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TEL: 510-307-9943; FAX: 510-232-2823

October 7, 2011

Ms. Lauri Kemper, P.E.
California Regional Water Quality Control Board
Lahontan Region
2501 Lake Tahoe Blvd.
South Lake Tahoe, CA 96150

Transmittal via email to: Lkemper@waterboards.ca.gov

Re: Task Order: PEER REVIEW OF CH2MHILL'S FEBRUARY 2007 *GROUNDWATER BACKGROUND STUDY REPORT, HINKLEY COMPRESSOR STATION, HINKLEY, CALIFORNIA* PREPARED FOR PACIFIC GAS AND ELECTRIC COMPANY (PG&E)

Dear Ms. Kemper:

This memorandum summarizes my review of CH2MHILL's February 2007 *Groundwater Background Study Report, Hinkley Compressor Station, Hinkley, California* (BSP3) prepared for PG&E. In addition to the 7 documents initially furnished by your office, and the 2002 Workplan which you furnished upon request, you also furnished the link to the Lahontan Water Board webpage (to access additional information, including maps since August 2006), so the complete list of reports besides the review report is as follows:

Workplans
Scope of the Background Chromium Study at the PG&E Compressor Station, Hinkley California, CH2MHILL, 2002 (BSP1)

Revised Background Chromium Study at the PG&E Compressor Station, Hinkley, California, CH2MHILL, 2004 (BSP2)

Regulatory Correspondence
Comments on Revised Background Chromium Study at the PG&E Compressor Station, Hinkley, San Bernadino County, 2004 Workplan Review and Conditional Acceptance

Regulatory Staff Report
Dernbach, L., 2008, *Background Chromium Study, Pacific Gas and Electric Company, Compressor Station, 35863 Fairview Road, Hinkley,* CRWQCB, Lahontan Region.

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Peer Reviews
February 2004 reviews on 2002 BSP: 3 reviews
Letters of February 2004, on 2002 BSP1:

- Thomas C. Harmon, University of California, Merced
- James R. Hunt, University of California, Berkeley
- Timothy R. Ginn, University of California, Davis

Groundwater Monitoring Reports
Groundwater Monitoring Report; October 2007 Sampling Event; Site-wide Groundwater Monitoring Program, PG&E Hinkley Compressor Station, Hinkley, California, CH2MHILL, 2007

Second Quarter 2010, Groundwater Monitoring Report, *Site-wide Groundwater Monitoring Program, PG&E Hinkley Compressor Station, Hinkley, California,* CH2MHILL, 2010

Review Subject: *Groundwater Background Study Report, Hinkley Compressor Station, Hinkley, California* (BSP3) CH2MHILL, February 2007.

Report Date: February 2007

Report Author: CH2MHILL, Oakland, California

Site of Release: Pacific Gas & Electric Company
Hinkley Natural Gas Compressor Station Site
35863 Fairview Road
Hinkley, California

Responsible Party: Pacific Gas & Electric Company (PG&E)

Requesting Agency: RWQCB, Lahontan Region (LRWQCB), Region 6
Review Program
Sponsor: US EPA

Representative: Ms. Anne Holden, aholden@waterboards.ca.gov, 530-542-5450
Representative: Ms. Lisa Dernbach, ldernbach@waterboards.ca.gov, 530-542-5424
Review sent to: Ms. Lauri Kemper, Lkemper@waterboards.ca.gov, 530-542-5400

Environmental Services
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229 Tewksbury Ave., Pt. Richmond, CA 94801
TEL: 510-307-9943; FAX: 510-232-2823

Agency providing Reviewers:	Cal/EPA Scientific Peer Review Program, Office of Research, Planning and Performance, State Water Resources Control Board
Due Date:	October 7, 2011
Reviewer:	James A. Jacobs, PG, CHG, is a Fulbright Scholar and has practiced geology for 30 years, teaches Sustainable Remediation Methods for Soils and Water at the UC Berkeley Extension and co-authored The Chromium (VI) Handbook, 2005, CRC Press.

Project Background

Per the LRWQCB staff letter of May 19, 2011 to Dr. Gerald Bowes, Manager of the Cal/EPA Scientific Peer Review Program, Office of Research, Planning and Performance, State Water Resources Control Board, the purpose of reviewing the 2007 report (BSP3) is as follows: "...to estimate the concentration of naturally occurring total chromium [Cr(T)] and hexavalent chromium [(Cr(VI)] in groundwater near the PG&E natural gas compressor station in Hinkley, California. The data contained in the 2007 Background Study Report are intended to assist the Lahontan Water Board in setting cleanup goals for chromium pollution in groundwater in the Hinkley area... At issue is whether the deviations in carrying out the Background Study from the conditionally approved background Study Workplan were appropriate or whether the deviations resulted in biased estimates of background chromium levels."

Project Report Setting

The method described in the 2007 report (BSP3) is premised on previous work. The purpose of the 2002 Background Study Plan (BSP1) was to determine background conditions as a cleanup goal for groundwater remediation. The BSP1 proposal to sample 12 wells over 4 quarters in the upper aquifer was amended in 2004 (BSP2) and resulted in the 2006 sampling and the 2007 reporting (BSP3).

According to Attachment 1 of the May 19, 2011 Lahontan RWQCB document, two aquifers are identified in the valley fill: the upper unconfined aquifer (referred to in this review as the Upper Aquifer) and the lower confined aquifer (referred to in this review as the Lower Aquifer). The aquifers are separated by an aquitard composed of fine-grained clay and silts, laid down as a lacustrine deposit, called the Blue Clay. As noted in previous studies, the Blue Clay and the Lower Aquifer pinch out to the north of Highway 58 and west of Mountain View Road (Dernbach, 2008).

Current Status

The overall objective of the Background Study Plan is to provide a background threshold contaminant level so that a cleanup goal can be established. After 10 years with three background study workplans and reports, the background condition (the remediation or cleanup goal) has not yet been established. Recent reports (Stantec, 2011) document that vertical migration and lateral expansion of the Cr(T) and Cr(VI) plume appear to be occurring.

Sampling from Existing Domestic and Agricultural Wells

Groundwater samples were obtained from the domestic and agricultural wells chosen for the background well study because the wells were already installed and available for sampling. Many of the wells which were sampled for the background study were not intended to provide the highest quality groundwater samples due to construction design. Of the wells that were used in the background study, the agricultural wells (about 10 percent of the wells sampled) and domestic wells (about 90% of the wells sampled) were designed for irrigation and home water supply purposes, respectively. Given the age of most of the wells, the well construction likely predated the current California well standards. Most of these wells are many decades old, and the well construction details, such as perforation or screen depth information and geologic boring logs, are not available.

NOTE: For the purposes of this review, although it is likely that some of the wells installed have perforated well openings in the steel well casings rather than slotted screens, I will refer to the zones where groundwater enters the well bore as the "screened" interval.

As would be expected in a heavily agricultural area, many of the wells, especially wells used for irrigation, were designed for maximum groundwater flow, and the screened zones in the well may include both the unconfined Upper Aquifer and confined Lower Aquifer. Screening across two or more aquifers, thus commingling the aquifers, is common in wells where groundwater production is the objective. Of the wells used for the background study, most of them (44 out of 48 or 92%) were either screened over more than one aquifer zone, or the screen depths were unknown and well construction information is currently unavailable. Although specific wells may vary in well diameter, domestic wells can be about 6-inches in diameter, and agricultural wells can be about 14 to 18-inches in diameter.

As opposed to wells designed for groundwater production, monitoring wells are designed and installed for geochemical sampling and background studies. Monitoring wells require a fundamentally different well design. Many monitoring wells are a minimum of 2-inches in diameter which reflects the design purpose of high-quality groundwater sampling and not water production. Detailed geochemical studies including background studies provide geologic information about the subsurface conditions by isolating specific aquifer units from other groundwater bearing units. This isolation is a key concept in the design of the monitoring well so that a specific groundwater bearing zone in a specific geologic unit can be sampled and analyzed in the laboratory for Cr(T) and Cr(VI) and other chemicals of concern.

Sampling Data

Sampling of agricultural or domestic wells containing commingled groundwater aquifers provides useful information as to overall groundwater quality of that particular well and specific exposure and toxicity data related to Cr(T) and Cr(VI) to human health if the water is ingested, or the environment, if the water is applied to the land through irrigation.

For the purposes of a detailed geochemical background study, however, no useful geologic information on background concentrations can be obtained from mixed well waters that are available in a well which is screened over two aquifer zones. The laboratory sample results from wells containing 'mixed aquifer' waters cannot be considered reflective of any specific aquifer and, therefore, they should not be used in a scientifically based background study of Cr(T) and Cr(VI). All of the wells used in the CH2MHILL background study are either domestic or agricultural wells. The majority of these wells (92%) have well screens covering more than one aquifer zone (i.e. both the Upper Aquifer and the Lower Aquifer), or the screen intervals are unknown.

According to the United States Geological Survey (USGS) Water Supply Paper 2220 (Heath, 1983), groundwater occurs in aquifers under two different conditions. Where groundwater only partly fills an aquifer, the upper surface of the saturated zone is free to rise and decline. The water head in a well installed in an unconfined aquifer reflects the elevation differences between the water source and the elevation of the groundwater in the well. The groundwater in such aquifers is said to be unconfined, and the aquifers are referred to as unconfined aquifers. Unconfined aquifers are also widely referred to as water-table aquifers. The Upper Aquifer is an unconfined aquifer.

Where groundwater completely fills an aquifer that is overlain by a confining bed such as the Blue Clay in the Hinkley, California area, the groundwater in the aquifer is said to be confined. Such aquifers are referred to as confined aquifers or as artesian aquifers. In some cases, the confined aquifers come to the surface as artesian springs. The Lower Aquifer is a confined aquifer, and as such, the water will rise due to the elevation differences as noted above, as well as the pressure in the aquifer.

Depending on the water pressures associated with each aquifer, the Upper Aquifer Cr(T) and Cr(VI) concentrations in 'mixed aquifer' wells will likely be diluted by the cleaner Lower Aquifer. If the Lower Aquifer has significantly higher pressure than the Upper Aquifer, the overall concentrations of Cr(T) and Cr(VI) will be more diluted.

In wells where the groundwater is sourced from two aquifer zones at the same time, such as is found in the Hinkley area, laboratory analyses of those groundwater samples to define specific background levels of Cr(T), Cr(VI) or other chemicals is not scientifically valid as no vertical definition or aquifer specific continuity is possible. Comparing sample results from 'mixed aquifer' wells allows for evaluation of human or environment exposure, but the laboratory data are devoid of any specific geologic or aquifer significance. Statistics based on 'mixed aquifer' laboratory data are not valid or relevant as to the aquifer-specific levels for Cr(T), Cr(VI), or other chemicals.

Focused Groundwater Sampling

For the purpose of groundwater sampling and geochemical characterization, wells with proper screens covering only one aquifer zone are needed so aquifer-discrete samples can be collected and analyzed. This is necessary and important if the vertical and lateral migration of the Cr(T) and Cr(VI) in the subsurface is to be understood and properly documented. The isolation of these two aquifers (Upper Aquifer and Lower Aquifer) has not occurred in most of the wells used in the background study, and as such, these domestic and agricultural wells are useful in showing concentrations of Cr(T) and Cr(VI) in groundwater in wells with commingled aquifers. These concentrations of the well water reflect the overall water quality from the individual wells and the overall Cr(T) and Cr(VI) exposure potential to humans or the environment. However, these wells have almost no value in showing background levels of Cr(T), Cr(VI), or other chemicals. As such, detailed statistical evaluation of laboratory data from wells that are screened in more than one aquifer, or in wells where the screen and filter packs (if present) are unknown, do not and cannot accurately reflect true background concentration levels. Statistical methods applied to these types of well sample results, for the purpose of trying to identify a background Cr(T) and Cr(VI) concentration, provide mixed-well aquifer statistics, not background levels.

Format of Peer Review Tasks

As part of the overall Scientific Peer Review process, the reviewers were asked to address Specific Requested Comments (**Task I**), to make General Comments on (BSP3) to address any additional scientific issues (**Task II**), and to comment on whether the scientific portion of (BSP3) is based upon sound scientific knowledge, methods, and practices (**Task III**). All the Tasks and my responses are provided below:

Task I - Specific Requested Comments on BSP3

Background: Are the deviations in carrying out the Background Study, BSP3, (from the conditionally approved Background Study Workplan, BSP2) appropriate or did they result in biased estimates of background Cr levels? Make a determination of each of the following four (as expertise allows):

1. Quality of spatial sampling of background chromium in 21 square miles (sq. mi.)
   Sampling Dataset: Total of 48 wells of which 14 were sampled all four quarters (see Table 3-1; CH2MHILL 2007 Study).

- Event 1 - 17 well locations
- Event 2 - 18 well locations
- Event 3 - 45 well locations (original 17 wells, plus 8 wells, plus 23 new wells which are near chromium impacted well BGS-04 in <1 sq. mi.)
- Event 4 – 38 well locations

Comments: The wells used for the background study reported in the CH2MHILL (2007) report show an inconsistent pattern of well sampling as shown above. The Hinkley Valley in the background study area can be divided into five main areas (see attached **Figure 1**; based on the Figure 4-1; CH2MHILL 2007 Study). The five main areas are as follows: Core Area, South Upgradient Area, East Cross Gradient Area, West Cross Gradient, and North Downgradient Area. Across these there is an Upper and a Lower Aquifer. These aquifers are separated in most areas by a confining clay aquitard, called the Blue Clay, except as noted below.

A. Core Area
This is the area of the Cr(VI) plume (Core Area) in 2006 (Figure 4-1; CH2MHILL, 2007), showing a Cr(VI) concentration of 4 micrograms per liter (µg/L). The Core Area has both Floodplain and Regional Aquifers as mapped on Figure 4-1. The Upper and Lower Aquifers are separated by a confining clay.

B. South Upgradient Area
This is the area south of the Core Area (shown on Figure 4-1; CH2MHILL, 2007), south of the hatched black line, reflecting an "upgradient boundary including buffer zone." According to Figure 4-1, the Regional Aquifer lies below the South Upgradient Area. The Upper and Lower Aquifers are separated by a confining clay.

C. East Cross Gradient Area
This is the area east of the Core Area (shown on Figure 4-1; CH2MHILL, 2007) which is shown as having the Floodplain Aquifer. In the northern portion of the area, the Upper and Lower Aquifers are separated by a confining clay. A small area to the northeast contains the Regional Aquifer.

D. West Cross Gradient Area

This is the area west of the Core Area (shown on Figure 4-1; CH2MHILL, 2007) containing the Regional Aquifer. A small portion of this area (to the southeast) contains Floodplain Aquifer. The Upper and Lower Aquifers are separated by a confining clay.

E. North Downgradient Area

This is the area north of the Core Area (shown on Figure 4-1; CH2MHILL, 2007), having both the Floodplain and Regional Aquifers as mapped on Figure 4-1. As with the confining clay layer called the Blue Clay, the Lower Aquifer also pinches out to the north of Highway 58 and west of Mountain View Road (Dernbach, 2008).

Table 1 summarizes the 48 background study wells within the five different areas based on the known, discrete aquifer differentiation. Of these wells, four wells are screened only in the Upper Aquifer. The remaining background study wells either have well screens over both the Upper and Lower Aquifer or there is no information available as to the screened zone. A monitoring well can be designed for sampling a specific aquifer or zone, but production wells, both irrigation and domestic, tend to be designed for maximum groundwater production and sometimes contain more than one aquifer or producing zone within their screened intervals. Consequently, the mixing of groundwater from the different aquifer zones in the production wells, where screen and filter pack information is either unknown or the wells are screened over both the Upper and Lower Aquifers, will provide a mixed well concentration for Cr(T) and Cr(VI); it will not accurately reflect the conditions of the specific aquifer zone. **Table 1** shows the background study wells based on the CH2MHILL (2007) report, Table 4-1.

Table 1 – Summary of Background Wells in Hinkley Area

Area	**Primary** Aquifers (as shown on Figure 4-1; CH2MHILL, 2007)	Specific Upper Aquifer Data (# of Wells)	Specific Lower Aquifer Data (# of Wells)	Background wells without specific aquifer screen information	Total # of Background Wells in CH2MHILL (2007) Study
Core Area	Regional and Floodplain	Not Evaluated	Not Evaluated	Not Applicable	Not Applicable
South Upgradient Area	Floodplain	**1 well**: 01-06	0	3	4
East Cross Gradient Area	Floodplain primarily with minor Regional Aquifer in northeast corner	0	0	14	14
West Cross	Regional and small	**3 wells**: BGS-01,	0	27	30

Gradient Area	portion in the southeast of Floodplain Aquifer	BGS-04, and BGS-15			
North Downgradient Area	Regional and Floodplain	0	0	0	0
Totals		4 wells	0 wells	44 wells	48 wells

Of the areas shown in **Figure 1**, the South Upgradient Area is the most likely to provide natural or background levels of Cr(T) and Cr(VI). Samples from the Mojave River, although more than one mile from the PG&E facilities, may show less anthropogenic influences for background samples of Cr(T) and Cr(VI) for the region.

The Upper Aquifer has levels of Cr(T) and Cr(VI) as shown in Figure 4-1 (CH2MHILL, 2007). Dernbach (2008) noted that the chromium plume was detected only in the Upper Aquifer. At the time of this review in 2011, the Lower Aquifer had been found to contain elevated Cr(T) and Cr(VI) in one area north of Highway 58 as shown on the Stantec Figure 3, in the report *Chromium in Groundwater Lower Aquifer*, by Stantec, dated August 1, 2011.

Since the Upper Aquifer is likely to contain the majority of the Cr(T) and Cr(VI), collecting samples where the well screens are unknown provides little useful information. Although video camera surveys in wells and geophysical logging can assess the screened areas and well construction information based on the large number of wells screened in both Upper and Lower Aquifer, the agricultural wells with unknown screen depths are likely to have been screened in both aquifer zones. Data from wells that are screened in more than one aquifer or having unknown screen depths should not be used in studies to establish background concentrations of Cr(T) and Cr(VI). Installation of new monitoring wells with proper screens in specific and isolated aquifer zones is the best way to get accurate data on groundwater concentrations of Cr(T) and Cr(VI).

In summary, the natural Cr(VI) and Cr(T) levels will be difficult to assess since the entire area has had intense agricultural pumping from both Upper and Lower Aquifers for up to eight decades. Artificial recharge has also been occurring in certain locations, affecting the natural background conditions of Cr(T) and Cr(VI). The background study for both Cr(T) and Cr(VI) in the current form is inadequate and inaccurate for reasons given above.

2. Quality of temporal sampling of background chromium in the 2007 Background Study Report

Background: To address the potential to introduce bias into the overall summary statistics due to the temporally unbalanced nature of the data set (not all wells sampled in each quarter), the arithmetic average value of Cr (VI) and Cr(T) concentrations from each well were used; Each well is represented by one arithmetic mean result, not the actual number of samples taken at that well.

Comments: As noted above, in **Table 1**, for discrete data from specific areas or specific aquifer zones, there are only three wells from the West Cross Gradient area and one well from the Southern Upgradient Area that are known to be screened specifically in the Upper Aquifer. Regardless, one to three wells in specific aquifer zones do not provide enough information to evaluate background concentrations or even current concentrations. From my field experience and given the size of the Hinkley area, a minimum of 20 to 40 properly constructed groundwater monitoring wells should provide the minimal number of groundwater sampling locations for a scientifically reasonable background study. Each new monitoring well should be sealed so the screens and well design sample only one aquifer zone. Detailed statistical evaluation of geochemical data coming from a majority of wells with unknown screen intervals or of screens covering commingled aquifers does not provide much scientific value.

Background: Was the integrity of the study lost by the addition of wells mid-course/mid-year?

Comments: It was noted that 14 background study wells were sampled for 4 quarters. Various additional wells were added to the study. Statistical analyses should be run on the data from the original 14 wells. Statistics from one dataset cannot be combined with statistics from another dataset. These two datasets should be reported separately.

3. Assumption of statistical normality

Background: The Shapiro-Wilk normality test was applied to only a subset of the data, the detected chromium values in the dataset. The P-values (both higher than 0.05) suggest that the data subset (all detections of chromium, leaving out the non-detect values) are normally distributed.

Comment: Aquifer-specific information and detailed statistics from wells screened in specific aquifers is required to put the laboratory analytical data into a geologic perspective. Properly performed statistics on inaccurate geochemical data are not valid.

4. Quality of groundwater modeling

The plume core, Cr(VI) above the Maximum Contaminant Level (MCL) of 50 parts per billion (ppb), migrated (based on October 2007 data) approximately 300 feet to the west along at least a one-half-mile length of the northwestern plume boundary; Are the background study wells representative of naturally occurring chromium, given the data showing plume expansion?

a) *Location of background wells must be upgradient and outside the range of influence of wells drawing the plume in*. Wells screened in unknown or multiple aquifer zones provide only limited information.

In addition to the issues listed above regarding the wells being screened in more than one aquifer, the chosen set of 'background' wells are not located adequately upgradient and outside the range of influence of actively pumping (historically or currently) extraction wells (which could be drawing the Cr(VI) plume in an upgradient direction) to be representative of background conditions. Virtually all of the chosen wells are located in a cross gradient position from the main plume with poorly defined cross gradient Cr(T) and Cr(VI) plume boundaries. As noted, well data should reflect specific aquifer zones, not mixed zones. Given the eight decades of intense agricultural pumping, it is possible that with preferred flow pathways (high permeability zones due to lithologic characteristics or geologic faults (Lockhart) or other potential conduits), some of the Cr(T) and Cr(VI) from the Core Area may have migrated over the past decades toward the east or west into the East Cross Gradient Area or the West Cross Gradient Area, respectively (see **Figure 1**).

b) *The role of actively pumping of current wells in the migration of the plume*
Groundwater flow and transport modeling are needed. Range of influence of individual pumping or injection wells should be mapped and modeled.

c) *Role of irrigation with Cr(VI) water in the increase of the plume*
Deposition of Cr(VI) throughout the basin land surface has not been mapped. Correlation between land irrigation of Cr(T) and Cr(VI) impacted groundwater at the Land Treatment Units and the presence of chromium in the underlying soil and groundwater needs more focused investigation. The mechanism of remediation of spraying Cr(VI) onto the soil and the conversion of the oxidized Cr(VI) into the reduced Cr(III) and ultimately into chromium hydroxide using soil as a treatment media are not well documented or verified. Peroxide and acids may clean the drip or irrigation lines, but may also help to mobilize and carry the Cr(T) and Cr(VI) deeper into the subsurface environment if the acids or peroxide are spilled onto the soil.

d) *Lack of control of groundwater extraction throughout the basin*
There has been none, and there is currently no hydraulic control over the groundwater basin, so the plume will continue to migrate. The Cr(VI) plume is expanding both laterally to the north, as well as vertically, as evidenced by plume maps from 2001 to current consultant studies.

e) *Historic patterns of Cr(VI) migration*
There may be historic patterns of Cr(VI) migration which have left residue available for future recapture and migration.

f) *Lack of site conceptual model*

A detailed site conceptual model of the Cr(T) and Cr(VI) initial release(s), migration in the subsurface soils and aquifers, extraction at Land Treatment Units, and application of this untreated Cr(VT) and Cr(VI) impacted water onto the land surface should be developed. There is a concern that the lack of above-ground treatment of Cr(T) and Cr(VI), in which the extracted groundwater is removed from the aquifers at the Land Treatment Units and dripped or (historically) sprayed onto surface soils, is potentially creating another Cr(T) and Cr(T) release, albeit, at lower Cr(T) and Cr(VI) concentrations. The concepts of groundwater extraction of Cr(T) and Cr(VI) impacted groundwater and the reapplication of this water onto the land without treatment has not been well proven or well documented as a method to immobilize Cr(T) and Cr(VI). Documentation should be provided showing the soil in these areas where untreated Cr(T) and Cr(VI) impacted groundwater is being released onto the land surface is a safe and effective remediation method for Cr(T) and Cr(VI) in groundwater. The documentation should also evaluate the potential for hyperaccumulation or uptake of Cr(T) and Cr(VI) in plants or deposition and concentration of Cr(T) and Cr(VI) in the shallow soil.

Although regionally the rain water has been low over the period of historic record keeping, large changes in climate and rain patterns could occur in the future, creating higher risks of remobilization of the Cr(T) and Cr(VI) in the shallow soil near the groundwater drip or spray systems at the Land Treatment Units. Sources at the PG&E Compressor Station must be mapped and plotted in relationship to the release and the current location of the contaminants in both the shallow soils as well as the Upper Aquifer and the Lower Aquifer.

g) *Well construction details and depth discrete sampling are critical*

Samples from agricultural or domestic wells which cross the Upper Aquifer and Lower Aquifer have little value in defining Cr(T) or Cr(VI) background concentrations based on aquifer or geologic units. Correlating the flows from the two different aquifer zones, one unconfined and the other confined, is not an appropriate or satisfactory method for determining background levels of Cr(T) and Cr(VI). Mixing within the wells that were screened over two aquifers is likely to occur by diffusion, and possibly by other mechanisms. If filter packs are part of the well construction, then additional groundwater flow pathways exist for mixing of two originally separated groundwater aquifers. Using decades old domestic and agricultural wells which were readily available but designed for water production is not appropriate for background studies of Cr(T) or Cr(VI) which are associated with two vertically discrete aquifer units.

Discussion:

Background: 4a) Background levels - Location of wells

The background wells were chosen by the following criteria (BSP2 2002 Workplan): "The position of the 0.05 mg/L limit line shown on BSP2 Figure 3 represents the *inferred extent of the* *water bearing intervals that contain Cr(T) above the MCL within the Upper Aquifer*."

Background Study Criteria:

- Wells were in Hinkley Valley
- Wells were Cross/Upgradient of the 0.05 mg/L plume
- Wells were 500-2,000' outside of plume influence
- Wells were Historic Non-detect of Cr(VI) at 500' cross gradient
- Downgradient wells were excluded
- Criteria was based on 1995 study samples
- Wells chosen were only in the upper aquifer; they were chosen in the upper aquifer because the lower aquifer is confined and there is an upward vertical gradient; 'only upper aquifer should be used to establish the cleanup goal'.
- One of the 2004 reviewers (Harmon) states, "The Mojave River aquifer is the most logical source of groundwater flowing under and around the compressor station. Obtaining chromium levels in that water appears essential for determining the background chromium levels."

Comments: Background wells were not excluded or screened for their proximity to extraction wells. If the background wells chosen for sampling were inside the radius of influence (ROI) of wells extracting contaminated groundwater, then they cannot be identified as background wells. A background well should not lie within the zone of influence of a pumping well, or within the influence of the wells in the Hinkley Compressor station or Land Treatment Unit extraction systems. In addition, the wells to be used as background wells should have screens in one of the aquifer zones, but not both.

Background: 4b) Groundwater modeling - One of the 2004 reviewers noted the following: Synthesis of existing data in a quantitative model would be beneficial to verify the current plume direction. Also, it was noted that the 2003 Appendices were not utilized.

Comment: All groundwater extraction volumes and their ROIs should be mapped. The above mapping should be evaluated with the ROI information. In the 2002 report, "...the Upper Aquifer hydraulic gradient...reflects no known pumping from irrigation wells or groundwater extraction wells." pg 5. The Lockhart Fault and other faults in the Hinkley, California area may affect groundwater migration or influence preferred groundwater flow pathways. These elements should be evaluated in future hydrogeologic studies.

Background: 4c) Influence of land application of groundwater - Is there any relationship between the land-applied Cr(VI) water and the levels of Cr(VI) in the groundwater below those fields? What level of Cr(T) and Cr(VI) in spray (LTU's) was being aerosolized on the alfalfa fields.

Comment: All water applications from the Land Treatment Units should be mapped with detail on duration in time and volume of water of the applications. The deposition of wind-borne contaminants is discounted since there is low rainfall, yet Cr(VI) in dust can be an important exposure pathway if concentrations of Cr(VI) are high. In areas where Cr(T) and Cr(VI) are high in the shallow soil, plant hyperaccumulation of Cr(T) and Cr(VI) and the potential of livestock accumulation of chromium from ingesting impacted plants or impacted soil should be verified and documented with laboratory analysis.

Background: 4d) Groundwater recharge - How were the groundwater recharge areas mapped?

Comment: All injection wells and their ROI should be mapped for the whole basin.

Background: 4e) Historic groundwater migration - Previous patterns of migration
One of the 2004 reviewers (Harmon) noted the following: That historical groundwater flow patterns during, for example, remedial pumping periods or extreme climate events (drought and wet periods) may have produced a different plume than is now observed ...left behind anthropogenic Cr which could impact background concentration estimates which would be figured out with a groundwater modeling effort.

Comments: Heavy groundwater extraction since the 1930's supports this concept that the Cr(T) and Cr(VI) plume has migrated cross gradient through preferred flow pathways. Major geochemical changes in the Hinkley Valley caused by large water movements, including extraction, are likely to have occurred over the past several decades, altering background levels of Cr(T) and Cr(VI).

Background: 4f) Site Conceptual Model of the release - A site conceptual schematic of the release and migration of the Cr(VI) projected in cross section from 0-90' below ground surface (bgs).

Comments: A scientific site conceptual model of the release, migration, extraction, and reapplication of the impacted waters onto soil should be carefully and methodically performed. If needed, additional geologic cross sections should be prepared. To help establish well construction details and depths of screened intervals, well condition and other downhole information should be documented using a video camera and geophysical logging tools. This will help to establish whether the wells are acting as vertical conduits. All migration pathways should be mapped.

Background: 4g) Producing contaminant concentration contours - Sampling of equivalent depths is critical.

Comments: The discrete depth sampling dataset is not sufficient. New monitoring wells should be constructed solely for the purpose of groundwater sampling. I recommend that 20 to 40 new groundwater monitoring wells be constructed to current California standards in the Upper Aquifer and Lower Aquifer. The wells should be constructed so only one aquifer is screened for each well.

Task II - List other scientific issues that are not addressed in Report BSP3 or in **Task I**, above.

Comments: The extraction of groundwater containing Cr(T) and Cr(VI) and application of this impacted water on to the land surface without above-ground treatment of the chromium-impacted water should be rigorously evaluated and scientifically justified and documented. The concern is whether the Cr(T) and Cr(VI) are really being cleaned up, or whether the Cr(T) and Cr(VI) are being smeared in the shallow subsurface and ultimately being allowed to impact deeper soil horizons and groundwater resources. Groundwater resources in the area are heavily used for agricultural and domestic water supplies. Any additional impact from Cr(T) and Cr(VI) on soil and groundwater resources should be examined, tested, and documented in a careful and systematic manner. The drip lines for the Land Treatment Units are being cleaned with hydrogen peroxide and acid. These chemicals, if in contact with heavy metals, including Cr(T) and Cr(VI), might allow for more impacts in the shallow soils by increasing heavy metal solubility and enhancing mobilization of Cr(T) and Cr(VI) in the shallow soils.

Task III- Critique of the scientific portion of the 2007 Background Study Report, for the following parameters: a) scientific knowledge, b) scientific methods, c) scientific practices.

Comments: On the basis of my understanding of the well construction information (or lack thereof) of the wells used for the background study of Cr(T) and Cr(VI), the scientific approach to this study is seriously flawed if wells used in the study do not have proper screens in one discrete aquifer zone. If these mixed-aquifer wells are used for the overall concentration maps for Cr(T) and Cr(VI), the maps will be in error and likely to underestimate the Cr(T) and Cr(VI) concentrations, since the wells screened over both the Upper and Lower Aquifer will have most of the water in the well bore derived from the cleaner Lower Aquifer.

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The wells currently in the background study were not designed for high-quality geochemical sampling, but rather they were probably designed for maximum water production. Applying detailed statistics to laboratory sample data from domestic and agricultural wells with 'mixed aquifer' water does not provide accurate results and likely underestimates the Cr(T) and Cr(VI) concentrations for reasons described above.

Although it might be economically attractive to use existing and available domestic and agricultural wells for a purpose for which they were not designed, the study does not meet the scientific objectives of trying to determine background concentrations of Cr(T) and Cr(VI). The use of statistical methods on the chemical data as well as averaging laboratory concentrations of Cr(T) and Cr(VI) from these wells does not provide accurate or correct results for background information.

RECOMMENDATIONS:

Natural background levels of Cr(T) and Cr(VI) for specific aquifers in the Hinkley, California, area can be determined with a significant drilling program of new wells with well screens limited to one aquifer zone in upgradient areas unaffected by historical pumping. It is possible that undisturbed hydrogeologic areas in the Hinkley, California, area do not exist due to the excessive groundwater pumping in the area. Samples upgradient toward the Mojave River may provide the best chance at finding what might be considered background Cr(T) and Cr(VI) concentrations.

Background levels are important to establish, but are very different from remediation goals or drinking water standards. The remediation goals are influenced by the best available technology to achieve a specific cleanup with regulatory oversight and public input. Maximum Contaminant Levels (MCLs) for Cr(T) and Cr(VI) or other drinking water standards are health based and provided by federal and state regulatory agencies. Together, these different levels (groundwater background levels, best available technology remediation levels, and the various drinking water standards and other exposure and toxicity concentrations) must be integrated to develop an appropriate and realistic remediation or cleanup goals for the site. After ten years of assessment and monitoring, remediation has been limited and the Cr(T) and Cr(VI) plume is expanding northward in the Upper Aquifer and there has been recent vertical migration into the Lower Aquifer as well (Stantec, 2011).

In summary, the following tasks are required:

a. Site Conceptual Model - Create a scientifically valid site conceptual model of the release, migration, extraction, and reapplication to land of the groundwater containing Cr(T) and Cr(VI).

b. Land Treatment Units - Map all the surface areas where groundwater containing chromium has been historically discharged to the land surface for irrigation purposes at the Land Treatment Units. Identify what levels (concentrations) of Cr(T) and Cr(IV) are in the shallow soil and the groundwater (besides the 5 foot lysimeters). Evaluate and verify the Land Treatment Unit extraction and water application process to document that Cr(T) and Cr(VI) are being properly immobilized.

c. Pumping Influence - Map the radius of influence of pumping wells located within the Hinkley Valley and the extracted waters discharge areas.

d. Obtain aquifer-specific background level data – Construct and install 20 to 40 new monitoring wells in accordance with current California well standards that are screened in one aquifer so that the Cr(T) and Cr(VI) aquifer contamination can be directly measured. A representative number of wells should be installed upgradient and outside the range of influence of historic or current pumping.

e. Plume control - Gain hydraulic control on the chromium plume in the Upper Aquifer which appears to be expanding northward. Gain hydraulic control of the Lower Aquifer which appears to be impacted from vertical movement of the Cr(T)- and Cr(VI)-containing groundwater sourced from the Upper Aquifer. The vertical migration and spreading of the chromium plume are a concern and should be addressed.

f. Identify background concentrations for Cr(T) and Cr(VI) in the area, and develop remediation goals.

g. Initiate more aggressive hydraulic control and remediation to contain and shrink the currently expanding Cr(T) and Cr(VI) groundwater plume in both the Upper Aquifer and Lower Aquifer.

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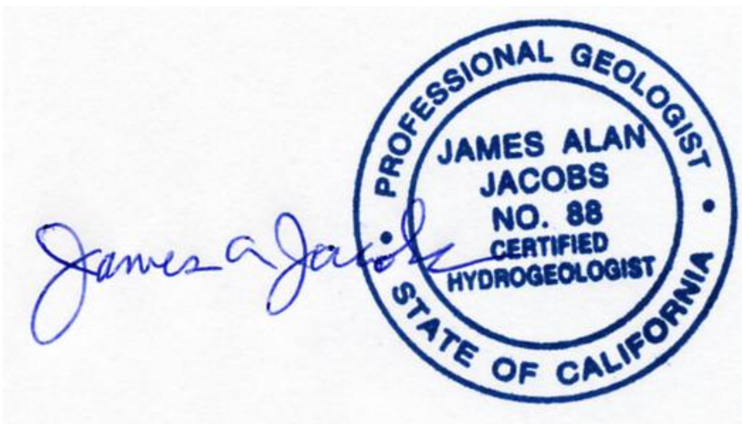
I hope these comments are helpful to the Lahontan Regional Board. Please call me at (510) 590-1098 if you have any questions.

Sincerely,
CLEARWATER GROUP



James A. Jacobs, P.G.#4815, C.H.G.#88
Chief Hydrogeologist

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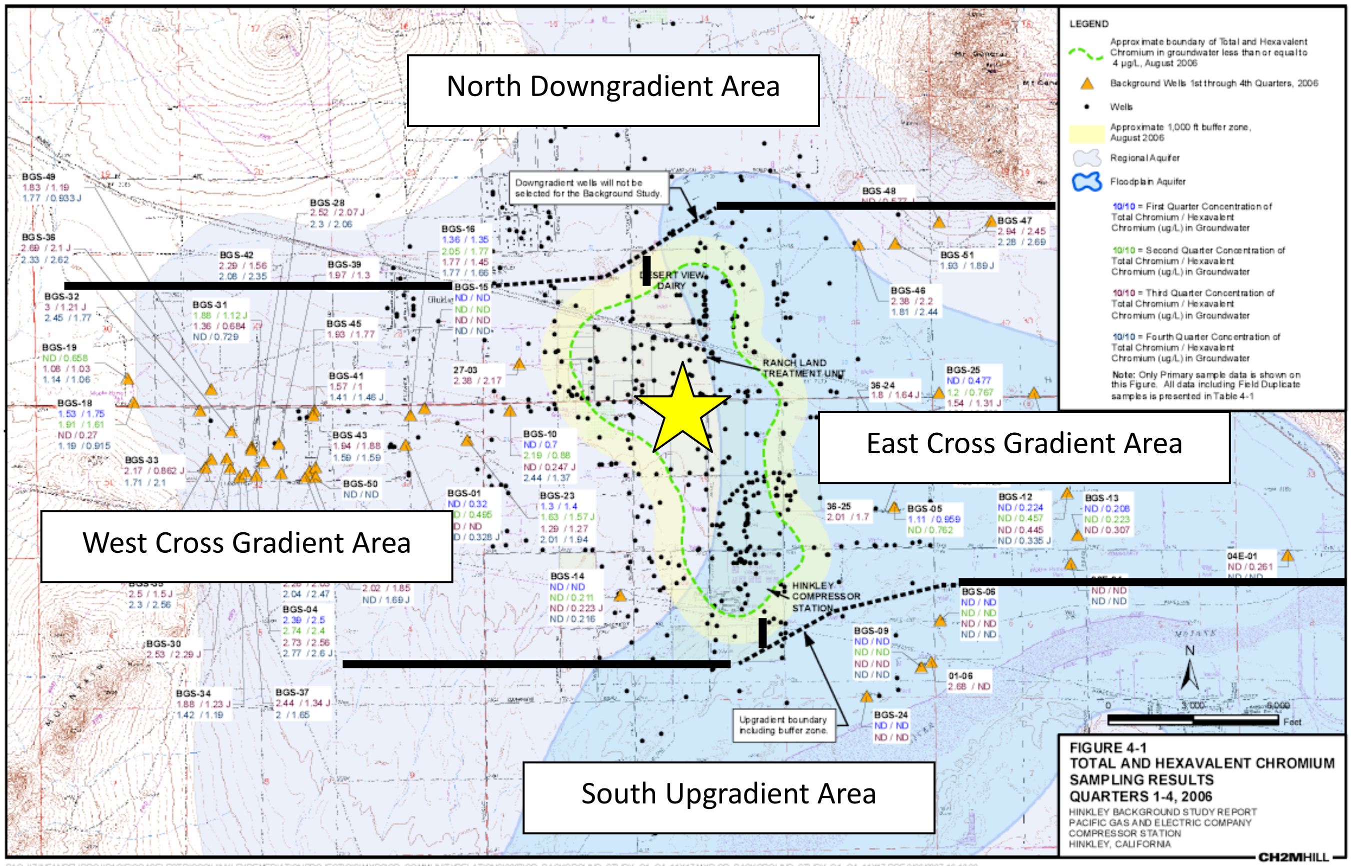

Core Area; green line shows approximate boundary of Cr(T) and Cr(VI) in groundwater less than or equal to 4 µg/L, August 2006.

Figure 1 Map of Cr(T) and Cr(VI) Sampling Results; Background Study

Hinkley, California

(Modified after CH2MHILL, 2007, Figure 4-1)

Date: 10/5/11; James Jacobs, P.G., C.H.G., Clearwater Group