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April 15, 2005

Mr. Norman Shopay
Project Manager
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Geology and Corrective Action Branch
700 Heinz Avenue
Berkeley, California 94710

Subject: Appendix B to Final Work Plan for Chromium Sample Filtration Comparison Test
Pacific Gas and Electric Company, Topock Project

Dear Mr. Shopay:

This letter transmits Appendix B to the Final Work Plan for Chromium Sample Filtration Comparison Test for the Pacific Gas and Electric Company (PG&E) Topock groundwater monitoring program. The Final Work Plan was submitted on March 4, 2005 without Appendix B. Appendix B, the proposed evaluation methods for data collected during the filtration study, is being submitted as required by your letter dated March 1, 2005.

If you have any questions, please do not hesitate to contact me at (805) 546-5243.

Sincerely,

*Terrri Herson
for Yvonne Meeks*

cc: Kate Burger/DTSC

Statistical Data Evaluation

B.1 Introduction

PG&E performed a filtration comparative study in March and April 2005 in accordance with the *Work Plan for the Chromium Sample Filtration Comparison Test, PG&E Topock Groundwater Monitoring Program* (CH2M HILL, 2005). The Study was conducted in response to California Department of Toxic Substances Control (DTSC) comments on the *Sampling and Analysis Plan, Groundwater and Surface Water Monitoring* (SAP) (CH2M HILL, 2004) regarding the filtration and preservation of hexavalent and dissolved chromium samples. Duplicate samples were collected from 16 selected wells for hexavalent chromium (Cr(VI)) and total chromium (Cr(T)); one set to be filtered and preserved in the field, and the second set to be filtered and preserved by the laboratory. These samples were collected during two consecutive monthly sampling events. Samples were collected in accordance with the *Sampling, Analysis, and Field Procedures Manual* (CH2M HILL, 2005). This Attachment describes the statistical methodology to be used to evaluate the data from the filtration comparative study. The statistical tools that will be used are described in the *Techniques of Water-Resources Investigations of the United States Geological Survey, Book 4 Hydraulic Analysis and Interpretation* (USGS 1995).

B.2 Data Evaluation

The comparative study generated three groups of data that will be evaluated independently: 1) hexavalent chromium analyzed by United States Environmental Protection Agency (USEPA) Method SW7199; 2) hexavalent chromium analyzed by USEPA Method SW7196A; and 3) total dissolved chromium analyzed by USEPA Method 6010B. For each group the results from the field filtered and preserved samples will be compared to the data from the laboratory filtered and preserved samples.

The applicability of the statistical analyses will be determined using the stepwise approach. The statistical analysis that will be used will be based on the distribution of the data. If the data are normally distributed, then the paired t-test will be used. If the data are not normally distributed, then the Wilcoxon Signed-Rank Test will be used to determine if there is a statistically significant difference between the data sets. Normality will be determined by calculating the correlation coefficient.

The paired t-test is a common parametric analysis used to evaluate matched pairs of data. The test requires the normal distribution of data. The Wilcoxon signed-rank test is a nonparametric test used to determine whether the median difference between paired observations is zero. As a nonparametric test, the sign rank test is a good alternative to the paired t-test when the data distribution is not normal.

B.3 Statistical Methodology

Normality will be determined using the probability plot correlation coefficient. The linearity will be tested by computing the correlation coefficient (r) between the data and their normal quantiles. For this test the closer the data are to normal distribution, the r will approach 1.0. The calculated r value will be compared to the critical r^* on Table B-1. If it is smaller than r^* , then the normality is rejected. If r is greater than or equal to r^* then the data set will be treated as normally distributed.

Paired t-Test

In the case of normally distributed data, the paired t-test will be used to compare field filtered and lab filtered sample data. This tests the hypothesis that two sets of data have the same mean assuming they have the same variance and shape. This null hypothesis is stated:

$H_0: \mu_x = \mu_y$, or the mean of group x is equal to the mean of group y

The alternative hypotheses are:

$H_1: \mu_x \neq \mu_y$, or the two groups have different mean values

$H_2: \mu_x > \mu_y$, or the mean of group x is greater than the mean of group y

$H_3: \mu_x < \mu_y$, or the mean of group y is greater than the mean of group x

Since there is no prior expectation of whether group x or y might be higher, alternative hypothesis H_1 will be used to evaluate the data for this study.

The paired t-statistic is computed by:

- 1) the differences between paired observations are computed
 $x_i - y_i = D_i$
- 2) Compute the sample mean (μ_D) of the differences.
- 3) Compute the sample standard deviation (s) of the differences
- 4) The paired t-statistic is calculated: $t_p = (\mu_D \sqrt{n})/s$
- 5) Reject H_0 if $t_p < -t_{(1-\alpha/2), (n-1)}$ or $t_p > t_{(1-\alpha/2), (n-1)}$ from the t distribution table (Table B-2).
For 95% confidence $\alpha = 0.05$.

The Signed-Rank Test

The signed-rank test will be used to compare the results from field filtered and lab filtered data if they are not normally distributed. This test compares the median difference between paired observations.

The Null hypothesis is that the median difference is zero:

$$H_0: \text{median}[D] = 0$$

Same as the paired t-test above, the alternate hypothesis was determined with no prior expectation of whether field filtered data are higher or lower concentration than lab filtered data. Therefore, the alternate hypothesis is stated:

$$H_1: \text{median}[D] \neq 0$$

The signed rank test is computed by:

- 1) Compute the absolute differences $|D_i|$, between paired data
- 2) Rank the $|D_i|$ from smallest to largest. If $D_i = 0$ then disregard the sample pair. If two non-zero differences are tied, assign the average rank to each difference involved in the tie.
- 3) Compute the signed rank

$$R_i = + \text{rank of } |D_i| \text{ for } D_i > 0$$

$$R_i = - \text{rank of } |D_i| \text{ for } D_i < 0$$
- 4) The test statistic (W^+) is the sum of all signed ranks having a positive sign.
- 5) H_0 is rejected if $W^+ \geq \alpha/2, n$ or $W^+ \leq \alpha/2, n$ from Table B-3. Otherwise do not reject H_0

Decision Criteria

In the case of either the paired t-test or the rank-sum test, if the null hypothesis is rejected, then there is 95percent probability that differences observed between field filtered and preserved samples and lab filtered and preserved samples are not due to random error. In that case, the current sampling procedures will have to be re-evaluated.

If the null hypothesis is not rejected, then there is no statistically significant difference between the results of the field filtered data set and the lab filtered data set.

References

- CH2M HILL. 2004. *Sampling and Analysis Plan, Groundwater and Surface Water Monitoring PG&E Topock Compressor Stations Needles, California*. July 14.
- _____. 2005. *Sampling, Analysis, and Field Procedures Manual, PG&E Topock Program*. February 11. [includes SOPs and QAPP].
- U. S. Geological Survey (USGS). 1995. *Techniques of Water-Resources Investigations of the United States Geological Survey, Book 4 Hydraulic Analysis and Interpretation*

TABLE B-1
 Critical r^* Values for the Probability Plot Correlation Coefficient Test of Normality
 Work Plan for Chromium Sample Filtration Comparison Test
PGE Topock Groundwater Monitoring Program

n	α -level					
	0.005	0.01	0.025	0.05	0.1	0.25
3	0.867	0.869	0.872	0.879	0.891	0.924
4	0.813	0.824	0.846	0.868	0.894	0.931
5	0.807	0.826	0.856	0.88	0.903	0.934
6	0.82	0.838	0.866	0.888	0.91	0.939
7	0.828	0.85	0.877	0.898	0.918	0.944
8	0.84	0.861	0.887	0.906	0.924	0.948
9	0.854	0.871	0.894	0.912	0.93	0.952
10	0.862	0.879	0.901	0.918	0.934	0.954
11	0.87	0.886	0.907	0.923	0.938	0.957
12	0.876	0.892	0.912	0.928	0.942	0.96
13	0.885	0.899	0.918	0.932	0.945	0.962
14	0.89	0.905	0.923	0.935	0.948	0.964
15	0.896	0.91	0.927	0.939	0.951	0.965
16	0.899	0.913	0.929	0.941	0.953	0.967
17	0.905	0.917	0.932	0.944	0.954	0.968
18	0.908	0.92	0.935	0.946	0.957	0.97
19	0.914	0.924	0.938	0.949	0.958	0.971
20	0.916	0.926	0.94	0.951	0.96	0.972
21	0.918	0.93	0.943	0.952	0.961	0.973
22	0.932	0.933	0.945	0.954	0.963	0.974
23	0.925	0.935	0.947	0.956	0.964	0.975
24	0.927	0.937	0.949	0.957	0.965	0.976
25	0.929	0.939	0.951	0.959	0.966	0.976
26	0.932	0.941	0.952	0.96	0.967	0.977
27	0.934	0.943	0.953	0.961	0.968	0.978
28	0.936	0.944	0.955	0.962	0.969	0.978
29	0.939	0.946	0.956	0.963	0.97	0.979
30	0.939	0.947	0.957	0.964	0.971	0.979
31	0.942	0.95	0.958	0.965	0.972	0.98
32	0.943	0.95	0.959	0.966	0.972	0.98
33	0.944	0.951	0.961	0.967	0.973	0.981
34	0.946	0.953	0.962	0.968	0.974	0.981
35	0.947	0.954	0.962	0.969	0.974	0.982
36	0.948	0.955	0.963	0.969	0.975	0.982
37	0.95	0.956	0.964	0.97	0.976	0.983
38	0.951	0.957	0.965	0.971	0.976	0.983
39	0.951	0.958	0.966	0.971	0.977	0.983
40	0.953	0.959	0.966	0.972	0.977	0.984

Note: This table is derived from Table B1 in *Techniques of Water-Resources Investigations of the United States Geological Survey, Book 4 Hydraulic Analysis and Interpretation (USGS, 1995)*

TABLE B-2
 Percentage Points for the t-Distribution Percentage Points of the t-Distribution
 Work Plan for Chromium Sample Filtration Comparison Test
PGE Topock Groundwater Monitoring Program

df	α	0.4	0.25	0.1	0.05	0.025	0.01	0.005	0.0005
1		0.32492	1	3.077684	6.313752	12.7062	31.82052	63.65674	636.6192
2		0.288675	0.816497	1.885618	2.919986	4.30265	6.96456	9.92484	31.5991
3		0.276671	0.764892	1.637744	2.353363	3.18245	4.5407	5.84091	12.924
4		0.270722	0.740697	1.533206	2.131847	2.77645	3.74695	4.60409	8.6103
5		0.267181	0.726687	1.475884	2.015048	2.57058	3.36493	4.03214	6.8688
6		0.264835	0.717558	1.439756	1.94318	2.44691	3.14267	3.70743	5.9588
7		0.263167	0.711142	1.414924	1.894579	2.36462	2.99795	3.49948	5.4079
8		0.261921	0.706387	1.396815	1.859548	2.306	2.89646	3.35539	5.0413
9		0.260955	0.702722	1.383029	1.833113	2.26216	2.82144	3.24984	4.7809
10		0.260185	0.699812	1.372184	1.812461	2.22814	2.76377	3.16927	4.5869
11		0.259556	0.697445	1.36343	1.795885	2.20099	2.71808	3.10581	4.437
12		0.259033	0.695483	1.356217	1.782288	2.17881	2.681	3.05454	4.3178
13		0.258591	0.693829	1.350171	1.770933	2.16037	2.65031	3.01228	4.2208
14		0.258213	0.692417	1.34503	1.76131	2.14479	2.62449	2.97684	4.1405
15		0.257885	0.691197	1.340606	1.75305	2.13145	2.60248	2.94671	4.0728
16		0.257599	0.690132	1.336757	1.745884	2.11991	2.58349	2.92078	4.015
17		0.257347	0.689195	1.333379	1.739607	2.10982	2.56693	2.89823	3.9651
18		0.257123	0.688364	1.330391	1.734064	2.10092	2.55238	2.87844	3.9216
19		0.256923	0.687621	1.327728	1.729133	2.09302	2.53948	2.86093	3.8834
20		0.256743	0.686954	1.325341	1.724718	2.08596	2.52798	2.84534	3.8495
21		0.25658	0.686352	1.323188	1.720743	2.07961	2.51765	2.83136	3.8193
22		0.256432	0.685805	1.321237	1.717144	2.07387	2.50832	2.81876	3.7921
23		0.256297	0.685306	1.31946	1.713872	2.06866	2.49987	2.80734	3.7676
24		0.256173	0.68485	1.317836	1.710882	2.0639	2.49216	2.79694	3.7454
25		0.25606	0.68443	1.316345	1.708141	2.05954	2.48511	2.78744	3.7251
26		0.255955	0.684043	1.314972	1.705618	2.05553	2.47863	2.77871	3.7066
27		0.255858	0.683685	1.313703	1.703288	2.05183	2.47266	2.77068	3.6896
28		0.255768	0.683353	1.312527	1.701131	2.04841	2.46714	2.76326	3.6739
29		0.255684	0.683044	1.311434	1.699127	2.04523	2.46202	2.75639	3.6594
30		0.255605	0.682756	1.310415	1.697261	2.04227	2.45726	2.75	3.646

TABLE B-3
 Critical Test Statistic Value for the Sign Rank Statistic W_+
 Work Plan for Chromium Sample Filtration Comparison Test
PGE Topock Groundwater Monitoring Program

Reject H_0 : when W_+ is \leq table entry (small W)				
α -level				
n	0.005	0.01	0.025	0.05
5				0
6			0	2
7		0	2	3
8	0	1	3	5
9	1	3	5	8
10	3	5	8	10
11	5	7	10	13
12	7	9	13	17
13	9	12	17	21
14	12	15	21	25
15	15	19	25	30
16	19	23	29	35
17	23	27	34	41
18	27	32	40	47
19	32	37	46	53
20	37	43	52	60

Reject H_0 : when W_+ is \geq table entry (Large W)				
α -level				
n	0.005	0.01	0.025	0.05
5				15
6			21	19
7		28	26	25
8	36	35	33	31
9	44	42	40	37
10	52	50	47	45
11	61	59	56	53
12	71	69	65	61
13	82	79	74	70
14	93	90	84	80
15	105	101	95	90
16	117	113	107	101
17	130	126	119	112
18	144	139	131	124
19	158	153	144	137
20	173	167	158	150

Note: This table is derived from Table B1 in *Techniques of Water-Resources Investigations of the United States Geological Survey, Book 4 Hydraulic Analysis and Interpretation (USGS 1995)*.