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Lahontan Regional Water Quality Control Board

M E M O R A N D U M

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FROM: LAURI KEMPER
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Lahontan Regional Water Quality Control Board

DATE: May 21, 2015

SUBJECT: **PROSECUTION TEAM RESPONSES TO ADVISORY TEAM REQUEST FOR ADDITIONAL INFORMATION, PROPOSED CLEANUP AND ABATEMENT ORDER REQUIRING PG&E TO CLEAN UP CHROMIUM IN GROUNDWATER IN HINKLEY**

The Regional Water Quality Control Board's Prosecution Team (Prosecution Team) appreciates the opportunity to present additional information and/or provide clarification on topics raised by the Advisory Team in a letter dated April 16, 2015. The following response takes into consideration the available information and statements set forth in the proposed Cleanup and Abatement Order (CAO) and additional relevant information that may assist the Advisory Team and the public.

ADVISORY TEAM REQUEST PART A

a. 1) Submit a written explanation, including all information relied on, to support the assertion in finding 8 that two detached plumes of hexavalent chromium (Cr6) exist in the northern area.
a. 2) Please respond to contradictory information provided by PG&E that asserts the Cr6 in the northern area may not be attributable to PG&E's discharge, including attachment B to the PG&E's March 12, 2015 comments on the proposed Order.

PROSECUTION TEAM RESPONSE PART A.1

In late 2011 and early 2012, PG&E identified a single contiguous area (or a single contaminant plume) from the compressor station to 5.5 miles northwest in Harper Dry Lake to contain chromium in concentrations above maximum background levels (see fourth quarter 2011 and first quarter 2012 quarterly plume maps[1]). Since that initial determination, PG&E has increased its extraction remediation rates 110 percent (from 476 gallons per minute annual average to 1,001 gpm annual average, see attachment A.i), primarily due to extraction at Agricultural Treatment Units (ATUs) near Thompson Road. These extraction increases have contained further migration of what is now called the southern plume, but created a separation to what the proposed CAO refers to as the North Hinkley Valley plume. The area of separation between the two plumes is defined by monitoring well data showing chromium concentrations at less than maximum background levels.

A second gap in the northern plume can now be seen on the more recent plume maps produced by PG&E, including the third quarter 2014 map. The gap is located at Red Hill where due to access issues, no monitoring wells exist. North of the geologic Hinkley Gap at Red Hill PG&E's third quarter 2014 map identifies the beginning of another plume, referred to in the proposed CAO as the Harper Dry Lake Valley northern plume. Based upon monitoring well data showing Cr6 levels up to 13 parts per billion (ppb) in MW-154S1 and MW-133S1 at the leading edge of the second or middle plume, it is entirely reasonable to conclude that Cr6 exists in groundwater in the Hinkley Gap by Red Hill, but PG&E has not been able to install wells to confirm. Thus, the second separation between the second and third plumes, also referred to as the two northern plumes (North Hinkley Valley and Harper Dry Lake Valley), is drawn based on the current monitoring data and the lack of monitoring wells in the gap between the plumes. Since third quarter 2013, PG&E has drawn in the 3.1 ppb maximum background plume boundary line for the southern plume, and using a dashed line and question marks for the North Hinkley Valley and Harper Dry Lake Valley plumes. The Prosecution Team continues to contend that all three groupings of well data above 3.1 ppb are derived from the same chromium discharge originating from the compressor station, as depicted in the first quarter 2012 chromium plume map.

There are multiple sources that the Prosecution Team relied on to support the assertion in finding 8 that two detached plumes of hexavalent chromium (Cr6) and total chromium (CrT) caused by PG&E's historical releases exist in the northern area. This information is based on groundwater monitoring data and quarterly chromium plume maps generated by PG&E (available at the web address in footnote 1). Additional supporting evidence (as summarized in CAO findings 9 and 10) include, but is not limited to, the following:

1. Supported by information in reports from the USGS (2001), the Mojave Water Agency/Cal State Fullerton (2007), U.S. Department of Energy (2011), and PG&E, (specific references provided in attachment A this document), it is established that groundwater moves from the Mojave River, through the Hinkley Valley, and into Harper Dry Lake Valley (aka Water Valley). The 2007 MWA/Cal State Fullerton paper includes Table 8 showing a range of 22 to 3,071 acre-feet per year of groundwater flow from the Hinkley Valley to the Harper Dry Lake Valley (attachment A.ii).
2. The northern area (north Hinkley Valley [north of Thompson Road] and Harper Dry Lake Valley) is hydrologically downgradient from the compressor station where the chromium waste discharge originated (chromium plume maps fourth quarter 2011 and first quarter

[1] Chromium plume maps from August 2010 to first quarter 2015 are available at http://www.waterboards.ca.gov/lahontan/water_issues/projects/pge/index.shtml. All maps referenced in this document will be added to the Prosecution Team's CAO exhibit list at the webpage shown in footnote 2.

2012, and 2013 EIR [CAO exhibit 23[2]]). Thus, plume migration from the compressor station is in the direction towards the northern area.

3. There are no other known anthropogenic sources of chromium waste discharges in the Hinkley Valley. All anthropogenic chromium in this area, and that which migrated in the downgradient flow direction, is considered to be the result of PG&E's activities (CAO R6V-2011-005A1). Per CAO R6V-2008-002A1, all chromium detected above maximum background levels of 3.1 ppb Cr6 and 3.2 ppb CrT is considered to be from PG&E's historical releases.
4. The chromium plume maps from fourth quarter 2011 and first quarter 2012 show one chromium plume extending from the compressor station to the north side of Red Hill (entrance to the Harper Dry Lake Valley).
5. Groundwater monitoring reports from 2010 to 2012 by CH2MHill cite 14 extraction wells from newly acquired farms added at and northeast of the Desert View Dairy (DVD) to attempt to contain plume migration to the north. This action was needed because chromium data, initially at MW-62A and later at other monitoring wells, showed the plume migrating to the north despite operating four extraction wells at the DVD.
6. The first time that PG&E successfully contained the width of the chromium plume from further migration northward was in second quarter 2012, as shown by the two separated plumes in the second quarter chromium plume map by CH2MHill. All previous pumping actions by PG&E and others at agricultural wells were only able to contain portions of the plume, allowing uncontained portions to continue migrating. Meaning that the 53 years before 2012 always saw some portion of chromium plume migrating to areas in the downgradient flow direction, including the northern area.
7. From second quarter 2012 to second quarter 2013, chromium plume maps show the detached northern plume as one plume. The northern plume is drawn separated from the southern plume based on monitoring well data between them showing less than maximum background chromium values.
8. Starting in third quarter 2013, chromium plume maps show the northern detached plume as divided into two plumes based on the lack of monitoring data in the Red Hill area, rather than less than maximum background chromium values. The lack of monitoring data in the Red Hill area is due to PG&E's inability to gain access to private property and endangered species habitat for placing a monitoring well. This lack of monitoring data previously existed in other quarters but was only used for mapping starting third quarter 2013.

PROSECUTION TEAM RESPONSE A. 2

All information and sources provided point to chromium detections above background concentrations in the northern area (north of Thompson Road) as being from PG&E's historical releases. Besides the lines of evidence cited in the Prosecution Team's response a.1 above, no new significant data or evidence is presented in PG&E's attachment B to change the conclusion that chromium above background levels in the northern area is reasonably attributable to PG&E's compressor station. The northern area has been the subject of a previous CAO (R6V-2008-0002A4, dated January 8, 2013, CAO exhibit 22), requiring investigation in that area. The findings in the 2013 CAO remain unchanged by PG&E's March 12, 2015 submittal. Chromium

[2] "CAO exhibits" referred to in this response are available at http://www.waterboards.ca.gov/lahontan/water_issues/projects/pge/cao/. All additional documents referenced here will be added to that exhibit list.

above background levels in the northern area is reasonably attributable to PG&E's compressor station, based on available data.

PG&E's Attachment B
In general, PG&E's attachment B contends it is appropriate to wait until USGS background studies are complete before further investigation and/or remediation in the northern area is required. USGS background studies are not anticipated to be complete until late 2019 at the earliest. The Prosecution Team agrees that uncertainty may exist regarding chromium background values but does not agree that PG&E's chromium plume never migrated to the northern Hinkley Valley and Harper Dry Lake Valley (aka Water Valley). While the USGS study should provide much-needed site-specific information to help reduce background level uncertainties in the north, it is the Prosecution Team's position that uncertainty in groundwater remediation, modeling estimates and hydrogeologic data is always present, and such uncertainty does not provide sound basis for delaying reasonable regulatory actions to protect public health contrary to data already obtained.

The Prosecution Team provides the following responses to each of PG&E's evidence categories for geology and sediment mineralogy, historic land use and pumping, lack of chromium concentration gradient, geochemistry, and 2007 Background Study.

i. Geology and Sediment Mineralogy

PG&E asserts that investigations conducted to date have documented the presence of rock types in the north that are commonly associated with elevated Cr6 levels in groundwater. PG&E has failed to provide any definitive evidence that their compressor station is not the source of the Cr6.

Chromium in the Northern Areas
It is not established that geologically-derived chromium may be present in concentrations greater than background values in the northern (or other) areas. The USGS 7.4 minute quadrangle including the Hinkley area shows the northern rock types as being granite, diorite, dacite, gneiss, marble, and metavolcanics, none of which is noted in geologic resources (Simon and Schuster's *Guide to Rocks and Minerals*, 1978 and *An Introduction to Igneous and Metamorphic Petrology*, 2001) as being high in chromium concentrations. And as noted in the Executive Officer's Report, Item 6 (attachment A.iii), from June 2014, none of the bedrock in the Hinkley area and north was believed by Dr. Dave Miller, a Research Geologist from the USGS office in Menlo Park, as having natural high levels of chromium. Even if it had, Dr. Miller noted that high evaporation rates in the area (more than 70 inches per year) prevent bedrock from infiltrating precipitation (averaging 4 inches per year) and being a source of groundwater in adjacent valleys. The assertion of high chromium concentrations in the northern areas stated in reports prepared by PG&E's consultant, Stantec, is contrary to investigations and mapping by the U.S. Geological Survey.

At this time there is no conclusive mineralogic evidence to demonstrate PG&E's assertion of higher chromium levels in the northern areas. Rather, reasonable weight of evidence exist that groundwater flow direction and velocities have probably resulted in movement of chromium-laden groundwater from the compressor station to the north Hinkley Valley and the Harper Dry Lake Valley. Thus, the Prosecution Team must give appropriate weight to such data with the benefit of the doubt going to Hinkley residents and property owners for public safety.

The USGS, in their Hinkley chromium background study, is embarking on sampling and analysis to address these questions related not only to geologic and mineralogic contributions of chromium to groundwater, but groundwater ages, sources and movement, and will provide the needed site-specific information in 5 years (or so). Until those studies are completed and accepted by the Technical Working Group, the available evidence points to PG&E's compressor station being the source of Cr6 in the northern plume.

Lockhart Fault and MW-163
The Prosecution Team notes that for MW-163, located west of the Hinkley Road and Community Boulevard intersection, PG&E presented a reasonably robust groundwater elevation dataset to support that groundwater did not flow from the compressor station to this cross gradient area. The documented presence of the Lockhart Fault as an impediment to groundwater flow (USGS, 2001) provided further support.

The Prosecution Team does not agree with PG&E that (1) there are rocks containing an abundance of mafic mineral west of the Lockhart Fault, and (2) chromium detections up to 10 ppb in MW-163 are from mafic minerals in soil. Rather, the illegal disposal of wastes on PG&E-owned land (attachment A.iv) upgradient of MW-163 is speculated as being the source of chromium and hydrocarbons affecting groundwater quality. Domestic well data from locations south of Community Boulevard are generally always less than 1 ppb for Cr6, consistent with the hydrology and geology data for west of the Lockhart Fault. Such information therefore does not point to natural chromium sources west of the Lockhart Fault resulting in high chromium concentrations in groundwater. Neither data nor site-specific evidence exists to suggest there are high mafic minerals present in the northern area.

ii. <u>Historic Land Use and Pumping</u>

PG&E asserts that the groundwater flow calculation (two feet/day) in the proposed CAO is inaccurate, not reasonable and as such does not provide a basis for the proposed investigation and remediation requirements. It states that decades of historic and current groundwater pumping in the Hinkley Valley has limited/prevented ground water movement to the north, and so groundwater has not been flowing north at a rate of two feet per day since the 1950s. In PG&E's attachment B, page 17, PG&E asserts that, "*in fact, little to no groundwater has flowed from the South Hinkley Valley north of Thompson Road during much of this time period.*"

Groundwater Velocity
The Prosecution Team contends that the groundwater velocity estimates used in the proposed CAO are conservative and not inaccurate or result in unreasonable assumptions. PG&E's assertion that because of historical and current agricultural pumping, little to no groundwater has flowed north of Thompson Road is not a reasonable scenario and it is not supported by available data, discussed below. PG&E itself used a rate of 2.54 feet/day as an average groundwater velocity for its 2010 Feasibility Study, when the proposed CAO uses two feet/day.

Regarding estimates of groundwater flow velocities in the proposed CAO area (i.e., from the compressor station to the northern areas, including north Hinkley Valley and Harper Dry Lake Valley), the Prosecution Team acknowledges in finding 9 that groundwater velocities are quite variable, based on PG&E's provided data for the plume area south of Thompson Road (estimated at 1 to 4 feet per day). Data from 2008 tracer tests in the Central Area IRZ (south of Highway 58) indicates that groundwater moves at 3.8 feet/day. This rate of groundwater movement is a value closer to the <u>maximum value</u> estimated than the average value of two feet/day used in the proposed CAO calculation. In other areas, groundwater no doubt moves slower or faster, depending on several factors, including Mojave River flow conditions (base flow, flood flows and drought conditions); aquifer properties (coarse sediments closer to the river versus finer sediments in the northern valleys), and seasonal groundwater pumping for agricultural pivots, both historical and current. Faster areas of groundwater velocity, such as in the Central IRZ, the Hinkley Gap, and the area northeast of the Desert Valley Dairy are balanced by slower areas of velocity such as in the northern areas. Given all these potential factors, a conservative average groundwater velocity of two feet/day throughout the length of the combined chromium plumes and used in the proposed CAO is reasonable.

According to PG&E's Fourth Quarter 2014 Groundwater Monitoring Report (see attachment A.v), there are more data available to support groundwater velocity estimates south of Thompson Road (these are the data used in the proposed CAO) compared to the northern areas. The reason for this is that the majority of monitoring wells, pump tests and tracer tests has historically been focused in the plume core area south of Thompson Road. Calculations for groundwater velocity in north Hinkley and Harper Dry Lake Valleys are less precise, and PG&E's groundwater model domain does not extend past Red Hill into the Harper Dry Lake Valley. In PG&E’s 2010 Feasibility Study, an average groundwater velocity of 2.54 feet/day was calculated to estimate cleanup times under different scenarios. Using the average velocity value derived from areas where the majority of high quality data were collected accounts for such uncertainty in a reasonable manner.

Historical and Current Groundwater Pumping
Although PG&E asserts that groundwater pumping for historical agricultural pivots provided plume containment, this is not supported by data. Numerous sources, including PG&E's reports (see exhibit 3-1 in the Fourth Quarter 2014 Groundwater Monitoring Program report, attachment A.v) and the 2013 EIR (CAO exhibit 23) cite or show maps indicating groundwater flow originating from the Mojave River through the Hinkley Gap into Water and Harper Lake Valleys. These sources are included in attachment A or are available on the Lahontan Water Board's webpage. Additionally, Figure 3.7-3 in the document, *Abengoa Mojave Solar Project Environmental Assessment*, (see attachment A.vi) shows the 2004 groundwater flow from the Mojave River through the Hinkley Valley and to the Harper Dry Lake Valley. These sources, and many others, document the groundwater flow between the two valleys even during times when PG&E’s land treatment systems operated.

PG&E’s assertion about how historical plume containment before PG&E’s remedial actions began in 1992 prevented northward plume movement is not supported in its technical reports. Monitoring reports from the 1990s for the East Land Treatment Unit show that up to 15 extraction wells had to be added to augment agricultural wells at the former Mojave Dairy to try to contain the width of the chromium plume. This information indicates the dairy’s agricultural wells did not achieve plume containment on their own. Even after the last extraction well, X-17, was installed at the East LTU in 1996, plume containment was still not achieved. This fact is evident in the chromium plume map dated August 2002 (attachment A.vii) showing one continuous plume boundary line of 50 ppb CrT. The lack of a detached or separated plume indicates the lack of plume containment at the East LTU. Also, the absence of monitoring wells north Santa Fe Avenue and the railroad tracks in the 2002 plume map indicates that the plume’s northern extent was actually unknown at the time; many of the northern domestic and agricultural wells used for sampling had very long screens that would dilute contaminant and provide unreliable chromium concentrations.

By the end of 2014, the leading edge of the chromium plume originating from the Hinkley compressor station has migrated for the past 55 years. Thirty-six of those 55 years or 65 percent involved migration via natural groundwater flow and partial capture by agricultural wells that operated year round or two-thirds of the year. Groundwater data from both monitoring wells and domestic wells show that when PG&E started to delineate the chromium plume in 1988, 29 years after first impact to groundwater, it was always chasing the plume and never able to get ahead of it. For example, the August 2010 chromium plume map shows the 3.1 ppb Cr6/3.2 ppb CrT plume line is drawn just south of Thompson Road. However, up to 6.7 ppb Cr6 and 6.9 ppb CrT are shown in domestic wells north of the drawn boundary line.

Furthermore, PG&E has conducted remedial actions only during the past 19 years, of which includes three years when no actions were undertaken from 2001 to 2004. Only in the most recent three of those 19 years included capture of the southern plume from migrating to the north Hinkley Valley and the Harper Dry Lake Valley. PG&E's chromium plume map from first quarter 2012 shows the chromium plume extending from the compressor station to the north side of Red Hill, which is the entrance to the Harper Dry Lake Valley. However, the leading edge of the chromium plume is calculated as having migrated approximately 7.6 miles from the compressor station at that point in time, which is one mile more than that shown on the map. Once in the Harper Dry Lake Valley, the chromium plume was driven by the lower water table elevations due to extensive pumping at farms, such as the more than 100 acres of tomatillos located less than one mile north and northwest. It is possible that these agricultural wells are capturing the chromium plume and preventing its further migration in the valley.

In sum, based on the weight of evidence and general hydrological principles, it is not just plausible but probable that the chromium plume in groundwater migrated from the compressor station through the Hinkley Valley into the Harper Dry Lake Valley. The proposed CAO appropriately uses the groundwater flow velocity data from the area in which the most robust dataset was developed, and uses a conservative average value to account for uncertainty. The requirements of the proposed CAO for investigation and remediation in the northern area are not unreasonably burdensome, and several actions have already been undertaken by PG&E (installation of monitoring well Red Hill 5; hotspot remediation at MW-196). The proposed CAO focuses remediation requirements to areas where hot spots exist (wells exceeding the maximum contaminant level for Cr6 of 10 ppb) to protect public health in this area.

iii. Lack of Chromium Concentration Gradient

PG&E argues that the areas of "hot spots" as referred to in the proposed CAO, including at MW-154S1 and MW-193S3, are geographically separated by vast acreage from other wells with similar concentrations, and that there is no concentration gradient from the plume area to these "hot spots". PG&E states there is no reasonable explanation for these isolated areas of higher chromium concentrations other than natural background levels, or source(s) other than the PG&E plume.

The Prosecution Team acknowledges that textbook groundwater plumes often show a pattern of higher concentrations near the source, with lessening concentrations in the down-gradient direction, known as a "concentration gradient." These textbook plumes have not under gone remediation or other plume capture actions that alter concentration gradients.

Detached plumes and chromium hotspots are a known occurrence in groundwater attenuation and remediation and extensively cited in literature (for example, see attachments A.viii and A.ix). Explanations for challenging plume geometries and varying concentration gradients include aquifer materials with differing hydraulic conductivity values (denoted as K, describing the ease with which a fluid (usually water) can move through pore spaces or fractures);

"pulsing" of any remaining contaminant sources, often due to rising or falling groundwater levels; "starving" of the plume from its contaminant source through remedial actions or natural attenuation, and subsurface geologic structures such as buried stream channels, faults, fractures or folds that may result in preferential or impeded groundwater flow paths.

In the case of Hinkley, hot spots occur as chromium moves through the aquifer with groundwater flow, but become "stuck" and concentrated in areas of less permeable aquifer materials, typically finer-grained, less transmissive materials. Areas such as these exist at the source area, where finer-grained aquifer materials are proving recalcitrant to in-situ remedial actions. Of particular note is that the three hot spots (MW-154, MW-193, MW-196) in the northern areas identified in the proposed CAO are all within the chromium plume boundaries and the probable flow path from the north Hinkley Valley to the Harper Dry Lake Valley. Also, the lack of chromium hot spots outside the groundwater flow path in these two valleys also indicates the source is from PG&E's historical release and not from natural geologic materials. Such hot spots could represent the "pearls" in the "string of pearls" chromium plume in which areas of higher concentrations are separated by areas lower concentrations (see attachment A.viii).

The Hinkley chromium plume is hardly textbook. The first 33 years of chromium plume migration from the compressor station included many incidences of partial plume capture by agricultural wells, which altered chromium concentrations. In addition, fluctuating wet and drought years also affected plume concentrations over time and distance. Following successful containment of the southern plume south of Thompson Road in 2012, the northern and southern plume areas are now separated by an area of less than background chromium concentrations, creating "detached" or non-contiguous plumes. As southern plume containment south of Thompson Road continued with time, it acted to starve the northern plume of its source of chromium, thereby creating a detached plume. The distance separating the northern detached plume increased with time as there were no actions undertaken to stop the northern plume from migration. Over time, monitoring results would show the northern plume extending to the Harper Dry Lake Valley, first as one plume and later as two discontinuous plumes when drawn as such for lack of monitoring data. Despite how they are drawn, the northern chromium plume or plumes are a result of the chromium release at the Hinkley Compressor Station.

To conclude, the Prosecution Team agrees with PG&E that the Hinkley chromium plume does not look like a textbook plume with evenly distributed concentration gradients. However, hot spots separated by areas of lower chromium concentrations are explained by decades of partial plume capture by agricultural wells, hydrology, and later by PG&E's remedial actions. A short chronology of the northern area plume investigations and concurrent remedial actions upgradient is summarized below (maps referred to below are available at http://www.waterboards.ca.gov/lahontan/water_issues/projects/pge/index.shtml):

- In the 4th quarter 2011 plume map, as additional monitoring wells were installed in the northern area, the 3.1 Cr6 plume boundary <u>was contiguous with the plume originating from the compressor station</u> up to just south of Red Hill, which was the northern limit of monitoring well installation. A hotspot of 10.6 ppb Cr6 was detected at MW-128S1.

- In the 1st quarter 2012 plume map, the 3.1 Cr6 plume boundary <u>was still contiguous with the compressor station</u>, and showing hotspots of 11.6 Cr6 at MW-139S1 and 10 ppb at MW-154S1.

- In the 2nd quarter 2012 plume, the plume map indicates a gap between the 3.1 Cr6 boundary connected to the compressor station, and the northern area plumes. Monitoring wells show concentrations less than the maximum background value of 3.1 ppb Cr6 in the area of south of Salinas and Tindall Roads, showing that the northern and southern plumes had detached from one another.

iv. Geochemistry

In attachment B to its comments, PG&E discussed data it collected on total dissolved solids, nitrates, oxygen and hydrogen isotopes, and tritium in the proposed CAO project area. The discussion aims to highlight PG&E's assertion that groundwater in the north Hinkley and Harper Dry Lake Valleys show different concentrations of certain geochemical markers, suggesting they are not related to compressor station discharges. Similar to other discussions in its attachment B, PG&E describes how the USGS will be studying these same parameters, and that the USGS studies are needed to interpret the results.

Similar to our responses above, it is premature to conclude that chromium in the northern areas is not PG&E's when an abundance of other information indicates the contrary. The reasonable, logical, and fair approach is to wait for the USGS to complete its unbiased background study and propose recommendations for chromium background levels along the nearly 8-mile length of the chromium plume.

v. 2007 Background Study and Adopted Background Values

The Prosecution Team acknowledges the uncertainty associated with the 2007 background study, including the limited geographic scope of the 2007 study, and its technical shortcomings. Nonetheless, these are the best available data, and it is important to note the Water Board did not choose to rescind the currently adopted background values in 2011and 2012 when the peer review issues where ongoing (see January 2012 Water Board meeting agenda item #12; June 2012 Water Board meeting agenda item #3, both available at http://www.waterboards.ca.gov/lahontan/board_info/minutes/2012/index.shtml). To date, PG&E has not provided alternate background data that convincingly refutes the 2008 adopted background data. Until such time as potential new background values are brought to the Water Board for consideration, the current background values remain the best data available to define the chromium plume.

ADVISORY TEAM REQUEST PART B:

b. Submit a written explanation of the reasons why PG&E's proposal (proposed MRP, submitted December 19, 2014) is not sufficient to: 1) detect and react to any unforeseen changes in water quality in the southern area, 2) verify that its remediation efforts are effective, and 3) track chromium concentration changes and protect public health in the northern area. The Advisory Team notes Finding 36 does not contain specific rationale to explain why PG&E's proposal is inadequate.

PROSECUTION TEAM RESPONSE PART B:

Introduction

The Prosecution Team developed its own monitoring and reporting program (attachment 8 of the proposed CAO) that we believed would meet monitoring objectives and provide flexibility to make changes going forward.

In the time since the release of the proposed CAO, the Prosecution Team has further reviewed PG&E's proposed monitoring and reporting program (proposed MRP), and has been able to evaluate its sufficiency to meet monitoring objectives. Monitoring objectives considered include: remediation effectiveness, chromium plume boundary tracking (evaluating changes in chromium concentrations around current plume boundaries), domestic well protection, and remediation target progress tracking.

Responses to b.1 and b.2

Southern Plume Monitoring

Monitoring Wells, Active ATUs and IRZs
Upon review of PG&E's proposed MRP, the Prosecution Team finds that PG&E's monitoring shown in its figure B-12 (specifically the pink-shaded and blue-shaded upper aquifer monitoring wells and associated sampling frequencies in the southern plume area) reflects the currently prescribed monitoring requirements in the ATU waste discharge requirements and staff's draft revised IRZ monitoring program that will be circulated for public comment in June along with a revised/combined Notice of Applicability for the general Waste Discharge Requirements for In-situ Activities.

Therefore, PG&E's wells and frequencies described above meet the monitoring objective to track remediation effectiveness in the southern plume area, and can be used in lieu of the monitoring proposed by the Prosecution Team in attachment 8 of the proposed CAO, sections I.C.1 and I.C.2.

Monitoring Wells, Western Finger and Lower Aquifer
To meet the monitoring objectives of tracking remediation effectiveness and chromium plume boundary tracking for the western finger area and the lower aquifer, the Prosecution Team finds that PG&E's proposed MRP can be used as a starting point, but needs augmentation, described below for each area.

Western Finger Area:
In addition to the green-shaded western finger area monitoring wells shown on PG&E's proposed MRP figure B-12 (west of Serra Road), the Prosecution Team recommends continuing to sample the following monitoring wells to better meet the objectives of plume boundary tracking and domestic well protection.

Table 1. Monitoring well additions for western finger

MW	Sampling Frequency	Rationale
MW-118S	Q	Domestic well protection
MW-121S	SA	Plume boundary tracking
MW-164S	SA	Domestic well protection
MW-201S/D	SA/A	Domestic well protection
MW-168S/D	SA/A	Plume boundary tracking
MW-59	A	Plume boundary tracking
MW-57S/D	SA	Domestic well protection

Q = quarterly; SA = semi-annually (twice yearly); A=annually

With the additions shown in Table 1, the Prosecution Team believes that PG&E's proposed MRP can be used in lieu of the proposed CAO monitoring in attachment 8, section I.C.3.

Lower Aquifer:
In addition to the nine monitoring wells that PG&E proposed to sample quarterly in the lower aquifer, the Prosecution Team recommends continuing to sample the following existing lower aquifer monitoring wells to better meet the objectives of remediation effectiveness and plume boundary tracking:

a) **Annual sampling** of all lower aquifer monitoring wells shown as white crosses[3] in PG&E's figure B-10 south of Highway 58.
b) **Semi-annual** sampling of all lower aquifer monitoring wells shown as white crosses in PG&E's figure B-10 north of Highway 58.

With the additions noted above, the Prosecution Team agrees that PG&E's proposed MRP for the lower aquifer shown in its figure B-10 can be used in lieu of the monitoring described in CAO attachment 8, section I.C.4.

<u>Southern Plume Monitoring for Plume Boundary Plume Tracking and Domestic Well Protection (Excluding Western Finger Area)</u>

PG&E's proposed MRP for tracking the southern chromium plume boundary is shown in its figure B-12 as green-shaded wells and wells with orange circles around them. The Prosecution Team finds that PG&E's proposed MRP can be used as a starting point, but needs augmentation. In addition to the monitoring wells that PG&E proposed, the Prosecution Team recommends keeping the following existing monitoring wells to better meet the objectives of plume boundary tracking and domestic well protection:

[3] White crosses on PG&E's figure B-10 indicate "no sampling" proposed for those wells.

Table 2. Monitoring well additions for plume tracking and domestic well protection, southern plume

MW	General Area	Sampling Frequency	Rationale
EX-23	Northwest area	Quarterly (Q)	Close gap between DW-03 and DW-02
MW-102D	Eastern area	Q	Increasing trend for Cr
MW-116D1	Eastern area	Q	Close gap between MW-95 and MW-110
MW-172	North of Thompson Road in area between north and south plumes	Q	Increasing trend for Cr
MW-126	Same as MW-172	Q	Increasing trend for Cr
MW-124	Same as MW-172	Q	Increasing trend for Cr

With the additions noted in Table 2, the Prosecution Team agrees that PG&E's proposed MRP for chromium plume boundary tracking shown in its figure B-12 for the southern plume can be used in lieu of the Proposed CAO monitoring shown in attachment 8, section I.E. (and I.C.1 and I.C.2, to the extent there is overlap in those sections).

However, the Prosecution Team recommends that PG&E use all chromium data collected at monitoring wells (for a similar aquifer depth) to depict the chromium plume boundary, and not just the monitoring wells with the orange circles around them.

Southern Plume Area Domestic Wells

The Prosecution Team notes that PG&E's proposed MRP requests revisions to the domestic well sampling program in the southern plume area (specifically, in the one-mile buffer area around the contiguous southern plume). Domestic well sampling requirements are contained in waste discharge permits regulating the ATU remediation activities. It is not appropriate to consider revisions to that permit as a part of this CAO. The Executive Officer, at any time, may consider revisions to the permit's associated monitoring and reporting program. However, the Water Board Prosecution Team does not agree that changes are needed in these requirements at this time.

As noted in proposed CAO attachment 8, at footnote 1 (page 4), southern plume monitoring for domestic wells is not a part of the CAO monitoring; therefore, no revisions to the southern plume domestic wells monitoring program contained in the Waste Discharge Requirements for Agricultural Treatment Units Order R6V-2014-0023 are recommended as part of this CAO.

Response to b.3

Northern Plumes Monitoring

Monitoring Wells and Domestic Wells, Northern Area

The Prosecution Team disagrees with PG&E's proposed MRP to eliminate certain monitoring wells and reduce the sampling frequency for monitoring and domestic wells in the northern area.

Such changes will result in an insufficient monitoring network to adequately track chromium changes and protect public health in the northern area, as described below. The Prosecution Team recommends retaining proposed CAO attachment 8, sections I.D.1, I.D.2, I.D.3 and section I.F as written. However, we agree that PG&E does not need to continue sampling three domestic wells due to their distance from the northern area plume boundaries: 02N-02, 32N-01, and 16N-01.

Monitoring well locations in the north Hinkley Valley and the Harper Dry Lake Valley are spaced at greater distances apart from each than in the southern plume. This is primarily due to PG&E's restricted ability to access private land and endangered species habitat. Monitoring well spacing currently ranges from 1,400 feet to greater than 6,000 feet. In the Hinkley Gap area at Red Hill, lack of access has prevented monitoring wells from being installed and adequately defining the chromium plume boundaries that could possibly connect the chromium plume in the north Hinkley Valley to the chromium plume depicted in the Harper Dry Lake Valley.

Besides the Hinkley Gap, Findings 10 and 11 in CAO R6V-2008-0002-A4 state the chromium plume is also inadequately defined in multiple areas, such as northeast of the southern plume, along the eastern boundary in the north Hinkley Valley, and in the Harper Dry Lake Valley. The Prosecution Team finds the current average monitoring well spacing of 2,000 feet is insufficient for accurately determining the location of chromium contamination, and therefore opposes increases in monitoring well spacing (by reducing the number of wells being monitored). This reduction in sampling and analysis would hinder the ability to evaluate plume migration and to protect nearby residents.

Unlike the southern plume, the chromium plumes in the northern areas are not being remediated or prevented from migration with natural groundwater flow. Therefore, there is an ongoing threat to public health for residents with domestic wells in the northern areas. Since groundwater is less abundant in the northern areas due to a shallower aquifer consisting of finer sediments than in the southern aquifer, its protection is more critical. It is the Water Board's practice to not reduce or eliminate monitoring while a contaminant plume threatening domestic water supplies is not fully defined or controlled. No exception applies here. Thus, the Prosecution Team continues to oppose PG&E's proposed MRP to remove or significantly reduce sampling frequency at a majority of monitoring wells or domestic wells until plume delineation and containment have been achieved.

Additional Issue: Mann-Kendall Statistical Test

Although not a part of the Advisory Team's request, the Prosecution Team offers that it has no objections to applying the Mann-Kendall statistical test to groundwater data, provided triggers for remedial corrective actions and step-out monitoring (as well as increasing monitoring frequencies) are established for statistically significant increasing outcomes if needed. Many sources cite the benefits of applying the Mann-Kendall statistical test to monitoring wells data, and as one author puts it, while it is not "the One-True-Statistical method…it is often a pretty darn good way to look at data."[4] Several sources, including the March 2009 U.S. EPA guidance statistical document (EPA 530/R-09-007), state that if the Mann-Kendall test indicates an increasing trend and the slope test is significant, triggers for corrective actions should be established. We concur with this suggestion.

[4] M. Vanderford, 2008

ADVISORY TEAM REQUEST PART C

c. 1) Provide a written explanation of the information and rationale relied upon for how Finding 43 defined an affected area as all domestic or community supply wells located laterally one mile down or cross gradient from the 3.1 Cr6 plume boundaries.
c. 2) What purpose does having a defined "affected area" serve?

PROSECUTION TEAM RESPONSE PART C. 1

The Prosecution Team relied upon many resources in defining an affected area in finding 43 of the proposed CAO, including three prior cleanup and abatement orders to PGE (R6V-2011-0005 and its two amendments). PG&E is currently taking actions to install and implement final remedial action (two new ATUs and expanded IRZ) for chromium contamination in groundwater. The potential consequences of implementing the final remedial action won't be known until later in time. In addition, the lack of plume containment for the northern areas where chromium was detected up to 100 ppb (in a non-tampered monitoring well) continues to pose a threat to 22 domestic wells and beneficial uses. We believe defining an affected area serves a legitimate purpose until final remedial actions are implemented and the chromium plumes are proven to be stable and not migrating. The need for defining an "affected area" in the proposed CAO is to provide an area of protection for well users who may be impacted by chromium and/or byproducts due to PG&E's waste discharge and remedial actions. Just as sampling domestic wells is necessary in the proposed CAO, so is defining an affected area to conduct such sampling.

History of "Affected Area"
The concept of an "affected area" for Hinkley came about in CAO R6V-2011-0005, dated January 7, 2011. This CAO did not use the term "affected area" but identified a "project area" requiring PG&E to sample domestic wells to determine if such wells contained concentrations of chromium over the maximum background levels; if so, then PG&E was required to provide "interim" (i.e., bottled) water to the well users. This is how the first comprehensive domestic well sampling requirements in Hinkley were established by the Water Board. The CAO project area was defined as 3,000 feet from the 3.1/3.2 ppb Cr6/CrT plume boundary. This area was set to account for the limited dataset of chromium in domestic wells at the time and evidence that the chromium plume was migrating (see CAO R6V-2011-0005 finding 6) and was undefined in areas where domestic wells could be threatened.

In July 2011, the Office of Environmental Health Hazard Assessment finalized a public health goal (PHG) for hexavalent chromium of 0.02 ppb, well below the maximum background level of 3.1 ppb set for Hinkley. Because the 2007 background study had found that naturally occurring chromium in Hinkley ranged from non-detectable amounts up to 3.1 Cr6, residents whose wells were previously at levels less than the maximum background became very concerned about any chromium in their wells, given the very low level of the PHG, and did not want to wait until their wells reached 3.1 ppb Cr6 before being eligible for bottled water.

An amended CAO R6V-2011-0005A1 was issued on October 11, 2011, recognizing that many domestic wells in Hinkley contained chromium less than the maximum background value, and that the PHG, along with background, should be used to determine an "impacted well" for the purposes of providing replacement water. The term "affected area" was now used (see finding 30 of the amended CAO), and was defined as one-mile down- or cross-gradient of the 3.1 ppb Cr6 plume. This expanded affected area was used to account for uncertainty in plume migration, undefined plume boundaries, and to provide a level of protectiveness for concerned Hinkley residents given the low PHG.

A second amended CAO R6V-2011-0005A2 was issued on June 7, 2012, requiring PG&E to implement its voluntary whole house water program. This amended CAO continued the definition of an affected area that the first amended CAO used. The Environmental Impact Report (ICF, 2013) prepared for the remediation project also uses the one-mile area for sampling and mitigation measures to require replacement water if chromium in domestic wells in the buffer area increase as a result of remedial actions.

On July 1, 2014, the Department of Drinking Water issued a final maximum contaminant level (MCL) for hexavalent chromium of 10 ppb. The MCL now must be used to define affected wells for the purposes of requiring replacement water in CAOs.

The Prosecution Team notes that the affected area definition evolved in response to several factors that were important at the time of issuing CAO R6V-2011-0005 and amendments: lack of data on chromium levels in domestic wells; lack of plume containment south of Thompson Road; lack of an MCL for Cr6 for which to define "affected wells" pursuant to Water Code section 13304, and lack of final remedial action implementation. We acknowledge the first three factors are no longer in play. Yet, the lack of final remedial action implementation justifies including an affected area in the proposed CAO. PG&E is currently taking actions to install and implement additional remedial actions (two new ATUs and expanded IRZ). The potential consequences of implementing these remedial actions won't be known until later in time. In addition, the lack of plume containment or any remediation actions for the northern areas where chromium was detected up to 100 ppb (in a non-tampered monitoring well) continues to pose a threat to domestic wells and beneficial uses. Therefore, we believe defining an affected area serves a legitimate purpose (see response c. 2, below) until remedial actions are implemented and the chromium plume is proven to be stable and not migrating.

PROSECUTION TEAM RESPONSE PART C. 2

Defining an affected area serves the purposes of providing protection for well users who may be impacted by chromium and/or byproducts due to PG&E's past waste discharges or its remedial actions, and also provides regulatory clarity to define where sampling must occur. As stated in the 2013 EIR, unavoidable impacts may result from remediation actions, and an appropriate mitigation measure is to sample domestic wells within a certain distance. Sampling domestic wells within an affected area will be necessary while remedial actions are being implemented and chromium and byproduct plumes are unstable.

In the past, staff has used two methods for requiring sampling of domestic wells in CAOs[5]: the "well listing method" and the "affected area" method. Experience has shown that the affected area method is preferred over listing well numbers, for several reasons: 1) new domestic wells may come into service after the CAO is issued; 2) staff may not be aware of all existing wells at the time of CAO issuance, and 3) existing wells whether listed or not may become polluted after the CAO is issued, and thus need sampling under the CAO. Water Board staff has also seen incidences at dairies and non-remedial crop fields where agricultural wells are operated at

[5] CAO R6V-2008-0034 (Ryken DVD CAO) defined an affected area, but the first amendment to this CAO then changed this to a specific list of wells. CAO R6V-2011-0058 (Harmsen CAO) defines an affected area, as does CAO R6V-2011-0057 (Ryken Heifer CAO).

changing rates, affecting the boundaries of the chromium plume. When this occurs, wells used for domestic purposes also become affected by the expanded plume. These well owners have the right to pump their wells within the water rights administered by the Mojave Water Agency and to expect clean groundwater, unaffected by discharges. In most cases, PG&E was not made aware ahead of time of changes in farmers' pumping and were caught off guard when plume migration occurred. Defining an affected area in the CAO is necessary to protect well users now and in the future.

It is intended that the affected area in the proposed CAO will provide a degree of flexibility in response to any new data collected and evaluated each quarter, and provide foresight into preventing Cr6 exceeding the drinking water standard of 10 ppb in domestic wells. Using an affected area is a preventative tactic as opposed to waiting to require action once a well measures at or above the drinking water standard.

CONCLUSION

The Prosecution Team provides an explanation, including extensive information and sources relied upon, to support the finding 8 assertion that two detached plumes of hexavalent chromium exist in the northern area and can be attributed to PG&E's past waste discharges from the compressor station. The Prosecution Team continues to contend that all three groupings of well data above 3.1 ppb Cr6 are derived from the same chromium waste discharges originating from the compressor station and extending to the Harper Dry Lake Valley, as depicted in the First Quarter 2012 Map.

A robust and extensive monitoring and reporting program is necessary going forward to track changes in the chromium plume boundaries, evaluate the progress and effectiveness of remedial actions, and protect public health and domestic wells. These comments describe where the Prosecution Team believes some agreement and changes can be made consistent with PG&E's proposed MRP. The comments also support why the Prosecution Team finds that some changes should not be made pursuant to PG&E's proposed MRP.

Finally, the Prosecution Team provides information and rationale relied upon to define an affected area for domestic or community supply wells. We also explain the purpose for defining an "affected area" in the proposed CAO as providing protection for well users who may be impacted by chromium and/or byproducts due to PG&E's waste discharge and remedial actions. Just as sampling domestic wells is necessary in the proposed CAO, so is defining an affected area to conduct such sampling is necessary.

We request that all of the materials referred to in this response be made a part of the administrative record for the consideration and development of the final CAO. All references will be posted to the Prosecution Team's exhibit list at http://www.waterboards.ca.gov/lahontan/water_issues/projects/pge/cao/.

Thank you for the opportunity to provide additional clarification regarding these issues.

Lauri Kemper, PE
Assistant Executive Officer

Attachment A:

References

i. Table 2-1, *Chronological Summary of Remedial System Start-up*, PG&E's March 30, 2015 Semi-annual Remediation Status Report.
ii. Excerpt from Cal State Fullerton/Mojave Water Agency, *Harper Lake Basin Hydrogeological Report (2007)*
iii. Executive Officer's Report, Item #6 (June 2014)
iv. Closure Report, Pivox Corporation, December 2013
v. Excerpt from PG&E (2014), fourth quarter 2014 groundwater monitoring report, Exhibit 3-1, *Groundwater Flow through the Hinkley Gap*, showing estimates of groundwater flow through the Hinkley Gap from a variety of sources.
vi. Abengoa Mojave Solar *Project Environmental Assessment*, U.S. Department of Energy (2011)
vii. August 2002 Chromium Plume Map, CH2MHill (2003)
viii. Excerpt from *Groundwater Plume Maps and Information Booklet*, by the Air Force Center for Engineering and the Environment, (SDMS DocID 454664, 2010)
ix. J.L.N. Kear, et al., *Birth of a Detached MTBE Plume: Groundwater Modeling Anchored in Groundwater Monitoring* (2005) Groundwater, NGWA
x. Excerpt from USGS (2001), Simulation of Ground-water Flow in the Mojave River Basin, California, showing groundwater flow direction and magnitude into Harper Lake Valley from Centro subarea, 1930-1994.

i. Table 2-1, *Chronological Summary of Remedial System Start-up*, PG&E's March 30, 2015 Semi-annual Remediation Status Report.

TABLE 2-1

Chronological Summary of Remedial System Start-up, Cumulative Number of Wells, and Combined Annual Average Extraction Rates

Semiannual Remediation Status and Final Cleanup Effectiveness Report (July through December 2014)

Pacific Gas and Electric Company, Hinkley Compressor Station, Hinkley, California

Period	Key Remedial System Event	Monitoring Wells[a]	IRZ Wells[b]	Freshwater Injection Wells	Extraction Wells	Combined Extraction Rate[c] (GPM)
1992 – 2001	Operation of East and Ranch Land Treatment Units.	26	--	–	32	744[d]
September 2004	Begin operations for DVD LTU.	84	–	--	2	46
November 2007	Begin Central Area In Situ Reactive Zone (IRZ) operations.	91	12	–	4	284
April – May 2008	Start-up of the Source Area IRZ system.	91	28	–	7	334
October 2009	Begin South Central Reinjection IRZ operation. Northwest Area extraction wells used for SCRIA IRZ supply.	91	40	–	9	334
March 2010	Begin localized injection for Northwest Freshwater Injection System.	99	40	4[e]	9	476
March – June 2011	Begin Agricultural Treatment Unit (ATU) operations at Gorman, Cottrell, and Ranch ATUs.	129	40	5[e]	23	1,001
April 2011	Begin expanded Source Area IRZ system.	129	49	5[e]	23	1,001
November 2012	Begin expanded Central Area IRZ system and Manganese Mitigation system operations.	271	70	5[e]	33	1,190
April 2013	Begin Yang ATU operations.	311	70	5[e]	33	1,157[f]
August 2013	Discharge to the Yang ATU was suspended and construction of the Yang ATU expansion was conducted.	311	70	5[e]	34	1,157[f]
October – December 2013	Restart irrigation at Yang ATU. Install 68 new Upper Aquifer monitoring wells and 2 new extraction wells at Yang ATU (starting operation in April 2014).	376	70	5[e]	34	1,250[g]
March 2014	Injection wells IN-03R and IN-06 began operating March 6, 2014. IN-03 may be used when IN-03R is shutdown for maintenance.	376	70	6[e]	34	1,111[h]
May 2014	Western Area groundwater extraction begins with operation of EX-36.	377	70	6[e]	37	1,111[h]

ii. Excerpt from Cal State Fullerton/Mojave Water Agency, *Harper Lake Basin Hydrogeological Report (2007)*

HARPER LAKE BASIN,
SAN BERNARDINO COUNTY, CALIFORNIA
HYDROGEOLOGIC REPORT

September 2007

California State University, Fullerton
Department of Geological Sciences

HARPER LAKE BASIN,
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Dedicated to the Memory of Brock Boeke

Prepared in cooperation with and submitted to
Mojave Water Agency

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Executive Summary

Harper Lake Basin is a closed basin northwest of the Mojave River. It lies in the Centro Sub-area of the Mojave Water Agency management area of the Mojave Desert. Drainage into the central dry lake portion of the basin [Harper (dry) Lake] occurs through late summer thunderstorms and winter storms. Average precipitation is approximately 5 inches (13 cm) a year while evapotranspiration is approximately 68 inches (173 cm) a year. Groundwater levels have gradually declined since the keeping of water-level records began. Although the sequence of records is incomplete in many instances, they are still a good general indicator. There are 377 known wells in Harper Lake Basin, most of which are located directly adjacent to the northwest edge of the Mojave River. The bulk of the remaining wells are located at the southeast edge of Harper Lake Basin. Water use has dropped by about half from the highs reported prior to the initiation of the "1996 Adjudication." The principal aquifer of Harper Lake Basin is composed of older alluvium, which underlies the Late Pleistocene lake sediments and surrounds the lake as alluvial fan deposits. Older alluvium ranges from being very thin to a thickness of several hundred meters mostly on the northeast side of Harper (dry) Lake. Groundwater recharge comes primarily from underflow from the middle Mojave River Valley basin through a small alluvial divide near Red Hill. Flow through the Red Hill gap is approximately 1,000 acre feet per year. Additional recharge occurs from precipitation but is poorly quantified and in general only occurs when seasonal rainfall exceeds 8 inches (20 cm). Measured water quality is limited to TDS values. TDS values are lower further away from the Harper (dry) Lake boundary. Reported water quality ranges have shown a decrease in the low values from 1,000 mg/l in 1979 to 179 mg/l in 2003, while the higher values have remained high at 2,300 mg/l on average over the same time period. Degraded groundwater quality near the dry lake is attributed to the infiltration of irrigation return flow.

Table 6. Harper Lake Basin annual verified water production.	
Water Year	Verified Water Production (acre-ft)
2005-06	3,429
2004-05	2,901
2003-04	3,388
2002-03	3,191
2001-02	3,915
2000-01	4,004
1999-00	3,616
1998-99	3,537
1997-98	3,322
1996-97	8,561
1995-96	10,093
1994-95	9,954
1993-94	4,729
Average	4,972

Table 7. Harper Lake Basin estimated groundwater storage.		
	DWR (1967)	DWR (2003)
Total Storage Capacity (acre-ft)	-	6,975,000
Groundwater in Storage (acre-ft)	2,497,000	101,500

5.5 Subsurface flow from Middle Mojave River Valley Basin

Harper Lake Basin receives subsurface groundwater inflow from the Middle Mojave River Valley Basin through a small alluvial divide near Red Hill (DWR, 1964; 1967; 1971; 2003; Mark Group, 1989; MWA, 1983; Stamos et al., 2001; Aquifer Science and Technology, 2007) (Figure 22: Mojave River–Harper Lake Basin Divide and Table 8: Previous works on subsurface groundwater flow into Harper Lake Basin from the Middle Mojave River Valley Basin. The narrow aquifer pathway near Red Hill ranges from 150 ft to 200 ft in thickness (The Mark Group, 1989; Aquifer Science and Technology, 2007). Sediments consist of buried river channel deposits that are interpreted to be the remnants of an abandoned channel between Harper Lake Basin and the Mojave River (MWA, 1983; Reynolds and Reynolds, 1994; Stamos et al., 2001; Aquifer Science and Technology, 2007). Calculations made by Mark Group (1989) indicate that recharge from the Middle Mojave River Valley groundwater basin into Harper Lake groundwater basin is 2,700 acre-feet/year through the region near Red Hill. Conversely, DWR (1967) estimates 1,000 acre-ft/yr of recharge and MWA (1983) estimates 22 acre-ft/yr of recharge through the same gap near Red Hill. Aquifer Science and Technology (2007) performed a geophysical survey through the Hinkley Gap near Red Hill and concluded an estimate of 1,468 acre-ft/yr of subsurface recharge. In a USGS report, Stamos et al. (2001) modeled the entire Mojave River Basin using MODFLOW and concluded 4,290 acre-feet/year of groundwater recharge into Harper Lake Basin from the Middle Mojave River Valley Basin in 1994, and averaged 3,071 acre-feet/year from 1931 to 1990. It should be noted Stamos et al. (2001) groundwater model did not focus solely on the Red Hill gap, but took into account the entire aquifer boundary between Harper Lake Basin and the Middle Mojave River Valley Basin. Subsurface flow calculation through the same alluvial channel west of Red Hill, presented here (Table 9: Flow calculations at Red Hill gap) indicates 1,100 acre-ft/yr of subsurface flow from the Middle Mojave River Valley Basin to the Harper Lake Basin. This calculation reasonable compared to other previous works in the area (Table 8). However, the varying aquifer characteristics, size, and methods used in each of the different studies yields a variety of results ranging from 22 acre-feet/year to 3,071 acre-feet/year.

There has been much consideration of subsurface groundwater movement through the Red Hill gap, however no significance has been placed on the potential for subsurface flow through the alluvial gap between Lynx Cat and Iron Mountain. Well logs along with geophysical data (Crosby 1990) indicate a sizeable cross-sectional area for groundwater to move through. Additionally groundwater elevations indicate a gradient moving towards this area from the Mojave River (Fig 22). The potential for subsurface flow through the gap between Lynx Cat and Iron Mountains is very plausible and should be considered in future investigations.

5.6 Water Budget

Analysis of general water budgets can yield insight to the hydrologic system at work within a basin. Water budgets take into consideration various parameters, some known and some unknown.

$$\text{Inflow}=\text{outflow}\pm\text{changes in storage}$$

Inflow: interflow, precipitation, return flow and overland inflow

Outflow: through flow, evaporation, transpiration, surface runoff, infiltration, overland outflow, and pumping

These parameters may include soil characteristics, precipitation, evapotranspiration, surface waters, groundwater flow, infiltration, and groundwater production. Tables 10 to 13 review the basic inputs and outputs that are included within the Harper Lake Basin watershed. This data is derived from previously published reports. The annual average water budget for

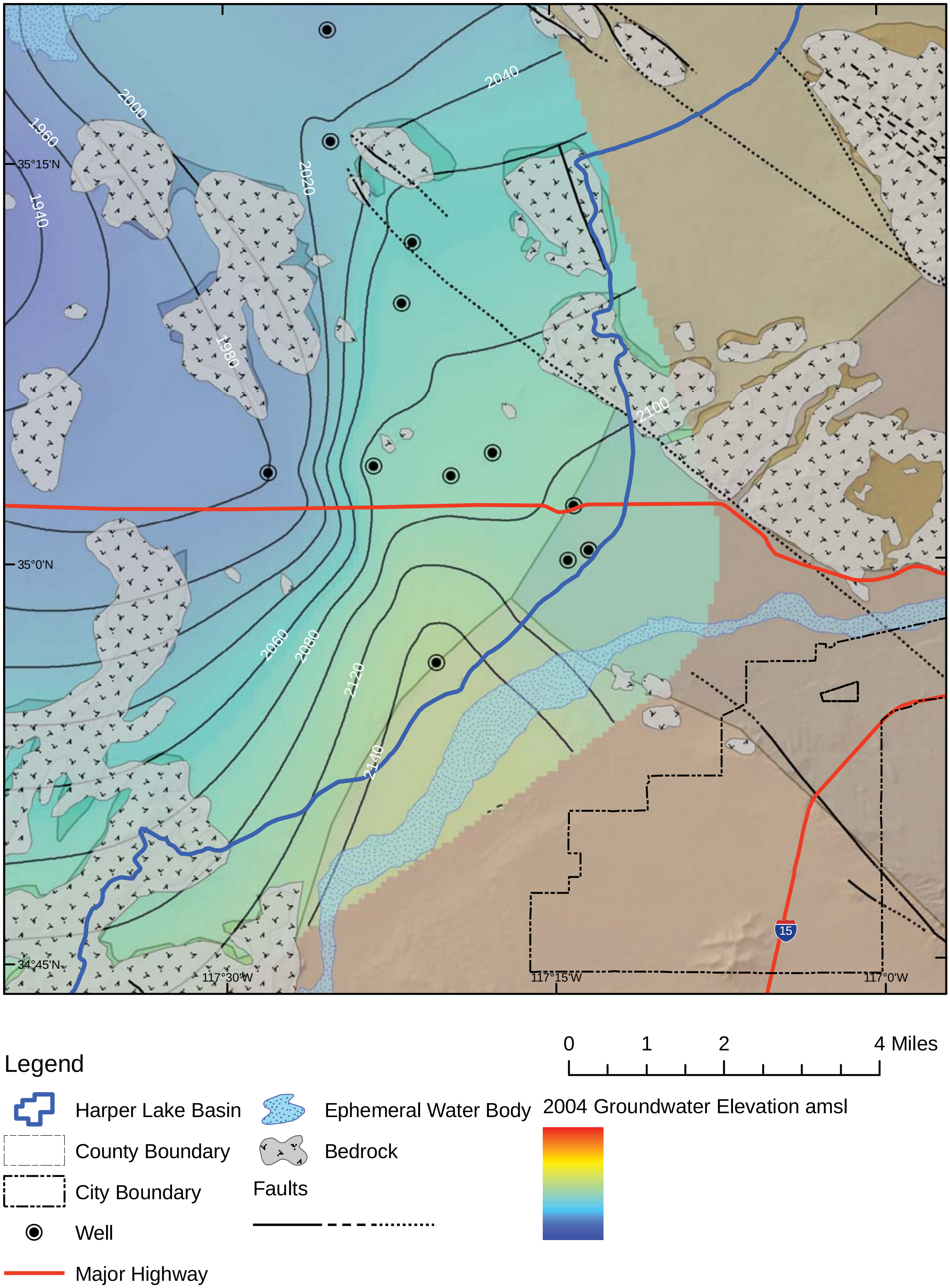

Figure 22: Harper River-Harper Lake Basin divide.

and Technology, 2007). Calculations made by Mark Group (1989) indicate that recharge from the Middle Mojave River Valley groundwater basin into Harper Lake groundwater basin is 2,700 acre-feet/year through the region near Red Hill. Conversely, DWR (1967) estimates 1,000 acre-ft/yr of recharge and MWA (1983) estimates 22 acre-ft/yr of recharge through the same gap near Red Hill. Aquifer Science and Technology (2007) performed a geophysical survey through the Hinkley Gap near Red Hill and concluded an estimate of 1,468 acre-ft/yr of subsurface recharge. In a USGS report, Stamos et al. (2001) modeled the entire Mojave River Basin using MODFLOW and concluded 4,290 acre-feet/year of groundwater recharge into Harper Lake Basin from the Middle Mojave River Valley Basin in 1994, and averaged 3,071 acre-feet/year from 1931 to 1990. It should be noted Stamos et al. (2001) groundwater model did not focus solely on the Red Hill gap, but took into account the entire aquifer boundary between Harper Lake Basin and the Middle Mojave River Valley Basin. Subsurface flow calculation through the same alluvial channel west of Red Hill, presented here (Table 9: Flow calculations at Red Hill gap) indicates 1,100 acre-ft/yr of subsurface flow from the Middle Mojave River Valley Basin to the Harper Lake Basin. This calculation reasonable compared to other previous works in the area (Table 8). However, the varying aquifer characteristics, size, and methods used in each of the different studies yields a variety of results ranging from 22 acre-feet/year to 3,071 acre-feet/year.

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Harper Lake Basin, as calculated by The Mark Group (1989) and DWR (2003) is a net gain of 1,000 acre-ft and 11,370 acre-ft, respectively (Table 13). Positive value conveys consumptive use is less then recharge to the basin. This should infer a water level rise. Likewise, the surplus of water estimated by DWR (2003) should yield increases in water level hydrographs (Fig. 10 to 18). These figures reveal a slight increase in groundwater levels based on a 678 mi^2 (1,756 km^2) basin area. The discrepancy, however, between the two reported values is considerable. One inconsistency is that The Mark Group utilizes a study area of 510 mi^2 (1,320 km^2) and DWR a 640 mi^2 (1,658 km^2) study area. The difference in size of the basin may still not be enough to yield such a considerable disparity. Future detailed studies of the Harper Lake Basin water budget should be considered to resolve this discrepancy.

Table 8. Previous works on subsurface groundwater flow into Harper Lake Basin from the Middle Mojave River Valley Basin.

Agency	Estimate (acre-ft/yr)	Location
DWR (1964)	-	"Much of inflow into Harper enters through the area surrounding Red Hill"
DWR (1967)	1,000	No specific location
DWR (1971)	-	"Main recharge into Harper Valley is underflow from by way of Hinkley Valley south of Blacks Ranch"
DWR (2003)	-	"Some groundwater diversion toward Harper Lake around the east and west sides of Iron Mountain"
DWR (2004)	-	"Harper Valley receives some groundwater underflow from the Middle Mojave River Valley."
MWA (1983)	22	"Narrow band of Holocene river sediments near Red Hill"
The Mark Group (1989)	2,700	Red Hill
Stamos et al. (2001)	3,071	"Groundwater moves through Red Hill gap and other side of Iron Mountain."
Aquifer Science & Tech (2007)	1,468	Gap west side of Red Hill
This report	1,100	Red Hill gap

Table 9. Flow Calculations at Red Hill					
Gradient = 0.0036 ft/ft Area = 295,207 ft^2	Range of hydrologic conductivity k (ft/day) and resultant calculations of subsurface groundwater flow				
Hydrologic Conductivity k (ft/day)	0.05	50	125	175	200
Subsurface Flow acre-feet/year	4	450	1,100	1,600	1,800

Table 10. Harper Lake Basin estimated groundwater inputs.			
Annual average	DWR (1967) (acre-ft)	The Mark Group (1989) (acre-ft)	DWR (2003) (acre-ft)
Surface inflow*	-	3,800*	36,300*
Subsurface inflow	1,000	3,000	-
Spreading of wastewater	-	-	487
Imported water	-	-	1,383
Total	-	6,800	38,170

*Surface inflow includes all types of natural recharge.

Table 11. Harper Lake Basin average production.	
Outputs	MWA Watermaster (2006) (acre-ft)
Consumptive use large producers	5,100
Consumptive use minimal producers	-
Total	5,100

Table 12. Harper Lake Basin estimated groundwater outputs.			
Annual Average	The Mark Group (1989) (acre-ft)	DWR (2003) (acre-ft)	MWA (2005) (acre-ft)
Surface outflow	-	-	-
Subsurface outflow	-	-	-
Consumptive Use*	5,500	26,800	5,100*
Total	5,500	26,800	5,100

*Consumptive use reflects only large users (>10 acre-ft/yr).

Table 13. Harper Lake Basin water budget calculations.		
Annual Average	The Mark Group (1989) (acre-ft)	DWR (2003) (acre-ft)
Total input	6,500	38,170
Total output	5,500	26,800
Total water budget	1,000	11,370

5.7 General Water Chemistry

Mineral compositions of groundwater in Harper Lake Basin are determined by interactions between groundwater, aquifer materials, surface water, and groundwater discharge. These interactions influence the ranges of total dissolved solids (TDS) observed in Harper Lake Basin wells (Table 14: Harper Lake basin measured TDS concentrations). A low of 179 mg/L was reported by DWR in 2003 and a high of 2,600 mg/L was reported in 1989 by DWR. Analysis done by The Mark Group (1989) showed values ranging from 400 mg/L TDS to 2,806 mg/L TDS. In general, wells located further from Harper (dry) Lake exhibit better water quality than those directly adjacent to the lake. The higher TDS concentrations adjacent to the lake are most likely due to the irrigation return flow from nearby farmland (The Mark Group, 1989).

Sulfate or sulfate-chloride rich waters are found in areas in and around Harper Lake Basin where older alluvium is present or where portions of the groundwater basin receive little recharge and minor groundwater movement (DWR, 1967). Sodium and sulfate-bicarbonate rich groundwater is found in the northern portion of the basin with relatively high concentrations of sodium fluoride and boron (DWR, 2003). Concentrations of sulfate and boron are also high in the western and southern regions of the Harper Lake Basin resulting in limited irrigation and domestic usages. A complete groundwater sampling survey should be conducted across the entire basin to assess changes in groundwater chemistry across the entire Harper Lake Basin.

Table 14. Harper Lake Basin measured TDS concentrations.		
Source	High TDS (mg/L*)	Low TDS (mg/L)
DWR (1979)	2,000	1,000
DWR (1989)	2,600	400
DWR (2003)	2,391	179

*1 milligram/liter (mg/L)=1 part per million (ppm).

iii. Executive Officer’s Report, Item #6 (June 2014)

6. **Geology Tour of the Hinkley Valley by USGS, San Bernardino County**
   - *Lisa Dernbach*

Water Board staff had the opportunity in April to attend a geology tour of the Hinkley Valley given by the U. S. Geological Survey (USGS). The tour was coordinated by Dr. John Izbicki, who is overseeing the chromium background study. Participants included a Hinkley Community Advisory Committee member, geologist consultants for PG&E, and other USGS staff.

Dr. Dave Miller, a Research Geologist from the USGS office in Menlo Park, provided the tour. Dr. Miller's specialty is mapping Quarternary geology, spanning from 2.588 million years ago to the present. Dr. Miller recently completed mapping the surficial geology in the Hinkley area, part of a project to update USGS quadrangles maps.

Participants were driven to four stops in different parts of the Hinkley Valley. At each stop, the surrounding rocks, deposition setting of sediments, and fault history were described and discussed. Bedrock forming the boundaries of the Hinkley Valley are composed of granite, diorite, dacite, gneiss, marble, and metavolcanics. None of the bedrock was stated as having natural high levels of chromium. High evaporation rates in the area prevent bedrock from infiltrating precipitation and being a source of groundwater in adjacent valleys.

A fresh water bi-valve shell was discovered at a stop in the northern Hinkley Valley. The discovery, along with evidence of shoreline deposits, indicated the southeastern extent of Pleistocene Harper Lake south of Red Hill at the Hinkley Gap. This location is approximately eight miles southeast of current surface water in the Harper Lake Valley.

The flooding history of the valley over time was thoroughly discussed during the tour. Hinkley Valley sediments primarily originate from granitic rocks in the San Bernardino Mountains and deposited by the Mojave River. Dr. Miller and the CAC member related extensive flooding events in the Hinkley Valley, including those in 1957 and 1969. This information was of particular interest since no prior historical information submitted to the Water Board for the Compressor Station relayed this fact or flooding impacts upon chromium waste water in unlined ponds.

Between Dr. Miller and Dr. Izbicki, tour participants got a comprehensive geologic and hydrologic understanding of the Hinkley Valley and the Mojave River basin. This information will be useful in future Water Board activities in Hinkley and other nearby locations.

7. **Adelanto North 2014 Comprehensive Plan** - *Jehiel Cass*

Staff recently provided environmental review comments on the City of Adelanto's – Adelanto North 2014 Comprehensive Sustainable Plan. This General Plan envisions the eventual build-out and urbanization of over 35,300 acres along with about 78,000 new residents in the northern part of Adelanto. The project area would have a wide mix of heavy and light industrial activities along with commercial and various levels of residential use.

The major points identified were as follows. The City needs to revise its ordinance structure to incorporate the Low Impact Development principles discussed in the General Plan. In the near future, and prior to project build-out, the City will need to comply with the Statewide General Order for Small Municipal Separate Storm Sewer Systems (MS4) and associated requirements. The major surface water body affected by the project

iv. Closure Report, Pivox Corporation, December 2013

CLOSURE REPORT
FOR
DEBRIS REMOVAL AND CLEANUP
WESTERN EXCAVATION SITE
HINKLEY, CALIFORNIA

PREPARED BY

PIVOX
Corporation

7595 IRVINE CENTER DRIVE, SUITE 150

IRVINE, CA 92618

(949) 727-1400

www.pivox.com

December 2013

Shakeel N. Jogia, P.E., CA 69108
Pivox Corporation

REGISTERED PROFESSIONAL ENGINEER
SHAKEEL NIYAZ JOGIA
No. C 69108
Exp 6/30/2014
CIVIL
STATE OF CALIFORNIA

1.0 INTRODUCTION

1.1 Objectives

PIVOX Corporation (PIVOX) has prepared this closure report to detail activities associated with debris removal, excavation, and restoration from the immediate vicinity and within an abandoned informal dump site located on the PG&E owned 80-acre property southwest of the intersection of Community Boulevard and Hinkley Road in Hinkley, CA (the Site) (Figure 1). This closure report is being submitted to detail the removal procedures and characterization of the soil and debris removed from the Western Excavation Site.

1.2 Site Location

The Site is located on San Bernardino County APN #0488-074-03 (34.90295° approximate latitude and 117.19647° approximate longitude) and is vacant, undeveloped land. The site is located on PG&E property, although the access roads that connect the site to Hinkley Road cross through non-PG&E owned rights-of-way. The Site is located approximately 0.5 miles directly southwest of the intersection of Community Boulevard and Hinkley Road.

v. Excerpt from PG&E (2014), fourth quarter 2014 groundwater monitoring report, Exhibit 3-1, *Groundwater Flow through the Hinkley Gap*, showing estimates of groundwater flow through the Hinkley Gap from a variety of sources; and groundwater velocity information.

Fourth Quarter 2014
Groundwater Monitoring Report and Domestic Well Sampling Results

Site-wide Groundwater Monitoring Program
Pacific Gas and Electric Company
Hinkley Compressor Station
Hinkley, California

Prepared for

California Regional Water Quality Control Board, Lahontan Region

On behalf of

Pacific Gas and Electric Company

January 30, 2015

CH2MHILL®

155 Grand Avenue
Suite 800
Oakland, CA 94612

Fourth Quarter 2014 Groundwater Monitoring Report and Domestic Well Sampling Results

Site-wide Groundwater Monitoring Program
Pacific Gas and Electric Company, Hinkley Compressor Station, Hinkley, California

Prepared for

California Regional Water Quality Control Board,
Lahontan Region

on behalf of

Pacific Gas and Electric Company

January 30, 2015

This report was prepared under the supervision of a California Professional Geologist:

Dennis Maslonkowski, P.G., C.Hg., C.E.G.

Executive Summary

This Groundwater Monitoring Report presents the results of groundwater sampling activities completed during Fourth Quarter 2014 as part of the Site-wide Groundwater Monitoring Program (GMP) and Domestic Well Sampling Program (DWSP) associated with the groundwater chromium plume at and near the Pacific Gas and Electric Company (PG&E) Hinkley Compressor Station in Hinkley, California (the Site).

The GMP is being conducted in compliance with Cleanup and Abatement Orders (CAOs), Waste Discharge Requirements (WDRs), and other directives issued by the California Regional Water Quality Control Board, Lahontan Region (Water Board). The most recent regulatory update to the GMP was prescribed in CAO No. R6V-2008-0002, issued August 6, 2008 (Water Board, 2008a), and, with its amendments, is collectively referred to as the 2008 CAO (Water Board, 2008b, 2009a, 2012, and 2013a). The 2008 CAO incorporates the methodology for monitoring and assessing chromium plume control. In accordance with Water Board CAO No. R6V-2011-0005 (2011 CAO; Water Board, 2011b), amended CAO No. R6V-2011-0005A1 (2011 Amended CAO; Water Board, 2011d), and *Conditional Acceptance of Northern Areas Investigation Proposal* (Water Board, 2014a), PG&E is also implementing a domestic well sampling program, the results of which are provided herein. The Water Board has additionally issued Investigative Order Nos. R6V-2011-0079 (Water Board, 2011a) and R6V-2013-0051 (Water Board, 2013c). Each of these documents requires PG&E to provide additional information in quarterly groundwater monitoring reports; this report includes the additional information required by the Investigative Orders.

Fourth Quarter 2014 Groundwater Monitoring

The GMP includes collecting groundwater samples from approved monitoring wells referenced in the 2008 CAO, remediation performance-monitoring wells, and domestic wells (collectively called GMP wells). During Fourth Quarter 2014, groundwater samples were collected from 512 monitoring wells (including water supply wells, extraction wells, and remediation performance monitoring wells) and 105 domestic and other private supply wells in response to the sampling requirements of the 2011 CAO and 2011 Amended CAO. All samples were analyzed for hexavalent chromium (Cr[VI]) and/or total dissolved chromium (Cr[T]) as appropriate. Samples collected from select monitoring wells were also analyzed for constituents other than Cr(VI) and Cr(T) (for example, nitrate) for other monitoring purposes. Groundwater levels in both the Upper Aquifer (UA) and Lower Aquifer (LA) were measured to assess groundwater gradient and flow directions.

For the purposes of Site-wide groundwater monitoring and reporting, the groundwater monitoring wells were subdivided and classified into the following three aquifer zones: (1) the shallow zone of the UA, (2) the deep zone of the UA, and (3) the LA.

Chromium Monitoring Results

The chromium sampling results from Fourth Quarter 2014 were used to update the Site-wide GMP chromium distribution maps for the UA and LA (Figures 5-1 through 5-5; all figures and tables are presented at the end of this report). The chromium plume configurations for the UA are compared with Third Quarter 2014 versions on Figure 5-6 and are discussed in Section 5.3.

Figure 5-5 presents chromium isoconcentration contours in the UA for Fourth Quarter 2014, following the methods prescribed in Investigative Order Nos. R6V-2011-0079 (Water Board, 2011a) and R6V-2008-0002A4 (Water Board, 2013a), which require connecting all detections of Cr(VI) above 3.1 micrograms per liter (µg/L) and Cr(T) above 3.2 µg/L in wells located within 2,600 feet. PG&E believes these contouring restrictions misrepresent the occurrence and distribution of chromium in certain parts of the Site and is presenting alternative interpretations for key areas as insets to Figure 5-5; these alternate interpretations were prepared using Site-specific hydrogeologic and geochemical information and based on standard industry accepted practices and professional judgment.

Valley as groundwater is recirculated in the IRZs (southern portion of the maps), groundwater mounding is produced by freshwater injection in the west, and capture of northward flow is achieved by extraction south of Thompson Road. Groundwater flow in the southwest is additionally influenced by the Lockhart Fault (CH2M HILL and Stantec, 2013a).

These groundwater contours are shown at 5-foot intervals (with the exception of the west where 1-foot contours are shown) to provide an overview of groundwater flow through the Hinkley Valley. This contouring confirms that hydraulic capture of chromium in groundwater in the South Hinkley Valley has been achieved. These capture zones are shown on Figures 3-1 and 3-2 as dashed blue lines.

Depth to groundwater in the UA in South Hinkley Valley currently ranges from about 75 to 100 feet below grade with some variability directly adjacent to remedial activities such as pumping or injection.

3.2 Upper Aquifer—North Hinkley Valley and Water Valley

UA groundwater elevation contours and flow direction arrows for the North Hinkley Valley are presented on Figure 3-3. Groundwater flow in the North Hinkley Valley continues the northward flow of the South Hinkley Valley, becoming more northwest towards the Hinkley Gap and into Water Valley.

Groundwater flow from the Hinkley Valley to Water Valley occurs through the Hinkley Gap (Figure 1-2), a narrowing at the northern end of the Hinkley Valley at Red Hill (Figure 3-3). Northward flow through the Hinkley Gap is interpreted to primarily occur on the western side of Red Hill through an ancestral Mojave River channel (Aquifer Science and Technology, 2007). Recent estimates of the amount of groundwater moving through the Hinkley Gap, as studied by others, is provided in Exhibit 3-1 below; this flow is interpreted by PG&E to occur below the brown clay and in the deep zone of the UA (Stantec, 2013).

EXHIBIT 3-1
Groundwater Flow through the Hinkley Gap

Reference	Acre-Feet per Year	Gallons per Minute
Aquifer Science and Technology (2007)	1,468	910
W.R. Laton et al (2007)	1,100	682
Layne Geosciences (2009)	2,100	1,301
Todd Engineers and Kennedy/Jenks Consultants (2013)	1,768	1,095
AVERAGE	**1,609**	**997**

3.3 Lower Aquifer

The LA is generally considered confined or semiconfined to the east of the line denoting the western extent of “Blue Clay” (Figure 5-3); west of this line, the LA sediments are considered part of the UA. However, the Blue Clay becomes thin and sandy in a transitional portion along its western boundary; where this occurs, the LA is in hydraulic communication with the UA.

As shown on Figure 3-4, regional groundwater flow in the LA generally follows the northward trend of the UA as shown on Figures 3-1 and 3-2. On the western side of the LA near Santa Fe Avenue, the hydraulic gradient in the LA significantly lessens. This low-to-flat gradient is interpreted to be the result of local UA groundwater extraction on the western boundary of the LA (near the limits of the “Blue Clay”) where both the UA and LA are affected by UA extraction.

3.4 Groundwater Velocity

Estimates of groundwater velocity for the UA and LA are posted as appropriate on Figures 3-1 through 3-4 and summarized on Table 3-1; these calculations are based largely on the assumptions of hydraulic conductivity (K) used in PG&E's groundwater flow model. The reliability of K values in this model, and therefore the reliability of these velocity calculations, depends upon the available dataset for each portion of the Site; estimates of K used in the model are derived from this available dataset. The significant number of wells and substantial extraction being performed in the central portion of the South Hinkley Valley has resulted in a large dataset from which to obtain reliable K values. By contrast, little pumping test data have been collected for the western part of the South Hinkley, North Hinkley, and Water Valleys due to the absence of remedial extraction. Calculations for groundwater velocity in these areas are, therefore, considered less precise. In addition, the current model domain does not extend into Water Valley, and aquifer parameters have been estimated from other information.

As shown in Table 3-2, K is estimated to be much lower in the finer-grained western part of the South Hinkley Valley than in the comparatively coarser-grained central and eastern portions. The North Hinkley Valley is also estimated to have a relatively lower K value due to the presence of more fine-grained sediments.

Previous modeling, tracer, and remedial system pumping tests indicate that maximum groundwater velocities in the central Hinkley Valley generally range from 1 to 4 feet per day (Haley & Aldrich, 2010) and the velocity calculations shown on Table 3-1 are generally consistent with these findings.

3.5 Vertical Gradients

Estimates of vertical hydraulic gradients between the shallow and deep zones of the UA and between the UA and LA are provided on Table 3-1. Well groups were selected to provide a representative illustration of vertical gradients throughout the Site, and these results are summarized below.

Vertical gradients between the shallow and deep zones of the UA in Hinkley Valley can be summarized as follows:

- **West of Serra Road—**A mix of downward and upward vertical gradients. Primarily downward vertical gradients are seen near the Northwest Freshwater Injection (NWFI) system (for example, MW-121S/D, MW-168S/D, and MW-169S1/D) where injection is occurring into the UA.
- **East of Serra Road and west of Summerset Road (plume area)—**A mix of downward and upward vertical gradients. Generally, downward gradients are present in the UA north of Highway 58 primarily due to groundwater extraction in the deep zone of the UA. South of Highway 58, many well clusters show upward gradients.
- **East of Summerset Road—**A mix of downward and upward vertical gradients were calculated for these well pairs.
- **North of Thompson Road, south of Salinas Road—**Downward gradients were calculated for all well pairs.
- **North of Salinas Road, south of Red Hill—**Downward gradients were calculated for all well pairs.
- **North of Red Hill in Water Valley—**Downward gradients were calculated for all well pairs.

Vertical gradients between the UA and LA are typically upwards as demonstrated by gradients calculated for the MW-23, MW-160, and SC-MW-16 UA/LA well pairs.

vi. Abengoa Mojave Solar *Project Environmental Assessment*, U.S. Department of Energy (2011)

BASIN CONCEPTUAL MODEL

MOJAVE SOLAR PROJECT, Solar Thermal Energy Facility
Harper Dry Lake, California

Prepared for:

Mojave Solar LLC

Victorville, CA

July 2009

Project No. 27- 1643

Prepared by:

Mike Cyrocki
Hydrogeologist
CA Professional Geologist No. 8350
CA Certified Hydrogeologist No. 159

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sediment beneath the playa surface likely derives from infrequent precipitation events rather than a hypothetical 125-ft-thick capillary fringe. A dry, white-colored, mineral crust covers the Harper Dry Lake playa, thus decreasing evaporation of moisture within near-surface lacustrine sediment. This mineral crust dissolves during precipitation events and reforms as the temporary playa surface water rapidly evaporates.

4.6.3 RECHARGE TO THE DOMAIN

Within the MRB, the HVB, and the Domain, recharge to alluvial aquifers occurs by the following sources:

- Storm runoff from the highlands that enters ephemeral streams with eventual percolation to the underlying aquifer;
- Precipitation falling on the basin floor;
- Precipitation falling on the surrounding mountain areas that percolates into bedrock with eventual flow into the basin;
- Underflow from groundwater basins adjacent to the HVB.

Over the long term, recharge to alluvial aquifers due to precipitation within the HVB is approximately equal to precipitation source recharge to the Domain. Percolation of rainwater into the 100,800 acres of hills surrounding the HVB with eventual flow into the basin is about 300 AFY (The Mark Group, April 7, 1987). Stable isotope tests show that recharge in desert environments varies from 0.34 to 0.51 percent of precipitation (Stone, 1986). Rainwater falling onto the 297,200-acre HVB floor and providing aquifer recharge is estimated at 420 AFY. Precipitation falling on the surrounding mountain areas that percolates into bedrock with eventual flow into the basin is estimated by the CA DWR as 550 AFY or about 1 percent of annual precipitation falling on those highland areas (CA DWR, 1967).

Additionally, the CA DWR states, based on a MWA report (MWA 1999) that for 1997-98 water year, HVB replenishment included an estimated 487 AFY from the spreading of treated wastewater and 1,383 AFY from spreading of imported water (CA DWR 2003).

Underflow estimates into the HVB were summarized in Table 8 of the CSU and MWA Document (September 2007) and included the following: 1,000 AFY

(DWR, 1967), 22 AFY (MWA, 1983); 2,700 AFY (The Mark Group, 1989); 3,071 AFY (Stamos, et al, USGS 2001); and 1,468 AFY (AST, 2007) and 1,100 AFY (CSU and MWA, 2007). Most of these estimates specify the underflow location as the Red Hill gap (aka the Hinkley Gap) or the area surrounding Red Hill. Total underflow listed on Tables 4-3a and 4-3b, BCM Report section 4.9.3 is 2,100 AFY. The underflow recharge estimate is the average of four estimates of underflow through the gap on the west side of Red Hill (aka Hinkley Gap) (CSU/MWA, 2007). The 1967 CA DWR underflow estimate was omitted since the underflow location was not specified. The 1983 MWA underflow estimate was omitted since it was superseded by the 2007 CSU and MWA underflow estimate. Underflow from the Middle Mojave River Valley Groundwater Basin through the Hinkley gap is facilitated by the presence of 150- to 200-ft-thick permeable ancestral Mojave River sediment within the HVB perimeter.

The sum of underflow through Hinkley gap and Lynx Cat - Iron Mountain gap was estimated by Ebbs (2007) as 2,100 AFY, with 1,100 AFY flowing through the Red Hill (Hinkley) gap and 1,100 AFY flowing through the Lynx Cat Mountain – Iron Mountain gap (Figure 2-13). However, LGS has been unable to identify a hydraulic connection between the Mojave River channel and the HVB through the Lynx Cat – Iron Mountain gap. Refer to Depth to Bedrock (Figure 2-1); Geologic Cross Section H-H' (Figure 2-12); and Depth to Bedrock, Lynx Cat – Iron Mountain gap area (Figure 2-13).

Additionally, V. Ebbs describes production data compiled by the MWA Watermaster indicating that an average of 4,000 AFY of groundwater within the HVB is used for irrigation (MWA Watermaster, 2007). Return flow -- water not consumed during the process of irrigation -- could account for up to 50 percent reentering the alluvial aquifers. A 50-percent return flow would contribute 2,000 AFY as recharge (Ebbs 2007).

Using selected cross section schematics that show depth to bedrock across the HVB perimeter (refer to Figure 2-1) along with information from previous investigation, LGS has evaluated the potential for underflow to the HVB through the Lynx Cat – Iron Mountain gap, along other portions of the Middle Mojave River Valley Groundwater Basin, and from other adjacent groundwater basins. In general, the HVB perimeter coincides with a groundwater divide caused by a bedrock structure consistent with basin geometry. Gaps within the perimeter bedrock structure exist, as demonstrated by the results of multiple focused investigations of the Hinkley Gap area. Hydrogeological investigation of other potential gaps within the HVB perimeter bedrock rim to understand flow from adjacent basins has not been done.

The CA DWR supports conjecture that the HVB receives some groundwater flow from the Cuddeback Valley Groundwater Basin (CA DWR 1975). However, The Mark Group indicates little to no groundwater flows into the HVB from the Cuddeback Basin (The Mark Group, April 1987).

As part of their Superior Valley Groundwater Basin description (Figure 1-5), the CA DWR stated that some groundwater may discharge to the HVB beneath Quaternary basalt flows along the southwest margins of the Superior Valley basin (CA DWR 1975). This possible flow has not been quantified. Based on surface observations of this area, LGS agrees that underflow from the Superior Basin to the HVB is possible through unconsolidated sediment in the notch area of Water Valley located northeast of Harper Dry Lake. Water Valley is a perimeter valley draining toward Harper Dry Lake. LGS recommends obtaining subsurface information from this area to assist with determining underflow.

According to CA DWR descriptions of the Antelope Valley Groundwater Basin (Figure 1-5), the Antelope Valley basin is bounded on the east by ridges, buttes, and low hills that form a surface groundwater divide (CA DWR 1975). Underflow from the Antelope Valley into the HVB is judged as unlikely.

Although additional gaps within the perimeter bedrock structure likely exist, information is currently not available to support underflow estimates within HVB perimeter areas other than Hinkley gap.

The following summarizes recharge estimates to HVB alluvial aquifers on the basis of the above sources and from the numerical model water balance (Appendix I):

- 420 AFY Precipitation falling on the basin floor;
- 300 AFY Precipitation falling on the surrounding mountain areas;
- 550 AFY Storm runoff from the highlands that enters ephemeral streams;
- 2,100 AFY Hinkley Gap underflow;
- 3,160 AFY Indeterminate recharge;

- 6,530 AFY Total Recharge

From the numerical groundwater model (Appendix I) water balance, indeterminate recharge is indicated. The model water balance is a result of the model calibration process. This category of recharge likely occurs as underflow through HVB perimeter gaps and it is indeterminate because location of this recharge is unknown.

4.6.4 GROUNDWATER SINKS

Groundwater flows within the HVB, because of gravity, toward Harper Dry Lake (Figures 1-7 through 1-10), which is the basin low for topography and may also be the maximum for depth to bedrock (Figures 1-3, 1-4 and 2-1,). Harper Dry Lake is the single natural groundwater sink within the HVB. According to one investigation, evaporation is considered negligible within the HVB, even though evaporation can occur with water ponds on dry lake surfaces or through bare-soil evaporation (Stamos et. al. 2001).

Groundwater production within the HVB mostly occurs due to pumping near Harper Dry Lake. Primary categories of groundwater production include the FPLE SEGS VIII and IX and the Ryken irrigation well (Desert Valley Dairy).

Since the adjudication, consumption of water within the HVB has dropped by nearly 50 percent (MWA 2007). The MWA Watermaster has tracked and estimated annual water production for the HVB. Verified water production for the water year 2005-06 was 3,429 AFY (MWA 2007).

4.7 AQUIFER PROPERTIES

Aquifer properties relevant to understanding groundwater flow to wells are T, aquifer thickness, and S. T and S values are obtained by processing aquifer pumping test data and when test data is not available, T and S values may be estimated from literature sources. Aquifer thickness is obtained from driller's logs or from surface geophysical data interpretations.

4.7.1 AQUIFER TESTING PROGRAM

This section presents results of the pumping tests conducted at the proposed MSP property between August 14 and August 25, 2008. This aquifer testing

vii. August 2002 Chromium Plume Map, CH2MHill (2003)

Second Semiannual Monitoring Report Year 2002

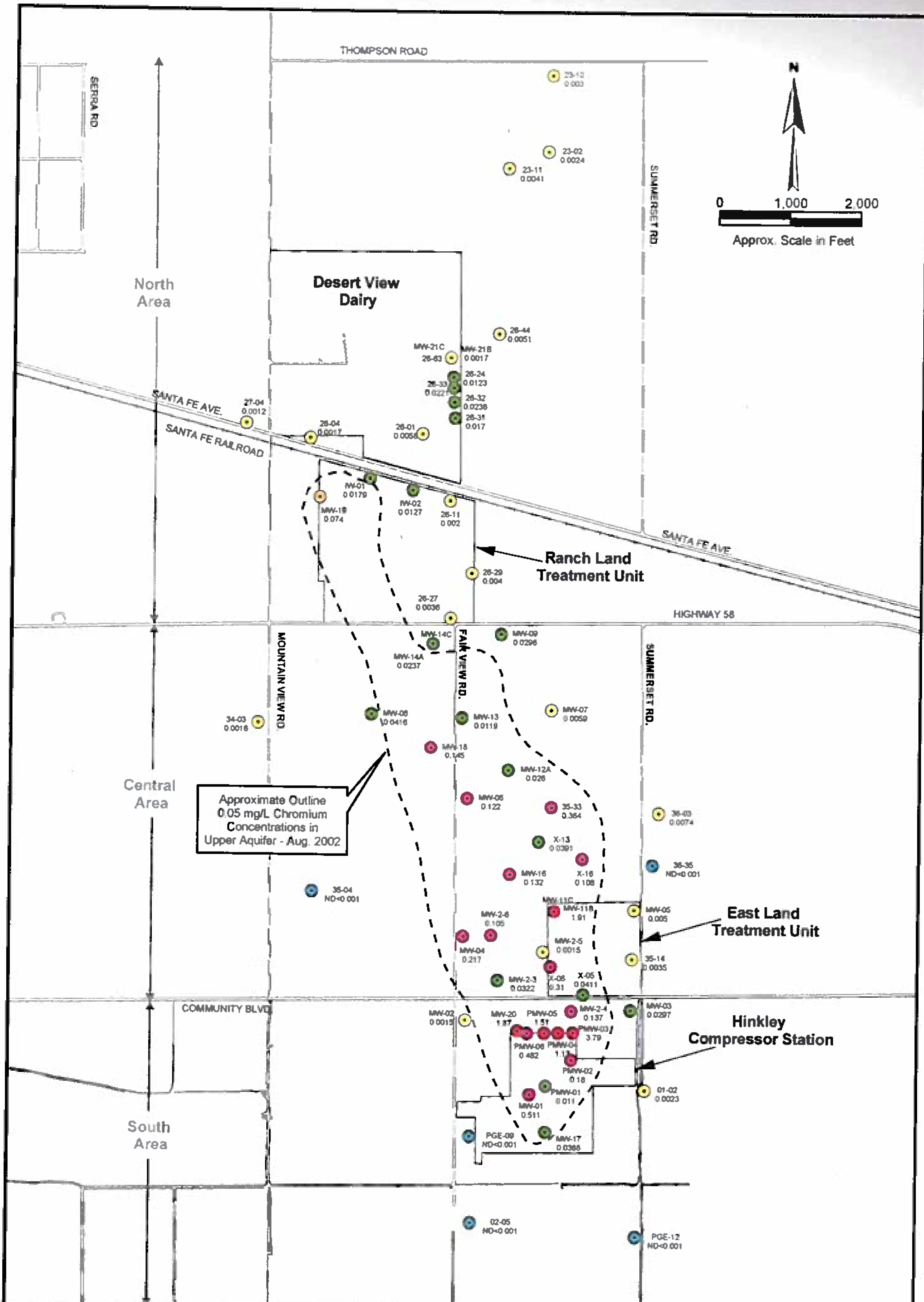
Groundwater Monitoring and Remediation Project PG&E Compressor Station Hinkley, California

Prepared for

Pacific Gas & Electric Company
California Gas Transmission

January 2003

CH2MHILL
155 Grand Avenue, Suite 1000
Oakland, California 94612



Groundwater Monitoring or Water Supply/Extraction Well Sampled During August 2002

0.050 Concentration of Total Chromium (mg/L) in Groundwater, August 2002 Sampling. Results for wells monitoring Lower Aquifer not shown.

Concentrations in milligrams per liter (mg/L)
- 0 - 0.001 mg/L or not detected
- 0.001 - 0.010 mg/L
- 0.010 - 0.050 mg/L
- 0.050 - 0.100 mg/L
- 0.100 - 1.000 mg/L
- > 1.000 mg/L

Figure 5
Distribution of Total Chromium in Groundwater
Upper Aquifer, August 2002
Groundwater Monitoring & Remediation Project
Pacific Gas & Electric Co. Compressor Station
Hinkley, California

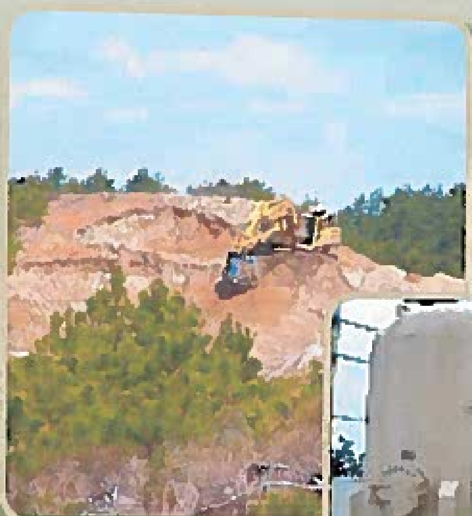
CH2MHILL

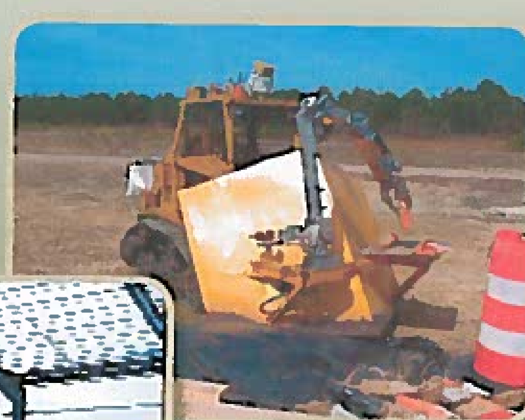
\\Cabernet\proj\PG&E\170400\GW_Database\ReportFigures\GW-2002-SA\HK-2SA-CRT-Aug02.mxd

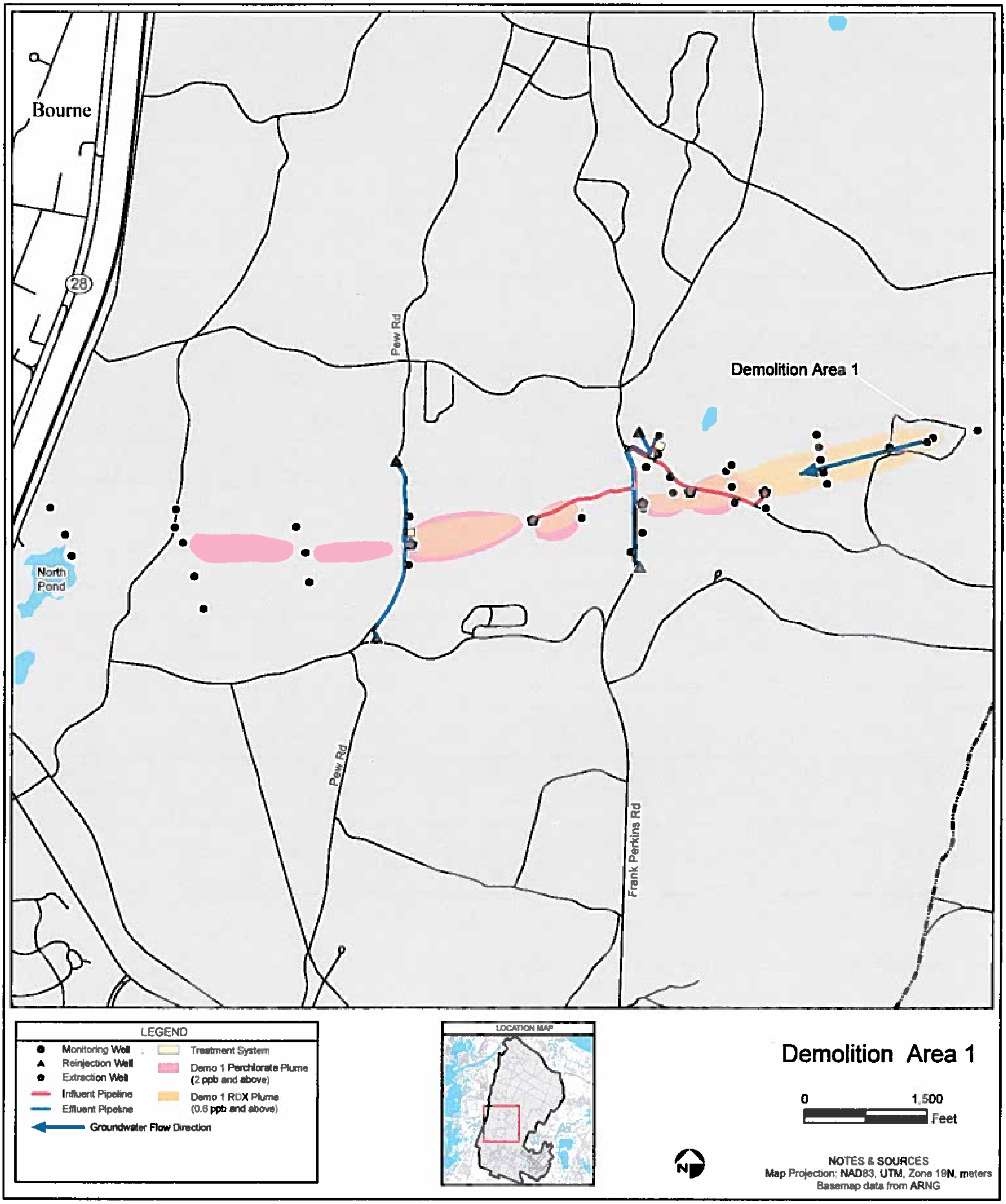
viii. Excerpt from *Groundwater Plume Maps and Information Booklet*, by the Air Force Center for Engineering and the Environment, (SDMS DocID 454664, 2010)

ARMY ENVIRONMENTAL COMMAND

IMPACT AREA GROUNDWATER STUDY PROGRAM






Bourne
28
North Pond
Pew Rd
Pew Rd
Frank Perkins Rd
Demolition Area 1
LEGEND
Monitoring Well
Reinjection Well
Extraction Well
Influent Pipeline
Effluent Pipeline
Groundwater Flow Direction
Treatment System
Demo 1 Perchlorate Plume
(2 ppb and above)
Demo 1 RDX Plume
(0.6 ppb and above)
LOCATION MAP
Demolition Area 1
0
1,500
Feet
N
NOTES & SOURCES
Map Projection: NAD83, UTM, Zone 19N, meters
Basemap data from ARNG

ix. J.L.N. Kear, et al., *Birth of a Detached MTBE Plume: Groundwater Modeling Anchored in Groundwater Monitoring* (2005) Groundwater, NGWA

Birth of a Detached MTBE Plume: Groundwater Modeling Anchored in Groundwater Monitoring

Jordan L.N. Kear, RG, CHG, Lindmark Engineering; and Ulf M. Lindmark, PE, DEE, Lindmark Engineering

Abstract

Shallow alluvial aquifers tend to be highly variable in the gamut of hydrogeologic parameters. In the northern portion of the Central Basin of the Coastal Plain of Los Angeles County, underlying a leaking underground storage tank facility, the shallowest aquifer is thin (less than 4 feet thick), apparently laterally extensive throughout the investigated area, semi-confined by overlying and underlying silt and clay strata, and consists of clayey, sandy gravel. Falling-head permeability testing of aquifer materials revealed a maximum hydraulic conductivity of 1.3 feet per day (4.6 x 10^{-4} cm/sec). Over the eight-year monitoring period, groundwater within the subject aquifer has maintained a consistent flow direction to the east-southeast and gradient of approximately 0.007 feet per foot. Based on these parameters and an effective porosity of 0.3, a relatively slow seepage velocity of 11.1 feet per year was calculated.

The process of installing groundwater monitoring wells to define the downgradient extent of the plume of methyl tertiary butyl ether (MTBE) originating at the facility outpaced downgradient migration of peak contaminant concentrations of the plume itself. In aquifers through which groundwater exhibits a higher seepage velocity, this outpacing scenario is less likely. Over time, a lack of detection of MTBE in proximal downgradient monitoring wells revealed two separate plumes: a near-source, stable plume and a distal, downgradient, detached plume. Economic and hydrogeologic factors, including the low groundwater seepage velocity, allowed the authors to define the plume before it became detached, then monitor the detachment and migration of the downgradient MTBE plume in real time.

With contaminants such as MTBE, tertiary butyl alcohol (TBA), and perchlorate, which may tend to migrate with groundwater flow rather than sorb to aquifer materials, it is important to recognize that the definition of a plume in groundwater near a source may be only part of the picture. While many near-source, contiguous plumes are often considered defined and determined to be stable or shrinking under natural attenuation, consideration of a detached plume would be wise. At a minimum, simple analytical modeling should be conducted to determine the potential downgradient effects of a detached plume, whether or not the plume has been observed to detach in real time. Where feasible, the groundwater modeling should be anchored in groundwater monitoring, especially if slow seepage velocities are calculated, sensitive receptors exist in a downgradient direction, or other factors support a detailed contaminant assessment.

Introduction

Groundwater monitoring began in 1996 following removal of underground storage tanks from the subject property and subsequent soil assessment and installation of groundwater monitoring wells. Full-scale remediation by dual-phase extraction commenced in December 2003. Based on site-specific information obtained from the soil and groundwater assessment and ongoing remediation of gasoline compounds, primarily methyl tertiary butyl ether (MTBE), the authors have generated a local cross section, presented as Figure 1. As shown thereon, the shallowest aquifer beneath the investigated site is a gravel stratum on the order of 4 feet thick (variably between 35 and 45 feet) that is bounded above and below by clayey strata. Contaminants appear to be limited to the aquifer and soil material above an approximate depth of 45 feet.

Using information from over seven years of environmental investigation, including groundwater monitoring, lithologic logs and electric logs from active municipal water supply wells and test holes, oil exploration well electric logs, and several now-destroyed municipal and private water supply wells, and published hydrogeologic and geologic information, the authors prepared a conceptual model that demonstrates the local regional hydrogeologic scenario and presents hypothetical potential contaminant pathways. A schematic cross section

Groundwater samples are collected after the water in each well has recovered to at least 80 percent of static levels. A new, disposable high-density polyethylene bailer is used to collect groundwater from each well. A low-flow draining tip is attached to the bailer to fill three 40-ml volatile organic ampoules and one 500-milliter plastic bottle for each well. The containers are sealed, labeled, placed on ice, and transported to the laboratory for analysis. Each sample is recorded on a chain-of-custody record identifying the sampler, couriers, responsible laboratory personnel, and requested analyses.

Laboratory Analysis

Each sample is analyzed for total petroleum hydrocarbons as gasoline (TPH[g]) and for benzene, toluene, ethylbenzene, and total xylenes (BTEX); MTBE; di-isopropyl ether (DIPE); ethyl tertiary butyl ether (ETBE); tertiary amyl methyl ether (TAME); and tertiary butyl alcohol (TBA) by EPA Method 8260B.

Contaminant concentrations for the 2003 monitoring are shown on Figures 3 through 6. During this time, the separation of the detached portion of the plume was observed by a lack of detection of MTBE in Well MW5.

Conceptual Modeling

Identification and locations of potential sensitive receptors and travel time estimates

Based on the local groundwater flow regime in the shallowest aquifer depicted in several groundwater monitoring reports, the groundwater in the uppermost aquifer beneath the site appears to flow toward the east-southeast at a consistent gradient. The dissolved-phase MTBE contaminants underlie residential areas immediately east of the site (Figures 3 through 6). Note, however, that the aquifer in which this plume is present is separated from these residences by fine-grained, semi-confining silt and clay strata (Figure 1). Furthermore, the chemical of concern (MTBE) is highly water-soluble and does not readily volatize in a dissolved state. Therefore, the MTBE plume in groundwater has no expected relevant exposure pathway to the overlying residential areas, but future modeling may be required to quantify this risk and may be included in future model updates as required by the regulatory agency. Contaminants introduced to this aquifer directly below the site are transported down-gradient, subject to the process of natural attenuation. Based on the authors' correlations, the shallowest aquifer beneath the site is significantly laterally extensive at its thickness and depth observed beneath the site.

Due to the relative consistency of groundwater flow direction and gradient, the analytical model BIOSCREEN is appropriate to estimate travel times and concentrations of MTBE to down-gradient distances and plume stability. Two model runs were utilized to match the apparent plumes observed during the December 2003 monitoring event: one representing a shrinking plume in the aquifer near the source and another representing a detached plume. Since no discrete aquifer testing has been conducted to date at the site, estimates of hydraulic conductivity were based on aquifer samples obtained from Wells DP2 and DP3 and subjected to falling head permeability tests. Results for DP2 were 1.3 feet per day (0.0004589 centimeters per second [cm/sec]), and results for DP3 were 0.034 feet per day (0.000012 cm/sec). For modeling purposes, the authors used a conservative conductivity value of 0.00046 cm/sec. Hydraulic gradient information (0.007 feet per foot) was derived from the groundwater monitoring program at the site. Dispersion and adsorption data are assumed from standard information and modified to produce an output that will match field conditions. Biodegradation-related parameters and contaminant concentrations are taken from assessment and monitoring activities.

Near-source portion of plume
Using a first-order decay model, the near-source plume of petroleum hydrocarbons, consisting almost exclusively of MTBE (based on relative constituent concentrations) in groundwater, appears to be stable. The maximum distance down-gradient that is anticipated for the MTBE plume (at a concentration of 0.001 mg/l on the centerline) is on the order of 140 feet, which is reached at a time of about six years from a theoretical complete release. Based on the field data from the site, this theoretical release would have been complete at or about 1996 when the underground storage tanks (USTs) were removed from the site. After the maximum

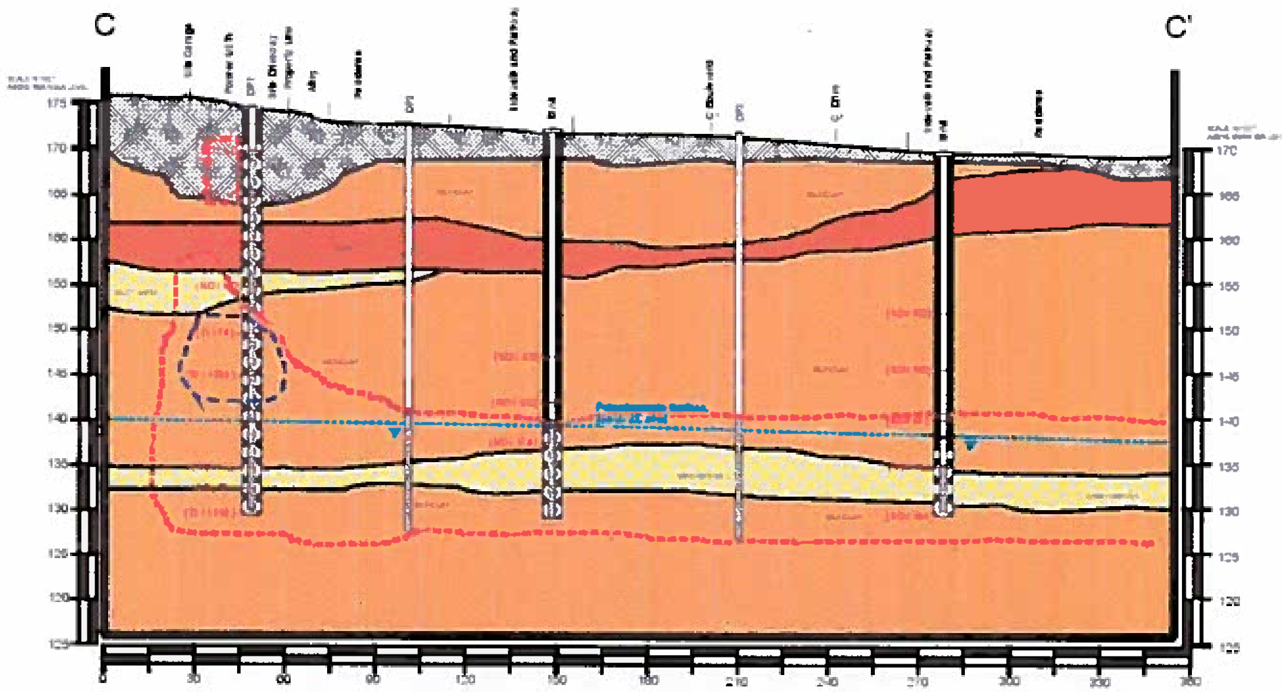


FIGURE 1 - Local cross section

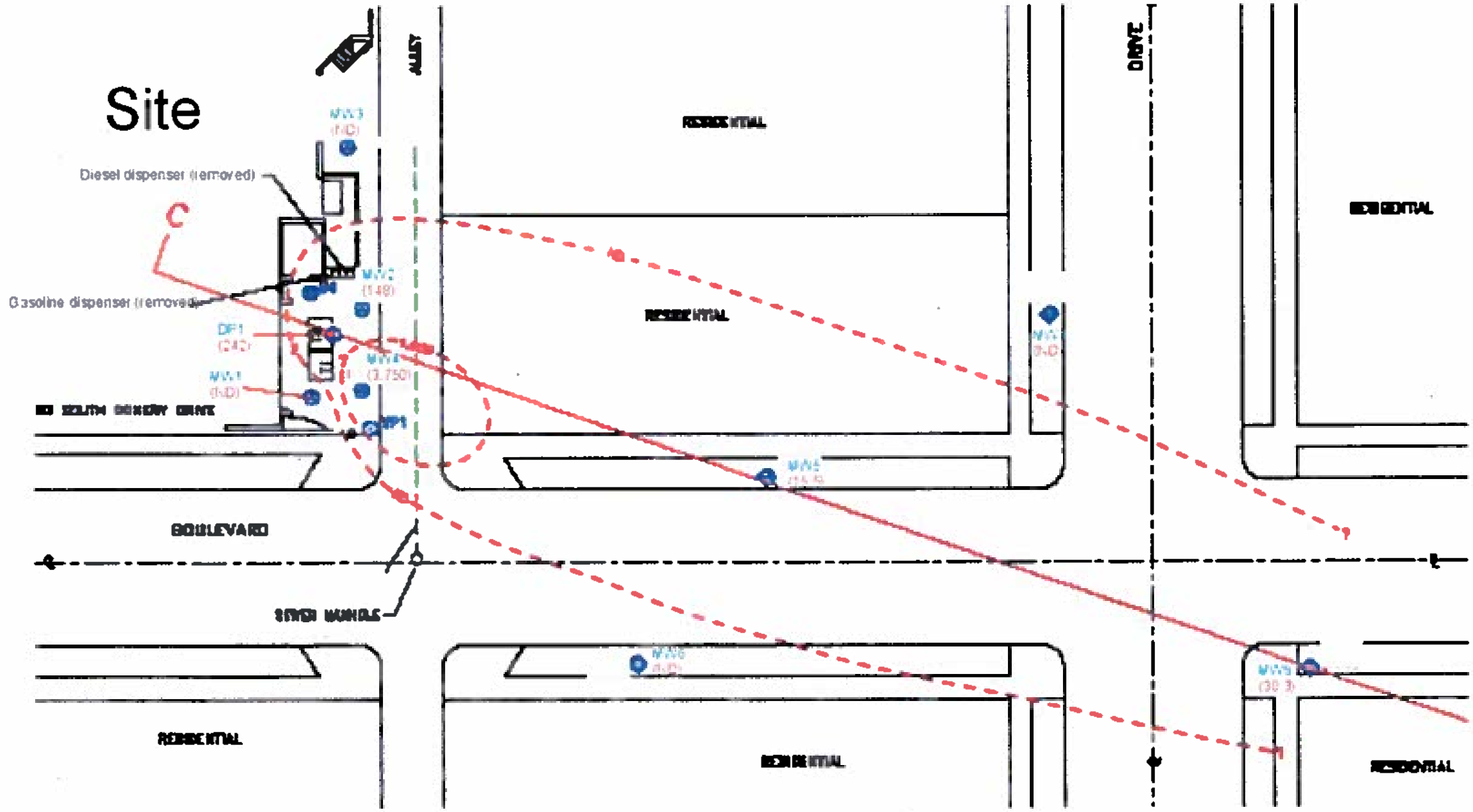


FIGURE 3 - Contaminant concentrations, March 2003

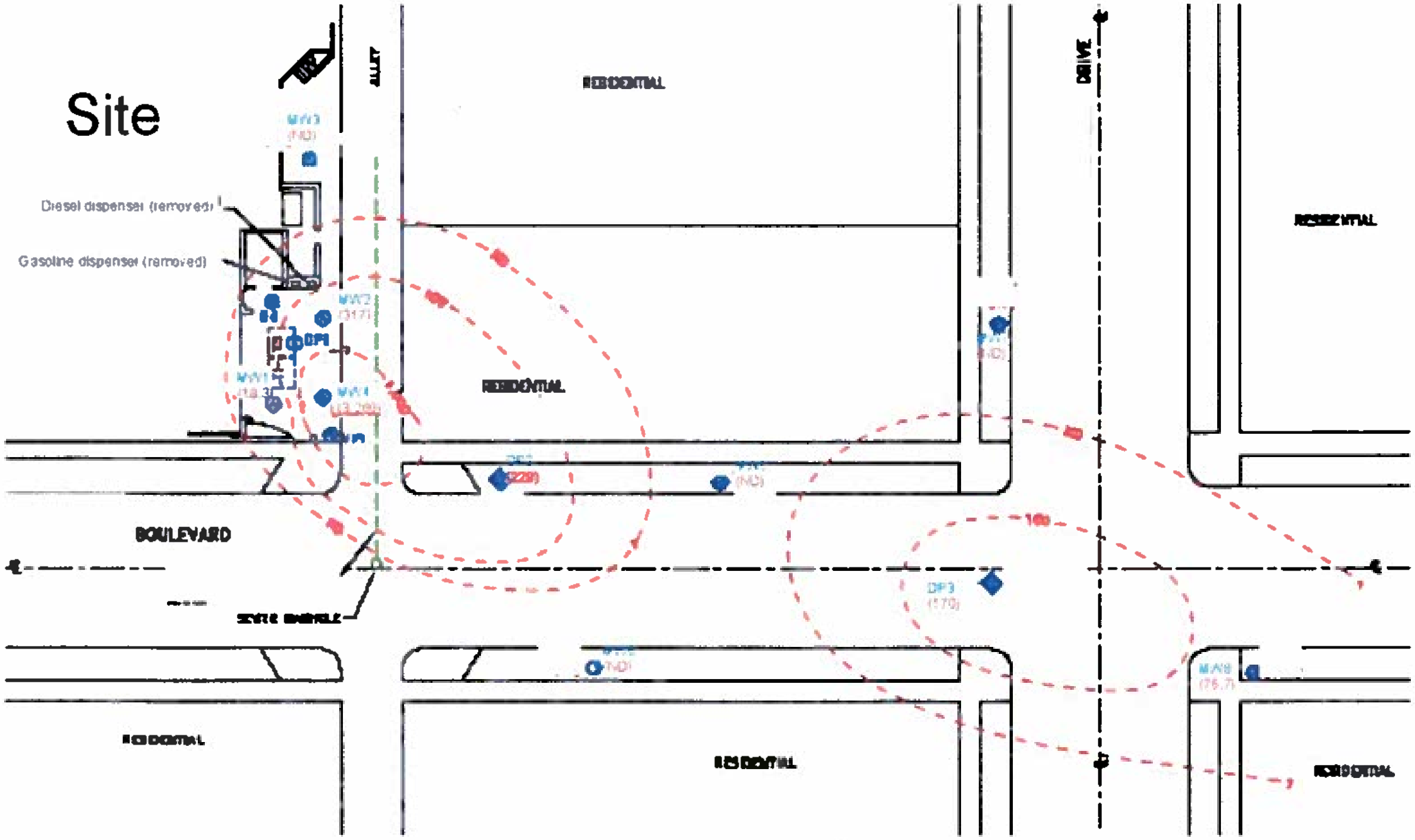


FIGURE 5 - Contaminant concentrations, September 2003

Biographical Sketches

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x. Excerpt from USGS (2001), Simulation of Ground-water Flow in the Mojave River Basin, California, showing groundwater flow direction and magnitude into Harper Lake Valley from Centro subarea, 1930-1994.

Simulation of Ground-Water Flow in the Mojave River Basin, California

By CHRISTINA L. STAMOS, PETER MARTIN, TRACY NISHIKAWA, *and* BRETT F. COX

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FIGURES

in flow rate was caused by pumping in the Harper Lake area. Ground water continued to flow downstream into the Baja subarea; however, the flow rates decreased (2,146 acre-ft/yr in 1930 and 1,677 acre-ft/yr in 1994). Ground-water flow was from the Baja to the Coyote Lake model subarea in 1930; however, there was a reversal of flow in 1994. Ground water exited the basin from the Afton Canyon model subarea at a higher flow rate in 1994 than in 1930 (26 acre-ft/yr compared with 46 acre-ft/yr).

The simulated rates of underflow for 1931–90 are the average rates for that period. The direction of ground-water flow between the model subareas for the 1931–90 period was the same as that simulated for 1994, except between the Transition zone and the Oeste model subareas where underflow again reversed direction, flowing from the Oeste model subarea to the Transition zone (fig. 34). A comparison between the simulated 1931–90 average and the steady-state rates of ground-water underflow indicates that underflow between the Centro and Harper Lake model subareas was about 840 acre-ft/yr less for the steady state; underflow between the Transition zone and the Centro model subareas was about 880 acre-ft/yr less for 1931–90; and underflow between the Centro and Baja model subareas about 680 acre-ft/yr less for 1931–90; there was a reversal of flow between the Baja and Coyote Lake model subareas (a net change of about 760 acre-ft/yr). The average 1931–90 underflow exiting the flow system from the Afton Canyon model subarea was about 480 acre-ft/yr greater than the steady-state value.

Steady-State Ground-Water Flow Directions and Travel Times

The computer program MODPATH (Pollock, 1994) was used in this study to simulate the direction of particles of ground-water flow and their travel times. MODPATH is a three-dimensional particle-tracking post-processing program designed for use with output from ground-water flow simulations obtained using MODFLOW. The results from this program represent ground-water travel times and pathlines for advective transport only. A complete description of MODPATH's theoretical development, solution techniques, and limitations is presented by Pollock (1994).

Two particle-tracking simulations were made for the 1930 steady-state conditions; the first simulation tracked mountain-front recharge and the second tracked stream leakage to the ground-water system (fig. 35). The mountain-front recharge particle-tracking results are presented in figure 35*A*. Particles were tracked from the mountain-front recharge-site cells forward along flowpaths in layer 1 of the model; one particle was located in the center of each cell. By using one particle per cell, the program allows one to infer flow directions and travel times, but no statistics can be generated from the results. In general, most of the particles traveled downstream and discharged to the river at the Upper Narrows in the Alto and Transition zone model subareas upstream from the Helendale Fault. Izbicki and others (1995) analyzed the source, movement, and age of ground water in the Alto subarea. Using carbon-14 data from production and monitoring wells, Izbicki and others (1995) estimated that water in the regional aquifer west of Victorville was recharged from 10,000 to 20,000 years before present. The simulated travel times for mountain-front recharge to reach the area west of Victorville were about 5,000 to 6,000 years; this result is in reasonable agreement with the results of Izbicki and others (1995). The simulated travel times did not include the travel times through a thick (greater than 1,000 ft) unsaturated zone.

For the particle-tracking simulation of stream leakage, one particle was placed in the center of every river cell of model layer 1 and tracked forward along the flowpaths (fig. 35*B*). All particles for which tracking started in the West Fork of the Mojave River (fig. 1) left the river, traveled north outside of the floodplain aquifer, and reentered the river at the Upper Narrows (fig. 35*B*). Using carbon-14 data from production and monitoring wells, Izbicki and others (1995) estimated that water along this flow path was recharged less than 2,400 years before present. The simulated travel times for particles started in West Fork of the Mojave River to reach the Upper Narrows were about 2,000 years; this result is in reasonable agreement with the results of Izbicki and others (1995). Particles tracked from the main stem of the Mojave River (below The Forks) and within the Alto model subarea, left the river, traveled north within the floodplain aquifer, and reentered the river at the Upper Narrows (fig. 35*B*); travel times for particles in this model subarea were about 1,000 years. Particles for which tracking started in the river within the Transition zone model subarea quickly left and reentered the river or never left the river system at all. Particles for which tracking started in the river within the Centro model subarea either traveled to the Harper

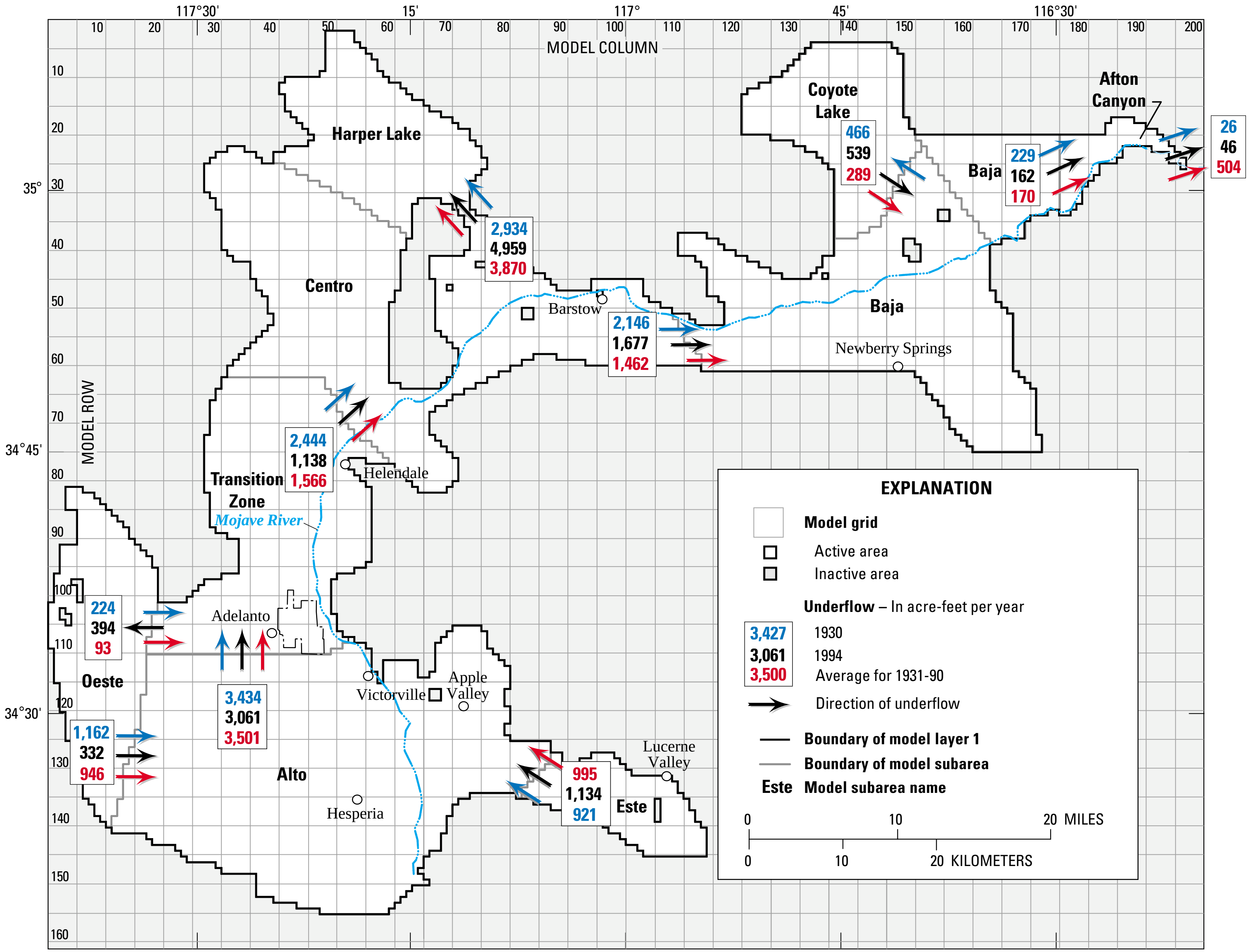

Figure 34. Simulated underflow between model subareas of the Mojave River ground-water basin, southern California, for 1930 and 1994, and the average underflow for 1931–90.