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Department of Toxic Substances Control

Maureen F. Gorsen, Director
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Arnold Schwarzenegger
Governor

May 21, 2008

Mr. Steve Slaten
NASA Remedial Project Manager
NASA Management Office
4800 Oak Grove Drive
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REVIEW OF NASA, JANUARY 31, 2007 TECHNICAL MEMORANDUM, ADDITIONAL INVESTIGATION RESULTS, JET PROPULSION LABORATORY, 4800 OAK GROVE DRIVE, PASADENA, CALIFORNIA 91109

Dear Mr. Slaten:

The Department of Toxic Substance Control (DTSC) has reviewed the January 31, 2007 Technical Memorandum, Additional Investigation Results, Jet Propulsion Laboratory, 4800 Oak Grove Drive, Pasadena, California. Enclosed, please find DTSC's comments on the Technical Memorandum.

If you have any questions, please contact Mr. Michel Iskarous, Project Manager, at (818) 717-6547 e-mail miskarou@dtsc.ca.gov or me, at (818) 717-6539 e-mail joborne@dtsc.ca.gov.

Sincerely,

Juli Oborne
Unit Chief
Brownfields and Environmental Restoration Program – Chatsworth Office

Enclosure

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MEMORANDUM

TO: Mr. Michel Iskarous, Project Manager
Site Mitigation and Brownfields Unit,
Chatsworth Office

FROM: Alice Campbell, PG, CEG, CHg
Senior Engineering Geologist
Chatsworth Geological Services Unit

CONCUR: Craig Christmann, PG
Senior Engineering Geologist
Chatsworth Geological Services Unit

DATE: May 13, 2008

SUBJECT: Review of NASA, January 31, 2007 Technical Memorandum, Additional Investigation Results, Jet Propulsion Laboratory, 4800 Oak Grove Drive, Pasadena, California 91109

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Introduction:

At your request, the Chatsworth Geological Services Unit (GSU) prepared this memorandum to provide comments on the Additional Investigation Results Report (AIR) cited above. The AIR describes the results of work done to first, evaluate the downgradient extent of contaminants originating form the JPL facility, and second, determine whether the occurrence of perchlorate at the Sunset Reservoir originated at JPL. This work is being undertaken under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) program at JPL. The investigation included re-analysis of existing data, collection of new isotope data, the installation of two new multiport wells, and preparation of well logs and construction documentation. Our review was performed to assess the results of the additional investigation.

GSU reviewed the AIR, and has the following comments:

1. Page 6. Background. The background lacks a description of the depositional environment of the alluvium of the Monk Hill basin. The depositional environment determines large-scale features of the groundwater system that may affect contaminant migration. Most of the alluvium near JPL was deposited by the Arroyo Seco, which is one of the largest local drainages. The landform is an alluvial fan, characterized by about 10% coarse channel deposits and 90% flood and overbank deposits, which may develop flat soil horizons. The stream channels have a permeability contrast with the materials they incise, and this stream fabric imparts a strong lateral anisotropy to groundwater flow. Other features of the alluvium include detrital charcoal, which is deposited after brushfires. This naturally occurring organic carbon also affects contaminant transport. The section should include a discussion of the geologic factors that affect groundwater flow.

2. Page 6, second bullet. Vertical hydraulic gradients are caused by pumping, and not by the degree of confinement. It is usual in most alluvial basins for the degree of confinement to gradually increase with depth. In the Coastal Plain, the four main divisions of the alluvium correlate with climate changes related to Sierra glaciations, and it would not be surprising to find much the same sequence in the smaller basins. The section should be revised to remove the relation of unconfined conditions to vertical gradient. In an alluvial fan environment, new channels characteristically cut across soil horizons, so the assumption that these layers are intact is not supported.

3. Inspection of topography reveals a slightly more complex situation than described. The base of the San Gabriel Mountains has several fans centered on prominent drainages. In the Monk Hill basin, Flint Ridge blocks southern continuation of the fans, so the drainage upon the fans is shunted east to join the Arroyo. Because of the structure of the fans, water moving in buried channels tends to follow the same general pattern. It is more correct to say that groundwater gradients are more easterly, because of pumping. The actual particle flow direction is determined by the vector sum of the gradient vector and the anisotropy vector. Pumpage is not the most significant determinant of groundwater flow. The most important factor is topography, and water in the basin does flow from higher to lower elevations. The second most important factor is anisotropy, because it is an aquifer property, and pumping vectors are third, because they are superimposed on the other two factors. The section should be revised.

4. Water resources models typically neglect the effects of lateral anisotropy, because bulk flow volumes are little affected. However, for contaminant transport problems, anisotropy cannot be neglected, because the issue is determining actual flow paths, not bulk movement. Thus, the RBMP model is not useful to predict contaminant flow unless it incorporates horizontal anisotropy. Inspection of the particle tracks indicates it does not account for the north-south channel deposits of the Arroyo Seco, which indicates that the aquifer has been assumed to be laterally isotropic. This is not consistent with the depositonal environment.

5. The methods used to calibrate the RBMP model are not described, nor are the actual values given of conductivity, vertical anisotropy, or recharge used in its calibration. No water balance is provided. It is not stated whether automated parameter estimation was used. Since any one calibration is not unique, there is a range of values and combinations of parameters that will all calibrate the model, yet some are more unlikely than others. The uncertainty of the calibration is not given. Likewise, no information on the JPL model is given other than results. The results of the particle tracing indicate that both models assume laterally isotropic conditions. Basically the models assume the basins are uniform layers of sand and silts/clays. The real basins, however, were laid down by streams flowing mainly north to southwards, and these stream channels create preferential southward flow pathways. The largest and most prominent of these is the Arroyo Seco. Any model that does not show the slightest deviation in particle tracks while crossing the Arroyo sediments at right angles is not a believable model.

6. The northern boundary of the model is stated as the San Gabriel mountains. The mountains are bounded by the Sierra Madre Fault, a thrust fault that moves bedrock over alluvium. The geometry of the fault indicates that substantial alluvium extends beneath the fault to the north. It is not clear whether this alluvium was included in the model.

7. The water balance for the model needs to be shown, along with interlayer water balances. Constant head boundaries have unlimited capacity to remove water from the basin, and errors in subsurface outflow are often calibrated out by increasing both recharge and conductivity. General head boundaries, which limit outflow to the aquifer conductance and gradient, are a better choice. Since a very large combination of flows and conductances can match the same gradient, inspection of outflow volumes is needed to identify whether reasonable outflow volumes are being produced by the boundary. Constant head boundaries are more appropriate to fully penetrating streams and lakes, and are not good choices for subsurface outflow.

8. Results of Groundwater Modeling. The flow fields of the two models are similar because they both assume the basins are laterally homogenous and isotropic, which is obvious from the way the streamlines cross one major stream course after another without deflection. Neither model appears to incorporate anisotropy, a key feature of the aquifer that governs particle flows. The models do not accurately model contaminant flow, only bulk flow. They are water resource models, not contaminant flow models. The particle tracks illustrate the gradient, but do not and cannot illustrate contaminant flow. The maps lack a north arrow and scale.

9. It is unlikely that the pumping in the Monk Hill basin contains JPL's contaminants, because water would be forced to move upstructure and across grain to get to the wells. Real water follows the path of least resistance, and the actual flow paths tend to follow the structure of the fans. In anisotropic media, true particle paths diverge from hydraulic head maps because of the sideways component of conductivity. One characteristic of anisotropic aquifers is that contaminant plumes follow the topography, not the groundwater gradient.

10. Figures 2 and 3. Over much of these two maps, particle tracks cross topography at high angles. Under these scenarios, there is no real flow of water to the Arroyo Seco near the Rose Bowl. There is no outflow to the southwest near South Pasadena either, yet Arroyo sediments clearly underlie the 110 freeway alignment. There are no groundwater monitroing wells within the Arroyo south of Devil's Gate which forms a significant data gap. Recent personal communications with the L.A. Department of Public Works indicate perchlorate was detected during dewatering near the 110 freeway, down the Arroyo Seco Channel.

11. The rate of groundwater movement is not well supported, because the model uses boundaries liable to cause conductance errors. The models do not prove that contaminants were contained in the Monk Hill basin, only that there was a flattened gradient.

12. Groundwater Geochemistry. Page 11. last bullet (artificial recharge). Who made the estimate? Was it verified? Has this percentage been constant over time? The Calif Dept of Water Resources observes that the use of dishwashers and automatic washers has changed the proportion of water used inside and outside the home. The introduction of low-flow toilets has also skewed proportions. Because this recharge is a significant portion of the basin's water, errors in this value will propagate as conductivity errors in the model. Changes in the percentage of sewered areas also change areal recharge. It is also not clear whether the proportion of delivered water to sewer flows were checked over time, which can lead to errors in estimating recharge.

13. Page 14, last bullet. The evidence for ion exchange is that sodium shows a wide range, and increases as calcium and magnesium decrease, generally by twice the amount, since sodium is monovalent and calcium and magnesium are divalent. The lower left triangle on the Piper shows that both type 1 and type 2 waters are softened by ion exchange, and type 3 is not. Type 2 water appears to be simply a softened version of type 1 native water. There appear to be two types of type 3 water, particularly evident in the left lower triangle as two distinct bands. These appear to be mixtures of type 2 and type 3 waters. No stability calculations are presented, but it is likely that type 3 waters are nearly saturated with respect to calcium sulfate, and precipitation of calcium sulfate can skew the proportion of calcium to magnesium. Some analyses seem to have unusually high magnesium proportions, which suggest some calcium has been precipitated.

14. There are alternative ways of interpreting the Piper diagram if precipitation has occurred. It is not obvious that ion exchange has been properly accounted for in the analysis. What is shown as a mixing line in the lower triangle is obviously an ion exchange line.

15. Another factor not included in the analysis is the impact of percolated wastewater and sulfate/nitrate reduction. Sulfate reduction causes a shift in the proportion of sulfate to bicarbonate that looks like a mixing line, but is actually a removal line. Water mixed with wastewater is often softened and loses much of its sulfate. These reactions, however, are not really mixing phenomena. In any case, saturation indices need to be checked before mixing is invoked to explain the data. Yet another factor is whether some native water derived from metasediments near Flintridge also have high sulfate. An analysis of nitrate would be instructive, particularly if young waters low in sulfate but high in chloride are also low in nitrate. This would suggest denitrification in addition to sulfate reduction.

16. Aerobic conditions are assumed, yet much of the chemistry suggests local anaerobic conditions.

17. While figures 7 and 8 may suggest recharge along the western corridor, the particle tracking maps certainly do not, and in fact, the conspicuous absence of a groundwater mound associated with the golf course is a strong argument for anisotropic conditions beneath the Arroyo.

18. Figure 8 also shows that sulfate migrates southerly along the Arroyo and its buried earlier channels. Note the similarity of the Ventura to the Copelin wells, and the Arroyo to the Sunset wells. The chemistry appears to track the geologic structure.

19. Figure 9 only reinforces the impression that groundwater moves down the Arroyo. The conspicuous data gap in the Arroyo only serves to suggest that more data would probably show that sulfate is high near the Rose Bowl, and that in fact, despite the direction of the gradient, contaminant transport is respecting the geology.

20. Page 19. A table with estimated pounds of perchlorate by source, and levels achieved by different dilutions, would be welcome here. Using the perchlorate levels in Las Vegas wash to imply high levels in Colorado River water is not justified, and would in any case have a high degree of uncertainty. While the resultant wide distribution of perchlorate would create a kind of background perchlorate smog in the basin, local sources greater than background can be easily distinguished.

21. Isotope data. The chart shows just as much mixing of type 3 water as it does of types 1 and 2 waters. This graph suggests that the deep water is not necessarily old, unmixed water, but is just ion-exchanged native water, possibly with some sulfate reduction.

22. The strontium isotope analysis also suggests that type 3 water is actually two different types, and that type 1 water can be turned into type 2 water by ion exchange. This was actually also shown on the Piper diagrams, but was misinterpreted.

23. Tritium samples. Although the data are not shown, it is likely that most of the type 2 water is young, not old, which suggest that the old, deep water is simply in a part of the aquifer that cannot be mobilized by wells. Often this happens in anisotropic aquifers where wells are at right angles to the stream fabric, and whose actual source of water is upstream and downstream, not across the stream fabric.

24. Carbon tetrachloride. Contrary to the statement in the report, PCE and TCE make excellent tracers when their molar ratios, not their absolute levels, are compared. Comparing and contrasting molar ratios is very successfully used to differentiate different solvent sources. The presence of PCE and TCE at the Sunset wells, despite the assertion that the Monk Hill pumping depression prevents JPL's plumes from migrating south, is a logical inconsistency.

25. While carbon tetrachloride has not been detected in the Sunset wells, onsite monitoring data indicates it is breaking down to chloroform, despite assertions that it is not biodegrading. MW-3 screen 2 shows both carbon tetrachloride and chloroform, its first daughter product. It also contains methylene chloride, another daughter product. While many people assume methylene chloride is a laboratory contaminant, in the presence of carbon tetrachloride and chloroform,

this is not justified. Sorption on natural carbon is also a possible process attenuating carbon tetrachloride, but the presence of daughter products is a stronger argument that it is degraded before reaching the Sunset wells. The data contradicts the statement that biodegradation is not occurring. It also suggests that water is not, in fact, flowing backwards towards Monk Hill.

26. The model cannot be used to predict the extent of carbon tetrachloride, since it incorrectly predicts the distribution of sulfate and perchlorate.

27. Perchlorate Isotope analysis. The isotope analysis shows that the perchlorate at the Sunset wells is a mixture of two sources, JPL and Las Vegas. This is what would be expected from spreading imported water in the vicinity of the JPL plume, which migrates down buried stream channels to the Sunset Reservoir area. MW-25 is the only well with a convincing difference from a mixture of JPL and Las Vegas perchlorate, which suggests fertilizer as a source.

28. The aquifer is very likely to contain detrital charcoal, and in substantial amounts. This substrate makes a very good locus for biodegradation, and may account for the degradation of carbon tetrachloride. Perchlorate is chemically similar to nitrate and sulfate, and is likely degraded under reducing conditions that may be widely scattered within the aquifer. The investigation did not consider the presence of detrital charcoal as a factor. Chemical evidence of reduction is generally a better indicator of reducing conditions than ORP or DO measurements, which can be contaminated by exposure to atmospheric oxygen by a deteriorated well seal. The functional genomics analysis does not take microenvironments into account.

29. The Sunset wells are down-structure from JPL. The fact that they are cross-gradient is nullified by the anisotropy of the aquifer. The isotope data shows that at least some of the perchlorate in the Sunset wells originated at JPL.

Conclusions and Recommendations

1. Neither groundwater model presented in the report incorporated lateral anisotropy, yet geologic evidence suggests that it is present. Since anisotropy does not affect bulk flow, the models may be used for water management, but neither model should be relied on to calculate particle flow paths.

2. The geochemical analysis misinterpreted some of the ion exchange data, and cannot be relied on to conclusively show differences between water at individual wells.

3. Monitoring data show that carbon tetrachloride is degrading in the aquifer.

4. The hydrogeology and structure of the alluvium provide a pathway from JPL to the vicinity of the Sunset wells.

5. The sulfate data indicate that sulfate moves down the Arroyo despite the groundwater gradient.

6. The perchlorate isotope data shows that some of the perchlorate at the Sunset wells matches the source at JPL.

7. Other data indicates that there is perchlorate in the lower Arroyo Seco along a flow path not predicted by the modeling, but consistent with and predicted by the geology.

Questions regarding this memo should be directed to Ms. Alice Campbell by contacting her at 818-717 -6623 or acampbel@dtsc.ca.gov.