Comments on City of Tracy's Proposed Demonstration Phase Aquifer Storage and Recovery Project (ASR Demonstration Project)

Submitted by
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The city of Tracy, CA, has proposed to inject Delta-Mendota Canal water (South Delta water) into the aquifer underlying the City for the purpose of storing water for future use for domestic water supply. The water that would be injected into the aquifer as part of the aquifer storage and recovery (ASR) project would only be treated to meet drinking water maximum contaminant levels (MCLs). This treatment would include disinfection with chlorine. This treatment would result in the formation of a variety of known trihalomethanes (THMs), haloacetic acids (HAA) and other disinfection byproducts (DBP) from the reactions between chlorine and organics (e.g., some of those organics included in "total organic carbon" (TOC) present in the water being treated). Questions have been raised about the potential public health and groundwater quality impacts that would arise from injection of known and/or unidentified disinfection byproducts, as well as a wide variety of other chemicals that can be in South Delta water that is pumped into the Delta Mendota Canal.

The CVRWQCB staff has recommended that the city of Tracy be allowed to conduct a 2-cycle demonstration project, in which Delta-Mendota Canal water, treated to meet drinking water standards, would be injected into the aquifer at Tracy and then recovered. This project would provide a basis for potentially developing a full-scale ASR project.

This proposed ASR project was recently brought to our attention by William Jennings (DeltaKeeper) as an issue that may need additional technical review. We have reviewed the materials that were recently posted on the CVRWQCB website on this proposed project and wish to provide the following comments.

From an overall point of view, we do not support the CVRWQCB staff's recommendation to the Board to allow the city of Tracy to proceed with this ASR demonstration project as currently proposed. There are significant deficiencies in the proposed approach that need to be corrected before proceeding with the proposed ASR demonstration project.

We strongly support conjunctive use of surface and groundwaters, including aquifer storage and recovery projects. However, proponents of aquifer recharge projects often try to conduct the ASR demonstration projects at costs below the funding that is needed to properly evaluate the projects' impacts on aquifer quality. This can lead to long-term project failure and polluted aquifers.

Background to These Comments

I (G. F. Lee) have considerable expertise and experience pertinent to evaluating the potential public health, and aquifer and groundwater quality impacts of groundwater recharge projects as part of developing domestic water supplies. In 1955, while a graduate student at the University of North Carolina School of Public Health, my master's degree work focused on studying reactions associated with the use of chlorine dioxide for disinfecting and controlling tastes and odors in domestic water supplies. In 1960, I earned my PhD degree from Harvard University in environmental engineering, focusing on aquatic chemistry. My PhD dissertation was concerned with the kinetics of chlorination of phenol as it relates to the development of taste and odor problems in domestic water supplies. At that time I found some of the first indications reported on the reactions between chlorine used for disinfection of water supplies and various types of organics present in domestic water supplies. Through my studies it became evident that chlorine interacted with aromatic compounds such as phenols to produce a variety of chemicals, only some of which at that time were identified; the majority of the products were not identified. Subsequently, studies conducted by others demonstrated that those reactions led to what became known as "trihalomethanes," which are chloroform-like compounds. These chemicals are regulated as carcinogens in domestic water supplies.

Throughout my more than 40-year professional career, 30 of which were spent as a professor at several major US universities, I have been involved in issues of domestic water supply water quality. I have served as a consultant to a number of water utilities on disinfection byproduct formation and control. I have published hundreds of professional papers on aquatic chemistry issues in peer-reviewed journals and conference proceedings.

In the 1960s, while a professor at the University of Wisconsin-Madison, I became involved in evaluating groundwater quality as it affects the use of groundwaters for domestic water supply purposes. In the early 1960s I became interested in groundwater quality protection issues. This interest led to my becoming involved in various professional society committees, including an American Society of Civil Engineers (ASCE) Groundwater committee that was chaired by Dr. Karl Longley. About 10 years ago, I became involved in the ASCE Artificial Recharge of Ground Water Committee. As one of the members of this committee knowledgeable in both surface and groundwater quality issues, I was responsible for helping to develop several sections on water quality aspects of groundwater recharge in this committee's guidance on groundwater recharge. In 2001, this committee published "ASCE Standard Guidelines for Artificial Recharge of Groundwater" EWRI/ASCE 34-01. One of the topics that was considered by the committee that is discussed in this manual is ASR projects. This committee is currently updating this manual.

As part of my activities on the ASCE groundwater recharge guidance manual committee, I spent considerable time becoming familiar with the technical literature on this topic and, with Dr. Jones-Lee, have developed several professional peer-reviewed papers on water quality aspects of groundwater recharge that have been presented at national conferences and published in conference proceedings. These include:

Lee, G. F. and Jones-Lee, A., "Water Quality Aspects of Incidental and Enhanced Groundwater Recharge of Domestic and Industrial Wastewaters" Proc. Symposium on Effluent Use Management, TPS-93-3, pp. 111-120, American Water Resources Association, Bethesda, MD (1993). http://www.gfredlee.com/rechg.htm

Lee, G. F. and Jones-Lee, A., "Water Quality Aspects of Groundwater Recharge: Chemical Characteristics of Recharge Waters and Long-Term Liabilities of Recharge Projects," In: Proc. Of the Second International Symposium on Artificial Recharge, American Society of Civil Engineers, New York, NY, July (1994).
http://www.gfredlee.com/ascegwr.htm

Lee, G. F. and Jones-Lee, A., "Total Dissolved Solids and Groundwater Quality Protection," In: Proc. of the Second International Symposium on Artificial Recharge, American Society of Civil Engineers, New York, NY, July (1994).
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Lee, G. F. and Jones-Lee, A., "Public Health and Environmental Safety of Reclaimed Wastewater Reuse," In: Proc. Seventh Symposium on Artificial Recharge of Groundwater, University of Arizona Water Resources Research Center, Tucson, AZ, pp. 113-128, May (1995). http://www.gfredlee.com/pubhealt.htm

Lee, G. F. and Jones-Lee, A., "Guidance on Pre-, Operational and Post-Operational Monitoring of Ground Water Recharge Projects," Report of G. Fred Lee and Associates, El Macero, CA, April (1994).
http://www.members.aol.com/apple27298/GW_Recharge.pdf

Lee, G. F. and Jones-Lee, A., "Appropriate Degree of Domestic Wastewater Treatment Before Groundwater Recharge and for Shrubbery Irrigation," AWWA, WEF 1996 Water Reuse Conference Proceedings, American Water Works Association, Denver, CO, pp.929-939, (1996). http://www.members.aol.com/apple27298/awwawat2.pdf

Lee, G. F. and Jones-Lee, A., "Issues in Recharge of Contaminated Surface Waters in Conjunctive Use Projects," presented at the National Groundwater Association Conference Session on Conjunctive Use, San Francisco, CA, February (2000). http://www.gfredlee.com/plandfil2.htm

Lee, G. F. and Jones-Lee, A., "Water Quality Issues in Conjunctive Use Projects," HydroVisions 9(3):9-10, Groundwater Resources Association, Sacramento, CA, Fall (2000). http://www.members.aol.com/apple27298/Hydrovision-conjun.pdf

Copies of these papers are available from Dr Jones-Lee and my website, www.gfredlee.com or from gfredlee@aol.com, by request.

During the past year Dr. Jones-Lee and I have spent considerable time developing a comprehensive report on Sacramento-San Joaquin River Delta water quality issues. This report,

Lee, G. F. and Jones-Lee, A., "Overview of Sacramento-San Joaquin River Delta Water Quality Issues," Report of G. Fred Lee & Associates, El Macero, CA, June (2004), http://www.members.aol.com/apple27298/Delta-WQ-IssuesRpt.pdf

includes a discussion of South Delta water quality issues and the water that is exported at the Tracy Delta-Mendota Canal pumps and the Banks State Water Project pumps.

When Bill Jennings recently informed us about the city of Tracy's proposed ASR demonstration project's being on the Regional Board's meeting agenda for September 9, we examined the information on this issue on the Regional Board's website. From the website we learned that Wendy Wyels was the lead staff on this issue. Last Friday I sent Wendy a note indicating that I had expertise and experience on ASR and that I was involved in the development of the ASCE guidance manual focusing on water quality issues of groundwater recharge. Over the weekend I made a copy of this guidance manual available to her and indicated that she should contact me if she had questions about water quality aspects of it.

Deficiencies in the CVRWQCB Staff's Proposed Conditions for Support of the Tracy Demonstration Phase Aquifer Storage and Recovery Project (ASR Demonstration Project)

We have reviewed the materials that are on the CVRWQCB's website regarding the city of Tracy's proposed ASR project and wish to provide the following comments on selected aspects of this proposed project.

Inadequate Consideration of the Range of Hazardous and Deleterious Chemicals Present in Delta-Mendota Canal Water. In our review of the material on the CVRWQCB website on the city of Tracy's proposed ASR demonstration project, I was shocked to find that the city of Tracy is proposing to inject Delta-Mendota Canal water with only the minimum treatment associated with the preparation of this water for domestic water supply purposes. Of all the waters in the state, probably the water with the greatest concern with respect to potentially adversely affecting an aquifer is South Delta water. The South Delta water is a brew of a wide variety of recognized, and even more significantly, unrecognized, unregulated, chemicals that are a threat to health, welfare and aquifer quality.

In a June 28, 2004, letter to Wendy Wyels, Joseph Spano, District Engineer with the Southern California Branch Drinking Water Field Operations, California Department of Health Services (DHS), provided a discussion of the issues of concern with respect to known and unknown/unregulated hazardous chemicals in Delta-Mendota Canal (South Delta) water. DHS recommended, and I strongly support, that if this demonstration ASR project proceeds, the city of Tracy be required to treat this water through activated carbon beds prior to injection to remove and/or greatly reduce the concentrations of a wide variety of chemicals that are present in this water but are not now adequately regulated. It should not be assumed that all THMs and haloacetic acids will disappear in the aquifer in an ASR project. Further, there can readily be other disinfection byproducts that have not been investigated, which could persist even though the normally measured THMs disappear. It is our recommendation that THMs and other disinfection byproducts be removed to the maximum extent possible through treatment in activated carbon beds. Spano (2004) in DHS comments stated,

"The technology is well developed and readily available to remove the identified and regulated DBPs, along with the numerous other DBPs, DBP precursors, pharmaceuticals, endocrine disruptors, and other organic contaminants from water. Since these contaminants are not removed from the Delta source water by conventional sand filtration of that water, Granular Activated Carbon (GAC) treatment of the filtered water, before it is injected into the ASR well, should be required as a public health protective measure that would also avoid degradation of the ground water quality."

It is important to understand that the city of Tracy and various communities in the San Joaquin River watershed discharge domestic wastewaters to the San Joaquin River or the Delta (including the city of Stockton), which become part of the waters that are pumped in the Delta-Mendota Canal. DHS mentioned the pharmaceuticals and personal care products as chemicals of concern in drinking water and in the South Delta. This issue is discussed in some detail in our Delta water quality report, including a reference to a presentation by Dr. Christian Daughton on the potential hazards associated with the vast array of unregulated, unrecognized hazardous chemicals in various municipal, industrial and agricultural wastewaters.

Lee and Jones-Lee (2004) in their Delta water quality issues report presented a discussion of the wide range of pollutants that are likely to be in Delta water. At the California Bay-Delta Authority (CBDA) Contaminant Stressors Workshop, Dr. Daughton, Chief, Environmental Chemistry Branch, US EPA National Exposure Research Laboratory, made a presentation entitled, "Ubiquitous Pollution from Health and Cosmetic Care: Significance, Concern, Solutions, Stewardship – Pollution from Personal Actions." This presentation covered information on pharmaceuticals and personal care products (PPCPs) as environmental pollutants. He also discussed the relationship between endocrine disrupters and PPCPs. (A copy of Daughton's PowerPoint presentation at the CBDA workshop is available from gfredlee@aol.com.)

Daughton (2004) pointed out that there is a wide variety of chemicals that are introduced into domestic wastewaters and are being found in the environment. These include various chemicals (pharmaceuticals) that are derived from usage by individuals and pets, disposal of outdated medications in sewerage systems, release of treated and untreated hospital wastes to domestic sewerage systems, transfer of sewage solids ("biosolids") to land, industrial waste streams, landfill leachate, releases from aquaculture of medicated feeds, etc. Many of these chemicals are not new chemicals. They have been in wastewaters for some time, but are only now beginning to be recognized as potentially significant water pollutants. They are largely unregulated as water pollutants.

According to Daughton (2004),

"PPCPs are a diverse group of chemicals comprising all human and veterinary drugs (available by prescription or over-the-counter; including the new genre of "biologics"), diagnostic agents (e.g., X-ray contrast media), "nutraceuticals" (bioactive food supplements such as huperzine A), and other consumer chemicals, such as fragrances (e.g., musks) and sun-screen agents (e.g., methylbenzylidene camphor); also included are

"excipients" (so-called "inert" ingredients used in PPCP manufacturing and formulation)."

* * *

"Since the 1970s, the impact of chemical pollution has focused almost exclusively on conventional "priority pollutants," especially on those collectively referred to as "persistent, bioaccumulative, toxic" (PBT) pollutants, "persistent organic pollutants" (POPs), or "bioaccumulative chemicals of concern (BCCs).

The "dirty dozen" is a ubiquitous, notorious subset of these, comprising highly halogenated organics (e.g., DDT, PCBs).

The conventional priority pollutants, however, are only one piece of the larger risk puzzle."

Daughton has indicated that there are over 22 million organic and inorganic substances, with nearly 6 million commercially available. The current water quality regulatory approach addresses less than 200 of these chemicals, where in general PPCPs are not regulated as potential water pollutants. According to Daughton, "*Regulated pollutants compose but a very small piece of the universe of chemical stressors to which organisms can be exposed on a continual basis."* Additional information on PPCPs is available at www.epa.gov/nerlesd1/chemistry/pharma/index.htm. Lee and Jones-Lee (2004) point out that, with the increasing urban population and industrial activities in the Central Valley, the significance of PPCPs and other pollutants derived from urban and industrial activities, as a cause of water quality problems in the Delta, will increase. This is an area that needs attention in a Delta water quality monitoring/evaluation program.

While the full range of impacts of PPCPs is just beginning to be investigated, PPCPs are being found to have adverse impacts on aquatic ecosystems. For example, they are believed to be responsible for causing sex changes in fish. Eggen et al. (2004), in a feature article ("Challenges in Ecotoxicology: Mechanistic understanding will help overcome the newest challenges") in *Environmental Science and Technology*, have reviewed a number of the issues that are pertinent to understanding the impacts of PPCPs and other chemicals that can cause endocrine disruption, DNA damage/mutagenesis, deficiencies in immune system and neurological effects in fish and other aquatic life. There is also concern about the effects of these chemicals in domestic waters supplies.

PPCPs may be particularly significant as a cause of water quality problems in the Delta, in the San Joaquin River near the city of Stockton's wastewater discharge, in Old River near the city of Tracy wastewater discharge directly to the South Delta, and in the Sacramento River near the Sacramento Regional County Sanitation District wastewater discharge, and other communities such as West Sacramento and Lodi. All of these communities and others contribute their wastewaters to the South Delta, either directly or through diversions of the San Joaquin River into the South Delta at the Head of Old River, through Turner Cut and Middle River to the South Delta, and (for the Sacramento River) through the Central Delta to the Tracy and Banks export project pumps which draw Sacramento River water to the South Delta. These issues are discussed by Lee et al. (2004a,b).

In addition to municipal wastewaters that are contributed to South Delta waters, there is a wide variety of San Joaquin River upstream and local agricultural wastewaters (tailwater) and stormwater runoff that are in South Delta water. As discussed by Kuivila (2000), there are approximately 150 pesticides used in the Central Valley that are a threat to cause water quality problems in the Delta. The CVRWQCB's current program to regulate pesticides considers only about half a dozen of these. Based on the vast array of chemicals that are used in commerce, many of which could be present in aquatic systems through wastewater and stormwater runoff, it is likely that many other chemicals will be discovered in the future that are a threat to public health through the use of the water for domestic water supply, or to aquatic ecosystems in the Delta.

All direct recharge of groundwater, as in ASR projects, that take place in the Central Valley that utilize San Joaquin River water, Delta water, and lower Sacramento River water should be treated with activated carbon beds before being pumped into an aquifer. This is prudent public health policy and necessary for aquifer protection. Further, when the cost of this activated carbon treatment to residential users of the city of Tracy water is evaluated, it will likely be a few tens of cents per person per day, i.e., less than the cost of one bottle of bottled water. It would be a serious error for the Regional Board to allow Tracy to go ahead with this demonstration project without requiring that Tracy treat all water to be injected by treatment with activated carbon beds that are operated to ensure limited breakthrough of weakly sorbed organics on the carbon beds.

There is a misconception that if the aquifer becomes polluted by inadequate treatment of the recharge water it can be cleaned up by pump-and-treat methods. The fact is that once an aquifer is polluted by a complex mixture of chemicals it can never be cleaned up so that that part of the aquifer can be safely used for domestic water supply. This issue has been reviewed by Lee and Jones-Lee (1994).

Geochemical Modeling

The city of Tracy's July 1, 2004 letter to the CVRWQCB (W. Wyels) regarding the proposed conditions for the city of Tracy's ASR demonstration project mentioned a geochemical model that had been developed by the City's consultants. No information was provided on the CVRWQCB's website on this geochemical modeling, although the city of Tracy claims that it reliably predicts water quality aspects of the ASR demonstration project. I (G. F. Lee) have a PhD degree in environmental engineering focusing on aquatic chemistry, and I taught aquatic chemistry to graduate environmental engineers and scientists for 30 years, including modeling of surface and groundwater reactions. I have repeatedly found that various consultants will claim to have a model that has shown that a particular project will have no effects or limited impact on water quality. However, a more in-depth review shows that the model has limited reliability in properly describing the situation.

We are concerned about the city of Tray's geochemical modeling from the point of view that the CVRWQCB staff and the city of Tracy do not include any measurements of oxygen demand in the recharge water. They also do not include measurements of dissolved oxygen in the aquifer water. As discussed in our writings and by others who understand aquatic chemistry,

one of the most important issues, if not the most important issue, associated with influencing the geochemical reactions in aquifers is the dissolved oxygen concentration. A modeling effort without adequate consideration of this issue is likely to be of limited or no reliability.

South Delta water, including the Delta-Mendota Canal water, has readily measurable biochemical oxygen demand (BOD). This BOD is not completely removed through conventional water treatment and would be part of the total organic carbon (TOC) that would be injected into the aquifer under the currently proposed ASR demonstration project. Any ASR project that does not include detailed measurements of dissolved oxygen concentrations in the aquifer at various locations and over time, and BOD in the recharge water is technically deficient and should not be approved, since the oxygen demand that would be injected as part of the BOD in the Delta-Mendota Canal water could readily use up the dissolved oxygen present in the affected area of the aquifer, completely changing the characteristics of that area. As discussed in our writings, this could, in turn, lead to significant water quality problems that would not occur if the injection waters had little or no oxygen demand. This could be one of the most significant problems with the ASR project as proposed. Properly conducted activated carbon treatment of the injected water, prior to injection, would greatly reduce the BOD so that the oxygen demand could be acceptable.

Another aspect of geochemical modeling is the potential effects of organics that would be injected in solubilizing aquifer constituents such as iron and other heavy metals through complexation reactions. While these reactions are well-known, it is not possible to reliably model them because the character of the complexes is not known.

Inadequate Monitoring

The proposed monitoring of the recharge water and the aquifer water is deficient from a number of perspectives. Spano (2004) of DHS stated,

> *"The project should include enough, properly placed monitoring wells to allow the City to verify the ground water gradient throughout the duration of the demonstration program. Although a gradient was established in December 2003, seasonal variations in pumping in the area could result in changes in the gradient with time and other factors. Since it is important to determine if stored water is migrating from the storage area, good operation of an adequate number of properly placed monitoring wells is essential."*

Having been involved in many groundwater quality monitoring projects and published several peer-reviewed papers on this topic, we find the city of Tracy's proposed water quality monitoring well placement to be inadequate. Many more monitoring wells are needed than those proposed by the City. There are also deficiencies in the monitoring parameters and frequency. In addition to monitoring for dissolved oxygen and BOD, there is need to measure concentrations of various constituents, including those listed by the CVRWQCB, over time during injection and, most importantly, during recovery. The analysis of metals and many other constituents injected and recovered from the aquifer should include both total and dissolved forms.

While the city of Tracy claimed that pumping 200% of the volume of injected water during the recovery operation would remove all water that was injected into the aquifer, that claim may have limited reliability. There can readily be significant problems with trying to reliably recover all of the water. Further, under no circumstances would all of the chemicals that were injected into the aquifer in this project be recovered. Part of them will remain, and there will be a buildup of constituents in the aquifer that can influence future ASR operations and aquifer quality. This issue is discussed in our writings on groundwater recharge recovery projects listed above.

The ASR project should include a mass balance evaluation of the total concentrations of selected chemicals injected into the aquifer and the amount recovered. This approach will require that much more frequent monitoring be conducted, such as weekly, to determine the total amount of selected chemicals added to the aquifer and recovered from it. This approach would reveal major discrepancies in the injected versus recovered chemicals.

The CVRWQCB staff has proposed that the city of Tracy submit a revised water quality monitoring program for the proposed ASR demonstration project. When that revised proposed water quality monitoring program is submitted, it should be made available to the public for review and comment.

Need for Independent Review

It is our recommendation that the CVRWQCB appoint an advisory board of experts to oversee this project, should the Board decide to permit the city of Tracy's proposed ASR demonstration project. Because of the complexity of the issues, the Board cannot rely on its staff's limited time or the city of Tracy's consultants to properly evaluate, present, and critically review this project. This independent review should be funded by the city of Tracy as part of the cost of conducting this project. This approach would help the staff and the Board develop an ASR project that could be precedent-setting for other projects in the Central Valley.

References

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