid statistical method to meet the requirements of the Order. Rather, the appropriate way to establish whether wells are impacted by PG&E's historic operations is through comparison with the Upper Tolerance Limit established under a background study. As noted above, PG&E will propose an updated background study in January, and looks forward to feedback from the Board and its peer reviewers on our proposal.

I hereby certify that I have examined this report, and based on my examination and my inquiries of those individuals who assisted in the preparation of the report, I believe the report to be true, complete and accurate.

Please do not hesitate to contact me if you have any questions regarding this report, or if you need additional information.

Sincerely,

Robert C. Ross