CITY OF EMERYVILLE
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January 12, 2012

Mark Detterman
Alameda County Health Care Services
Department of Environmental Health
1131 Harbor Bay Parkway, Suite 1131
Alameda, CA 94502

Re: Celis Service Station, 4000 San Pablo Avenue, Emeryville, CA 94608
Fuel Leak Case No. RO0000453; (Global ID # T0600101794)

Dear Mr. Detterman,

This letter responds to your letter of November 28, 2011. We appreciate your assistance moving this site in a productive direction towards closure.

Your observations and requests are reiterated below. Case facts are presented in the section that follows. Your observations and requests are then revisited in light of the facts at the end of this letter. Recognizing that you bring a "fresh set of eyes", it is important to underscore that the historic data must be closely scrutinized in order to gain an accurate understanding of site conditions. Some interpretive license has been taken by prior practitioners; my review has shown that certain representations cited as fact in your letter may not be as they appear.

ACEH Observations and Requests

1. "Previously submitted figures (see for example Figure 3 in the referenced report, and Figures 4 and 7 in the previously cited August 2007 report) appear to suggest conduits in both streets may allow preferential migration of contaminants away from the site vicinity." The ACEH requests an updated conduit study (prior studies did not describe conduit conditions beneath 40th Street).
2. "At present the majority of wells being monitored at the site and vicinity are west of the identified potential conduits in San Pablo Avenue. Well WCEW-1 (redesignation of EW-1 by The San Joaquin Company) located at the northeast corner of San Pablo Avenue and 40th Street, appears to be the only well monitoring groundwater near the former site (well MW-5 monitors an area upgradient of the Celis site, in vicinity of an identified paleochannel). All other wells are located west of potential utility conduits which may in part be responsible for lower concentrations west of the utilities." The ACEH requests a

workplan to investigate the downgradient extent of contamination (based on the assertion that migration may be affected by utilities or "paleochannels").

3. "The last groundwater monitoring event occurred in March 2010, with the recommendation to await developments associated with the work at the Oak Walk site. Remedial actions at that site were finished in early 2009. In order to understand current and future conditions, to determine the effect remedial work at that site may have had at the Celis site, and to determine if contaminant rebound, if any, may be present, ACEH requests the resumption of groundwater monitoring at the subject site using the identified analytical suite, on an initial quarterly basis."

Case Facts

Local Hydrostratigraphy

I have reviewed the technical project files for the Celis, Oak Walk and Andante properties for the purpose of gaining a better understanding of the nature of local sedimentology and hydrostratigraphy. As we discussed during our site visit on December 8, 2011, technical reports suggest that the transport and fate of petroleum hydrocarbons in this locality are affected by the presence of "paleochannels", the first of which is shown on diagrams presented in the June 2003 Andante Report of Remediation (San Joaquin Company). The suggested "streambed" shown on Figure 3 of this report has been repeated on project maps ever since it's creation in 2003 and by repetition has come to be viewed as a proven technical fact (see attached figure excerpt for channel depiction).

With all due respect to its author, I do not find supporting evidence for the feature as drawn. The logs for Trench 2 and Trench 3 on the Andante site describe two layers of fill overlying what is identified as native clay. Surface grade to approximately 2.5 feet below ground surface (bgs) is described as coarse-grained sand and aggregate base rock fill underlain by an approximately 1.5 foot-thick layer of fine-grained fill (silty clay with some sand and gravel), which is in turn underlain from 4.5 feet to 10 feet bgs (the total depth explored) by "highly impermeable stiff silty clay." The text of the report, however, describes "a sand lens that extended through the site from the northeast to mid site on the west boundary." The top of this lens was said to be encountered at 5 feet bgs, and to have been observed to be approximately 5 feet thick by 20 feet wide. Logs for neither borings nor trenches within the depicted dimensions of this feature (presumed to be the "paleochannel" shown on site drawings) correspond with this description.

I reviewed boring and trench logs for the purported channel feature shown to the north (on the Oak Walk property) and did not observe the strong correlation implied by what is depicted on the figures. There is no question that certain borings and trenches intercepted coarse-grained sediments. Their uninterrupted continuity as a suddenly buried channel, however, does not appear supported by the data.

As we discussed during our visit, extensive continuous paleochannels such as those recorded on project-area maps and drawings are rarely seen in the sedimentologic record of an alluvial plain. What is much more common is heterogeneity, with channel, overbank and crevasse-

splay deposits observed cross-cutting and intermingling, reflective of the depositional environment of a meandering stream. In the case of the subject area, it appears as if the depositional regime was influenced by Temescal Creek, which at the time of the earliest map I could locate (1850) flowed in a channel several blocks north of the 40th Street/San Pablo Avenue intersection (the topographic map upon which the creek trace is superimposed shows modern improvements and topography). Access the link below for the link to the 1850 map:

http://museumca.org/creeks/1160-OMTemescal.html#

That the creek had meandered to a location the equivalent of several blocks from the study area calls into question the existence of a well-defined channel at the time the ground was leveled and filled for development in the late 1800's.

I also reviewed aerial photographs for the intersection, with the earliest I could locate being 1931. The 1965 photograph is attached. Features shown are largely similar to those observed in the 1931 photograph (but with better resolution in 1965). The portion of the Andante site that is shown in technical reports as containing evidence of a paleochannel is occupied by several railroad tracks trending in the exact direction as the postulated channel. As the tracks are at surface grade, it is reasonable to expect that lower-lying areas were filled with relatively permeable materials prior to the construction of the roadbed. These materials may have been described in the field as streambed deposits.

One of the most effective methods for evaluating sediment interconnectivity is by way of a pumping test. Making "transects" and the correlation of trench or boring log data is useful, but given the heterogeneity of alluvial terrane, the numerous different technical personnel making the measurements, and the density of investigative locations required for accuracy, such observation-based correlation is of questionable value in settings such as the study area (see attached excerpt from a technical paper on hydrostratigraphic analysis in alluvial terranes). A pumping test, however, would have yielded quantitative data with respect to the existence of connected higher-permeability subterranean features. There is no indication in historic technical reports or agency directives that such a test was ever contemplated.

In summary, it does not appear sufficient evidence exists to support a confident determination of the paleochannels depicted in technical reports. Review of trench and boring logs evidence permeable sediments, and it is likely that these sediments in places interconnect. The nature of their interconnectivity, however, is likely more complex than the depicted continuous features.

It must be further noted that the portion of the Celis site that historically evidenced the most substantial contamination (in the vicinity of former monitoring well LF-1 and the northwestern portion of the Celis tank/site excavation) was adjacent to neither the railroad lineament not the relatively coarse-grained sediments that have been depicted as a channel deposit on the parcel to the north.

Utilities

I reviewed the City of Emeryville utility maps for conduit in place beneath 40th Street. My review showed that no deep utilities were buried beneath the 40th Street extension connecting San Pablo Avenue to Adeline, and that deeply buried utilities beneath 40th Street to the west do not tie to those under San Pablo Avenue. The utility survey presented in the May 31, 2006 URS report entitled "Additional Investigation at Former Celis' Alliance Service Station" is accurate and sufficiently comprehensive.

I also reviewed the Conduit Study and technical reports describing site exploration along San Pablo Avenue. With respect to the potential interaction between groundwater and buried utilities I paid particular attention to the depth at which groundwater was first encountered in exploratory borings and trenches advanced across the project properties. With the exception of the Andante site, groundwater was generally encountered at depths substantially greater than 8.5 feet bgs (if it was encountered at all). A selection of boring/trench data is shown below:

8-29-07 Monitoring Well Installation at Former Celis' Alliance Fuel Station Site (URS)
MW-1 – 15.13' first water (borings advanced in June 2007 – dry season)
MW-2 – 20' first water
MW-3 – 20' water
MW-4 – 19.2' water
MW-5 – 18.5' water

5-31-2006 Additional Investigation at Former Celis' Alliance Service Station (URS)
URS SB-1 – 8.62 first water (borings advanced in February 2006 – wet season)
SB-3 – 9.5' first water
SB-6 – no water (20' TD)

4-29-04 Results of Preliminary Subsurface Investigation: The Oak Walk Site Emeryville California (SJC)
Trench 1 – 8.5 feet deep/dry (trenches excavated in December 2003 – wet season)
2 – 8.5' deep/dry
3 – 9.5'/9' first water
4 – 10.5'/dry
5 – 8.5'/dry
6 – 8.5'/dry
7 – 9.5'/8' water
8 – 9'/dry

In their May 2006 report, URS states "With historic groundwater depths ranging from 5 to 10 feet bgs, it appears that each of these utility trenches have the potential to act as preferential pathways for contaminant migration especially in light of the fact that they are located just downgradient (with respect to shallow groundwater flow direction) of the Site." This statement by URS is not accurate. As shown in boring and trench logs, groundwater is first encountered

beneath this locality at depths of 8.5 feet bgs and greater. Groundwater levels in monitoring wells have been measured at more shallow depths, but these measurements are indicative of a potentiometric surface – not the top of the water-bearing zone (water levels rise in wells after completion). The URS evaluation of water-trench interaction should have relied upon the depth at which water occurred, not the height of its potentiometric surface.

Additionally misleading is the URS Figure 3 in the May 2006 report (one of the lines of evidence for groundwater-utility trench interaction you cite in your letter). As we discussed during our recent site visit, Figure 3 depicts a contaminant plume configuration that imagines and suggests to the quick reader an interaction between contaminant-bearing groundwater and underground utilities. I can locate no data to support the creative planaria-shaped contaminant plume depicted on this drawing; the elongation of the highlighted area along the utility corridor has absolutely no bearing in reality. Irrespective the lack of data, as with the paleochannels, this utility-groundwater interaction has been mentioned so many times it is treated as fact.

The bottom of the utility trenches is likely in places near the upper reaches of water-saturated sediments. Where these sediments are coarse-grained, there is possibly a measure of groundwater to trench infiltration. Where the sediments are fine-grained, the trenches likely do not receive contribution from groundwater. Boring and trench data indicate the Celis sediments nearest San Pablo Avenue are fine-grained; it seems unlikely that substantial groundwater infiltration to this portion of the utility corridor is occurring.

It should be noted that an interaction between the utility trenches and ephemeral water in the former railroad bed is plausible, as is interaction with permeable sediments in other places (the sediments to the north, beneath the Oak Walk property, for example). The introduction of less than pristine water from roadway infiltration to utility backfill is also plausible.

<u>Historic Assessment and Remediation – Celis Property</u>

A preliminary investigation conducted by Levine Fricke in 1993 consisted of the advancement of numerous soil borings on and around the Celis site and the construction of three groundwater monitoring wells. Results of analysis of samples collected during these activities showed the presence of fueling system-related hydrocarbon contamination, with the most substantial impact measured near the single gasoline UST buried beneath the northwestern portion of the property (other USTs were buried beneath the southwestern portion of the property; contaminant concentrations near these were moderate to low). Separate-phase hydrocarbons (SPH) were measured in LF-1, the monitoring well installed near and downgradient from the northern tank. Concentrations of contamination measured elsewhere beneath the site (including from samples taken upgradient of the fueling system) were moderate to low.

A workplan describing the objectives and methodology for tank removal, excavation and sampling was presented to the ACEH in June 1994. The plan called for tank removal and the excavation of underlying soil to the top of the water-bearing zone. The workplan was approved by the agency and implemented without modification. At the direction of the ACEH, a groundwater/SPH extraction well (WCEW-1) was installed near the former gasoline UST; weekly

groundwater/SPH extraction events were conducted from September through December of 1997. Technical documents indicate SPH was observed in the extraction well at the early stages of recovery but none was observed during the final four extraction events. Concentrations of dissolved contaminants decreased steadily over the following year, as documented in the October 1998 Request for Closure. By 2010 concentrations of benzene in groundwater samples collected from this well had decreased from the 2,100 ppb measured in 1998 to below instrument detection limits.

Groundwater samples collected from monitoring well LF-4, installed across San Pablo Avenue downgradient from the Celis site, have shown a similar consistent decline in contaminant concentrations following the removal of the Celis USTs. Samples collected in 1994, prior to tank removal, were shown by laboratory analysis to contain 1,000 ppb benzene and 8,480 ppb total aromatic volatiles. By 1998 lab analysis showed LF-4 to contain 7.9 ppb benzene and 68 ppb total aromatic volatiles; at its last sampling in 2010 LF-4 contained 3.5 ppb benzene and 16.3 ppb total aromatic volatiles. Concentrations of longer-chain hydrocarbons have been measured in LF-4 to this day. It is suspected that these hydrocarbons are associated with migration from other upgradient sources (these other sources are referenced in the recent ACEH letter).

The original caseworker, Susan Hugo, wrote in a November 5, 1997 letter that the ACEH "concurred that no further action for soil is warranted and groundwater monitoring program should be implemented to demonstrate plume stability and chemical degradation. In addition, the site will be evaluated for closure as a low risk soil and groundwater case with the following conditions: free product is not present in any of the wells. The plume is stable, chemical degradation is present and benzene concentration in groundwater is below the site specific target level." No further correspondence evidencing agency oversight was evident in the ACEH file until a 2004 letter written by Ms. Hugo's successor, Barney Chan. In this letter Mr. Chan requested additional assessment due to assertions by others that the release at the Celis site had caused off-property contamination. This additional assessment was completed. Mr. Chan's final letter (November 2007) before being succeeded by Mr. Stephen Plunkett acknowledged completion of the directed activities, indicated that the Celis site could not be closed until the upgradient sites were closed, and requested the initiation of a period of groundwater monitoring. Mr. Plunkett's only file correspondence was a letter requesting one year of continued groundwater monitoring (July 2009 ACEH directive letter).

All technical activities requested or directed by the ACEH since 1994 have completed.

Your November 2011 letter suggests that Barney Chan requested an additional conduit study in October 2006. Respectfully, this is not the case. On page two of this letter, he requests only the installation and sampling of additional monitoring wells (to study the utility conduit).

Conclusions

The recent ACEH requests are reiterated below, followed by a presentation of applicable companion facts and recommendations for appropriate follow-on activity.

1. "Previously submitted figures (see for example Figure 3 in the referenced report, and Figures 4 and 7 in the previously cited August 2007 report) appear to suggest conduits in both streets may allow preferential migration of contaminants away from the site vicinity." The ACEH requests an updated conduit study (prior studies did not describe conduit conditions beneath 40th Street).

   As described above, the referenced figure is not an accurate graphic depiction of documented fact. Examination of the data record shows no relationship between the utility corridor (which exists only beneath San Pablo Avenue) and migrating groundwater. Additionally, the sampling record shows concentrations of gasoline-related compounds in monitoring well LF-4, located downgradient from the Celis site, have declined steadily since UST removal and remedial action, evidencing a connection between groundwater in this area and the former Celis site. Residual contaminants remain, possibly associated with both the Celis site and other upgradient sources of contamination, but the migration of groundwater unimpeded by San Pablo Avenue utilities is proven by this concentration trend.

   No additional evaluation of the San Pablo Avenue utility corridor is warranted.

2. "At present the majority of wells being monitored at the site and vicinity are west of the identified potential conduits in San Pablo Avenue. Well WCEW-1 (redesignation of EW-1 by The San Joaquin Company) located at the northeast corner of San Pablo Avenue and 40th Street, appears to be the only well monitoring groundwater near the former site (well MW-5 monitors an area upgradient of the Celis site, in vicinity of an identified paleochannel). All other wells are located west of potential utility conduits which may in part be responsible for lower concentrations west of the utilities." The ACEH requests a workplan to investigate the downgradient extent of contamination (based on the assertion that migration may be affected by utilities or "paleochannels").

   As discussed above, an examination of trench and boring log data indicates that the "paleochannel" theory is overstated. Areas of relative subsurface permeability exist, and in places these areas are certainly interconnected. The model utilized, however, seems an over-simplification, one that if relied upon could motivate involved parties to conduct unnecessary actions (and possibly neglect aspects of site characteristics that warrant further evaluation).

   Further, while the recent ACEH letter correctly states that the majority of monitoring wells are located across San Pablo Avenue, well WCEW-1 was constructed to remediate and monitor the most substantially impacted area of the Celis property. That this well is

now virtually free of gasoline-related contamination indicates that the remedial efforts were successful and that no substantial residual fraction of contamination persists in this area. In the recent letter, the ACEH suggests that contaminant decline in this well is the result of remediation on the Oak Walk property. An examination of the sampling record clearly shows the cause of contaminant decline is instead Celis tank, soil, and groundwater/SPH removal from WCEW-1.

Based on a detailed review of contaminant trends, utility/groundwater interaction (or lack thereof), and the notion of "paleochannels", no further investigative activity associated with the Celis site is warranted.

3. "The last groundwater monitoring event occurred in March 2010, with the recommendation to await developments associated with the work at the Oak Walk site. Remedial actions at that site were finished in early 2009. In order to understand current and future conditions, to determine the effect remedial work at that site may have had at the Celis site, and to determine if contaminant rebound, if any, may be present, ACEH requests the resumption of groundwater monitoring at the subject site using the identified analytical suite, on an initial quarterly basis."

   With respect to the rebound that could have been associated with remedial activities on the Oak Walk property, the ACEH letter identifies the completion date for this remedial action as early 2009. In actuality, the remedial action was completed in the summer of 2007; the activity was only *documented* in 2009. Post-remedial monitoring has already occurred. No rebound was observed.

   Further, for clarity, the conclusion of the May 2010 groundwater monitoring report did as you observed note that the ongoing work at Oak Walk may produce data indicating that further Celis activity might be useful or appropriate. So far, this has not been the case. No new data indicating the need for further Celis site direct activity has been produced. For the sake of complete clarity, the May 2010 report concluded by saying:

   The purpose of the well installation and sampling proposed in the 2006 URS Workplan has been accomplished. Results of testing conducted over the past years have established subsurface conditions related to the Celis operation and adjoining sites. No further sampling of these wells is recommended at this time. The wells should not be abandoned, as work on the neighboring Oak Walk site may benefit from their accessibility. A portion of the Oak Walk project purports to be associated with a release from the Celis site; for this reason the Celis file is not petitioned for agency closure at this time. Developments in association with the work at Oak Walk will inform appropriate next steps for Celis (if any are required).

Celis monitoring in the period following excavation/pumping in 1994-1998 clearly shows the benefits of tank removal and remedial action. Monitoring in the period since shows a steady and continued decline in concentration; no "rebound" in wells was observed following the 2007

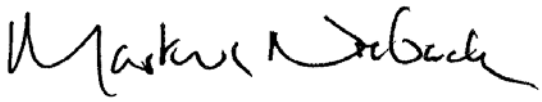
remedial action at Oak Walk. Assertions have been made with respect to Celis and other sites/"paleochannels"/utility corridors. The data record in no way supports these assertions.

While we believe that no further action should be required of Celis, we take no issue with this site remaining open until the Oak Walk and Andante files are closed. We support Oak Walk's recent recommendations for risk assessment and deed restriction. As we discussed during our visit in the field, this is what must drive concluding activities at these properties. As you know well, this neighborhood is affected by remnants of historic industrial activity (as is much of the City). It was for this reason that Emeryville conducted its EPA-funded Pilot Study in the 1990s, and it is for this reason that Emeryville passed its water-supply well prohibition. Groundwater beneath Emeryville is not extracted for any purpose. Elevated concentrations of contaminants may in places remain, but so long as they pose no threat to human or environmental health, no further action should be required. If the results of the Oak Walk Risk Assessment are supportive of such a conclusion, they should be allowed to close their file.

As for the upgradient sites, if a risk to human health is posed by contamination associated with these properties, this risk should be abated and land use restrictions relied upon to the extent practicable to account for the residual contamination. My review of the data does not indicate a substantial risk to an identified receptor in this area. There may be data gaps yet to be filled, but I'd encourage closer scrutiny of the historic record to identify exactly what these might be. Much effort and investment has been made at the direction and under the oversight of the ACEH and other agencies. Rather than beginning again, it would seem more logical to build on these accomplishments and devise a practical way to put a period at the end of this very long sentence.

Thanks for receiving this. Give me a call after your review to discuss at your convenience.

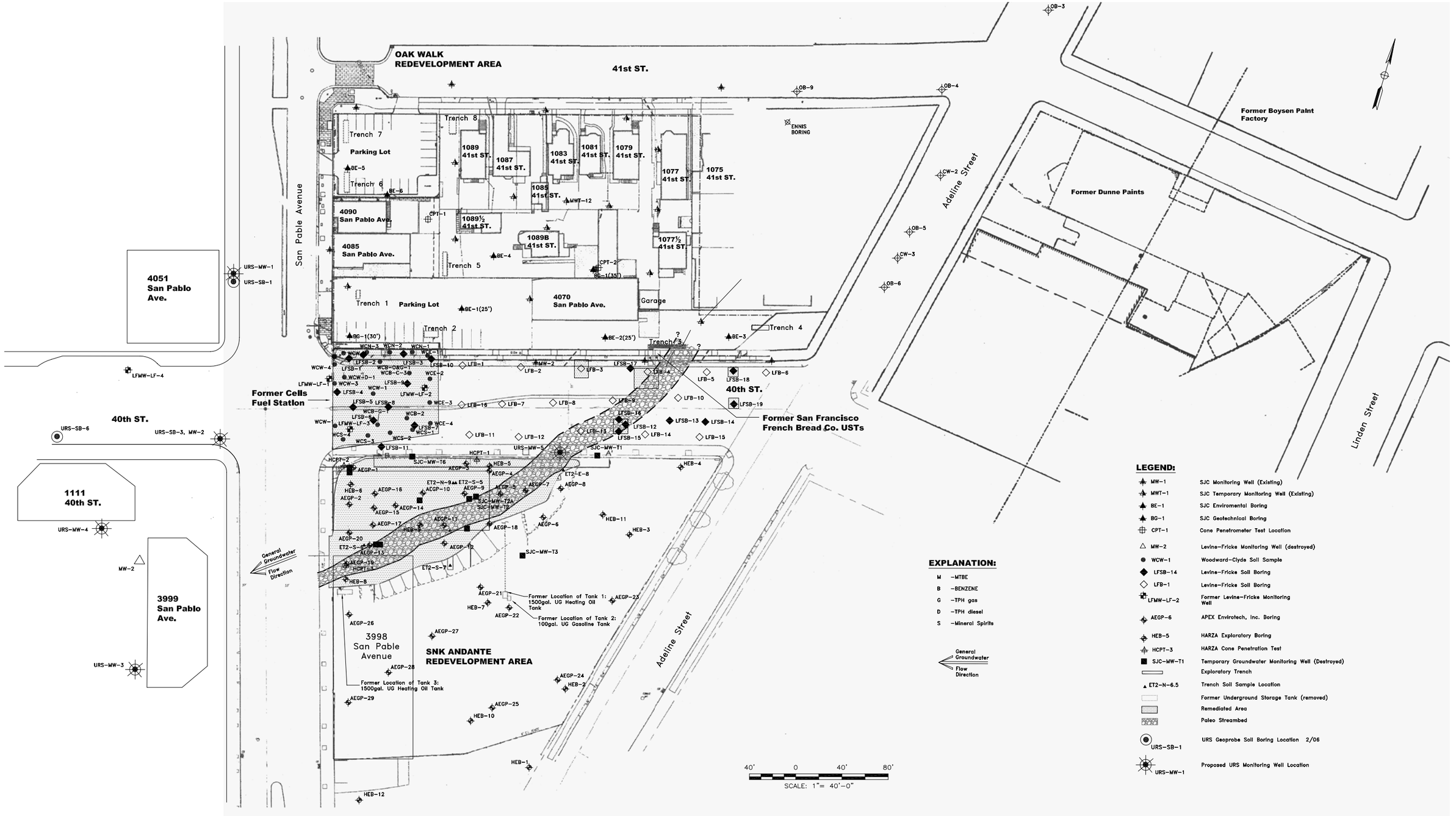
Most sincerely,



Markus Niebanck
Program Coordinator

Attachments

2003 SJC Figure Showing "Paleochannel"
1965 Study Area Aerial Photograph
Excerpt from "*Defining Hydrostratigraphic Units within the Heterogeneous Alluvial Sediments at Lawrence Livermore National Laboratory*", (see the complete article at http://www-erd.llnl.gov/library/JC-139779.pdf)



Base Map From The San Joaquin Company, Inc. (Dec 2004)

REV	DESCRIPTION OF REVISION	BY	DATE

City of Emeryville Redevelopment Agency
1333 Park Avenue
Emeryville, CA 94608

URS

1333 BROADWAY, SUITE 800
Oakland, CA 94612
Tel: (510) 893-3600
Fax: (510) 874-3268

DESIGNED	–
DRAWN	MS
CHECKED	–
PEER REVIEWED	
PROJECT MANAGER	–
DATE	–

Proposed Additional Monitoring Well Locations

FORMER CELIS ALLIANCE FUEL STATION SITE, SNK ANDANTE REDEVELOPMENT AREA AND OAK WALK REDEVELOPMENT AREA EMERYVILLE, CA.

REVISION	1
PROJECT	26814847
FIGURE	2

Dec 13, 2006 – 5:08pm
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INQUIRY #: 2611024.5
YEAR: 1965
= 333'
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Defining Hydrostratigraphic Units within the Heterogeneous Alluvial Sediments at Lawrence Livermore National Laboratory

by Charles M. Noyes[a], Michael P. Maley[b], Richard G. Blake[c]

Abstract

At Lawrence Livermore National Laboratory (LLNL) Superfund site, the properties of ground water flow were used to define a series of hydrostratigraphic units (HSUs) within a thick sequence of previously-undivided, heterogeneous alluvial sediments. A methodology using multiple independent data sets was used to define the hydrostratigraphic unit boundaries. The methodology employs an iterative process to minimize uncertainty in the correlations. Monitoring of the ground water system under stressed conditions during extraction well pumping and long-term pumping tests provided the most effective data set for identifying and verifying HSU boundaries. Hydrostratigraphic analysis identified low-permeability horizons within the alluvial sequence that exert significant control over ground-water flow and contaminant transport. These geologic features, which inhibit vertical hydraulic communication and contaminant migration, form the boundaries of the HSUs. At LLNL, the HSUs generally consist of a hydraulically-interconnected network of higher-permeability deposits set within finer-grained, lower-permeability sediments.

By identifying the primary hydraulic controls within the LLNL alluvial sequence, a hydrostratigraphic framework consistent with ground water flow and contaminant transport processes was established. The HSU framework has allowed for the mapping of a complex network of co-mingled plumes, each of which can be traced back to their respective source areas. Ground water cleanup systems at the site have been designed to treat and capture individual contaminant plumes, and are optimized with respect to their location, geometry, and mobility.

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[c]Lawrence Livermore National Laboratory P.O. Box 808, L-530, Livermore, CA 94550, 925-422-9910, blake2@llnl.gov

This has proven a successful strategy for implementing the ground water cleanup based on the site remediation history.

Introduction

The design and implementation of an effective ground water remediation system requires a thorough understanding of the hydrogeologic factors that control site-specific flow and transport in the subsurface. However, at sites underlain by a heterogeneous geological environment, understanding contaminant transport at the necessary scale is a difficult task (Narasimhan 1998; Koltermann and Gorelick 1996; Anderson 1989; Fogg 1986). Yet, until this basic hydrogeologic framework has been established, planning and designing an effective remedial strategy can be problematic (LeGrand and Rosen 1998). For example, extraction wells may not be located and designed for maximum mass removal and optimal hydraulic capture, leading to ineffective, or prolonged and costly remediation. At many sites, attention has been focused on identifying individual high-permeability paleochannels. However, the relatively limited areal extent of individual paleochannels requires a high density of data for proper definition (Fogg et al. 1998; Koltermann and Gorelick 1996). This type of characterization is not feasible for many environmental sites.

At Lawrence Livermore National Laboratory (LLNL), the characterization objective was to define a practical set of subsurface units to provide a framework for planning a large ground water remediation system. These units needed to accurately represent ground water flow and contaminant transport at the site, and group together sets of hydraulically-interconnected, high-permeability sediments. The primary characteristics used to define hydrostratigraphic units (HSUs) at LLNL include:

- a high degree of hydraulic interconnectivity within an HSU;
- a low degree of hydraulic interconnectivity with adjacent HSUs; and

- boundaries that significantly limit vertical hydraulic communication and contaminant migration.

To identify and correlate the HSUs, a methodology that integrated the evaluation of geologic, geophysical, pumping test, ground water elevation, and soil and ground water chemistry data was employed. During this process, efforts were focused on identifying and correlating low-permeability layers because they proved to be more laterally continuous than the higher-permeability layers. It was found that certain low-permeability layers did significantly limit hydraulic communication and contaminant transport within the alluvial sediments across the entire site. These layers were used to define the HSU boundaries. However, there was no unique feature from the analysis of core or geophysical logs that distinguished layers that formed boundaries from those that did not. Therefore, it was necessary to integrate multiple data sets with a strong reliance on ground water data to define the HSUs at LLNL.

Background

Lawrence Livermore National Laboratory (LLNL) is located in Livermore, California, about 65 kilometers east of San Francisco (Figure 1). The LLNL facility is a highly-developed research and industrial facility that covers about 2.5 square kilometers. The site was converted from agricultural use into a Navy Air Field in 1942. In 1951, the site became a weapons design and basic physics research laboratory. In 1982, multiple plumes of volatile organic compounds (VOCs), predominantly trichloroethene (TCE) and tetrachloroethene (PCE), were discovered in ground water beneath LLNL (Dreicer 1985). Prior to the start of remediation, the plumes situated on the western margin of the site extended up to 1,200 meters (m) off site toward municipal supply wells in the city of Livermore. In 1987, LLNL was placed on the U.S. Environmental Protection Agency's National Priorities List. To comply with federal regulations, LLNL has completed a Remedial Investigation (Thorpe et al. 1990), Feasibility Study (Isherwood et al.