San Joaquin River Water Quality Issues

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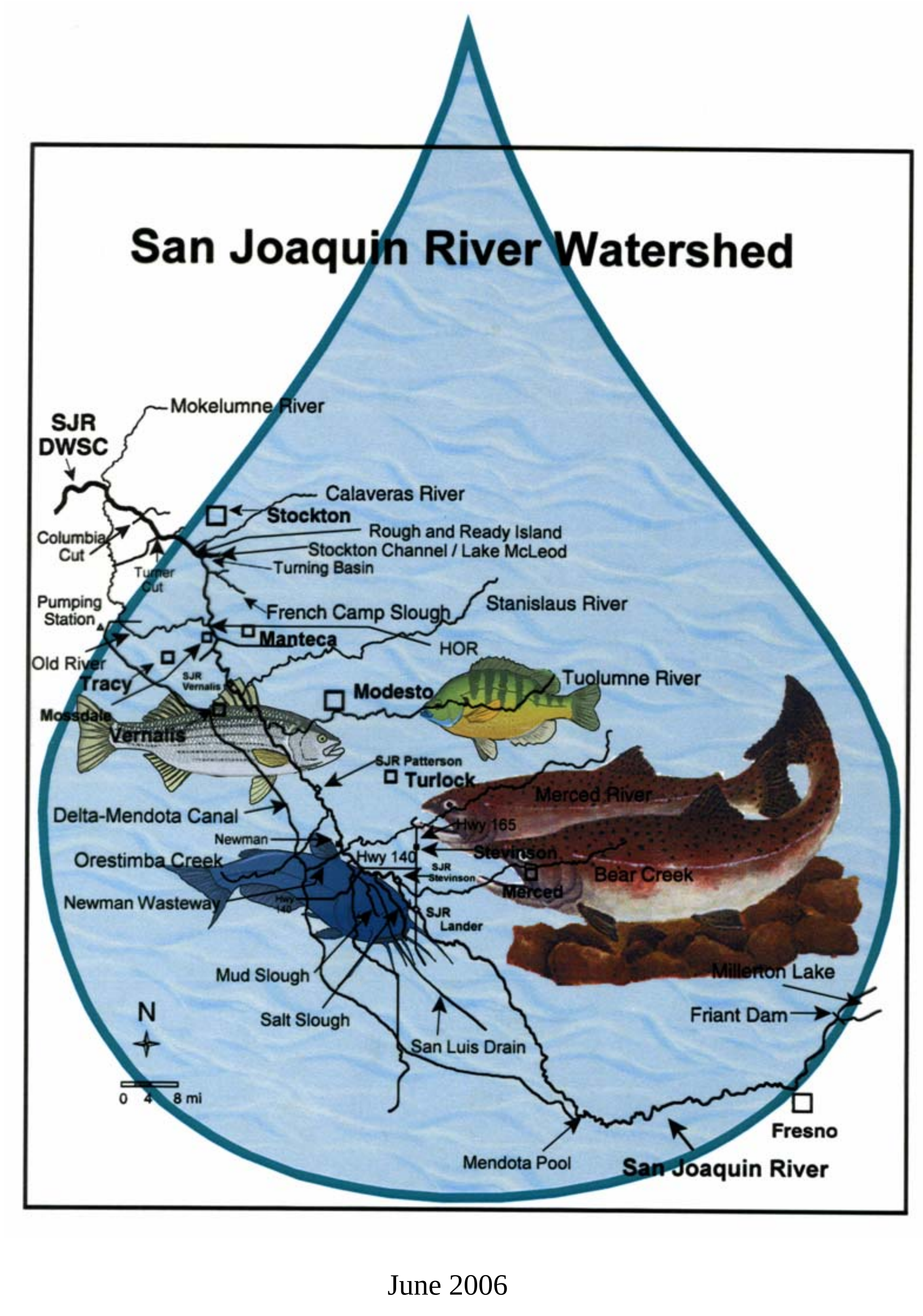

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Background to Developing this Report

Our work on Delta water quality issues began in the summer of 1989 as part of reviewing the expected water quality in the Delta Wetlands in-Delta water storage reservoirs. In the spring 1999 we became involved in the San Joaquin River (SJR) Deep Water Ship Channel (DWSC) low-DO problem as a technical resource to the SJR DO TMDL Steering Committee. It was through this activity that we began to become familiar with SJR water quality issues and the impacts of the SJR watershed water diversions and pollutants on Delta water quality. In 2000, with CALFED support, we became the coordinating PIs for a $2-million project designed to investigate the impact of SJR watershed-derived chemicals on the SJR DWSC low-DO problem. This activity resulted in our developing a 2003 Synthesis Report of what was known about the cause of the DWSC low-DO problem and the sources of oxygen demand derived from the SJR DWSC watershed. Since the completion of the Synthesis Report, without support, we have continued to become familiar with CVRWQCB water quality management efforts in the SJR watershed. We have published a series of reports on SJR and Delta water quality issues which are available on our website, www.gfredlee.com, in the Watershed Studies section, San Joaquin River Watershed Delta subsection.

The report presented herein contains an Abstract, a Summary of water quality issues and a more detailed discussion of water quality issues, with references to sources of information that provide additional discussions of these issues. It is an integration and synthesis of our reports and other information on SJR water quality issues and the impact of SJR watershed-derived constituents and water diversions on Delta water quality. It also updates the information on Delta water quality that was presented in our 2004 Delta Water Quality Issues report.

Appendix B presents a summary of our background and expertise that serve as a technical base for the development of this report.

Acknowledgments

We wish to thank all of those who took time to discuss with us, write about, organize meetings, and make presentations on SJR water quality issues, which serves as a basis for much of the information presented in this report.

A draft of this report on SJR Water Quality Issues was made available to over 120 individuals to provide an opportunity for review and comments. Appropriate changes were included in the final version. This report is planned to be a living report of SJR water quality issues, where we plan to release addenda/updates as additional information is developed. Suggestions on future updates are appreciated.

Financial support for developing this report was primarily provided by Drs. G. Fred Lee and Anne Jones-Lee as part of their professional career-long efforts devoted to improving the quality of science and engineering used in water quality management. We wish to acknowledge the editorial assistance of Debra Stevens in developing this report.

G. Fred Lee, PhD, DEE and Anne Jones-Lee, PhD

Abstract

The water quality in the SJR in the Central Valley floor is significantly degraded due to runoff/discharges from irrigated agriculture, other agricultural activities (such as dairies and feed lots), municipalities and other sources. Of greatest concern are nutrients (nitrogen and phosphorus compounds), pesticides/insecticides, herbicides, heavy metals, suspended solids, PCBs, pathogens and TOC. In addition there is aquatic life toxicity of unknown cause. These pollutants and conditions such as water diversions cause adverse impacts to aquatic life; low DO in channels; excessive bioaccumulation of organochlorine legacy pesticides, PCBs, dioxins and mercury in fish and other aquatic life; threat of disease though contact recreation; development of carcinogens in disinfected drinking water; adverse impacts on irrigated agriculture through excessive salinity; blocking of Chinook salmon homing for spawning; turbid water and sediment accumulation; excessive aquatic weed growths; toxicity to algae; adverse impacts on the recharge of waters as part of enhanced groundwater recharge; and other yet to be identified impacts. Further, pollutants derived from the SJR could be contributing to the Delta pelagic organism decline.

Some of the chemicals that are adversely impacting water quality in the SJR and Delta have been listed by the CVRWQCB/SWRCB/USEPA as a cause of Clean Water Act 303(d) impairments that will require the development of TMDLs to control pollutant discharges. Insufficient funds have been made available to the regulatory agencies to develop the information needed for the CVRWQCB to begin to work on all the pollutants/waterbodies for which TMDLs have been scheduled. Further, there are a number of other water quality problems (impairments of beneficial uses) in the SJR, its tributaries, and the Delta that are known but have not yet been designated as CWA 303(d) impaired waterbodies for which there is need to initiate the TMDL process. The water pollution control programs in the Central Valley, like other programs in many other locations, are grossly underfunded compared to the magnitude of the known water quality problems.

Many of the known and yet to be recognized water quality problems are impacted by SWRCB Water Rights approved water diversions in the SJR watershed, SJR and the Delta, which impact the magnitude and location of the water quality impacts of pollutants. There is no requirement for the holders of Water Rights that permit water diversions to reliably determine the impact of the water diversions/flow manipulations on water quality.

The water diversions/exports from the Delta are causing increased sea water intrusion into the Delta which contributes disinfection byproducts (bromide) into the South Delta and apparently into the SJR through the CVP. These exports are also bringing large amounts of low nutrient/algae Sacramento River water into the upper and mid-Delta, thereby reducing the primary production in these areas. Also, these exports are causing a loss of the Chinook salmon SJR Sierra home stream water chemical signal in the northern and western Delta. This can contribute to increased "straying" of Chinook salmon, which could result in less effective spawning associated with altered timing of reaching a suitable spawning area. These CVP and SWP exports are causing low water levels in the South Delta channels, which interferes with pumping of Delta water from some channels for South Delta irrigated agriculture. Further, these

exports are causing water quality problems in South Delta channels such as DO WQO violations through reduced flow in some channels.

One of the most significant water diversions in the SJR watershed is associated with the USBR Friant Dam project, where the Bureau diverts all the SJR Sierra water to the Central Valley for irrigation. This dries up the SJR between Friant Dam and Lander Avenue; it also causes the SJR water where Mud and Salt Sloughs enter the SJR to consist of irrigated agriculture wastewaters (subsurface drain and tail waters) and drainage from public and private wildlife refuges and private gun clubs wetland areas. During the summer and fall these wastewaters and drainage are of poor quality and cause major water quality problems in the SJR and downstream all the way into the Delta. The court order to require the USBR to provide sufficient flows from Friant Dam to the SJR channel to restore the fisheries of the SJR in the area that is currently dried up by diversions could be a major factor in improving SJR water quality.

In addition to known pollutants, there are a large number of chemicals discharged by agricultural and urban areas in stormwater runoff and wastewaters that are not monitored and evaluated for potential adverse impacts to the beneficial uses of the SJR and the Delta. The current water quality monitoring/evaluation in the SJR, its tributaries and the Delta as impacted by SJR-derived pollutants is highly deficient to begin to define the pollutants that are adversely impacting SJR and Delta water quality, to identify sources of pollutants, and to evaluate the impact of pollutant control programs. Without greatly increased funding, the water pollution control programs for the SJR and Delta will largely be of limited success in restoring these waterbodies to unimpaired beneficial uses. Funds to support this monitoring, evaluation and management program should be derived from all who discharge wastewaters and stormwater runoff, including irrigated agriculture, to the SJR tributaries and the SJR, and all who derive benefits from using SJR watershed waters.

Summary of SJR Water Quality Issues

Upstream of Friant Dam/Millerton Lake near Fresno, California, the San Joaquin River (SJR) is of high-quality water, consisting primarily of rainfall and snowmelt from the Sierra Nevada mountains. Downstream of Friant Dam, the water quality of the San Joaquin River is highly impacted by agricultural and municipal discharges and stormwater runoff and by water diversions for irrigated agricultural and municipal use. The federal Clean Water Act (CWA) requires that the Central Valley Regional Water Quality Control Board (CVRWQCB) list waterbodies that have violations of the applicable water quality objectives (WQOs) as Clean Water Act Section 303(d) "impaired." This listing requires that the CVRWQCB develop a Total Maximum Daily Load (TMDL) to control the sources of the chemicals/conditions that cause the WQO violations. Table 1 lists the current, pending and potential future 303(d) listings of water quality impairments and TMDLs in the SJR and in the Delta, which is impacted by SJR watershed-derived constituents.

Table 1. San Joaquin River Watershed TMDLs
Updated from Lee and Jones-Lee (2002a)

Current (Active)

- Selenium
- Salinity at Vernalis, Total Dissolved Solids (TDS), Electrical Conductivity (EC)
- Boron
- Organophosphorus (OP) Pesticides (Diazinon, Chlorpyrifos)
- Oxygen-Demanding Substances (BOD/Algae, Ammonia, Organic N)

Pending (to be Developed)

- Organochlorine "Legacy" Pesticides (DDT, Chlordane, Dieldrin, Toxaphene, etc.)
- PCBs
- Dioxins/Furans
- Mercury
  - Sulfate (Bioaccumulation of Mercury)
- Pathogen-Indicator Organisms, *E. coli*, Fecal Coliforms
- Toxicity of Unknown Cause
- Salinity Upstream of Vernalis

Potential Future (to be Evaluated)

- Nutrients, Excessive Fertilization (Nitrogen and Phosphorus Compounds)
  - High pH, Low DO caused by Excessive Fertilization (Photosynthesis/Respiration)
- Alternative Pesticides to OP Pesticides including the Pyrethroid-Based Pesticides that are Causing Water Column and Sediment Toxicity
- PBDEs
- Total Organic Carbon, and other Chemicals such as Bromide that Develop into Disinfection Byproducts (Trihalomethanes) in Treated Domestic Water Supplies
- Excessive Sediment, Erosion, Turbidity
- Herbicides (toxicity to algae)
- Aquatic Sediment Toxicity (Pesticides, Nutrients/Algae/Sediment Ammonia, Heavy Metals, PAHs and other Chemicals)
- Unrecognized Pollutants
  - Pharmaceuticals and other Unregulated Chemicals Discharged by Confined Animal Facilities (dairies, feedlots, etc.) and Domestic Wastewaters

This report presents a summary of the water quality issues associated with each of the existing, pending and potential TMDLs for the SJR. It also discusses the impact of SJR watershed-derived chemicals on Delta water quality. References are provided to other reports that provide additional information on the issues discussed.

Selenium

The finding of malformed waterfowl in the Kesterson area, which was attributed to excessive selenium derived from irrigated agriculture in the Grasslands area, caused the CVRWQCB to develop a TMDL to limit the concentrations of selenium discharged from this area. This is a phased TMDL, where in 2009 additional restrictions on Grasslands area selenium discharges will be implemented. The control of the selenium to meet the 2009 TMDL requirements will likely significantly affect the discharges of other constituents from the Grasslands area, such as salts, nutrients, etc., and the amount of water discharged from this area that ultimately reaches the SJR. There is also concern that the current CVRWQCB water quality objective for selenium is not protective of some fish, such as sturgeon, in the Delta.

Salinity and Boron

The SJR and the South Delta have been found to contain sufficient concentrations of salinity (total salts) to be adverse to some irrigated agriculture. There is also the potential for boron concentrations in the SJR to be adverse to some irrigated agriculture. This has caused the CVRWQCB to develop a TMDL to control salinity and boron concentrations in the SJR at Vernalis. The State Water Resources Control Board (SWRCB) has required that the CVRWQCB develop more restrictive allowed salinity concentrations in the SJR upstream of Vernalis. The CVRWQCB is in the process of developing this objective. The management of salinity discharges to the SJR, especially associated with meeting the potential projected upstream salinity WQO, could significantly impact the discharges of other pollutants and the amount of water that enters the SJR from Mud and Salt Sloughs.

OP Pesticides

OP pesticides and other pesticides (such as pyrethroid-based pesticides) used in urban and agricultural areas in the SJR watershed and Delta are causing aquatic life toxicity in the State's waters. This toxicity is a violation of the CVRWQCB Basin Plan WQO. The CVRWQCB has adopted a TMDL for control of OP pesticide discharges in the SJR watershed that cause violations of the OP pesticide water quality objective in the mainstem of the SJR. There are significant deficiencies in the approach that the CVRWQCB is following in attempting to develop aquatic life toxicity control programs in the SJR watershed. These include inadequate control of OP and other pesticide discharges from agricultural and urban areas in the SJR watershed, and inadequate monitoring of compliance with the recently adopted TMDL for OP pesticides in the mainstem of the SJR. At this time inadequate requirements have been adopted by the CVRWQCB for sediment toxicity testing associated with National Pollutant Discharge Elimination System (NPDES) permitted urban stormwater discharges.

Oxygen-Demanding Substances

Nutrient discharges (nitrogen and phosphorus), primarily from irrigated agriculture, cause the SJR upstream of the DWSC to contain large amounts of planktonic algae. The planktonic algae do not cause low-DO problems in the SJR because of its shallowness and flow characteristics.

However, the planktonic algae in the SJR, upon entering the DWSC at the Port of Stockton, die, decompose and exert a significant oxygen demand. This oxygen demand causes DO WQO violations in the DWSC. The city of Stockton's domestic wastewater discharges of ammonia and organic nitrogen to the SJR just upstream of the DWSC, through nitrification reactions, are at times another important source of oxygen demand leading to low-DO problems in the DWSC.

The development of the DWSC, as part of developing the Port of Stockton, is a major cause of the low-DO problem in the DWSC. Increasing the depth of the SJR from 8-10 feet upstream of the Port to 35 feet in the DWSC greatly slows down the flow of the SJR through the DWSC, thereby enabling greater exertion of the oxygen demand in the SJR. Another factor that contributes significantly to the low-DO problem is the upstream diversions of water for agricultural and municipal use, which reduce the amount of SJR flow through the DWSC. This reduced flow increases the flow-through time of the SJR oxygen demand loads in the DWSC near the Port of Stockton and thereby leads to greater DO depletion.

The low-DO problem in the DWSC near the Port of Stockton is caused by the existence of the DWSC, water diversions upstream of the DWSC and oxygen demand loads that develop on nutrients provided to the SJR upstream of Vernalis, as well as discharge of ammonia to the SJR by the city of Stockton's domestic wastewater treatment plant.

The CVRWQCB has adopted a TMDL, which requires that those responsible for causing or contributing to the low-DO problem in the DWSC develop approaches to eliminate DO WQO violations. This TMDL allows the responsible parties for the low-DO problem until 2009 to develop information that can be used to formulate a final TMDL to control the SJR DWSC DO WQO violations.

There are a number of significant problems with the current CVRWQCB and California Federal Bay-Delta Program (CALFED) approach, which need to be addressed now so that the information will be available in 2009 to formulate the final TMDL. One of the approaches for solving the low-DO problem is aeration of the DWSC near the Port of Stockton. The approach adopted by CALFED and allowed by the CVRWQCB of using pure oxygen in the aeration demonstration project will lead to violations of the CVRWQCB Basin Plan objective of no discharge of toxics in toxic amounts. The pure oxygen in the aerated water at the point of discharge will exceed the US EPA water quality criterion for dissolved gas supersaturation. This exceedance is toxic to fish.

As a result of implementing the selenium and salt TMDLs in the SJR watershed, major changes could occur in the discharges of nutrients, algae, other constituents and water from the Grasslands area of the SJR watershed. These changes could cause the current monitoring and modeling of oxygen demand sources and impacts to have limited applicability to the conditions that will exist in the SJR in 2009 and beyond.

Another significant problem with the current CALFED/CVRWQCB approach is the failure to adequately evaluate technical feasibility and cost of alternative approaches for solving the low-DO problem. This information will be needed in 2009 as part of developing the final TMDL.

Another factor that needs to be addressed by the CVRWQCB in helping to solve the low-DO problem in the DWSC is a change in the DO WQO during the fall months. The current September through November 6 mg/L DO WQO, which was implemented to protect fall-run Chinook salmon migration through the DWSC, can be decreased to 5 mg/L, without adversely impacting Chinook salmon migration through the DWSC when the operable barrier is installed at the Head of Old River. Also, there is need to change the DO WQO implementation to allow averaging of the diel (night to day) DO in the near-surface waters and allow some depletion of DO near the sediment water interface. Both of these changes will be protective of fish and other aquatic life, and their implementation could greatly reduce the cost of controlling DO WQO violations in the DWSC.

Some of the channels in the South Delta also experience DO WQO violations, which are likely caused in part by oxygen demand (algae) that develops in the SJR upstream of Vernalis. There is need to better evaluate the causes of these South Delta DO problems and the potential for the California Department of Water Resources' (DWR's) proposed approach for operating the operable barriers in the South Delta, as part of the South Delta Improvement Program (SDIP), to eliminate low-DO problems in the South Delta channels.

Organochlorine "Legacy" Pesticides

The organochlorine-based pesticides (OCls) such as DDT, dieldrin, toxaphene, etc., were widely used in the Central Valley on agricultural land. Many of these pesticides are highly persistent in soils and aquatic sediments. They tend to bioaccumulate in certain types of fish that are used as human food. Because of their potential to cause cancer in people, these pesticides were banned a number of years ago from further use in the US. Certain types of fish (such as catfish and bass) taken from Central Valley waterbodies contain excessive organochlorine "legacy" pesticides compared to concentrations that are believed to be adverse to human health. This has caused the CVRWQCB to list the SJR as 303(d) impaired because of excessive bioaccumulation of OCls.

While this problem has been well established based on fish tissue monitoring that has occurred over the past 20 years, no work has been done by the CVRWQCB to begin to develop TMDLs to control the excessive bioaccumulation of OCls in edible fish. This situation is the result of the CVRWQCB and the funding agencies, such as CALFED, placing a low priority on beginning to address the excessive bioaccumulation of the OCls in edible fish. Because of the importance of this problem as a human health threat, especially to those who use large amounts of Central Valley fish as a necessary part of their diet, a higher priority should be given to funding the necessary studies to define current sources of OCls that are leading to the bioaccumulation of OCl residues in edible fish. This is an environmental justice issue that is not being adequately addressed by the CVRWQCB, SWRCB and CALFED.

PCBs

Fish taken from some parts of the SJR and parts of the Delta influenced by the SJR have been found to contain excessive concentrations of polychlorinated biphenyls (PCBs). PCBs are organochlorine chemicals (non-pesticides) that were used in industrial processes and in electrical transformers. The bioaccumulation of these chemicals in edible fish is of concern since PCBs are suspected to be human carcinogens. PCBs, like the other OCls, have been listed for a TMDL to control the excessive bioaccumulation, but work on this problem has not received funding from the CVRWQCB or CALFED to enable the initiation of the studies needed to begin to develop the TMDL. This is another environmental justice issue that needs to be addressed.

Dioxins/Furans

Fish taken from the SJR DWSC near the Port of Stockton have been found to contain excessive concentrations of dioxins/furans. The consumption of fish containing dioxins/furans is a significant threat to human health. This situation has caused the US EPA to list the SJR DWSC near the Port of Stockton on the 303(d) list of impaired waterbodies, which requires a TMDL to be developed to control the excessive bioaccumulation. The dioxins/furans present in the fish taken from this area are derived from the McCormick & Baxter former wood-treating operation. This has led to the situation of the area being designated as a national Superfund site, where the US EPA is the lead agency for site investigation and remediation.

The sediments of Old Mormon Slough, which is part of the McCormick & Baxter Superfund site, contain elevated concentrations of dioxins/furans. Rather than removing the Old Mormon Slough sediments, the US EPA has chosen to cover these sediments with clean sand, in an attempt to prevent further bioaccumulation of dioxins/furans in edible fish of the area. Presumably, implementation of the sand cover of the dioxins/furans in Old Mormon Slough sediments will represent the implementation of the TMDL. There are several questions about the long-term reliability of this remediation approach. Of particular concern is the adequacy of the proposed monitoring of the integrity of the sand cover and its ability to prevent dioxin/furan release to the overlying waters, where they could bioaccumulate in edible fish, for as long as the dioxins/furans are present in the sediments.

Mercury

Mercury is a neurotoxin that is a threat to fetuses and young children. Mercury in its various forms is converted to methyl mercury at the sediment water interface. Methyl mercury bioaccumulates in edible fish and, therefore, represents a threat to young children and fetuses whose mothers consume fish containing elevated concentrations of mercury. Some fish taken from the SJR and the South Delta have been found to contain excessive concentrations of mercury compared to US EPA and the California Office of Environmental Health Hazard Assessment (OEHHA) guidelines for protection of human health. This has caused the CVRWQCB to list the SJR and South Delta as 303(d) impaired for mercury. The CVRWQCB is conducting studies to better define the approach for controlling excessive mercury bioaccumulation in SJR and South Delta fish.

One of the issues of concern is that sulfate influences the rate of methyl mercury formation at the sediment water interface, and the SJR contains elevated concentrations of sulfate compared to the concentrations found in Delta waters that are derived from Sacramento River water. This could mean that the movement of SJR water through the South Delta, and its associated sulfate, could influence the bioaccumulation of mercury in edible fish in the South Delta. There is need for DWR, as part of the SDIP, to evaluate how the operation of the operable barriers that will be installed by 2009 will influence the distribution of sulfate in the South Delta and the bioaccumulation of mercury in edible fish.

There is an environmental justice issue associated with regulating excessive mercury bioaccumulation, in that the current human health protection guidelines are based on a national average fish consumption rate. There are situations in the SJR and Delta where minorities, economically disadvantaged and others are likely consuming more fish than the national average consumption rate. This could require that the allowable fish tissue concentrations of mercury be lowered to protect those who eat more fish than the national average.

Sanitary Quality

The sanitary quality of water is dependent on the presence of human pathogenic organisms derived from human and some animal fecal matter. In an effort to protect contact recreation in waters (swimming, wading, etc.), the US EPA is requiring that states adopt a sanitary quality contact recreation standard based on *E. coli*. This standard has been shown to be more reliable in protecting human health than the fecal coliform standard that is widely used today. The CVRWQCB has adopted the *E. coli* standard recommended by the US EPA. This standard, however, has not yet been approved by the SWRCB. There is need for the SWRCB to approve this standard in order to implement the *E. coli* standard for Central Valley waters.

The waters of the SJR and DWSC in the city of Stockton have been listed as impaired for contact recreation because of excessive concentrations of pathogens. It is highly likely that the SJR and its tributaries, as well as some of the waters in the South Delta, also contain excessive concentrations of pathogens that are a threat to contact recreation. There is need to more adequately evaluate the presence of *E. coli* in the SJR and South Delta waters, and list those waters as 303(d) impaired where concentrations of *E. coli* exceed US EPA recommended concentrations.

In addition to the concern about the sanitary quality of water for contact recreation, there is also concern about using waters with elevated pathogen-indicator organisms (such as *E. coli*) as a domestic water supply source. With increased potential use of SJR and Delta waters near Stockton for domestic water supply, there may be need to more effectively control pathogen-indicator organisms at their sources, in order to protect domestic water supply use.

In addition to bacterial-caused diseases such as typhoid, there are human diseases caused by protozoans, such as giardia and cryptosporidium, as well as viruses, that are a threat to human health through contact recreation. The *E. coli* standard does not adequately reflect the threat that these pathogens represent to humans who participate in contact recreation.

Toxicity of Unknown Cause

Toxicity tests on SJR and Delta waters using US EPA recommended standard test organisms have shown the presence of aquatic life toxicity that is of an unknown cause. Since the presence of aquatic life toxicity is a violation of the CVRWQCB Basin Plan, this has caused the CVRWQCB to list the SJR and other waterbodies as impaired due to unknown-caused toxicity. As part of developing information needed to begin to formulate a TMDL to control this toxicity, the CVRWQCB has developed a research program focusing on developing TIEs for selected pesticides used in the Central Valley. It is suggested that a more reliable approach for addressing the unknown-caused toxicity problem would be to focus the funds available on those situations where unknown-caused toxicity is currently found, and then, through a combination of TIEs and forensic studies, as well as information provided by the Department of Pesticide Regulation and the County Agricultural Commissioner on the use of pesticides in the watershed where unknown-caused toxicity is found, work to develop information on the cause of the unknown-caused toxicity.

Nutrients

Nutrients (nitrogen and phosphorus compounds) discharged from irrigated agriculture and from agricultural and urban stormwater runoff and wastewaters are causing significant water quality problems in the SJR and in the Delta as well as in water utility water supply reservoirs that use Delta water as a domestic water supply source. These problems are manifested through excessive growths of algae and/or water weeds such as water hyacinth and Egeria. At this time the CVRWQCB's regulation of excessive fertilization water quality impacts is to be accomplished through a Basin Plan narrative water quality objective for the control of "biostimulatory substances." At this time the CVRWQCB has not developed specific guidelines on how to evaluate the presence of excessive biostimulatory substances in a waterbody. However, at the request of the CVRWQCB staff, the authors have provided guidance on the approach that can be used for implementation of the biostimulatory substance narrative water quality objective. Basically, this approach involves site-specific evaluation for each waterbody of concern of the desired nutrient-related water quality, the nutrient loads to the waterbody to achieve this water quality, and the sources of nutrients that need to be controlled to achieve the desired water quality.

The CVRWQCB Ag Waiver water quality monitoring program will require that agricultural interests subject to regulation under this program start to monitor nutrient concentrations at their monitoring locations beginning in the spring of 2006. Associated with this monitoring will be the need to develop guidance on how the agricultural interests and the CVRWQCB staff should interpret the nutrient concentration data developed in the Ag Waiver monitoring program. This interpretation will need to be based on guidance provided by the CVRWQCB on implementing the narrative water quality objective for biostimulatory substances. The implementation of this objective will require a comprehensive monitoring/evaluation program of the impacts of the nutrients found at a particular monitoring point on water quality at that point and downstream. Through the Ag Waiver monitoring program, if adequately implemented, the development of nutrient control programs from irrigated agriculture and urban sources could begin to be developed in the SJR watershed and the Delta.

It has been repeatedly demonstrated over the years that particulate phosphorus derived from land runoff is largely unavailable to support algal growth. It will be important in developing control programs for nutrients from agricultural and urban runoff to focus on available forms of phosphorus, rather than total phosphorus.

Polybrominated Diphenyl Ethers

Polybrominated diphenyl ethers (PBDEs) are being found as widespread pollutants that have bioaccumulated in aquatic life and are known to occur in human mothers' milk. PBDEs have been used for many years as fire retardants in a variety of household items and clothing. PBDEs are similar to PCBs in their persistence and potential impacts on aquatic life and humans. There is need to conduct studies of SJR watershed and Delta aquatic life to determine if PBDEs are present at sufficient concentrations to cause waterbodies to be listed as 303(d) impaired, requiring a TMDL to control the PBDE sources.

Aquatic Sediment Toxicity

Toxicity associated with aquatic sediments is becoming recognized as a potentially significant cause of water quality impairment. This toxicity can affect the numbers and types of benthic and epibenthic organisms, which are important components of fish food. The presence of aquatic life toxicity due to pesticides in sediments is a violation of the CVRWQCB Basin Plan that needs to be controlled. Of particular concern today is the finding that pyrethroid-based pesticides, which are being used in agricultural and urban areas as replacements for organophosphorus-based pesticides, not only cause toxicity in the water column during the time of discharge from areas where they are applied, but also cause toxicity in the sediments where they accumulate following a runoff event. This situation will ultimately require that agricultural and urban uses of pyrethroid-based pesticides (and any other pesticides that accumulate in aquatic sediments and cause aquatic life toxicity) be controlled.

Another source of sediment toxicity occurs in those sediments that accumulate dead algae, which create anoxic conditions in sediments through their decay. This leads to an accumulation of ammonia in the sediments, which is toxic to a number of forms of aquatic life. It also leads to low-DO conditions, which is also toxic to many forms of aquatic life. At this time, regulatory agencies at the federal and state level are largely ignoring the toxicity caused by nutrient discharges, which leads to growths of algae that die, settle, decay and cause ammonia accumulation and anoxic conditions in sediments. This is the most important cause of sediment toxicity in some areas.

Currently the SWRCB is developing sediment quality objectives that ultimately will be used to regulate the discharge to estuarine and marine waters of pollutants that accumulate in sediments and cause sediment toxicity. Also of concern is the control of sediments that serve as a source of bioaccumulatable chemicals, such as organochlorine legacy pesticides and PCBs. The SWRCB's efforts to develop sediment quality objectives are focusing on the integrated use of sediment toxicity, altered benthic organism assemblages compared to habitat characteristics, and chemical information. It will be important that the chemical information be based not on total concentrations of chemicals (cooccurrence-based approaches), but on identifying the amounts of those chemicals that are causing aquatic life toxicity, serving as a source of bioaccumulatable chemicals, and/or altering benthic organism assemblages. The SWRCB has recently made available $2.5 million to develop sediment quality objectives for the Delta. Ultimately this effort could significantly impact the discharges of chemicals from the SJR watershed that accumulate in the SJR sediments downstream of Vernalis (i.e., within the Delta), which are adverse to the beneficial uses of the waters.

Some of the sediments in the SJR DWSC that have been dredged for maintenance of channel depth to enable ocean-going ships to reach the Port of Stockton have been found to be acid-producing when placed in situations such as in on-land dredged sediment disposal areas as well as on a levee for levee stability enhancement. The acid production situation associated with exposure of DWSC sediments to oxygen is another consequence of SJR watershed nutrients that lead to algal development that, upon their death and decay, leads to the accumulation of reduced forms of iron and sulfur in the sediments. The acid produced from these sediments arises from the oxidation of iron and sulfur compounds present in the sediments that, when in contact with oxygen, leads to low pH. This low pH can cause toxicity to aquatic life and can cause the release of heavy metals from the sediments, which can also be toxic to aquatic life. There is need to more reliably evaluate how DWSC sediments dredged from the navigation channel can be used for beneficial purposes, without adverse effects on water quality.

Heavy Metals

There is concern that heavy metals derived from the Delta watershed, including the SJR watershed, such as copper and cadmium, which tend to bioaccumulate in aquatic organisms, could cause toxicity to the host organism. These heavy metals are derived from former mining activities in the Sierra Nevada Mountains. These heavy metals may not be adequately regulated by the current US EPA and State water quality criteria/standards. This is an area that needs further study.

Pyrethroid Pesticides

Pyrethroid-based pesticides have been found to cause aquatic life toxicity in stormwater runoff and other runoff/discharges from urban and agricultural areas where they have been applied. These pesticides accumulate in sediments following runoff events, causing sediment toxicity. Since water column and sediment toxicity are violations of the CVRWQCB Basin Plan, there is need to begin to control the use of pyrethroid-based pesticides that cause water column and/or sediment toxicity in the receiving waters for runoff from areas where they are applied. It is unclear, however, when the CVRWQCB is going to begin to control the use of pyrethroid-based pesticides that are causing violations of the Basin Plan WQO. This is an issue that needs immediate attention by the CVRWQCB, in order to avoid a long period of continued toxicity due to the use of these pesticides.

Total Organic Carbon

The total organic carbon (TOC)content of a water that is to be used for domestic water supply is of concern since TOC interacts with many types of disinfectants (such as chlorine and ozone/bromide) to produce disinfection byproducts. These are chloroform-like chemicals that are regulated as carcinogens in domestic water supplies. The waters exported from the Delta for domestic water supply use at the State Water Project (SWP) at times contain excessive concentrations of TOC compared to the US EPA's regulatory limit. This causes water utilities to practice additional water treatment at additional cost.

One of the major sources of TOC for the Delta is the SJR watershed. Within this watershed the runoff from irrigated agriculture and discharges from wetland areas, including the large wildlife refuges, are major sources of TOC. Also, domestic and agricultural wastewaters and stormwater runoff are sources of TOC. Another major source of TOC in the Delta is from Delta island agricultural areas associated with organics derived from the peat soils of many of these areas. Water utilities could reduce their cost of treatment if TOC were controlled at the various sources, which will be difficult to achieve.

At this time there are no water quality criteria or objectives covering TOC. This means that, even though the TOC in Delta waters is causing impairment of these waters for use for domestic water supply, the waters with elevated TOC are not listed as CWA 303(d) impaired, with the result that there is no regulatory approach to control TOC discharges from its various sources in the SJR watershed and within the Delta. This situation could change if the CVRWQCB, as part of implementing the Source Water Quality Protection provisions of the US EPA Safe Drinking Water Act, adopts a Drinking Water Policy that includes the development of a TOC water quality objective. The development of such a policy is under review by the CVRWQCB, where within a few years the Board will likely consider a proposal to develop a WQO for TOC in Central Valley waterbodies. Adoption of a TOC WQO could have a significant impact on agricultural and urban interests and wildlife refuge (wetlands) managers in the SJR watershed, since they could be required to reduce the TOC content of their discharges/runoff.

Regulation of TOC should not be based on total concentrations. Some of the TOC that develops in the SJR watershed and within the Delta, such as soluble BOD, is labile (non-persistent) and decomposes before reaching a water supply intake. Also of concern is the labile TOC in the form of algae, which die and decompose before the waters are taken for domestic water supply purposes by many of the water utilities that use Delta water as a raw water source. It is important that TOC control programs focus on those sources of TOC that are refractory – i.e., do not decompose before reaching a domestic water supply intake.

One of the major issues that needs to be evaluated is whether controlling TOC at its sources is more appropriate than providing additional treatment at a water treatment facility to control the TOC at that location. About half of the water exported from the Delta is for domestic water supply; the remainder is for agricultural use. The TOC in waters used for agricultural irrigation is not adverse to crop production; in fact, it may be beneficial.

TOC in South Delta waters impacts the potential use of these waters for groundwater recharge using aquifer storage and recovery (ASR) approaches. Elevated-TOC waters, which are acceptable for use in treated domestic water supplies, can be adverse to recharge of these waters through an ASR project, because of adverse impacts on the aquifer characteristics. Potential ASR projects such as that proposed by the city of Tracy based on Delta Mendota Canal (DMC) water, which is derived from the South Delta, should treat the water to remove TOC before injection into the aquifer.

Suspended Sediment

Some agricultural lands on the west side of the SJR are subject to severe erosion, resulting in runoff waters from these lands containing high concentrations of suspended sediments, which leads to highly turbid waters and shoaling/siltation where the sediment settles in the Delta. While this is a significant water quality problem, the CVRWQCB has not listed the SJR as impaired due to suspended sediment/turbidity.

Efforts are being made by some of the agricultural interests where erosion is occurring to control erosion through the addition of polymers to the soil. It is important that chemicals used to control erosion be adequately evaluated to be certain that they do not cause water quality problems in the SJR, its tributaries and the Delta.

There is a significant problem with the way in which the CVRWQCB Basin Plan evaluates excessive suspended sediment/turbidity in waters, which needs to be addressed in order to develop a more readily implementable approach for evaluating excessive suspended sediment and turbidity in a waterbody.

An issue of concern is that the control of turbidity in the SJR could lead to increased planktonic algal growth in the SJR, which could increase the oxygen demand load that the SJR discharges to the DWSC.

Herbicides
Toxicity testing of the waters in the SJR watershed and Delta has shown that some samples of these waters are toxic to the US EPA standard toxicity test alga (*Selenastrum capricornutum*). TIE studies have shown that at least part of this toxicity is due to diuron, a widely used herbicide for controlling terrestrial weeds in some fields and along highways. Toxicity to algae is a violation of the CVRWQCB Basin Plan, which requires control. At this time the CVRWQCB has not listed algal toxicity as a CWA 303(d) water quality impairment, and therefore no work is being done to control the algal toxicity that is being found in the SJR watershed and Delta. This is an issue that will need to be addressed in future CVRWQCB activity.

An aspect of this situation that should be considered is that the algal toxicity that is being found is often in waterbodies that have excessive growths of algae. It appears that the herbicide effects do not cause sufficient toxicity to greatly reduce the algal biomass in the SJR watershed and South Delta. However, finding algal toxicity in the Sacramento River and the northern and middle part of the Delta could be of significance, since these areas are deficient in algal biomass, which serves as the base of the aquatic food web. The focus of the algal toxicity studies should be on Sacramento River water and the northern/central Delta, where algal toxicity could be significant to the aquatic food web.

There is a potential for algal toxicity in the SJR to affect the concentrations of algae that represent oxygen demand loads to the DWSC. This situation could create pulses of algae, which would make managing the low-DO problem in the DWSC more difficult and expensive as a result of requiring a more intensive monitoring program to assess oxygen demand loads to the DWSC.

Bromide
There are data that indicate that bromide concentrations in the SJR may be increasing. Such an increase would be detrimental to the use of South Delta water for domestic water supply purposes, since bromide interacts with certain water supply disinfectants (such as chlorine and ozone) to form brominated disinfection byproducts. There is need to initiate a comprehensive monitoring program for bromide in the SJR at Vernalis.

Unrecognized Pollutants
Pharmaceuticals and other Unregulated Chemicals from Confined Animal Facilities (CAFs) and from Domestic Wastewaters. The current approach for monitoring potential pollutants in the SJR and Delta is significantly deficient in that it considers only a hundred or so chemicals of the many tens of thousands of chemicals that are discharged to these waters from urban and

agricultural sources. There is increasing concern about pharmaceuticals and personal care products (PPCPs) that are discharged to wastewater systems, which enter surface and ground waters receiving domestic and agricultural wastewaters. For example, pharmaceuticals that are used at confined animal facilities (CAFs) such as dairies, feedlots, etc., and are discharged in domestic wastewaters are unregulated chemicals, from a water quality impact perspective, that have the potential to be significantly adverse to aquatic life. Adverse impacts of these chemicals on aquatic life are being found. There is need, however, to greatly expand the scope of potential pollutant monitoring programs to more adequately identify chemicals that could be adverse to aquatic life and other beneficial uses of waterbodies. This monitoring should focus on those areas near where domestic and agricultural wastewaters are discharged to surface waters in the Delta and its SJR tributaries. Studies conducted at University of California, Davis (UCD) have demonstrated sublethal impacts of chemicals in SJR and Delta waters. There is need to better understand the water quality significance of these biomarker responses.

Blocking of Chinook Salmon Homing

One of the impacts of the Central Valley Project (CVP) and SWP is to draw all summer and fall SJR water to the South Delta export pumps via Head of Old River or through Turner Cut. This situation prevents the Chinook salmon home stream water chemical signal from reaching San Francisco Bay and the northwestern Delta. It has been found that fall-run Chinook salmon in the Central Valley show considerable "straying" from their home streams for spawning. It is possible that this straying is the result of a lack of home stream chemical signal as the fish enter upper San Francisco Bay and the Delta. There is also concern that chemicals in the SJR water could adversely impact Chinook salmon homing through affecting their olfactory sensitivity.

Impact of SJR-Derived Chemicals on the POD

The dramatic decrease in several small fish species that has been found in the Delta has stimulated a large-scale study program to try to understand the cause of the pelagic organism decline (POD). One of the potential causes of the POD is the presence of chemicals that are adverse to larval fish and/or fish food such as zooplankton and benthic organisms. Another potential cause of the POD is the CVP and SWP export of South Delta water. These two factors may be interacting to contribute to the POD. The Interagency Ecological Program (IEP), DWR, California Department of Fish and Game (DFG) and US EPA have organized a large-scale multi-year water quality monitoring/evaluation program to attempt to gain inference on the role of pollutants in contributing to the POD. To the extent that the POD is caused by pollutants, the SJR watershed is a likely source of the pollutants responsible for the POD.

Another issue of concern with respect to the POD is the finding that bluegreen algae (*Microcystis*) blooms are occurring in parts of the Delta. These algae produce toxins that could be adverse to aquatic life. This is an area under study as part of the POD investigation.

Impact of Friant Dam Water Releases

The court-ordered releases of water from Friant Dam to the SJR channel could have a significant beneficial impact on water quality in the SJR and Delta. There is need to ensure that adequate water is released and that this water is allowed to pass through the SJR to at least Turner Cut in the DWSC, in order to receive maximum benefit of the Friant releases on SJR and Delta water quality. Such releases could significantly reduce the cost of managing currently known and potential water quality problems in the SJR.

Overall

The SJR, many of its tributaries and those parts of the Delta that receive SJR water are highly impacted by known pollutants derived from irrigated agriculture, other agricultural activities involving animal husbandry, public wetland wildlife refuges and private gun clubs, and urban stormwater and wastewater discharges. These impacts on the beneficial uses of SJR waters and the Delta are significantly impacted by SWRCB Water Rights decisions that allow water diversion/exports. The ability of the CVRWQCB to address these problems is greatly hampered by a lack of funding from state and federal sources.

There is an urgent need to develop a large-scale water quality monitoring/evaluation program to address known water quality impairments as well as to identify other water quality impairments that are not now recognized. Without such a program the ability of the CVRWQCB to adequately restore the SJR, its tributaries and the Delta to unimpaired beneficial uses will be limited. Funds to support this monitoring, evaluation and management program should be derived from all who discharge wastewaters and stormwater runoff, including irrigated agriculture, to the SJR tributaries and the SJR, and all who derive benefits from using SJR watershed waters.

Table of Contents

Background to Developing this Report ... ii
Acknowledgments ... ii
Abstract ... iii
Summary of SJR Water Quality Issues ... v
Table of Contents ... xviii
Acronyms and Definitions ... xx

San Joaquin River Water Quality Issues

Current SJR TMDLs ... 6
    Selenium ... 6
    Salinity and Boron ... 6
    OP Pesticides ... 11
    Oxygen-Demanding Substances ... 13
Pending TMDLs ... 17
    Organochlorine “Legacy” Pesticides ... 17
    PCBs ... 18
    Dioxins/Furans ... 20
    Mercury ... 21
    Sanitary Quality ... 22
    Toxicity of Unknown Cause ... 23
Potential Future TMDLs ... 24
    Nutrients ... 24
    PBDEs ... 27
    Aquatic Sediment Toxicity ... 28
    Heavy Metals ... 30
    Pyrethroid Pesticides ... 30
    Total Organic Carbon (TOC) ... 31
    Suspended Sediment ... 34
    Herbicides ... 35
    Bromide ... 36
Unrecognized Pollutants ... 37
Microcystis Toxicity Issues ... 39
Inadequate Water Quality Monitoring ... 40
    Need for Water Rights Water Quality Monitoring ... 41
Other SJR Water Quality Data Sources ... 41
    SWAMP ... 41
    DPR ... 42
    USGS ... 42
Blocking of Chinook Salmon Homing ... 42
Role of SJR-Derived Pollutants on POD ... 43
Impact of Friant Dam Water Releases ... 44
Overall Assessment ... 44
References ... 46

Table of Contents (continued)

Appendix A. Review Panel Report: San Francisco Estuary Sacramento-San Joaquin Delta Interagency Ecological Program on Pelagic Organism Decline 61
Appendix B. Drs. G. Fred Lee and Anne Jones-Lee's Background Pertinent to Assessment of San Joaquin River and Delta Water Quality 68

List of Tables

Table 1. San Joaquin River Watershed TMDLs 2

List of Figures

Figure 1. Map of the SJR Watershed 3
Figure 2. Map of the Delta 4
Figure 3. Chemical Analysis Output for a Typical Environmental Sample 37

Acronyms and Definitions

APMP	Aquatic Pesticide Monitoring Program
ASR	aquifer storage recovery (groundwater recharge)
BOD	biochemical oxygen demand
CAF	confined animal facility
CALFED	California Federal Bay-Delta Program (former name of CBDA)
CBDA	California Bay-Delta Authority (formerly CALFED)
CDEC	California Data Exchange Center
Corps/COE	US Army Corps of Engineers
CTR	California Toxics Rule
CVP	Central Valley Project (Federal Project)
CVRWQCB	California Regional Water Quality Control Board, Central Valley Region
CWA	Clean Water Act
DBW	California Department of Boating and Waterways
DDT	dichlorodiphenyltrichloroethane (legacy pesticide)
DFG	California Department of Fish and Game
DMC	Delta Mendota Canal
DO	dissolved oxygen
DOC	dissolved organic carbon
DPR	California Department of Pesticide Regulation
DTSC	California Department of Toxic Substances Control
DWR	California Department of Water Resources
DWSC	Deep Water Ship Channel
EC	electrical conductivity
EIR	environmental impact report
EIS	environmental impact statement
HOR	Head of Old River
IEP	Interagency Ecological Program
MCL	maximum contaminant level
µmhos/cm	micromhos (reciprocal ohms) per centimeter
µS/cm	microsiemens per centimeter
N	nitrogen
NAWQA	National Water Quality Assessment Program (USGS)
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
OCls	organochlorines, including organochlorine legacy pesticides (DDT, chlordane, dieldrin, toxaphene), PCBs and dioxins/furans
OEHHA	California Office of Environmental Health Hazard Assessment
OGWDW	US EPA Office of Ground Water and Drinking Water
OP	organophosphorus pesticide
OPP	US EPA Office of Pesticide Programs
P	phosphorus
PAHs	polynuclear aromatic hydrocarbons
PBDEs	polybrominated diphenyl ethers
PBO	piperonyl butoxide

Acronyms (continued)

PCBs	polychlorinated biphenyls
POD	pelagic organism decline
PPCPs	pharmaceuticals and personal care products
SDIP	South Delta Improvement Program
SJR	San Joaquin River
SQO	sediment quality objective
SWAMP	Statewide Ambient Monitoring Program
SWP	State Water Project (State Project)
SWRCB	California State Water Resources Control Board
TAG	Technical Assistance Grant (US EPA)
TDS	total dissolved solids
THMs	trihalomethanes
TIEs	toxicity identification evaluations
TMDL	total maximum daily load
TOC	total organic carbon
TUC	toxicity of unknown cause
UCD	University of California, Davis
USBR	US Bureau of Reclamation
US EPA	US Environmental Protection Agency
VAMP	Vernalis Adaptive Management Plan
WQO	water quality objective

San Joaquin River Water Quality Issues

Upstream of Friant Dam/Millerton Lake near Fresno, California, the San Joaquin River (SJR) is of high-quality water, consisting primarily of rainfall and snowmelt from the Sierra Nevada Mountains. Downstream of Friant Dam, the water quality of the San Joaquin River is highly impacted by agricultural and municipal discharges and stormwater runoff and by water diversions for municipal and irrigated agricultural use. The federal Clean Water Act (CWA) requires that the Central Valley Regional Water Quality Control Board (CVRWQCB) list waterbodies that have violations of the applicable water quality objectives (WQOs) as Clean Water Act Section 303(d) "impaired." This listing requires that the CVRWQCB develop a Total Maximum Daily Load (TMDL) to control the sources of the chemicals/conditions that cause the WQO violations.

Jones & Stokes (2006), under contract with the CVRWQCB, has developed a draft discussion of existing conditions for waterbodies in the Central Valley of California. This draft discussion is part of a California Environmental Quality Act Environmental Impact Statement that is being developed to cover the CVRWQCB's Ag Waiver water quality management program. Chapter 3 of the Existing Conditions discussion provides background information on the San Joaquin River and each of its tributaries. The topics covered include a general discussion of waterbody watershed characteristics, flows, land use patterns, Basin Plan listed beneficial uses, impaired status (TMDLs) and water quality issues.

Lee and Jones-Lee (2002a) provided a discussion of the 303(d) listings for the SJR. They also listed chemical constituents that, based on their experience, are present at sufficient concentrations to impair the beneficial uses of the SJR and/or downstream waters. Considerable additional information has been developed since Lee and Jones-Lee developed their 2002 paper on SJR water quality. The discussion presented herein is an update of the Lee and Jones-Lee (2002a) discussion of SJR water quality issues. This discussion also considers the characteristics of the SJR that impact Delta water quality.

Table 1 presents an updated list of the water quality parameters of concern as they impact SJR/Delta water quality. The constituents in Table 1 are listed as "current," "pending" and "potential future" TMDLs. The current TMDLs listed in this table include those for which there is active work being done by the CVRWQCB to formulate and adopt a TMDL for the constituent(s) of concern.

The pending list includes the TMDLs for water quality parameters that have been listed as causing the SJR to be "impaired" but for which at this time the CVRWQCB does not have sufficient funds to formulate the TMDL. This group has been given a lower priority for attention by the CVRWQCB. The current and pending TMDLs are based on information provided by the CVRWQCB/SWRCB (2003) listing of TMDLs.

The potential future TMDLs are for those constituents that, based on the authors' experience and familiarity with SJR water quality, could be found to violate existing or to-be-developed water quality objectives. Such violations would lead to the need to develop a TMDL(s) to control the input of the pollutant to the SJR and its tributaries and/or to control those conditions such as water diversions in the SJR and the Delta that impact the beneficial uses of these waterbodies. The discussions presented below provide a brief summary of the water quality significance of the parameters listed in Table 1. Additional information on many of these issues is presented by Lee and Jones-Lee (2002b). Lee and Jones-Lee (2002c) have provided information on various management practices that can be used to control excessive concentrations of constituents derived from irrigated agriculture for which there are existing, pending or potential future TMDLs in the SJR, its tributaries and parts of the Delta.

Information on the authors' (Drs. G. Fred Lee and Anne Jones-Lee's) qualifications to conduct this review is presented in Appendix B. Each discussion presented below briefly summarizes an SJR water quality issue. Where possible, references are given to literature that provides a more comprehensive discussion of the issue.

Table 1. San Joaquin River Watershed TMDLs

Updated from Lee and Jones-Lee (2002a)

Current (Active)

- Selenium
- Salinity at Vernalis, Total Dissolved Solids (TDS), Electrical Conductivity (EC)
- Boron
- Organophosphorus (OP) Pesticides (Diazinon, Chlorpyrifos)
- Oxygen-Demanding Substances (BOD/Algae, Ammonia, Organic N)

Pending (to be Developed)

- Organochlorine "Legacy" Pesticides (DDT, Chlordane, Dieldrin, Toxaphene, etc.)
- PCBs
- Dioxins/Furans
- Mercury
    - Sulfate (Bioaccumulation of Mercury)
- Pathogen-Indicator Organisms, *E. coli*, Fecal Coliforms
- Toxicity of Unknown Cause
- Salinity Upstream of Vernalis

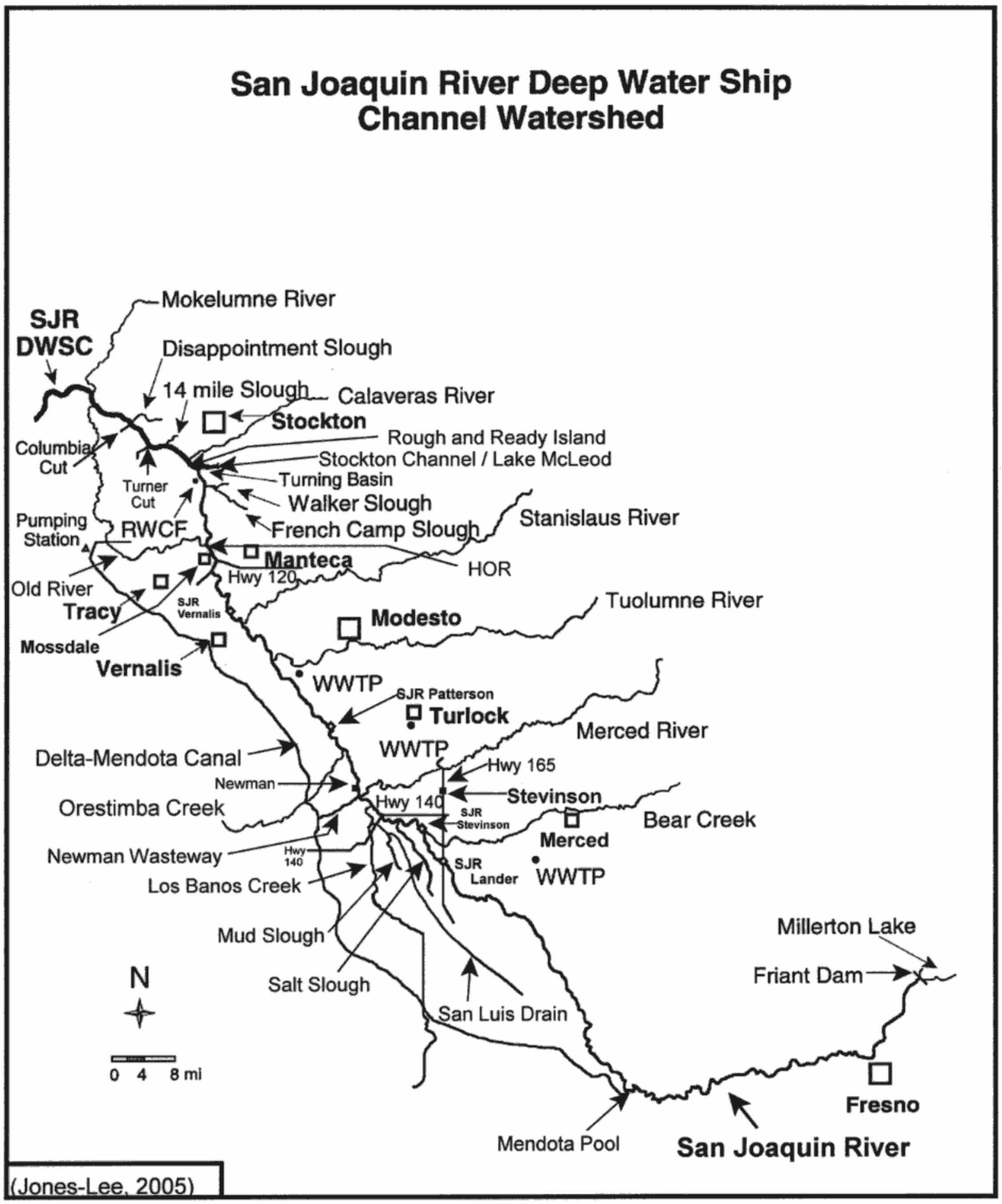
Potential Future (to be Evaluated)

- Nutrients, Excessive Fertilization (Nitrogen and Phosphorus Compounds)
    - High pH, Low DO caused by Excessive Fertilization (Photosynthesis/Respiration)
- Alternative Pesticides to OP Pesticides including the Pyrethroid-Based Pesticides that are Causing Water Column and Sediment Toxicity
- PBDEs
- Total Organic Carbon, and other Chemicals such as Bromide that Develop into Disinfection Byproducts (Trihalomethanes) in Treated Domestic Water Supplies
- Excessive Sediment, Erosion, Turbidity
- Herbicides (toxicity to algae)
- Aquatic Sediment Toxicity (Pesticides, Nutrients/Algae/Sediment Ammonia, Heavy Metals, PAHs and other Chemicals)
- Unrecognized Pollutants
    - Pharmaceuticals and other Unregulated Chemicals Discharged by Confined Animal Facilities (dairies, feedlots, etc.) and Domestic Wastewaters

Figures 1 and 2 present maps showing the location of areas discussed in this report. The SJR can be divided into several regions. The SJR upstream of Friant Dam is of high-quality water consisting primarily of precipitation (rainfall and snowmelt) runoff from the Sierra Nevada

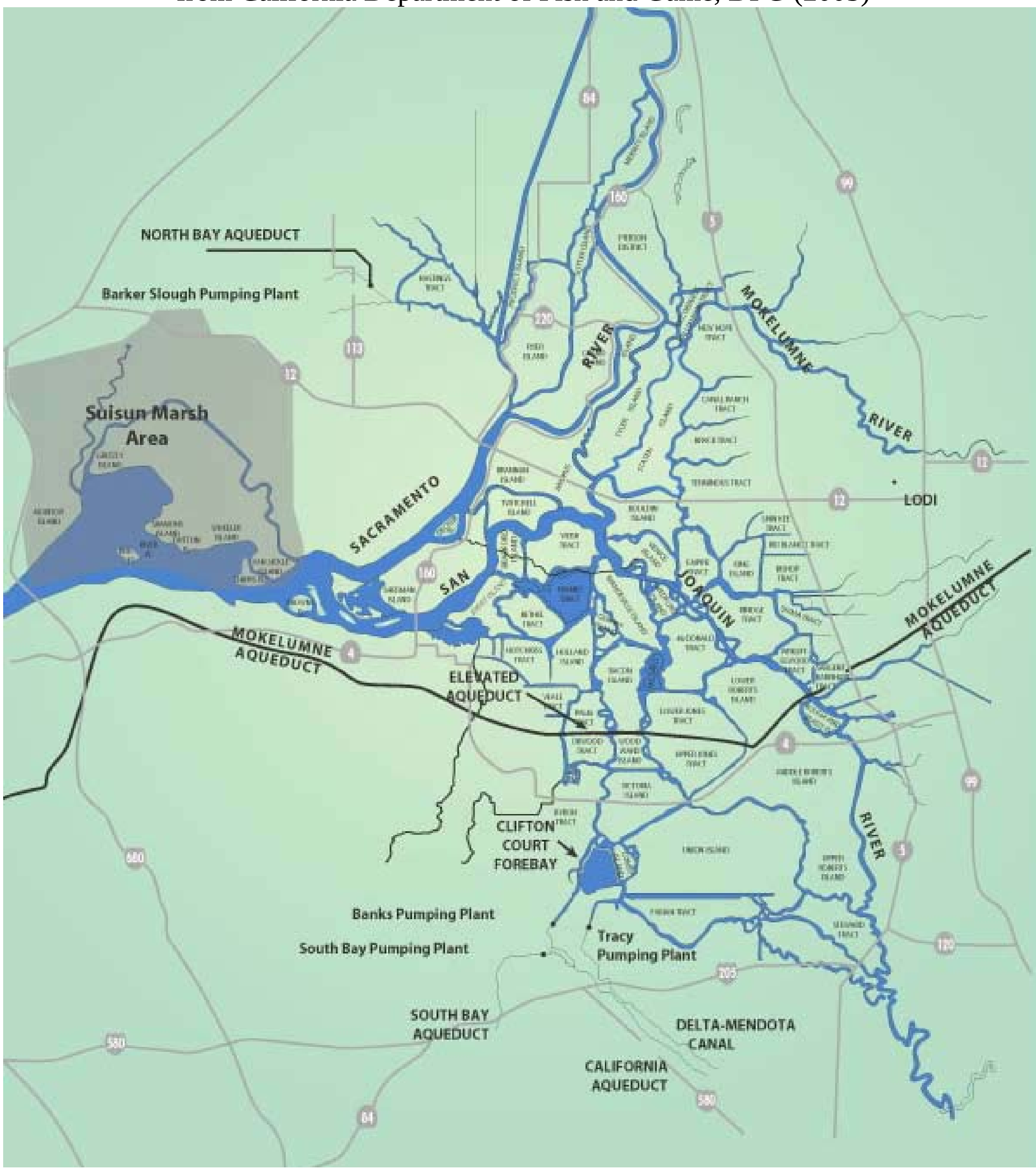
Mountains. Between Friant Dam and SJR Lander Avenue, the SJR is typically dry due to the US Bureau of Reclamation (USBR) diversion of SJR water at Friant Dam for Central Valley irrigated agriculture. In some years, USBR releases excess water at Friant Dam to the SJR channel with the result that for a limited period of time in the spring and early summer, the reach of the SJR upstream of Lander Avenue has water. As discussed below, the USBR's drying up of the SJR from Friant Dam to Lander Avenue could change in the future as a result of US District Judge Lawrence K. Karlton's (2004) ruling which requires that the USBR release sufficient water from Friant Dam to restore the fisheries in the upper SJR.

Figure 1



During the summer and fall, below the SJR at Lander Avenue, the SJR water quality is dominated by irrigation diversions and irrigation tailwater and subsurface drain water discharges to the river or its tributaries. During the summer and fall, the eastside tributary rivers (Merced, Stanislaus and Tuolumne) contribute a limited amount of higher-quality water to the SJR.

Figure 2
Map of the Delta
from California Department of Fish and Game, DFG (2005)



The CVRWQCB (1998) Basin Plan lists the Clean Water Act Designated Beneficial Uses for the San Joaquin River from Friant Dam to Mendota Pool, Mendota Dam to Sack Dam and Sack Dam to Mouth of Merced River, as "Existing" for Domestic Water Supply, Agriculture, Process Industry, Recreation, Warm Fresh Water Habitat, Migration, Spawning and Wildlife Habitat. The Mendota Dam to Sack Dam and Sack Dam to Mouth of Merced River are listed as "Potential" for Municipal Water Supply. All sections of the SJR from Friant Dam to the Mouth of the Merced River are listed as "Potential" for Spawning of Salmon and Steelhead.

The 2002 CWA Section 303(d) list of Water Quality Limited Segments (CVRWQCB/SWRCB 2003) lists the San Joaquin River (Bear Creek to Mud Slough and Mendota Pool to Bear Creek) as "impaired" for Boron, Chlorpyrifos, DDT, Diazinon, Electrical Conductivity (EC - salt), Group A Pesticides and Unknown Toxicity. The San Joaquin River from Merced River to the South Delta Boundary at Vernalis is listed as impaired for the same constituents as well as mercury. The Group A pesticides include aldrin, dieldrin, chlordane, endrin, heptachlor, heptachlor epoxide, hexachlorocyclohexane (including lindane), endosulfan and toxaphene. This listing means that the concentration of these constituents exceeds the CVRWQCB (1998) Basin Plan water quality objective (WQO) or that some fish have bioaccumulated sufficient concentrations of these chemicals to be a health threat to those who use these fish as food. Lee and Jones-Lee (2004a) have listed and discussed the Delta channels that have 303(d) listings as CWA impaired, some of which are the result of the input of pollutants contributed by the SJR.

The SJR enters the Delta at Vernalis. Part of the SJR Vernalis water is diverted into the South Delta at the Head of Old River (HOR). The remainder of the SJR Vernalis water continues down the SJR channel, eventually entering the Deep Water Ship Channel (DWSC). During the time that the USBR Central Valley Project (CVP) pumps at Tracy and/or the California Department of Water Resources (DWR) State Water Project (SWP) pumps at Banks are pumping water from the South Delta, the SJR Vernalis water in the DWSC is drawn into Turner Cut, and then joins with Middle River in the Central Delta, where it is ultimately drawn to the CVP/SWP export project pumps. During the Vernalis Adaptive Management Plan (VAMP) period of April 15 to May 15, a barrier is installed across the Head of Old River, which prevents most of the SJR Vernalis water from entering the South Delta. Also during this time, the CVP and SWP pumping of South Delta water is greatly curtailed. As a result, during VAMP, SJR Vernalis water proceeds down the SJR DWSC past Turner Cut, ultimately joining with Sacramento River water in the northwest Delta. Therefore, pollutants in the SJR at Vernalis primarily impact Delta water quality in the South Delta, either through the Head of Old River or Turner Cut.

At Turner Cut, the mixing of SJR water with Sacramento River water greatly dilutes SJR watershed-derived pollutants, as well as those that have been contributed to the SJR downstream of Vernalis. Lee and Jones-Lee (2003a, 2004b), as well as other reports on the Lee and Jones-Lee website (www.gfredlee.com) in the Watershed Studies section, San Joaquin River Watershed Program and Delta subsection (http://www.gfredlee.com/psjriv2.htm), provide additional details on the flow of SJR watershed water and its associated pollutants in the Delta. As discussed below, the SJR water-derived pollutants have the potential to significantly adversely impact Central and especially South Delta water quality.

Current SJR TMDLs

The California State Water Quality Control Board (CVRWQCB/SWRCB 2003) and the US EPA approved the 2002 Clean Water Act Section 303(d) list of water quality limited segments for the State's waters. This list provides information on the pollutants/stressors causing water quality objective violations that were known in 2002. A review of this listing shows that some parts of the San Joaquin River and its watershed already have or are in the final stages of developing TMDLs designed to control discharges of several pollutants. Additional information on the currently active TMDLs is available from the CVRWQCB website http://www.swrcb.ca.gov/rwqcb5/available_documents/#agDischarge.

Selenium. Some of the soils on the west side of the San Joaquin River naturally contain elevated concentrations of selenium. The initiation of irrigated agriculture on these soils in the Grasslands area has resulted in the leaching of selenium from these soils that is discharged in subsurface drain waters and tailwater, which ultimately is carried to the San Joaquin River and the Delta. The USBR, as part of developing water supply for the irrigation of lands west of the San Joaquin River, was to develop a drainage channel that would convey the salt and other chemicals to the Delta. This channel was only partially completed, where the waters carried in it discharged to the Kesterson area. Selenium in these waters accumulated in the Kesterson area to a sufficient extent to cause malformed waterfowl.

The CVRWQCB (2001) has adopted restrictions on selenium discharges to tributaries of the SJR (Mud and Salt Sloughs) from the Grasslands irrigated agricultural area. At this time the implementation of the TMDL for selenium has problems meeting the WQO just downstream of where Mud Slough enters the SJR. In 2009 the allowed discharges of selenium to the SJR from the Grasslands area will need to be significantly reduced to meet currently established selenium TMDL requirements for the SJR near where Mud and Salt Sloughs discharge to the SJR. Meeting this requirement could incidentally greatly change the amounts of several pollutants and water that are discharged to the SJR. This situation could have a significant impact on the water quality of the SJR and Delta. Further, as discussed by Lee and Jones-Lee (2004a), there are discussions about the need to further reduce selenium discharges to the SJR because of selenium accumulating to excessive levels in clams and some fish (sturgeon) in the Delta.

Salinity and Boron. Salinity is typically estimated by TDS (total dissolved solids) or EC (electrical conductivity). TDS and EC are related to each other, where EC times 0.65 = TDS. Salinity is of concern in the SJR and in the Delta because of its adverse impacts on agricultural crop production and domestic water supply water quality as related to the ability to recharge wastewaters and not exceed groundwater recharge TDS limits. Boron is of concern because it is adverse to certain types of agricultural crops. The CVRWQCB (1998) Fourth Edition of the Water Quality Control Plan (Basin Plan) for the Sacramento River and San Joaquin River Basins states,

> *"Water quality in the San Joaquin River has degraded significantly since the late 1940s. During this period, salt concentrations in the River, near Vernalis, have doubled. Concentrations of boron, selenium, molybdenum and other trace elements have also increased. These increases are primarily due to reservoir development on the east side tributaries and upper basin for agricultural development, the use of poorer quality,*

higher salinity, Delta water in lieu of San Joaquin River water on west side agricultural lands and drainage from upslope saline soils on the west side of the San Joaquin Valley."

* * *

"The amendment emphasized toxic elements in subsurface drainage discharges. The Regional Water Board however still recognizes salt management as the most serious long-term issue on the San Joaquin River."

The State Water Resources Control Board (SWRCB 2000), as part of developing Water Rights Decision 1641, identified the development of Friant Dam diversions of SJR water as a major cause of water quality problems in the SJR. For example, the SWRCB in its Water Rights Decision 1641, in Section 10.2.1.1 EFFECTS OF UPSTREAM WATER DIVERSION AND USE (page 80), states,

"The largest diversions of water from the San Joaquin River and its tributaries are by (1) USBR at New Melones Reservoir and Millerton Lake; …."

* * *

"The water diverted from the upstream tributaries to the lower San Joaquin River is of high quality. Thus, these diversions result in a substantial reduction in the assimilative capacity of the San Joaquin River."

Also page 83 states,

"Based on the above discussion, the SWRCB finds that the actions of the CVP are the principal cause of the salinity concentrations exceeding the objectives at Vernalis. The salinity problem at Vernalis is the result of saline discharges to the river, principally from irrigated agriculture, combined with low flows in the river due to upstream water development."

* * *

"The USBR, through its activities associated with operating the CVP in the San Joaquin River basin, is responsible for significant deterioration of water quality in the southern Delta."

"10.2.2 Actions to Meet the Vernalis Salinity Objectives
The Vernalis salinity objectives can be achieved either by providing sufficient fresh water to dilute upstream discharges of saline water above Vernalis or by using measures to control the discharge of saline water to the river upstream of Vernalis. (R.T. p. 3731.) Some parties in the hearing suggested that the USBR should consider potential sources of dilution water other than New Melones Reservoir."

* * *

"The USBR has not considered using water stored in Millerton Lake because it believes that conveyance losses due to percolation and uncontrolled diversions are in the order of 50 percent. Because other sources of water are available, the USBR has not made an effort to determine the actual conveyance losses that would occur if water is released from Friant for salinity control at Vernalis. (R.T. pp. 6545-6550.)"

Page 85 states,

"The USBR's actions have caused reduced water quality of the San Joaquin River at Vernalis. Therefore, this order amends the CVP permits under which the USBR delivers water to the San Joaquin basin to require that the USBR meet the 1995 Bay-Delta Plan salinity objectives at Vernalis. The USBR has wide latitude in developing a program to achieve this result. The USBR could consider sources of dilution water other than New Melones Reservoir and other means of reducing the salinity concentration in the southern Delta. This decision conforms Condition 5 of D-1422 to the southern Delta salinity objectives in the 1995 Bay-Delta Plan and to the current Basin Plan."

Page 88 states,

"The construction of permanent barriers alone is not expected to result in attainment of the water quality objectives. (R.T. pp. 3672, 3710, 3787-3788; DWR 37, p. 15; SWRCB 1e, pp. [IX 30]-[IX-41].) The objectives can be met consistently only by providing more dilution or by treatment. (R.T. p. 3737.)"

The potential magnitude of EC reduction associated with Friant Dam releases to the SJR channel can be understood by examining the change in SJR Lander Avenue gage EC in 1998 when there were Friant Dam releases to the SJR. (The Lander Avenue gage is just upstream of where the SJR is joined by the Merced River and is not influenced by the Merced River discharge.) Based on data on the DWR CDEC database, typically Friant water has an EC of about 50 to 55 µmhos/cm (µS/cm). This was about the value of SJR water EC at the Lander Avenue gage during June and July 1998 when Friant Dam releases to the SJR were occurring. However, in other years in June and July at the Lander Avenue location, when there were no Friant Dam releases to the SJR, the EC was over 1,000 µmhos/cm (µS/cm) (1 mS/cm). This suggests that releases of water from Friant Dam which reach the Lander Avenue gage have the potential to dramatically reduce the EC of the SJR at the point of its confluence with the Merced River.

Another example of the impact of adding lower-EC water to the SJR in the Patterson area is the results of the USBR (2004) "recirculation" studies, where during August 19-30, 2004, water from the Delta Mendota Canal (DMC) was, for a two-week period, allowed to pass through the Newman Wasteway (see Figure 1) to add water to the SJR to dilute the TDS/EC in the SJR. About 250-300 cfs of DMC water with an EC of 300 to 400 µmhos/cm was added to the SJR via the Newman Wasteway. DMC water is derived from the USBR Central Valley Project Tracy pumping of South Delta water. South Delta water is a mixture of SJR water and low-EC Sacramento River water. The EC of the SJR upstream of where the Newman Wasteway enters the SJR was about 1,500 to 2,000 µmhos/cm during the recirculation study. The flow of the SJR during the recirculation study in the region of the Newman Wasteway was in the range of 200 to 600 cfs. The EC in the SJR just downstream of where the Newman Wasteway discharges to the SJR was decreased to about 1,000 µmhos/cm. As expected, the recirculation study, involving the addition of lower-salinity (EC) water to the SJR, significantly decreased the EC in the SJR near where the Newman Wasteway discharged to the SJR.

It is evident that the addition of low-TDS/EC water from Friant (which has lower EC than the DMC) could reduce the magnitude of the excessive salt concentrations in the SJR, especially in the area near Patterson. This will become especially important when the EC compliance point for the salt TMDL is moved upstream of Vernalis in order to reduce the excessive salts in that part of the SJR as well in the SJR at Vernalis that impact South Delta EC. The economic benefits of such Friant Dam releases, in terms of reducing the costs of controlling salt discharges from urban and agricultural areas in the SJR watershed and reducing the adverse impacts on agricultural crop production, could be substantial.

The SWRCB (2000) Decision 1641, states on page 85,

> *"Several parties argued that the Central Valley RWQCB should adopt water quality objectives for salinity for the San Joaquin River at locations upstream from Vernalis. In SWRCB Order WQ 85-1, the SWRCB directed the Central Valley RWQCB to initiate a process to develop specific water quality objectives for the San Joaquin River basin that will result in the adoption of appropriate basin plan amendments by the Regional Board and the development of a program to regulate agricultural drainage discharges. (SWRCB 5(l), p. 34.) The Central Valley RWQCB is currently in the process of setting salinity objectives for the San Joaquin River. (R.T. p. 4847.) The Central Valley RWQCB is hereby directed promptly to develop and adopt salinity objectives and a program of implementation for the main stem of the San Joaquin River upstream of Vernalis."*

In accordance with SWRCB (2000) Water Rights Decision D-1641, the CVRWQCB is in the process of developing salinity (EC) WQOs for the SJR upstream of Vernalis. At the November 2005 SWRCB hearing devoted to adoption of the TMDL for EC at Vernalis, the SWRCB established the requirement that the CVRWQCB is to develop WQOs for EC upstream of Vernalis by September 2006. Grober (2006) recently held a public workshop devoted to a "Basin Plan Amendment to Establish New Salinity and Boron Objectives and a TMDL in the Lower San Joaquin River," in which the staff's current approach for developing the SJR upstream salinity objectives was discussed.

The Central Valley Regional Water Quality Control Board (CVRWQCB 2004a) has adopted the first phase of a TMDL to control salinity (TDS, EC, total salt) and boron in the San Joaquin River and its watershed. The CVRWQCB (2004a) has prepared "Appendix 4: Economic Analysis for the Implementation of a Control Program for Salt and Boron Discharges to the Lower San Joaquin River," which provides information on the cost of salt control for the current TMDL that is designed to achieve the EC WQO in the SJR at Vernalis. The CVRWQCB (2004a) stated that,

> *"There is no single set of implementation practices or technology that will ensure that the water quality objectives for salt and boron will be met. Salt and boron water quality improvement in the LSJR can be achieved through one or more of the following methods:*
>
> > *I) Reducing salt and boron loads imported to the LSJR watershed in supply water*
> > *II) Increasing the assimilative capacity of the LSJR by providing dilution flow*
> > *III) Reducing salt and boron loading from point and/or nonpoint sources*
> > *IV) Increasing the amount of salt exported from the LSJR watershed, including through re-operation of drainage and real-time water quality management or through the use of an out-of-valley drain."*

The CVRWQCB (2004a) stated,

> *"II. INCREASING THE ASSIMILATIVE CAPACITY OF THE LSJR BY PROVIDING DILUTION FLOW*
> *1. Increasing San Joaquin River Flows*
> *Increasing instream flow in the LSJR would provide dilution and mixing options. Additional or existing on-stream or off-stream storage could be used to provide more instream flows. For example, more releases of water from Friant Dam and east side tributary reservoirs to the LSJR, and recirculation of Delta Mendota Canal water back to the LSJR via Newman wasteway or other channels could supplement flow and provide benefits to multiple LSJR beneficial uses. Institutional factors, such as the Bay-Delta hearings, the Vernalis Adapted Management Plan, pending laws suits, and FERC rulings affect LSJR water flow. Climatic factors complicate management of the LSJR system and limit flow during dryer years.*
>
> *Status: Flows in the LSJR continue to vary widely due to factors beyond the control of the Regional Board."*

The development of the TMDL for the revised EC WQO to control excessive EC (salt) in the SJR near the confluence with the Merced River will likely require increased salt discharge control from agriculture and some municipalities. Further reductions in salt loads from these sources will represent increased costs to the salt dischargers. The magnitude of the near-term and eventual costs to control salt loads to the SJR will be reduced as a result of the release of low-EC water to the SJR by Friant Dam.

The University of California Water Resources Center has recently held its 2006 Salinity/Drainage Conference. At this conference Wescot (2006) presented "Salinity and Salt Management Issues in the Central Valley," which was based on his over 20 years of work on salinity issues in the Central Valley. He discussed many of the factors that will need to be considered in developing a salinity management program for the Central Valley that will protect water quality in the most cost-effective manner. He indicated that it is the CVRWQCB's position that ultimately the accumulation of salt in the Central Valley associated with irrigated agriculture and other salt sources will require that a salt drainage system be constructed to the Pacific Ocean for salt disposal. This disposal could occur in the Pacific Ocean near San Francisco, Monterey or San Luis Obispo. Those in these areas are opposed to any discharge of Central Valley salt to their nearby waters because of the potential that the salt discharge could contain a variety of pesticides and other toxic chemicals (including unrecognized, unregulated pollutants) that would be adverse to marine life in the area of the discharge.

The San Joaquin River Water Quality Management Group (SJRWQMG 2005) has been developing an approach to manage the EC concentrations in the SJR at Vernalis. It is claimed by this group that the SJR at Vernalis has not experienced violations of the 700 µmhos/cm and 1,000 µmhos/cm 30-day running average EC standard at Vernalis. This assessment is based on CALSIMS II modeling. CALSIMS II is a new DWR/USBR model that is supposed to represent flow conditions in the SJR. CALFED Science Program (CALFED 2005) has been conducting a review of the reliability of CALSIMS II, where the expert review panel (Lund et al. 2006) in its initial review has reported that there are significant questions about the reliability of CALSIMS II, especially in reliably tracking SJR flow under drought conditions such as those that occurred in the early 1990s. Concern was also expressed by the panel about the reliability of the EC predictions at Vernalis.

OP Pesticides. The CVRWQCB (2005a) has recently adopted a TMDL to control organophosphorus pesticides (diazinon and chlorpyrifos) in the San Joaquin River and its watershed. These pesticides, as well as others, such as the pyrethroid-based pesticides, are derived from agricultural use, and, through stormwater runoff and tailwater discharges, cause aquatic life toxicity in the SJR and its tributaries. There is also concern about the continued use of some OP pesticides (especially chlorpyrifos), as well as the pyrethroid-based pesticides that are widely used in urban areas as replacements for diazinon/chlorpyrifos, as a cause of aquatic life toxicity in urban streams and downstream areas (Lee 2001a, 2005a,b; Lee and Jones-Lee 2005a). This toxicity is known to be detrimental to some zooplankton, which can be important components of larval fish food.

Lee (2005c) has raised questions about the reliability of the CVRWQCB's approach for implementation of the TMDL compliance monitoring program, where the Regional Board adopted the staff-recommended approach of tying the OP pesticide compliance monitoring to the yet-to-be-developed Ag Waiver monitoring program. As Lee (2005c) and Lee and Jones-Lee (2005b) discussed, there are significant questions about the adequacy of the Ag Waiver comprehensive water quality monitoring program for pesticide-caused aquatic life toxicity and whether it will have a high probability of detecting this toxicity in the SJR watershed. The current Ag Waiver aquatic life toxicity monitoring program is significantly deficient in adequately monitoring the discharges of pesticides by agricultural users. Lee (2005c) recommended that, because of the uncertainty of when a comprehensive pesticide-caused aquatic life toxicity monitoring program will be developed (and, most importantly, adequately implemented), the CVRWQCB should be required to develop a comprehensive OP and other pesticide TMDL compliance monitoring program at this time. If a comprehensive Ag Waiver pesticide-caused aquatic life toxicity monitoring program is developed, then the independently developed OP pesticide TMDL compliance monitoring program could be coordinated with the Ag Waiver water quality monitoring program.

According to the CVRWQCB staff presentations at the OP pesticide TMDL workshops, the presence of non-OP-pesticide-caused aquatic life toxicity is supposed to be assessed by toxicity investigation evaluations (TIEs) of the cause of aquatic life toxicity for agricultural area discharges and knowledge of the pesticides used in a watershed where toxicity is found in a waterbody. In urban areas, the control of non-OP-pesticide-caused aquatic life toxicity is to be assessed through establishing comprehensive aquatic life toxicity monitoring requirements associated with NPDES stormwater runoff permits. However, there is a lack of coordination of the OP pesticide TMDL requirements and the monitoring requirements included in CVRWQCB urban stormwater NPDES permits. Further, communities with populations less than 100,000 are governed by US EPA Phase II stormwater NPDES permits that do not require water quality monitoring. There is need for the CVRWQCB to develop a comprehensive pesticide/aquatic life toxicity TMDL implementation program to ensure the control of aquatic life toxicity caused by pesticides used in agricultural and urban areas in the SJR watershed.

Lee and Jones-Lee (2002d) have presented a report to the CVRWQCB on the development of a TMDL to control OP-pesticide-caused toxicity in two city of Stockton sloughs (Mosher and Five Mile) that are on the CVRWQCB 303(d) list of impaired waterbodies. They discussed that the focus of this TMDL should be devoted to determining the current amounts of aquatic life toxicity in the Stockton sloughs in the water column and sediments and the cause of this toxicity. As discussed by Lee (2005a,b) and by Lee and Jones-Lee (2005a), it is highly likely that the shift from diazinon to pyrethroid-based pesticides for residential uses has expanded the toxicity from just the water column to the water column and sediments. The pyrethroid-based pesticides cause toxicity in the water column at the time of runoff, and also in the sediments following a runoff event.

All urban stormwater NPDES permits should require monitoring of the receiving water column and sediments for aquatic life toxicity. Lee and Jones-Lee (2005c) have provided guidance on the recommended aquatic life toxicity and pesticide monitoring programs. These programs should include not only measuring the toxicity of water, but also assessing the magnitude of this toxicity through dilution series studies and the use of piperonyl butoxide (PBO) to determine whether the toxicity can be accounted for, at least in part, by OP pesticides and pyrethroid-based pesticides. The potential for pyrethroid-based pesticides to be the cause of sediment toxicity can be evaluated through measurement of the total concentrations of selected pyrethroid-based pesticides in the sediments and information on their potential toxicity, through LC50 studies. Information is provided on this approach by Lee and Jones-Lee (2005c).

While the current focus on OP pesticide-caused toxicity is associated with diazinon and chlorpyrifos use in irrigated agriculture, there are several other OP pesticides used in the SJR watershed that have been found in the CVRWQCB Ag Waiver water quality monitoring program that are derived from other agricultural activities such as dairies. There are a large number of pesticides used in the SJR watershed. 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 and its tributaries. The CVRWQCB's current program to regulate pesticides considers only about half a dozen of these.

The current approach for registration of pesticides by the US EPA Office of Pesticide Programs (OPP) and California Department of Pesticide Regulation (DPR), where pesticides that are highly toxic to aquatic life are registered (labeled) for use under conditions where stormwater runoff and water discharges can cause aquatic life toxicity in the State's waters, is significantly deficient in protecting the beneficial uses of the State's waters. Since the problem of inadequate registration of pesticides by the US EPA OPP to prevent aquatic life toxicity from labeled (permitted) use has been known for several years, and the US EPA OPP has inadequately addressed this issue, it will be necessary to implement additional studies on fate and transport of pesticides after their use to screen new or expanded-use pesticides for potential aquatic life toxicity problems. Jones-Lee and Lee (2000) and Lee (2001b) have discussed a "Proactive Approach" for evaluating new and expanded-use pesticides for the potential to cause aquatic life toxicity in waterbodies receiving stormwater runoff and wastewater discharges from areas where the pesticides are first being used.

Associated with the initial use of a new or expanded-use pesticide, a comprehensive water quality edge-of-the-field/area monitoring/evaluation program should be implemented to determine if water released/discharged from the area of use causes aquatic life toxicity in the receiving waters for the runoff/discharges. This approach is designed to make up for the deficiencies in the approach used by the US EPA OPP in registering pesticides. It would be implemented by state and local regulatory agencies to detect, before widespread use occurs, aquatic life toxicity in the water column and sediments caused by a new or expanded-use pesticide. The funds needed to conduct these studies would be provided by those who wish to use the new pesticide or expand the use of a pesticide, and by the pesticide manufacturer.

The CVRWQCB (Karkoski 2006) has announced that the Board is developing a modification of the Basin Plan for regulating pesticides. The purpose of this modification is to improve the ease of Board regulation of aquatic life toxicity due to pesticides that enter the State's waters. This modification includes attempting to develop water quality and sediment quality criteria for pesticides and an assessment of the aquatic life beneficial uses of those waterbodies in the Central Valley that do not have defined designated beneficial uses. Based on the staff's presentation at the February 9, 2006, workshop, there are potentially significant problems with the proposed approach for regulating pesticide-caused aquatic life toxicity. Comments on the appropriateness of the proposed approach are provided by Lee and Jones-Lee (2006a).

Overall, pesticides used in urban and agricultural areas in the SJR watershed and Delta are causing aquatic life toxicity in the State's waters. This toxicity is a violation of the CVRWQCB Basin Plan WQO. There are significant deficiencies in the approach that the CVRWQCB is following in attempting to develop aquatic life toxicity control programs in the SJR watershed, as well as elsewhere in the Central Valley, which need to be addressed.

Oxygen-Demanding Substances. Dissolved oxygen concentrations below the water quality objective in the San Joaquin River Deep Water Ship Channel near Stockton have caused the CVRWQCB (2004b) to develop a TMDL to control discharges of the oxygen-demanding materials and/or conditions that contribute to the DWSC low-DO problem. This TMDL was recently adopted by the SWRCB. The low-DO problem is largely restricted to the first seven miles of the DWSC downstream of the Port of Stockton. Frequently in the summer and fall, and sometimes in the winter, the dissolved oxygen concentrations in the Channel near the Port of Stockton are sufficiently low to block Chinook salmon migration to their upstream home waters for reproduction. Further, at times the concentrations of dissolved oxygen in the DWSC near the Port of Stockton are sufficiently low to be harmful to fish growth and occasionally lethal to fish.

Lee and Jones-Lee (2000, 2003a, 2004b) have provided reviews of the low-DO problem in the DWSC. As they report, a major cause of the DWSC low-DO problem is the discharge of nutrients from agricultural lands, which develop into algae in the SJR tributaries and the mainstem, and are transported into the DWSC where they die and decompose, leading to low DO. The CVRWQCB staff (Foe et al. 2002) have found, based on the 2000 and 2001 data, that the Mud and Salt Slough watersheds and the SJR upstream of Lander Avenue (Highway 165) are the primary sources of the algae that cause this problem. Dahlgren (2005) has recently presented a review of four years of his SJR watershed monitoring which has shown that Mud and Salt Sloughs are the primary source of the seed algae and nutrients that, through additional algal growth in the SJR, cause the oxygen demand (BOD) that leads to low DO in the DWSC.

One of the major factors affecting the magnitude of the low-DO problem in the DWSC is the amount of SJR flow through the DWSC. As discussed by Lee and Jones-Lee (2003a, 2004b) and Lee (2005d), at flows of the SJR through the DWSC above about 1,500 cfs, DO concentrations below the WQO do not occur. However, at SJR flows through the DWSC of less than a few hundred cfs, severe low-DO problems occur in the DWSC. This is a result of the low SJR flow through the DWSC causing the hydraulic residence time of oxygen demand in the DWSC to be sufficiently long to allow a substantial part of the BOD load to the DWSC to be exerted within the DWSC. This issue has been discussed in detail by Lee and Jones-Lee (2003a, 2004b) and in several additional reports by Lee and Jones-Lee such as Lee (2005d), all of which are available on their website, www.gfredlee.com in the Watershed Studies section under the San Joaquin River Watershed Program and Delta subsection at http://www.gfredlee.com/psjriv2.htm. During most years the controlling factor for the amount of flow through the SJR DWSC is the presence of the Head of Old River barrier and the amount of SJR Vernalis water that is drawn through the Head of Old River into the South Delta for export by the CVP and SWP.

In the absence of adequate flows to solve the problem, controlling the low-DO problem in the DWSC will require the implementation of oxygen demand source control from the city of Stockton domestic wastewaters and possibly from nutrient runoff/discharges from agricultural lands in the SJR watershed. The city of Stockton has committed to spending over $70 million to control its ammonia discharges to the SJR from its domestic wastewater treatment plant. This expenditure would not be needed if there were adequate flow of the SJR through the DWSC. There is the potential that USBR releases of water from Friant Dam to the SJR, which is allowed to pass through the SJR to the DWSC, could help solve the low-DO problem in the DWSC.

According to the CVRWQCB (2004b) DO TMDL, to the extent that the combination of increased flow and control of oxygen demand sources is not technically/economically feasible, it may be necessary to provide aeration of the DWSC. The cost of this aeration will have to be borne by the dischargers of oxygen demand and those who contribute to conditions in the DWSC that adversely impact dissolved oxygen concentrations. Of particular concern is the existence of the Deep Water Ship Channel, which was developed by the US Army Corps of Engineers in support of the development of the Port of Stockton. As discussed by Lee and Jones-Lee (2003a), if the DWSC did not exist and the SJR channel downstream of the city of Stockton had the same channel physical characteristics as upstream of Stockton, there would likely be few if any low-DO problems in the SJR.

The existence of the DWSC causes the Port of Stockton and the US Army Corps of Engineers to become responsible parties for helping to solve the low-DO problem in the DWSC. Similarly, those who divert flow from the SJR upstream of the DWSC – including agricultural diversions, municipalities such as the city of San Francisco, and the CVP and SWP – through drawing SJR Vernalis water into the South Delta at the Head of Old River, are responsible for causing the low-DO problem in the DWSC. Flow from Friant Dam, even if it does not completely obviate the need for oxygen demand source control and aeration, would reduce the amount of aeration/source control needed and thereby reduce the cost to the stakeholders in the SJR DWSC watershed.

As discussed by Lee and Jones-Lee (2003a; 2004a,b), several of the channels in the South Delta (Old River near the Tracy Blvd bridge, and in Middle River) have low-DO problems that are related to excessive growths of algae that die and decompose, where, due to poor circulation caused by the USBR CVP and DWR State Water Project, lead to low DO in the channel. In August 2003, G. F. Lee observed a large-scale fish kill in Old River near the Tracy Blvd bridge, where thousands of threadfin shad were floating on the water surface. They had been killed the night before when the DO in the channel had decreased to zero. It is likely that nutrients and algae derived from the SJR upstream of Vernalis contribute to the low-DO problems in the South Delta. According to the DWR (2005) recently released draft EIR/EIS for the South Delta Improvement Program (SDIP), there is intent to try to operate the operable barriers, which are to be installed in 2009, to improve the circulation of water in the South Delta channels. However, Lee (2005e) has questioned the reliability of the DWR SDIP assessment of the improvement in South Delta water quality that will be achieved by operable barrier operations. The CVRWQCB (2006) has reported that the DWR/USBR draft EIS/EIR for the SDIP is significantly deficient in addressing a number of water quality issues in the Delta that can be impacted by increased exports and/or operations of the operable barriers.

The CVRWQCB approach for development of the SJR DWSC low-DO control program is to allow responsible parties until 2009 to develop additional information needed to formulate the final TMDL. One of the issues of concern is how CALFED/CBDA is supporting the development of technical information that can be useful to the CVRWQCB in developing the final TMDL in 2009. For a variety of reasons discussed by Lee and Jones-Lee (2003a), the CALFED-supported SJR upstream water quality studies that are currently being conducted will not provide the information needed to refine the development of the CVRWQCB final TMDL implementation approach. Lee (2003a) pointed out at the time of CALFED's consideration of the support of the proposed upstream studies that these studies will likely have limited applicability to formulating the final TMDL, since there will be major changes in upstream loads of algae and nutrients and water derived from Mud and Salt Sloughs to the SJR. McGahan (2005) stated that the discharges of water, selenium, EC and other constituents from Mud and Salt Sloughs will be changed significantly by 2009 associated with implementation of other TMDLs. These changes are expected to change the implementation of the SJR DWSC low-DO TMDL.

The current modeling of oxygen demand load, transport and exertion in the SJR watershed and DWSC will not likely be reliable in predicting how altered loads of oxygen demand and water will impact DO depletion in the DWSC. The types of models that are being used, which are tuned to existing conditions, will not likely be reliably applicable to the new conditions that will exist in 2009, after major changes in upstream loads have been implemented.

There is another significant problem with the current approach for developing the information needed to develop the final SJR DWSC implementation approaches. Lee (2005f,g) has discussed that the current CALFED/CVRWQCB demonstration aeration project approach is not technically valid, since it allows the discharge of pure oxygen at sufficient concentrations to violate the CVRWQCB Basin Plan WQO for the discharge of toxics in toxic amounts. National Oceanic and Atmospheric Administration (NOAA) staff have also raised the same concern about the discharge of pure oxygen to the SJR DWSC in violation of the US EPA (1987) water quality criteria for dissolved gas supersaturation. In order to eliminate the potential WQO violations associated with the discharge of toxics related to the current design of the aeration demonstration project, there will be need to redesign the project to eliminate the discharge of toxics in toxic amounts. This issue needs to be addressed now, not several years from now. Failure to begin to address this issue now could jeopardize the appropriate use of aeration to help solve the SJR DWSC low-DO WQO violations in formulation of the final TMDL by the CVRWQCB.

At this time, the CVRWQCB DO WQO is implemented as an absolute value that is to be met at all times and locations. Lee and Jones-Lee (2005d) discussed the need for the CVRWQCB to modify its implementation of the DO WQO to allow diel (night/day) averaging of DO concentrations in evaluating compliance with the DO WQO. Also, there is need to allow some DO depletion near the sediment water interface. In addition, the current September through November 6 mg/L DO WQO can be decreased to 5 mg/L, without adversely impacting Chinook salmon migration through the DWSC when the operable barrier is installed at the Head of Old River. As discussed by Lee and Jones-Lee (2005d), these changes would be protective, allowed by the US EPA and followed in some other states.

Another issue that needs to be addressed by the CVRWQCB at this time is to reactivate the evaluation of alternative approaches for solving the SJR DWSC low-DO problem. Lee (2003b) has discussed various areas that need attention in order to develop the information needed to formulate the final TMDL. The CVRWQCB should begin now to address these and other issues that need to be considered in 2009 to develop the final TMDL. As discussed by Lee (2003b), particular attention should be given to developing the information needed to evaluate the technical feasibility and cost associated with various oxygen demand/nutrient control programs, supplemental flow of the SJR through the DWSC, and other approaches for elimination of the DO WQO violations in the DWSC.

The San Joaquin River Water Quality Management Group (SJRWQMG 2005) has been developing an approach to achieve compliance with the EC/Boron WQO in the SJR at Vernalis. This effort includes attempts to increase the amount of SJR Vernalis water that enters the DWSC as part of helping to alleviate the low-DO problem in the DWSC. The current recommended approach by this group is deficient in providing adequate flow of SJR Vernalis water in the DWSC to eliminate or essentially eliminate DO WQO violations in the Channel. This situation is complicated by the fact that DWR (2005) has not, as part of the South Delta Improvement Program (SDIP), adequately addressed the issue of increasing the amount of Sacramento River water that is pumped across the permanent operable barriers that are to be installed in the South Delta by 2009.

As discussed below, many of the current water quality problems in the South Delta, as well as the low-DO problem in the DWSC, could be greatly reduced or eliminated if Sacramento River water that is currently drawn to the west side of the South Delta by the CVP and SWP were pumped across the operable barriers by low-head, reverse-flow pumps. This approach has been discussed by Lee and Jones-Lee (2003a) and by Lee (2005e). Pumping additional Sacramento River water into the South Delta across the operable barriers could allow the SJR Vernalis water to proceed down the SJR to the DWSC, and thereby eliminate the need to allow some of the SJR Vernalis water to proceed into Old River through the Head of Old River, in order to maintain the water levels in the South Delta channels to provide water for South Delta irrigated agriculture. This approach would not reduce the amount of water in the South Delta that is available to USBR and DWR for export, since any SJR Vernalis water that enters the DWSC would be drawn to the South Delta via Turner Cut/Middle River.

In summary, there is need for the CVRWQCB to begin to address several issues in order to define the information that will be needed in 2009 to formulate the final TMDL to control DO violations in the DWSC near the Port of Stockton. Addressing these issues now would provide the opportunity to develop studies to provide the information needed in 2009 to formulate the final TMDL.

Pending TMDLs

The CVRWQCB has identified a number of other Basin Plan violations of water quality objectives that have caused parts of the SJR and its tributaries to be placed on the 303(d) list of impaired waterbodies. This, in turn, has led to listing of these waterbodies as needing a TMDL to control the excessive discharges of the pollutants that are causing the water quality objective violations. The CVRWQCB/SWRCB (2003), in accordance with its limited staff and other financial constraints, has listed several of these TMDLs as medium or low priority for attention. Information on these TMDLs is summarized in this section.

Organochlorine "Legacy" Pesticides. During World War II, DDT, an organochlorine-based pesticide, was developed and widely used. Subsequently other organochlorine-based pesticides were developed, such as chlordane, toxaphene, dieldrin, etc. By the 1960s it was found that many of these pesticides were having adverse effects on wildlife, especially fish-eating birds. A number of these pesticides (such as DDT) were suspected of causing cancer in people. Eventually organochlorine pesticides were banned from further use in the US. The organochlorine pesticides (OCl pesticides) are now characterized as "legacy" pesticides. However, because of their widespread use by agriculture and their persistence in soil, they are still present in agricultural soils and in waterbody sediments that have received runoff from irrigated agriculture in many areas of the Central Valley of California. Lee and Jones-Lee (2002e) have presented a comprehensive review of the excessive bioaccumulation of the organochlorine pesticides (DDT and "Group A" pesticides) and PCBs that has been found in fish taken from the SJR, its tributaries and the Delta. The Group A pesticides include aldrin, dieldrin, chlordane, endrin, heptachlor, heptachlor epoxide, hexachlorocyclohexane (including lindane), endosulfan and toxaphene.

Past and current runoff/discharges from irrigated lands in the San Joaquin River watershed have resulted in excessive concentrations of several of the legacy pesticides in the edible tissue of fish taken from waterbodies influenced by agricultural runoff in the Central Valley, especially the SJR watershed. Several of the fish frequently sought in the SJR at Vernalis (bass and catfish) contain excessive OCls. This bioaccumulation is of concern since these pesticides are a threat to cause cancer in those who use the fish as food. This has caused the CVRWQCB and the State

Water Resources Control Board (CVRWQCB/SWRCB 2003) to list about a dozen waterbodies in the Central Valley as 303(d) “impaired” waterbodies due to OCl bioaccumulation, which requires that a TMDL be developed to control the excessive bioaccumulation of the organochlorine pesticides. Work on developing this TMDL will be initiated when other TMDLs have been completed and funds become available. Based on existing data, the excessive bioaccumulation of OCls in fish in the South and possibly Central Delta is likely significantly influenced by the OCls derived from the SJR watershed upstream of Vernalis.

Lee and Jones-Lee (2005b) discussed that there is a major problem with the current and proposed Ag Waiver monitoring program for the OCl legacy pesticides in that it requires that agricultural interests monitor the water column for OCls. This approach is not reliable for determining the concentration of OCls that can bioaccumulate to excessive levels in edible fish tissue. Concentrations below those that can be detected in the water column can bioaccumulate to excessive concentrations in fish tissue. Lee and Jones-Lee (2005b) recommend that, rather than wasting funds trying to monitor the OCls in the water column, each fall fish should be collected from the waterbodies and analyzed for the OCls. If excessive OCls are found in the fish tissue, then studies of the type that Lee and Jones-Lee (2002e) discussed should be conducted.

Lee and Jones-Lee (2005e) have indicated that the human health threat of excessive bioaccumulation of OCls should cause the regulatory agencies (CVRWQCB) and potential funding agencies, such as CALFED, to give higher priority to funding the studies to more adequately define the current magnitude of the OCl bioaccumulation problem in Central Valley waterbodies. The excessive bioaccumulation of OCls is an environmental justice issue since it is often minorities and the economically disadvantaged who depend on SJR and Delta fish for a major part of their diet. Overall, the excessive bioaccumulation of the OCls is a far more important water quality problem to some of the public than is currently reflected by the priority given to it by regulatory and potential funding agencies.

As discussed below under mercury, the current approach of the US EPA and the California Office of Environmental Health Hazard Assessment (OEHHA) is to establish the critical concentration of a hazardous chemical in fish tissue based on a national average fish consumption rate. This approach exposes the subsistence fisherperson to hazardous chemicals at levels which are recognized as detrimental to human health. This approach creates an environmental justice issue, where those who need to eat local fish as a source of food are exposed to levels of chemicals in the fish they eat considerably above those considered hazardous based on the national average fish consumption rate.

PCBs. Polychlorinated biphenyls (PCBs) are a group of OCls that were used as industrial chemicals in a variety of industrial processes and in electrical transformers. Their use in manufacturing has been banned for over 20 years. However, they are highly persistent in the environment and tend to bioaccumulate in edible fish and other organisms to levels that are recognized as a threat to cause cancer in those who use the fish as food. Sections of the San Joaquin River and the Deep Water Ship Channel near the Port of Stockton have been listed as Clean Water Act 303(d) impaired waterbodies due to excessive bioaccumulation of PCBs in edible fish. The excessive bioaccumulation of PCBs, like the excessive bioaccumulation of organochlorine legacy pesticides, is covered by a TMDL that will be developed by the

CVRWQCB when a higher priority is given to funding the studies needed to formulate the TMDL.

Recently, it has become more widely recognized that various types of sealants for joints in concrete, wood structures, etc., can contain appreciable concentrations of PCBs. This issue has been recognized in Europe, Australia and other countries. There are a number of papers and reports on this issue from other countries, which provide additional information on the presence of PCBs in various types of structures. Of particular concern are the publications by Åstebro et al. (2000), BUWAL (date unknown) and CFMEU (date unknown). A comprehensive review of what was known in 2004 about PCBs in structures as a diffuse source of PCBs for the environment has been developed by Kohler et al. (2005). The widespread former use of PCBs, such as for sealants, may help account, at least in part, for their ubiquitous occurrence in fish tissue in many areas.

Lee et al. (2002) conducted a study of excessive PCBs in fish taken from Smith Canal in the city of Stockton. Smith Canal is a fresh water tidal dead-end slough in the city that receives city stormwater runoff. Some of the fish taken from Yosemite Lake at the head end of Smith Canal contained excessive PCBs compared to the human health guidelines developed by US EPA and OEHHA. The Yosemite Lake sediments were found to contain elevated concentrations of PCBs. These sediments also contained elevated concentrations of total organic carbon (TOC). The TOC concentration in sediments determines the bioavailability of OCl pesticides and PCBs in sediments. Lee et al. (2002) investigated the uptake of PCBs in Yosemite Lake sediments using the US EPA standard test organism (*Lumbriculus variegates*). They found that the PCBs in the Yosemite Lake sediments were to some extent bioavailable. The sediments of Smith Canal at half the distance between Yosemite Lake and where Smith Canal joins the SJR at the mouth of Smith Canal did not have elevated PCBs. Further, while the sediments in Smith Canal at Yosemite Lake were toxic to *Hyalella azteca*, the sediments at halfway to the mouth and at the mouth of Smith Canal were not toxic to this organism. Lee et al. (2002) did not determine the cause of this toxicity. However, as discussed below, it could be due to pyrethroid-based pesticides that are derived from stormwater runoff from the city of Stockton that discharges to Yosemite Lake. Studies should be conducted to determine the cause of this toxicity.

The PCBs in Yosemite Lake were likely derived from stormwater runoff from the city of Stockton. Of potential importance would be spills from an electrical transformer or industrial discharges. There is need to conduct a forensic study of storm sewer sediments at various locations in the city to attempt to determine the likely source of the PCBs.

Since Yosemite Lake is a popular area that is intensely fished, there is need to remediate the PCBs in the sediments of this area to prevent the continued bioaccumulation of PCBs in edible fish. This is another environmental justice issue that is not being adequately addressed. Instead of dredging these sediments and managing the contaminated sediments in a landfill, it may be possible, based on the work of Luthy (2003), to immobilize the PCBs in these sediments through the addition of activated carbon. This approach, if effective, could be far less expensive than dredging the sediments and managing them in a landfill. There is need for the city of Stockton to conduct a demonstration project in which the activated carbon addition approach is evaluated.

Lee and Jones-Lee (2005f) have discussed the importance of properly selecting a landfill for disposal of contaminated sediments. As they discuss, the current allowed minimum Subtitle D landfill will only temporarily prevent groundwater contamination by pollutants in the landfill. This situation leads to an unreliable estimate of the true cost of landfilling of wastes, including contaminated sediments, since ultimately, when the landfill liner systems fail, there will be need for "Superfund"-like cleanup at minimum design US EPA approved Subtitle D landfills. The cost of this cleanup will likely have to be borne by those who put wastes in such a landfill.

Dioxins/Furans. Dioxins/furans are chlorinated organic chemicals derived from industrial process wastewater and airborne discharges, which are highly toxic to humans and some forms of aquatic life. They are also formed as a combustion product in fires and are found in stormwater runoff from highways and streets. They are known to cause cancer in humans. Like other OCls they tend to bioaccumulate in edible fish and other organisms. The US EPA (CVRWQCB/SWRCB 2003) has listed the SJR DWSC near the Port of Stockton as an area where excessive concentrations of dioxins/furans have been found in edible fish. It is believed that at least part (possibly a large part) of the excessive dioxins present in SJR DWSC fish are derived from releases from the McCormick & Baxter Superfund site located near the Port of Stockton.

The US EPA (2005a) is the lead agency for the McCormick & Baxter Superfund site investigation/remediation. There are questions about the adequacy of the US EPA approach for remediation of the contaminated sediment in the channel (Old Mormon Slough) at the Superfund site, where the Agency proposes to cover these sediments, which contain dioxins/furans, with clean sand. This approach can lead to a short-term control of the release of dioxins from the buried sediments. However, as long as the dioxins are present in these channel sediments they will be a threat to bioaccumulate in the aquatic food web and ultimately in the edible fish of the area.

The US EPA, as the lead on Superfund sites where there is no responsible party to pay for site cleanup and the cleanup has to be funded by US EPA funds, at some sites takes the approach of a limited-scope site cleanup that enables the Agency to claim that the site is "remediated" and thereby turn the long-term responsibility for Superfund site monitoring and eventual re-remediation over to the state agency (California Department of Toxic Substances Control - DTSC) for funding. However, DTSC may not have the funds to adequately monitor the integrity of the sand cover of the dioxin-contaminated sediments. Since dioxins are extremely persistent in the environment, a comprehensive monitoring program will need to be conducted, effectively, forever. Unless assured funding is made available for this monitoring, the capping of the Old Mormon Slough dioxin-containing sediments with a layer of sand is not a reliable approach for remediation of this site.

There is another issue regarding the adequacy of the McCormick & Baxter site remediation with respect to whether sediments outside of Old Mormon Slough, which are not now scheduled for remediation (covering), are sources of dioxins that are bioaccumulating to excessive levels in fish in the Port of Stockton and the DWSC. There is need to evaluate, using benthic organism uptake studies of the type used by Lee et al. (2002), whether sediments outside of the scheduled remediation area are sources of dioxins to the food web.

One of the problems with the remediation of the McCormick & Baxter site is that there is no public oversight of the US EPA's approach for site investigation/remediation. The area of the site is an economically depressed area of Stockton where there is a substantial population of minorities. There is need for public oversight, through US EPA Technical Assistant Grant (TAG) funds to enable the public to actively participate in evaluating the adequacy of site investigation/remediation and, especially, to provide for outside review of the monitoring program of the integrity of the sand cover of the dioxin-containing sediments in Old Mormon Slough.

Mercury. The CVRWQCB/SWRCB (2003) has listed the San Joaquin River from the Merced River to the Delta as impaired based on excessive mercury bioaccumulation in edible fish. This listing has caused the CVRWQCB to conduct studies that provide information for a TMDL designed to control excessive bioaccumulation of mercury in fish in the San Joaquin River and Delta. Mercury in the SJR watershed is typically derived from former Sierra gold mining areas where mercury was used to help recover gold from sediments and crushed rock. Also, some mercury in the SJR is derived from mercury mining activities in the Coast Range. Mercury in aquatic sediments is converted to methyl mercury by sulfate-reducing bacteria at the sediment water interface. The methyl mercury bioaccumulates to excessive levels in fish and other aquatic life. This is of concern because mercury is a neurotoxin, to which fetuses and young children are particularly sensitive.

The CVRWQCB (2005b) has released a staff report on the mercury problem in the Delta, which includes information on mercury bioaccumulation in the SJR at Vernalis. The CVRWQCB staff have found a strong correlation between the methyl mercury concentrations in water and fish tissue concentrations of mercury. They have also found that all forms of mercury, including metallic mercury and cinnabar (mercury sulfide), can be converted to methyl mercury. However, the factors that influence the rate of conversion of various forms of mercury to methyl mercury are not well understood.

The concentration of sulfate affects the methylation of mercury. The CVRWQCB (2005b) staff have indicated that the manipulation of flows in the South Delta as part of DWR's proposed operation of the operable barriers as part of the South Delta Improvement Program could affect the distribution of sulfate in the South Delta which in turn could affect the bioaccumulation of mercury in edible fish. Sulfate derived from the SJR watershed that is brought into the South Delta through the Head of Old River could increase the rate of methylation of mercury and therefore its bioaccumulation in South Delta fish. There is need to evaluate how the operation of the South Delta operable barriers that are scheduled to be installed and operational by 2009 affects the bioaccumulation of mercury in South Delta fish.

Lee (2005e) in testimony before the SWRCB hearing on the DWR and USBR draft Cease and Desist Order to prevent violations of the South Delta salinity standard established as part of D-1641, indicated that DWR, as part of developing the operation of the South Delta operable barriers, will need to expand its scope of evaluation of barrier operation to include not only EC but also the impact of sulfate on mercury bioaccumulation. In addition, as discussed by Lee and Jones-Lee (2006b), this evaluation should include the impact of barrier operations on the impacts of the other pollutants on the CVRWQCB 303(d) list for South Delta channels and other constituents that, while not on the 303(d) list, are impacting South Delta water quality. Lee (2005e) also suggested that DWR needs to more reliably evaluate the potential benefits of installing low-head, reverse-flow pumping across the permanent operable barriers to bring more Sacramento River water into the South Delta. Adoption of this approach could be highly cost-effective in improving South Delta water quality as well as the quality of the CVP-exported water. As discussed above, it could also help solve the low-DO problem in the DWSC.

If the sulfate added to the South Delta via Head of Old River increases the excessive mercury bioaccumulation problem in South Delta waters, then this would be additional justification for allowing the SJR Vernalis water to bypass the Head of Old River and proceed down the SJR channel to Turner Cut. The CVRWQCB (2005b) has reported that Central Delta fish, including those in the DWSC, have lower concentrations of mercury. According to Foe (2005), Sacramento River water has about 10 times less sulfate than SJR Vernalis water. The addition of sulfate from the SJR watershed to the Central Delta would not likely significantly increase the mercury bioaccumulation in the Central Delta, since the sulfate added to the Central Delta at Turner Cut is greatly diluted by low-sulfate Sacramento River water. The low water conditions that would result in South Delta channels when the Head of Old River barrier is closed and the CVP/SWP pumps are operating could be overcome by the low-head, reverse-flow pumping of Sacramento River water across the permanent barriers into the South Delta.

Foe (2005) has indicated that there is evidence that higher flows of the SJR lead to flooding of areas such as wetlands, where methyl mercury is mobilized and is transported down the SJR. This is an issue that is under study by the CVRWQCB.

As with the organochlorine legacy pesticides and PCBs, there is an environmental justice issue that needs to be addressed associated with the adequacy of the protection afforded by the allowed fish tissue concentration based on a national average fish consumption rate since, as discussed in the section on the excessive bioaccumulation of OCls, some of those consuming the greatest amount of fish with elevated mercury are minorities and economically disadvantaged. In order to adequately protect those who consume more fish than the national average from exposure to concentrations of mercury that are considered to be hazardous to fetuses and young children, the allowed fish tissue concentration of mercury will need to be lowered.

Sanitary Quality. Because of the presence of human pathogens and their associated diseases, the sanitary quality of water is of concern to those who contact recreate (swim, wade, etc.) in the water. The US EPA (2002) is requiring that states adopt and enforce more appropriate contact recreation sanitary-indicator organism (*E. coli*) water quality standards than the fecal coliform standard that has been used and is being used in some areas today. In response to this requirement, the CVRWQCB has adopted the US EPA recommended contact recreation water quality criteria limiting the *E. coli* concentrations in waters to protect the health of those who contact recreate in Central Valley waters. This standard has been under review by the SWRCB for several years. The *E. coli* contact recreation standard should be adopted by the SWRCB to improve the reliability of assessing the sanitary quality of fresh waters of the State.

E. coli is a bacterium that is typically an indicator of the presence of pathogenic organisms of human and animal origin. Lee and Jones-Lee (1993, 1994) have reviewed the various pathogens that can cause human diseases through contact recreation. As they discuss, in addition to bacterial diseases such as typhoid, cholera, etc., there are also diseases caused by protozoan (single cell animals) cyst-forming organisms, such as giardia and cryptosporidium. These organisms are more persistent in the environment and are more resistant to water disinfection than *E. coli*. These organisms can cause human diseases through contact recreation. They are transmitted to humans through some types of animal fecal matter.

Another major cause of human disease is viruses. Viral-caused waterborne diseases of concern include some forms of hepatitis. In addition, there are a number of viral diseases that cause gastroenteritis (upset stomach) and infections of the eye, ear and nose. Meeting the *E. coli* contact recreation standard will not necessarily prevent humans who come in contact with the water from acquiring diseases from other bacteria, protozoans or viruses.

The sanitary quality of a water is also of importance to domestic water utilities, since failure to adequately treat water that has been contaminated with fecal coliform organisms from humans and some animals can cause disease in those who consume the treated water. While the SJR water is not now used as a source of domestic water supply, there are likely some individual water supplies that use the SJR or one of its tributaries as a domestic supply. Also, the city of Stockton is developing a water supply intake that will divert Delta water on Empire Tract northwest of Stockton. The sanitary quality of Delta waters in the vicinity of this water supply intake will be important to Stockton in providing a safe treated water supply.

The CVRWQCB/SWRCB has listed the SJR DWSC near the Port of Stockton as impaired due to pathogens. It is likely that excessive *E. coli* occurs at other locations in the San Joaquin River and its watershed. Increased SJR flow resulting from releases from Friant Dam will reduce the concentrations of *E. coli* and therefore improve the sanitary quality of the SJR, thereby reducing the potential of acquiring diseases associated with contact recreation. The decreased concentrations of *E. coli* in the SJR will be of value to those who discharge *E. coli* (such as in urban and agricultural stormwater runoff), in terms of reduced cost of managing their concentrations in runoff and wastewater discharges.

Toxicity of Unknown Cause. The San Joaquin River and some of its tributaries have been found to be toxic to aquatic life standard test organisms used in US EPA toxicity testing procedures. This toxicity has been found to zooplankton, which are small fish food organisms and, therefore, can be adverse to fish populations. Studies on some of this toxicity have thus far failed to identify the chemicals that cause the toxicity. This has led the CVRWQCB to develop a TMDL to control this toxicity as “toxicity of unknown cause (TUC).” Possibly a substantial part of the unknown-caused toxicity could be derived from pesticide releases from agricultural lands.

The USBR, as part of the Grasslands Bypass Project (USBR 2005), is monitoring drainage from the Grasslands area for several chemicals and toxicity at several locations in the Project area. SFEI (2002) has provided information on this Project. Brock and Malan (2002), as part of this Project’s annual report, have reported toxicity to *Daphnia*, fathead minnow larvae and the alga *Selenastrum* in waters taken at several locations in the Project monitoring area. The cause of this toxicity has not been identified. However, it is unusual to find toxicity to all three test species in a water sample.

The Sacramento River Watershed Program, Toxics Subcommittee, has developed a Strategy to Address Toxicity of Unknown Cause (SRWP 2001). This Strategy summarizes the information available on toxicity of unknown cause in the Central Valley and the approach that the CVRWQCB is taking to address this issue. As part of this Strategy, the CVRWQCB has initiated a research program to develop "tools" to determine the cause of what is now unknown-caused toxicity. The focus of these studies is to develop TIEs for several potentially significant pesticides that are used in the Sacramento River watershed. A more appropriate approach to identify the cause of unknown-caused toxicity would be to first find waters that currently demonstrate unknown-caused toxicity. Then, site-specific TIE studies should be conducted, in which knowledge of the pesticides used in the watershed is used to help guide the identification of chemicals responsible for toxicity of unknown cause.

Potential Future TMDLs

Listed below are water quality problems that could lead to 303(d) listing of sections of the SJR, which would require TMDLs to control pollutant inputs. For several pollutants discussed below, it is known that there is a water quality impairment due to the presence of these chemicals in SJR water; however, the CVRWQCB, SWRCB and US EPA have not developed numeric water quality criteria/standards/objectives that would serve as a basis for defining a water quality objective violation that would lead to a 303(d) listing of the waterbody as impaired and a TMDL to control the WQO violation. Since some of the water quality problems discussed below are associated with narrative water quality objectives, there is need for the CVRWQCB to develop guidance on the approach that should be implemented to evaluate an impairment of a narrative water quality objective, such as caused by nutrients that lead to excessive fertilization of waterbodies.

Nutrients. The US EPA (2001, 2005b) announced that water quality criteria/objectives will need to be developed by all the states to limit the concentration of nutrients (nitrogen and phosphorus compounds) that lead to excessive growths of aquatic plants (algae and water weeds), which impair the beneficial uses of waterbodies. The SJR, DWSC and parts of the Delta influenced by SJR discharges to the Delta (such as the South Delta) experience water quality problems due to excessive growths of aquatic plants (planktonic algae, water hyacinth and Egeria).

One of the most significant water quality problems caused by nutrient discharges from irrigated agriculture and other agricultural activities is the growth of algae in the SJR and its tributaries that leads to the oxygen demand load that enters the SJR DWSC at the Port of Stockton. There is also the likelihood that SJR watershed-derived nutrients stimulate the growth of algae in the SJR and the South Delta channels, which leads to the low-DO problems experienced in some of these channels. These issues have been discussed above in the section devoted to Oxygen-Demanding Substances.

The growth of algae and other aquatic plants can cause water quality objective violations for pH and dissolved oxygen. These violations arise from aquatic plant photosynthesis/respiration and death and decay. While not listed now as a cause of a water quality objective violation, future

303(d) lists of impaired waterbodies in the Central Valley could include listings for dissolved oxygen concentrations below the water quality objective that occur in the early morning hours, and excessive pH that occurs during late afternoon, associated with algal photosynthesis and respiration.

Review of recent years' SWRCB/CVRWQCB Surface Water Ambient Monitoring Program (SWAMP) data for the SJR shows that there are some pH values above the CVRWQCB WQO for pH of 8.5. The exceedance of this objective has not caused the CVRWQCB to list the SJR as impaired due to excessive pH. The elevated pH above this objective is likely due to algal photosynthesis in the SJR. Lee and Jones-Lee (2005b) have raised questions about the appropriateness of the CVRWQCB pH WQO. The US EPA, in its water quality criteria, allows a pH of 9.0. Further, it is well known that pH values above 9.0 can occur without significant impacts on fish populations. The CVRWQCB needs to examine the appropriateness of the current pH WQO as necessary to protect beneficial uses of waterbodies. Failure to do so could readily lead to large-scale expenditures for nutrient control to limit algal growth so that waterbodies do not contain a pH above the WQO.

Jassby (2005) and Jassby and VanNieuwenhuyse (2005) have discussed the role of nutrients in the SJR in impacting phytoplankton concentrations in the SJR and the low-DO problems in the DWSC. Additional information on these issues is provided by Lee and Jones-Lee (2000, 2003a) and Dahlgren (2005).

The high-nutrient waters in the South Delta channels are derived from the San Joaquin River watershed and Delta island agricultural tailwater discharges. However, the *Microcystis* blooms that are occurring in the north and western Delta waters are not based on nutrients derived from the SJR watershed, since, as discussed above, SJR waters do not reach these areas during the summer and fall months as a result of being drawn to the CVP and SWP export pumps through the Head of Old River or Turner Cut. The *Microcystis* blooms may be deriving their nutrients primarily from in-Delta irrigation tailwater discharges and municipal wastewater discharges.

The senior author of this report, G. F. Lee, has been involved in investigating bluegreen algae blooms for over 40 years in various parts of the US and other countries. The *Microsystis* blooms in the Delta are not typical bluegreen algae blooms. This appears to be related to the nutrient-poor conditions of the northern and western Delta compared to the normal conditions where bluegreen algae cause water quality problems.

The city of Stockton experiences severe bluegreen algae blooms with associated scum, odors etc., in McLeod Lake near Weber Point in downtown Stockton. Weber Point is at the end of a dead-end channel that connects McLeod Lake to the Port of Stockton (see Figure 1). Each summer large bluegreen algae blooms occur that impair the use of the Stockton waterfront area. The algae responsible for these blooms form the typical bluegreen algal scum. The nutrients that are responsible for these blooms are apparently derived from local storm sewer inputs to McLeod Lake. The City, in an attempt to reduce the scum impacts of the bluegreen algae blooms, has been operating a tugboat to mix the water, which breaks up the algal scum. This approach likely results in increased algal growth in McLeod Lake, since more algae are exposed to surface light conditions. If adequately practiced, this approach can be effective in breaking up the surface water scum; however, it results in a "pea soup" green water.

The nutrient content of South Delta water is sufficiently high so that when it is placed in a water supply reservoir (such as in the San Francisco Bay region or Southern California), excessive growths of algae occur, which leads to severe tastes and odors that require expenditure of funds by water utilities to control them. The Metropolitan Water District (MWD) of Southern California has developed a report, "Early Warning and Management of Surface Water Taste-and-Odor Events" (Taylor et al. 2006). This report documents over 25 years of taste and odor management at MWD and provides case studies for about 10 other participating utilities around the country. Chapter 2 of this report provides references to taste and odor events in the State Water Project.

Nutrients are a significant cause of water quality problems in the Delta and in water utilities' waterbodies that receive Delta water. At this time the SWRCB is working to formulate nutrient water quality objectives for the State's waterbodies. When these objectives are developed, it is likely that the concentrations of nitrogen and phosphorus compounds present in the SJR and its tributaries will be found to be excessive, which would lead to the development of a TMDL to control the nutrient WQO violations. Agricultural stormwater runoff, irrigation tailwater and subsurface drain water, as well as urban domestic wastewaters and stormwater runoff, are sources of aquatic plant nutrients for the SJR. Also of concern is animal manure from dairies and other sources.

The development of a TMDL to control nutrients will require that these sources spend considerable funds to control nutrients discharged by them. Lee and Jones-Lee (2005g) have discussed the issues that need to be considered in developing a water quality management program for nutrients in the Central Valley. Lee and Jones-Lee (2004c) have reviewed the issues pertinent to managing phosphorus runoff from agricultural lands. They discuss that there are a number of factors that need to be investigated in order to develop technically valid, cost-effective phosphorus runoff management programs.

A key issue that needs to be considered is that planktonic algae are the base of the aquatic food web and, therefore, determine the overall productivity of a waterbody. Lee and Jones (1991) have developed a relationship between phosphorus loads to waterbodies and fish production. In developing a nutrient control program, it is important to balance improved water quality associated with decreased aquatic plant production, and desirable fish production.

Lee (2002, 2006a) and Lee and Jones-Lee (2002f, 2004c, 2005g) have discussed the unreliability of the US EPA's national nutrient criteria development approach. Instead of using the default numeric criteria development approach, Lee and Jones-Lee recommend a waterbody site-specific assessment of the water quality problems caused by aquatic plants. Those impacted by a nutrient-caused water quality problem should work with the regulatory agency for the waterbody to establish the desired level of aquatic plant concentrations that will minimize the water impairment and still support desirable aquatic food web productivity. Next, it is necessary to establish the nutrient loads to the waterbody to achieve the desired water quality. Through an iterative process, the nutrient loads can be controlled to achieve the desired nutrient-related water quality.

The CVRWQCB regulates excessive fertilization of waterbodies through a narrative WQO for "biostimulatory substances." Lee and Jones-Lee (2002f, 2005g) have provided guidance on an approach for implementation of the excessive biostimulatory substances WQO. They recommend a site-specific evaluation of the desired aquatic-life-related water quality. Lee and Jones-Lee (2002c) also provided information on management practices that potentially could be used in the SJR watershed to control excessive nutrient discharges/releases from agricultural areas.

Nutrients derived from the SJR watershed and from in-Delta sources contribute to excessive growths of water hyacinth and Egeria that require California Department of Boating and Waterways (DBW 2005) to spend large amounts of funds to control excessive growths of these plants. There is concern about the potential for DBW's control of excessive aquatic weed growth in the Delta through the use of chemical spraying to cause adverse impacts to non-target aquatic life. The approach that has been used by DBW to evaluate the impacts of the chemical spraying for weed control is deficient compared to that needed for a proper evaluation of this situation. Lee (2004d), Lee and Jones-Lee (2004d) and Siemering (2005) have discussed the water quality problems associated with aquatic weed control programs. They have also discussed the type of water quality evaluation/monitoring program that needs to be conducted to reliably evaluate non-target organism impacts of the use of herbicides for aquatic weed control in the Delta and other areas, such as in the SJR watershed where herbicides are used by irrigation districts to control aquatic weed growth in their water transmission canals.

One of the issues of concern in developing a control program for nutrients from land runoff and wastewater discharges is the need to focus nutrient control on available forms of nutrients, especially phosphorus. The US EPA's approach of attempting to develop nutrient criteria based on total phosphorus is known to be technically invalid, since substantial parts of the particulate phosphorus in runoff from agricultural and urban areas is not available to support algal growth. Nutrient control programs in the SJR watershed need to be based on a proper evaluation of the amounts of phosphorus derived from a particular source that can impact nutrient-related water quality in the receiving waters and downstream from that source.

Overall, nutrients, through stimulating the growth of algae and other aquatic plants in the SJR, Delta and downstream waterbodies, are causing significant water quality deterioration that impairs the beneficial uses of these waters. In order to appropriately establish nutrient control programs for the SJR watershed, it will be necessary to conduct comprehensive studies on the sources, impacts and potential control of nutrients derived from the SJR watershed.

PBDEs. There is increasing concern about widespread contamination of aquatic life and humans by polybrominated diphenyl ethers (PBDEs). These chemicals are similar to PCBs in their bioaccumulation in aquatic life and potential to cause cancer in humans. PBDEs are widely used as fire retardants in household items. McDonald (2003) has discussed the finding of PBDEs in San Francisco Bay aquatic life. PBDEs have also been found in human mothers' milk. Renner (2000) has published a review of the occurrence and potential significance of PBDEs as water pollutants. They are likely present in Sacramento River, San Joaquin River and Delta fish. Studies need to be conducted to determine if PBDEs are present in aquatic life in the Delta and its tributaries. If found, there is need to determine their sources, and develop control programs.

Aquatic Sediment Toxicity. Increasing attention is being given to aquatic sediment water quality impacts. This is causing the California State Water Resources Control Board to develop sediment quality objectives. These objectives focus on determining excessive concentrations of chemical constituents in sediments which affect water quality. Of particular concern are chemicals in the sediments that are toxic to organisms that live within or are associated with the sediments. These organisms can be an important part of the aquatic food web and, therefore, can affect fish and other aquatic life production in a waterbody. Pesticides, heavy metals, organics and nutrients that develop into algae which die and become part of the sediments are common causes of sediment toxicity. The algae cause sediment toxicity through their death and decay in the sediments, which results in the release of ammonia which is highly toxic to aquatic life.

At this time, sediment toxicity due to pesticides is a violation of the CVRWQCB Basin Plan. It appears that sediment toxicity that is caused by non-pesticides is not a violation of the Basin Plan. William Jennings of the Sportfishing Protection Alliance is working with the SWRCB to develop a statewide water quality objective that would make any sediment toxicity a violation of the SWRCB WQO.

The focus of the studies of OP toxicity to aquatic life has been on water column impacts. However, Katznelson (URSGWC 1999) has reported elevated concentrations of diazinon associated with aquatic sediments in urban streams in Alameda County in the San Francisco Bay area. It is not clear at this time whether diazinon found associated with the sediments was attached to sediment particles (sorbed) or found in the interstitial water associated with the sediments.

McCutchan (2000) has reported that organophosphate pesticide pulses are apparently causing adverse impacts on benthic arthropods in the Sacramento-San Joaquin Delta. It is likely that the OP pesticide pulses associated with stormwater runoff have been adverse to benthic organisms. It is also likely that the adverse impacts to benthic organism populations would be transitory, where in a few weeks/months(?) the sediment populations could recover from the toxic pulse caused by pesticide runoff. It is possible that similar situations are occurring in the SJR and its tributaries. This means that pulses of pesticides that are not readily measured by sediment toxicity testing could be responsible for transitory adverse impacts on benthic organism populations. The toxic pulse transitory impacts on benthic organisms could be adverse to fish populations if they occur at a critical time in the life stage of a larval fish population that is dependent on benthic organisms as a source of food.

At this time there is limited information on sediment toxicity in the SJR and its tributaries. As mentioned above, sediment toxicity was found in the city of Stockton Smith Canal Yosemite Lake sediments by Lee et al. (2000). The cause of this toxicity was not determined; however, it could be due to pyrethroid-based pesticides used in urban areas. This sediment toxicity was not found in the sediments halfway between Yosemite Lake and the mouth of Smith Canal or at the mouth of Smith Canal. Some data on sediment toxicity are being developed on agricultural drains and waterbodies dominated by agricultural runoff/discharges as part of the CVRWQCB Ag Waiver water quality monitoring program, where sediment toxicity testing is being required. As discussed below, toxicity is being found in some Central Valley waterbody sediments, which is apparently due to pyrethroid-based pesticides.

Aquatic sediments can also serve as a source of chemicals, such as the organochlorine pesticides, PCBs, mercury, dioxins and furans, which tend to bioaccumulate to excessive levels in edible aquatic life.

Recently, through the efforts of William Jennings of the Sportfishing Protection Alliance, the SWRCB has allocated over $2.5 million to develop sediment quality objectives (SQOs) for the Delta. This is a followup to current SWRCB efforts to develop SQOs for enclosed bays, estuaries and nearshore marine waters. It is likely that in several years, SQOs will be developed that will utilize sediment toxicity, benthic organism assemblages and chemical information to determine if a chemical and/or a group of chemicals in a sediment is adversely impacting sediment quality and the beneficial uses of the waterbody in which the sediment is located. Jones-Lee and Lee (2005) and Lee and Jones-Lee (2004e) have discussed the approach that should be used to incorporate chemical information into an evaluation of sediment quality. They stress the importance of not using total concentrations of chemicals in a cooccurrence-based so-called sediment quality guideline approach to sediment quality evaluation.

A special problem associated with dredged sediment management occurred in the SJR DWSC near the Port of Stockton in 2004, where dredged sediments from the DWSC that had been initially placed in the Roberts Island disposal area were used by DWR to enhance Trapper Slough Levee in the Delta. It was found that these sediments are acid-producing, in which low pH values are developed in oxygen-containing waters in contact with these sediments. The oxygen reacts with ferrous iron and sulfide in the sediments to produce ferric iron and sulfate. Associated with this oxidation is the production of hydrogen ions, leading to low pH. It appears, from the information available, that the pH of the waters associated with runoff from the Trapper Slough Levee was sufficiently low to release heavy metals from the dredged sediments. Therefore, not only are these sediments a source of toxicity due to low pH, but they can also be a source of toxicity due to release of heavy metals, such as copper, cadmium, etc.

The acid-production characteristics of the DWSC sediments near the Port of Stockton have been known for many years, since waters discharged from the Roberts Island dredged sediment disposal area have been found to be of low pH. The CVRWQCB has been requiring the US Army Corps of Engineers/Port of Stockton to add lime to the Roberts Island disposal area in an attempt to neutralize the impacts of acid production. Lee (2004a) has discussed the Trapper Slough Levee situation with respect to DWR's use of Roberts Island-derived DWSC dredged sediments. He has provided guidance on how this issue should be evaluated.

The acid production from DWSC sediments near the Port of Stockton is likely the result of SJR watershed nutrients that develop into algae which are transported to the DWSC, where they die and decompose. As part of the decomposition process, reduced iron and sulfur compounds accumulate in the sediments due to anoxic (oxygen-free) conditions associated with the decay of algae. This type of problem could be expected in the SJR, DWSC and other channels in the

Delta, at locations where the sediments have accumulated oxygen demand associated with algal death and decay.

Heavy Metals. Lee and Jones-Lee (2004a) have reviewed the potential impacts of heavy metals on Delta water quality. Some of the metals of concern in the Delta are derived from the SJR watershed. As discussed above, there is a major water quality problem in the Delta due to mercury. In addition to mercury, selenium is a metal that is potentially causing water quality problems in the Delta due to adverse impacts on certain fish (sturgeon) associated with its bioaccumulation in clams through the Delta food web. Linville et al. (2002) and Schlekat et al. (2000) have reported that particulate selenium can be taken up by clams, which are then consumed by sturgeon.

Luoma (2004), at the California Bay-Delta Authority (CBDA) contaminant stressor workshop, expressed the view that possibly the bioaccumulation of cadmium and nickel in aquatic life in Delta tributaries and the Delta could be adverse to Delta and San Francisco Bay aquatic life. These heavy metals are derived from former mining activities in the Sierras. The current water quality criteria for cadmium and nickel do not consider the potential for food web accumulation of these chemicals and the potential toxicity to host organisms. This is an area that needs study.

Urban street and highway stormwater runoff has been found to be a source of copper, zinc, cadmium and lead at concentrations above the US EPA California Toxics Rule (CTR) water quality criteria. However, Lee and Taylor (2001), as well as others (see review by Lee and Taylor, 2001), have found that the heavy metals in urban area and highway stormwater runoff are in nontoxic forms. While urban area stormwater runoff is toxic to *Ceriodaphnia*, TIEs have shown that the toxicity is due to the organophosphate pesticides diazinon and chlorpyrifos. It is likely that the heavy metals of potential concern in highway and residential street runoff will remain in nontoxic forms in Delta waters and sediments. There is need, however, to determine, if SJR and Delta sediments are toxic, whether this toxicity is due to heavy metals, using appropriate TIE procedures. Information on this area within the Delta could evolve out of the SWRCB's efforts to develop sediment quality objectives for Delta sediments.

Pyrethroid Pesticides. Several years ago the CVRWQCB initiated the Ag Waiver water quality monitoring program. This program has found sediment toxicity that is apparently caused by pyrethroid-based pesticides used on agricultural lands. These types of pesticides are being used as substitutes for the organophosphorus pesticides whose use is being curtailed by the TMDL that is designed to limit the aquatic life toxicity caused by diazinon and chlorpyrifos. Lee (2005a,b) and Lee and Jones-Lee (2005a) have reviewed the issues associated with the use of alternative pesticides, such as pyrethroid-based pesticides, as replacements for the OP pesticides, pointing out that the use of pyrethroid-based pesticides can lead to sediment toxicity. It is now clear that the use of pyrethroid-based pesticides as replacements for the OP pesticides has led to water column aquatic life toxicity during the time of runoff and sediment toxicity following the runoff event. As discussed above, this situation points to the inadequate evaluation of potential pesticide impacts by the US EPA Office of Pesticide Programs as part of registering pesticides. It is likely that the pyrethroid pesticide sediment toxicity will need to be controlled through the CVRWQCB WQO for sediment toxicity associated with pesticides.

Oros and Werner (2005) have developed a discussion that summarizes

> *"… current knowledge of the potential role of pyrethroid insecticides in the pelagic organism decline in the upper San Francisco estuary (Suisun Bay and the Sacramento-San Joaquin Delta). Included in this white paper is a discussion on pyrethroid use patterns, transport and fate, regional monitoring results, uses of special concern such as orchard dormant season and urban area applications, analytical testing methods, and toxicity to critical species focusing on aqueous exposure since the concern here is pelagic species. Information and data gaps are identified and recommendations for immediate and future work on pyrethroids are made."*

Their discussion focuses on water column impacts, where they conclude that there is insufficient information to determine if the use of pyrethroid-based pesticides is a cause of the pelagic organism decline (POD) that is being experienced in the Delta. While, as discussed by Lee (2005a,b), there is a potential for water column toxicity during a runoff event to some forms of zooplankton and fish in waters near areas where pyrethroid-based pesticides are applied, the greatest impact will likely be to benthic organisms associated with sediment toxicity caused by pyrethroids.

Weston and his associates have published several papers (Weston et al.2004, 2005; You et al. 2004; Amweg et al. 2005; Amweg et al. 2006a) on various aspects of their studies on the occurrence of pyrethroid-based aquatic sediment *Hyalella* toxicity. Recently, Amweg et al. (2006b) made a presentation to the Sacramento River Watershed Program summarizing their work on pesticide toxicity in rural and urban sediments. This toxicity is widespread and, apparently, due to pyrethroid-based pesticides. A review of their work, as well as that of others, on pyrethroid-based aquatic life toxicity has been recently published by Raloff (2006).

Weston and his associates report that many aquatic sediments in the Central Valley exhibit toxicity to *Hyalella*. It is evident from their and other studies that there are a variety of factors that influence whether a sediment is toxic due to the use of pyrethroid-based pesticides in nearby areas. Overall, it is concluded that the use of pyrethroid-based pesticides could be factor adversely impacting aquatic life populations in the Central Valley and the Delta.

Total Organic Carbon (TOC). Another potential TMDL that could develop for the San Joaquin River and its watershed is based on the concentrations of total organic carbon (TOC) that are discharged by the San Joaquin River to the Delta. CALFED Science Program has developed a review on the Delta TOC issues that is available at
http://science.calwater.ca.gov/pdf/water_quality_carbon.pdf.

Excessive TOC causes water utilities that utilize Delta water as a raw water source to have to develop more expensive water treatment processes to control the formation of trihalomethanes (THMs) and other disinfection byproducts. Trihalomethanes are chloroform-like compounds that develop as part of disinfection of water supplies to control pathogens. TOC interacts with chlorine and some other disinfectants to form disinfection byproducts. Several of these byproducts are regulated as carcinogens in domestic water supplies.

The SJR and Delta waters contain excessive total organic carbon compared to regulatory limits that the US EPA is imposing on water utilities to minimize trihalomethane formation as part of disinfection of the water supply. While the problems of excessive TOC in Delta waters with respect to the use of these waters for domestic water supply are well known, the regulation of TOC has not occurred because the CVRWQCB and the US EPA do not have water quality criteria/standards/objectives for TOC. If these objectives are developed, the San Joaquin River and the Delta would likely be listed as 303(d) impaired due to excessive TOC. This listing could require that a TMDL be developed to potentially control TOC discharges from wetlands, including the public wildlife refuges, private gun clubs, irrigated agriculture, domestic wastewaters, urban stormwater runoff and other sources.

Of particular concern is drainage from wetlands areas, such as the wildlife refuges and private gun clubs in the SJR watershed, which can discharge large amounts of TOC. As discussed by Lee and Jones-Lee (2003a), at times the discharges from these areas are highly colored due to the presence of large amounts of TOC. Hall and Lee (1974) found a high correlation between color and TOC in water. The color discharged by the wetlands areas in the SJR watershed can affect algal photosynthesis through reduced light penetration and, as a result, can affect the magnitude of the low-DO problem in the DWSC, through reduced algal growth in the SJR channel and reduced algal photosynthesis in the DWSC.

An area of special concern with respect to TOC in the South Delta is the situation that developed in connection with the city of Tracy's attempts to develop a groundwater recharge project based on the injection of Delta Mendota Canal (DMC) water as a raw water source for its domestic water supply. The DMC water is derived from the South Delta as part of the USBR CVP project. Tracy proposed that the CVRWQCB allow DMC water that is treated to meet minimum US EPA drinking water standards (MCLs) to be injected into the groundwater aquifer underlying the city. The CVRWQCB (2005c) developed an aquifer storage recovery (ASR) report that discusses the water quality issues that the Board staff feel need to be considered in developing an ASR project.

G. F. Lee has been involved in the water quality aspects of enhanced groundwater recharge projects for over 15 years. Lee and Jones-Lee (2005h) provided a review of the water quality issues that need to be considered in ASR groundwater recharge projects. They point out that waters that meet US EPA drinking water standards are not necessarily suitable for groundwater recharge in an ASR project. Of particular concern is the dissolved organic carbon (DOC) present in the treated domestic water supplies. Waters with a high DOC such as the treated DMC waters can cause major changes in the aquifer characteristics that can lead to significant aquifer quality and water quality problems.

An issue that needs to be considered in developing a regulatory program for TOC is that some forms of TOC are labile – i.,e., do not persist from their source to the water utility intake for sufficient periods of time to cause water quality problems for water utilities. Examples of labile TOC are soluble BOD and algae. When algae die they decompose almost completely and do not contribute to the persistent TOC. As discussed by Lee and Jones-Lee (2003b), it is important to focus TOC control from various sources in the SJR watershed on those sources of TOC that are refractory (persistent) and thereby contribute to TOC at a water utility intake and impact THM formation.

The Delta serves as a domestic water supply source for over 22 million people in California. As such, there is considerable interest on the part of water utilities, regulatory agencies and the public in maintaining high water quality in the Delta with respect to its use for domestic water supply. Since the SJR watershed is one of the major sources of pollutants for the Delta that could affect the use of Delta waters for domestic water supply purposes, there is considerable interest in developing pollutant control programs in the SJR watershed that impact the use of Delta waters for domestic water supply. Of particular concern is the potential control of TOC in the SJR watershed.

The US Congress adopted the Safe Drinking Water Act in 1986. This Act is administered by the US EPA Office of Ground Water and Drinking Water (OGWDW). It provides minimum national regulations for protection of the quality of treated domestic water. Information on the Safe Drinking Water Act is available at http://www.epa.gov/safewater/. A key provision of this Act is Source Water Quality Protection. The US EPA (2005c) website provides guidance on this program. According to this website,

> *"Source water is untreated water from streams, rivers, lakes, or underground aquifers which is used to supply private wells and public drinking water.*
> *Preventing drinking water contamination at the source makes sense:*
> - *good public health sense;*
> - *good economic sense; and*
> - *good environmental sense.*
>
> *Preventing contamination of drinking water supplies is an important mission within EPA's Office of Ground Water and Drinking Water."*

In accordance with the Source Water Quality Protection provisions of the Safe Drinking Water Act, water utilities have conducted a source water quality protection assessment which identifies those features/activities in their domestic water supply watershed that could impact domestic water supply water quality. As part of developing a domestic water supply source water quality protection program, the CVRWQCB (2005d) is developing a Drinking Water Policy. According to the CVRWQCB website,

> *"A multi-year effort is currently underway to develop a drinking water policy for surface waters in the Central Valley. As water flows out of the sierra foothills and into the valley, pollutants from a variety of urban, industrial, agricultural, and natural sources affect the quality of water, which leads to drinking water treatment challenges and potential public health concerns. Current policies and plans lack water quality objectives for several known drinking water constituents of concern, such as disinfection by-product precursors and pathogens, and do not include implementation strategies to provide effective source water protection. The exact types of regulatory requirements that will be included in the drinking water policy have not been determined but the goal is to develop a policy that provides clear guidance to ensure consistent source water protection."*

The proposed approach for developing this policy was reviewed by the CVRWQCB (2005d). Lee (2004b) has had extensive experience in domestic water supply water quality for over 50 years. Based on this experience and the characteristics of the Delta waters, Lee (2004c) has provided comments on the CVRWQCB proposed Drinking Water Policy. As he discussed, the key to developing an appropriate drinking water policy is developing an approach to assessing the balance between controlling TOC at the source, versus providing treatment for TOC at the water treatment facility.

The California Department of Water Resources, Office of Water Quality provides a "Weekly Water Quality Report" that provides via email detailed information on several drinking water quality parameters such as TOC, TDS, etc., for the SJR at Vernalis, Sacramento River and each of the points of project exports (Tracy-CVP, Banks-SWP). This report is available by contacting Rob DuVall by email at rduvall@water.ca.gov, or by phone at (916) 651-9680.

While the Safe Drinking Water Act establishes the quality of raw (untreated) water at a water supply intake, it does not provide the authority to require that sources of pollutants such as TOC in agricultural and urban stormwater runoff be controlled. The regulation of TOC at a source requires that the CVRWQCB develop a WQO for TOC. The development of a TOC WQO is one of objectives of the CVRWQCB staff as part of implementing the Drinking Water Policy. The adoption of this policy, with a TOC WQO, could have a significant impact on agricultural and urban interests and wetlands managers in the SJR watershed, through their having to develop TOC control programs. As discussed by Lee and Jones-Lee (2002c), the control of TOC in agricultural and urban stormwater runoff and domestic and industrial/agricultural wastewaters will be difficult and expensive.

Suspended Sediment. Some agricultural lands, especially on the west side of the San Joaquin River, are experiencing significant erosion. This leads to westside tributaries and the SJR being highly turbid due to suspended sediment. This erosion also leads to excessive shoaling/siltation (sediment accumulation) within the Delta. At this time the SJR and its tributaries are not listed as CWA 303(d) impaired because of excessive suspended sediment/turbidity. It is possible that a 303(d) listing and TMDL could be developed to control the excessive turbidity/sediment in the San Joaquin River and Delta. Controlling the excessive erosion that is occurring from some agricultural lands in the SJR watershed will have an impact on a number of other water quality problems. Lee and Jones-Lee (2003a) have indicated that reduced turbidity could result in increased algal growth in the SJR and the DWSC, since the current algal growth rates are light-limited.

Some agricultural interests in the SJR westside watershed that are experiencing high erosion rates are using chemicals (polymers) to reduce the rate of erosion from their lands. It is important that the chemicals used for erosion control be adequately evaluated to determine whether there are any adverse water quality impacts through the use of these chemicals. Lee and Jones-Lee (2004f) have provided a discussion of the approach that should be used to evaluate chemicals that are added to soils as dust suppressants. Their recommended approach should be used to evaluate the chemicals used to control erosion from agricultural and urban areas.

Lee and Jones-Lee (2002b, 2005b) have discussed the need for the CVRWQCB to review the WQO for turbidity and suspended sediment to provide guidance on how to develop the information needed to assess excessive concentrations in a waterbody. Failure to provide this guidance will inhibit the development of programs to control erosion from agricultural and urban areas.

Herbicides. It has been found that at times SJR and Delta water is toxic to algae. This toxicity reduces the growth of algae. Diuron, a widely used agricultural and roadside herbicide, has been found by Miller et al. (2002, 2005) to be a cause of at least some of this toxicity. This situation could lead to a 303(d) listing that would result in the development of a TMDL for the control of herbicides such as diuron that are causing toxicity to algae. While there is excessive algal growth in the SJR, the northern and central parts of the Delta are recognized as algal deficient compared to what is needed to develop a good base for the aquatic food web and fish production. Algal toxicity in these areas, which are fed by the Sacramento River, could be adverse to the aquatic food web. The SJR and Southern Delta have excessive growths of algae, which, as discussed above under nutrients, are significantly adverse to SJR and South Delta water quality.

One of the potential consequences of herbicide toxicity to algae in the SJR is the possibility that pulses of herbicides that are toxic to algae lead to pulses of reduced algal concentrations that develop in the SJR and become part of the oxygen demand load to the DWSC. The pulsing of algal concentrations in the SJR will make the control of the low-DO problem in the SJR DWSC more difficult and expensive, since it will require a more comprehensive monitoring program of the oxygen demand loads to the DWSC to keep DO concentrations above the WQO. Lee (2003c) has provided a discussion of this issue, where in addition to discussing the potential adverse effects of herbicide discharges to the SJR, he also mentions the potential impacts of pesticide/insecticide discharges to the SJR that are adverse to zooplankton in the SJR. Dahlgren (2005) has found that there is intensive zooplankton grazing of algae in the SJR, which impacts algal concentrations. Reduced zooplankton, through pesticide/insecticide toxicity, would lead to increased algal concentrations, and thereby increase the oxygen demand load to the DWSC. There is concern that insecticide pulses that impact zooplankton grazing in the SJR will make control of the oxygen demand loads to the DWSC and the use of aeration to control DO depletion below the WQO more difficult and expensive.

Siemering (2005) presented a discussion of the potential impacts of the use of aquatic herbicides on the POD. This white paper presents information that was gathered by the Aquatic Pesticide Monitoring Program (APMP), funded by the California State Water Resources Control Board. The APMP conducted research on aquatic pesticides, including insecticides and herbicides. Siemering (2005) discusses *"… two issues of special concern— (1) the use of unregulated adjuvants and (2) adjuvant and herbicide induced endocrine disruption."* He indicates,

> *"… that the APMP evaluations suggested that potential impacts of aquatic herbicides on pelagic organisms in the Delta are not likely to be significant for most herbicides in use. Worst-case-scenario monitoring and studies conducted over three years showed little indication of short-term and no long-term toxicity of herbicide applications.*

Surfactants and other adjuvants applied with aquatic herbicides are more likely to contribute to pelagic organism declines in the Delta. The risk quotient calculations resulted in several LOC exceedances for NPE surfactants. Few chemical monitoring or toxicity data are available for the vast majority of the adjuvant chemicals in use. NPE surfactants and 2,4-D DMA were shown to cause vitellogenin induction in rainbow trout and hence could contribute to pelagic organism declines. However, it is important to note that NPEs are ubiquitous in industrial, household and agricultural chemicals, and the relative amount contributed by aquatic herbicide applications is comparatively small. Similarly, terrestrial applications of 2,4-D DMA dwarf the amounts used in aquatic applications. The effects of terrestrially applied herbicides, through runoff and drift, on the aquatic system have not been studied.

While the APMP monitored aquatic herbicide applications at a number of sites for three years, the total amount of data gathered was small, and indicated that additional monitoring is necessary. The current NPDES permit-required monitoring has limited value for addressing continued scientific questions. In conclusion, while there is no compelling linkage between what we know about the pelagic organism decline and aquatic herbicide use, there are several outstanding questions that merit further evaluation."

Seimering (2005) recommends,

"1. Use existing datasets from large monitoring programs to conduct additional risk-quotient calculations. These calculations would provide greater clarification of the additional information needed to make a complete risk assessment of aquatic herbicides. In particular, the Boating and Waterways aquatic herbicide use data should be combined with some screening fate and transport modeling to determine if the risk quotient levels are sufficient to warrant further sampling.
2. Conduct additional endocrine-disruption research on active ingredient herbicides and adjuvant chemicals.
3. Conduct toxicity testing of adjuvant chemicals.
4. Consider the combined impacts of aquatic and terrestrial applications of target herbicides. Frequently, the same herbicide is applied in far greater quantities for terrestrial applications, and it is likely that both applications are impacting upper Delta water quality.
5. Conduct risk assessments of new herbicides (e.g., imazapyr) as they receive their aquatic- use label .
6. Advocate for PUR data submission procedures that clearly identify aquatic applications and differentiates them from terrestrial applications."

There is increasing concern that combinations of insecticides and herbicides lead to significant adverse impacts to aquatic life that do not occur at concentrations of these chemicals when they are present alone. Lydy (2004) has reported that there is a synergistic (greater than additive) toxicity that develops between some of the commonly used herbicides and the OP pesticides. This is an area of increased concern, since it is not being adequately addressed in current regulatory evaluations of the potential impacts of combinations of types of pesticides (insecticides and herbicides) that are permitted for use on agricultural lands and in urban areas.

Bromide. Paulson and Dow (2005) and Brown and Caldwell (2005) have submitted reports to the California Bay-Delta Authority Drinking Water Subcommittee that discuss Delta drinking water quality problems. It was reported that bromide concentrations may be increasing in the San Joaquin River. This is of concern since bromide is detrimental to the use of Delta water for domestic water supply through forming additional disinfection byproducts that are a threat to the health of those who use the water as a domestic water supply. There is need to develop a comprehensive monitoring program of SJR water at Vernalis to include bromide measurements.

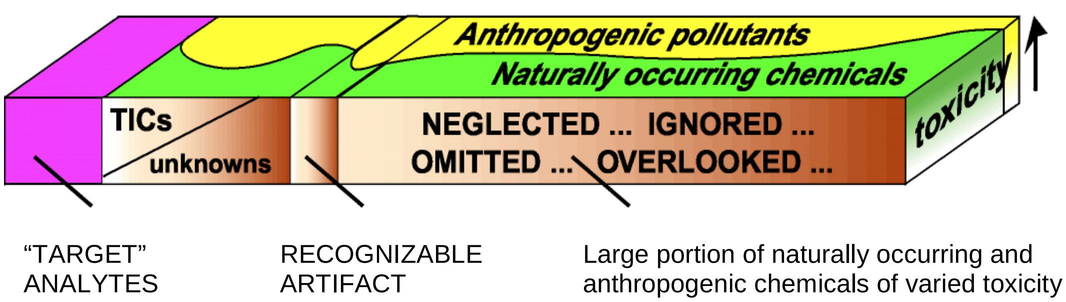
Unrecognized Pollutants

Daughton (2002, 2004) of the US EPA has discussed the inadequacies of the current approach for monitoring water quality compared to the vast arena of chemicals discharged to the environment that are a potential threat to water quality. The inadequacy of current regulatory programs in defining hazardous chemicals has been discussed by Daughton in his presentation, "Overview of Science Involved with Pharmaceuticals," that was made in August 2005, at a Las Vegas workshop. Daughton stated in one of his PowerPoint slides,

> *"Further Truisms Regarding Environmental Monitoring*
> - *What one finds usually depends on what one aims to search for.*
> - *Only those compounds targeted for monitoring have the potential for being identified and quantified.*
> - *Those compounds not targeted will elude detection.*
> - *The spectrum of pollutants identified in a sample represent but a portion of those present and are of unknown overall risk significance."*

He presented a diagram of this situation, which is presented in Figure 3.

Figure 3
Chemical Analysis Output for a Typical Environmental Sample



This figure is from the following web page:
Daughton, C. C., "The Critical Role of Analytical Chemistry," July (2002)
http://www.epa.gov/nerlesd1/chemistry/pharma/critical.htm

Daughton's presentation at the Las Vegas workshop is available from
http://es.epa.gov/ncer/publications/meetings/8-23-2005/Daughton_0915_d1.pdf.

While this presentation focused on pharmaceuticals, as Daughton has discussed in other presentations and his writings, it is applicable to the full arena of hazardous chemicals that are not adequately identified, monitored and regulated.

Lee (2005h) and Lee and Jones-Lee (2005i) have provided additional information on this issue. As the scope of water quality monitoring programs is expanded to better characterize water quality impairment, additional pollutants will be found in the SJR that will require TMDLs to be developed to control the input of the newly found pollutants. Of particular concern is the presence of pharmaceuticals and personal care products (PPCPs) discharged by municipalities in their domestic wastewaters to the SJR and its tributaries and to the Delta, such as from Stockton and Tracy, and to the Sacramento River by the Sacramento Regional Sanitation District and by West Sacramento. Lee (2005h) and Lee and Jones-Lee (2005i) have recently summarized some of the presentations on pharmaceuticals in wastewaters that were presented at the US EPA (2005d) workshop.

Domestic wastewater discharges contain a wide variety of pharmaceuticals that are excreted by those who are taking the pharmaceuticals and/or are discharged as wastes in household wastewaters. Lee and Jones-Lee (2005j) have discussed the need to begin to monitor domestic and agricultural wastewaters and runoff for pharmaceuticals in the Delta and its tributaries near areas where they are likely discharged. This monitoring should include studies to determine whether the aquatic life populations in these areas are adversely impacted by constituents in the discharges.

Lee and Jones-Lee's (2004a) review of Delta water quality issues included discussion of some of the University of California faculty studies on sublethal toxicity to aquatic life. The following is from that discussion.

At a California Bay-Delta Authority meeting in June 2003, S. Anderson of the University of California, Davis, Bodega Marine Laboratory, presented a discussion (see Anderson, 2003) of some of her graduate students and her work on examining fish biomarker responses in the San Joaquin River and Orestimba Creek, a westside tributary of the SJR. She reported that caged fish in Orestimba Creek (which receives considerable runoff/discharges from irrigated agriculture) showed no cholinesterase inhibition during a February 2000-2001 stormwater runoff event when the concentrations of the OP pesticides diazinon and chlorpyrifos would be expected to be at their greatest. The measured concentrations of OP pesticides during this runoff event were in the low tens of nanograms per liter. These concentrations were below those that are known to be toxic to *Ceriodaphnia* and well below those that are known to be toxic to fish.

Anderson (Whitehead et al., 2003) also made measurements of DNA strand breakage and Ames test mutations in the caged fish. There was evidence for positive responses in both tests, indicating that there may have been chemicals in the water that have the potential to be adverse to aquatic life. This type of testing is typically considered measurements of biomarkers – i.e., less than whole organism response to exposure to chemicals. It has been known since the 1960s that fish, under various exposure conditions, show biomarker responses to a variety of chemicals that have been investigated.

In 1996, the American Society for Testing and Materials held a biomarker symposium, at which the experts in the field presented the information they had on biomarkers in fish and other aquatic life in response to various types of chemicals or environmental settings. Bengston and Henshel (1996) edited the symposium proceedings. The overall conclusion from those at the symposium was that a properly conducted test of a biomarker response does indicate an organism exposure to a chemical or group of chemicals. In 1996 and, for that matter, today, there is still little understanding of what a biomarker response in fish means to fish populations. Since there is limited funding for work on this topic, the deficiency in understanding biomarker responses with respect to whole organism responses will likely prevail for a considerable period of time.

Werner and Eder (2003) conducted studies on the sublethal effects of chlorpyrifos and esfenvalerate on juvenile Chinook salmon, in which they measured acetylcholine esterase inhibition, stress proteins (indicators of cellular protein damage) and cytokine expression (immune system response). Four-month-old juvenile Chinook salmon were exposed for four days to chlorpyrifos and esfenvalerate, ranging in concentration for chlorpyrifos from 1.2 to 81 µg/L, and for esfenvalerate from 0.01 to 1 µg/L. They stated that,

> *"Exposure to sublethal concentrations of commonly used insecticides resulted in long-term alterations of cellular components of the immune system, nervous system (AChE inhibition), and the stress response."*

These responses are indicative of cellular alterations, which can be energetically costly to the organism. They also noted that the sensitivity of fish repeatedly exposed over the winter may be increased due to the increased exposure (Eder et al., 2003a,b; 2004).

Werner et al. (2003b) and Wheelock, et al. (2005) have provided additional information on their work on sublethal effects of chemicals on aquatic life, focusing on impacts on cellular stress proteins in the freshwater fish medaka and examining the histopathology of Asian clams in the Delta. Further work is underway on these issues as part of the POD studies.

***Microcyctis* Toxicity Issues**

During the winter 2005 the Interagency Ecological Program (IEP) and DFG noted that there have been dramatic decreases in several aquatic organism populations in the Delta waters. This has led to several studies on the potential causes of pelagic organism decline (POD). One of the areas of concern in the POD is toxicity to aquatic life. Excessive growths of some bluegreen algae, such as *Microcystis*, are known to excrete toxins which can be adverse to aquatic life, livestock, domestic animals and waterfowl. Based on the work of Lehman et al. (2005), there is concern that the toxins excreted by *Microcystis* may be responsible, at least in part, for the severe decline in pelagic organisms (fish and zooplankton) that is occurring in the Delta. Lehman is conducting studies on the occurrence and toxicity of *Microcystis* blooms in the Delta as part of the DWR pelagic organism decline studies.

Lehman (2005) developed a white paper on the potential for *Microcystis* blooms to be responsible for the POD. She states,

> *"*Microcystis *was initially observed in bloom forming surface scums in the late 1990's when it was localized. Currently the blooms extend over wide regions of the Delta, from salinities ranging 0.1-18 ppt. It was found from Suisun Bay to the freshwater habitat of upstream rivers (Lehman 2005). This presence and expanding distribution is likely having an impact to the pelagic foodweb."*

Lehman stated,

> *"Toxic strains of* Microcystis, Anabaena*, and* Oscillatoria *produce microcystins (a class of heptacyclic peptide toxins), which are classified according to their target organs. Microcystins are hepatotoxins, as they mainly injure the liver, though tumor formation is also reported (Carmichael, 1996). Microcystins inhibit protein phosphatases 1 and 2A, causing liver damage in a wide variety of animals, and negatively affecting certain plants, algae, and protozoa."*

She concludes,

> *"Since* Microcystis *is on the rise in the Delta, it must be considered as a potential factor that is contributing to the observed decline in planktonic organisms."*

She recommends further study of the potential for *Microcystis* blooms to contribute to the POD.

Unreported studies by Dahlgren on the characteristics of the Sacramento River as it enters the Delta have shown that the river water is low in nutrients and planktonic algal chlorophyll. As discussed by Lee and Jones-Lee (2004b), the CVP and SWP's drawing of large amounts of Sacramento River water through the Central Delta to the South Delta brings low-nutrient water into parts of the northern and Central Delta. This low-nutrient water reduces the primary production of algae in parts of the northern and Central Delta. This situation accounts for the reduced primary productivity of the Delta that has been found by Jassby et al. (2003). This reduced primary production in the Central Delta could be part of the pelagic organism decline that the Delta is currently experiencing.

Inadequate Water Quality Monitoring

The information available on the water quality problems in the SJR and the Delta is based on limited water quality monitoring data. Lee and Jones-Lee (2004a) have reviewed the current water quality problems in the Delta and its tributaries, including the San Joaquin River, where they have discussed the need for a significantly improved water quality monitoring program to better define the full range of the water quality impacts of pollutants in the San Joaquin River and the Delta. The development of this type of water quality monitoring program could readily reveal a number of additional water quality impairments that would lead to TMDLs to control the sources. An example of the grossly inadequate water quality monitoring is the finding of PBDEs as widespread pollutants of aquatic life in the US and Europe.

Another example of a widespread pollutant that has been in the environment for many decades is perchlorate. Perchlorate has been found to be a significant human health threat. Lee and Jones-Lee (2005i) have discussed that, while the potential impact of perchlorate on human health has been known for many years, its occurrence as a widespread water pollutant was not recognized because it was not included in water quality monitoring programs.

Need for Water Rights Water Quality Monitoring. One of the major problems that has existed in how the SWRCB regulates water quality is that, for years, the SWRCB, as part of Water Rights decisions, has not been requiring adequate independent monitoring of the impacts of water diversions on water quality. Lee and Jones-Lee (2005k), in testimony to the SWRCB, have discussed the need to significantly expand independent water quality monitoring associated with all Water Rights decisions that could impact water quality. As discussed by Lee and Jones-Lee (2004a), the SWRCB's reliance on the Interagency Ecological Program's (IEP) monitoring of the impacts of D-1641 diversion/exports has proven to be inadequate in developing the information needed to determine how the CVP and SWP exports impact Delta water quality. This has resulted in a current "crash" program of expanded water quality monitoring as part of the POD-caused studies. Lee and Jones-Lee (2005l) have discussed the potential problems of trying to conduct crash monitoring programs in order to determine the role of chemical contaminants in the POD.

Other SJR Water Quality Data Sources

There are several other sources of SJR water quality data. A summary is presented below.

SWAMP. Several years ago the SWRCB belatedly initiated a Surface Water Ambient Monitoring Program (SWAMP). The CVRWQCB has been using SWAMP funds to collect data on the water quality characteristics of the SJR and some of its tributaries. According to information provided on the CVRWQCB website devoted to SWAMP,

> *"Main Stem of the San Joaquin River: The San Joaquin River serves as the drainage channel for the entire 16,000 square mile basin and discharges into the Sacramento-San Joaquin Delta. Eight sites, each one downstream of a major inflow to the lower river, will be monitored weekly, monthly, or quarterly (depending on the constituent) to determine overall water quality and potential source of the constituent. In addition to selenium, salt, and boron, evaluations may be conducted for dissolved oxygen, pH, temperature, hardness, general minerals, trace elements, nutrients, pesticides, total suspended solids, total organic carbon, and water column toxicity."*

P. Crader (pers. comm., 2005) of the CVRWQCB staff has provided the following information on the CVRWQCB SWAMP for the SJR.

> *"The San Joaquin River SWAMP began in October, 2000 and was built on the existing Subsurface Agricultural Drainage Monitoring Program, which dates back to 1985. The data from both programs is located on our website at the following URLs:*
>
> *(1996-present),*
> *http://www.waterboards.ca.gov/centralvalley/programs/agunit/swamp/index.html*
>
> *(1985-1995),*
> *http://www.waterboards.ca.gov/centralvalley/programs/agunit/load/10yrload.htm*

The SWAMP data is current through June, 2005. A review of the data will reveal that the extent of the San Joaquin River SWAMP varied from year to year, based on available funding.

As of November 2005, San Joaquin River SWAMP monitoring has been limited to analyses for TOC, TSS, E. coli*, and bioassay on the mainstem San Joaquin River until our remaining funds expire. We are also continuing to maintain our portion of the Grassland Bypass Compliance Monitoring Program (weekly monitoring along the San Joaquin River, Mud Slough (north) and Salt Slough for salt, boron, and selenium).*

In addition to SWAMP, the San Joaquin River TMDL Unit has just started some limited monitoring in Stockton area sloughs for DO, BOD, nutrients, and pathogens (Jennifer Heyd is the point of contact), and has also conducted some limited pesticide monitoring (Diane Beaulaurier is the point of contact).

The agricultural coalitions have also begun their monitoring in this area (Margie Lopez-Read is the point of contact)."

At this time the SWRCB is conducting a review of SWAMP. This review includes appointing the Scientific Planning and Review Committee. This committee (SPARC 2005) issued a preliminary report of its findings. In connection with this review, Lee and Jones-Lee (2005j) have discussed the need to greatly expand SWAMP to provide detailed coverage of the SJR and the Delta, as well as to become proactive in searching for unrecognized pollutants. The lack of a comprehensive water quality monitoring program in the Delta has been related to the pelagic organism (fish and zooplankton) decline that has occurred in the Delta during the past three years. Lee and Jones-Lee (2005l) have discussed the issues that need to be evaluated relative to the role of pollutants in the Delta that could play a role in the POD.

DPR. The California Department of Pesticide Regulation (DPR) conducts the "DPR Surface Water Protection Program," through which pesticide-related water quality monitoring is conducted in the SJR watershed. Information on this program is available at http://www.cdpr.ca.gov/docs/sw/.

USGS. The US Geological Survey (USGS) has been conducting the National Water Quality Assessment Program (NAWQA) that has included studies in the mid-1990s and early 2000s that produced data on nutrients, pesticides, and other parameters in the SJR watershed. Information on these studies is available at http://search.yahoo.com/bin/search?p=usgs%20San%20Joaquin%20River.

Blocking of Chinook Salmon Homing

Lee and Jones-Lee (2003c) have reviewed issues relative to blocking of Chinook salmon homing through the DWSC to reach the SJR eastside Sierra rivers for spawning. In addition to low DO being a potential factor in blocking fall run Chinook salmon homing, there is also concern about elevated temperature blocking Chinook salmon migration through the DWSC. The temperature of the SJR and DWSC during late summer and part of the fall has been sufficiently high at times to potentially block Chinook salmon homing through the DWSC and up the SJR.

Another factor that potentially impacts Chinook salmon homing is that the CVP and SWP export pumping of South Delta water draws all SJR water into the South Delta via Head of Old River or to the middle Delta through Turner Cut and subsequently to the South Delta by the export pumping. Lee and Jones-Lee (2003c) have reviewed how the exporting of South Delta water by the CVP and SWP prevents all Chinook salmon home water chemical signal to the SJR eastside river spawning areas from reaching the northwestern Delta and San Francisco Bay during the summer and fall. Studies have shown that the Chinook salmon that reproduce in the Central Valley rivers show high levels of "straying" from their home streams for spawning. This straying could impact spawning success through impacting optimum spawning timing. The role of the loss of home stream water signal in the upper Delta during the summer and fall in contributing to this straying is unknown. Studies on salmonids' homing in other areas have shown that some chemicals such as pesticides can impact the olfactory sensitivity of fish in locating their home stream water.

Role of SJR-Derived Pollutants on POD

In the spring of 2005 it was noted by the Interagency Ecological Program that the trawl data for parts of the Delta showed unexpected declines in several fish species. This led IEP, DFG, DWR and others to organize a crash monitoring program for the summer 2005 to gather data that could provide inference on the pelagic organism decline. Armor et al. (2005) released a draft report for review at a November 2005 meeting to discuss the current understanding of the factors potentially influencing the POD. California Bay-Delta Authority (CBDA) organized a November 2005 public meeting where various summer 2005 POD investigators summarized the results of the past studies. CALFED/CBDA Science Program organized an external review panel of experts to independently review the POD studies results. This panel (POD Review Panel, 2005) released a report, "San Francisco Estuary Sacramento-San Joaquin Delta Interagency Ecological Program on Pelagic Organism Decline," in late December 2005 that presented their initial findings.

The Executive Summary and the sections of the panel report concerned with pollutant water quality issues are presented in Appendix A. This panel reported several of the same issues pertinent to assessing the water quality impacts of known and unrecognized pollutants as Lee and Jones-Lee (2004a, 2005l). The grossly inadequate water quality monitoring/evaluation programs are one of the most significant deficiencies in the current IEP, DWR, USBR, SWRCB and CVRWQCB management of water quality issues in the Delta. The panel also noted that there can readily be sublethal impacts on aquatic life that are not recognized in Delta waters by the current water quality monitoring program. The discussion of the POD issues by the POD expert panel for the Delta also applies to the SJR and its tributaries with respect to inadequate understanding of the impacts of chemicals on aquatic life. To the extent that chemicals are responsible for the POD, the SJR is likely a source of pollutants that are contributing to the POD.

In connection with the development of information on the POD, the IEP worked with several individuals to develop "white papers" in the summer and fall 2005 that discuss the current information on the potential relationship between a particular chemical and the POD. These white papers are available from the CALFED website at
http://science.calwater.ca.gov/workshop/workshop_pod.shtml

The results of these white papers have been discussed above in the section of this report devoted to the chemical of interest.

Impact of Friant Dam Water Releases

The Karlton (2004) court order states that the Department of Interior's failure to release sufficient water from Friant Dam to keep historic salmon fisheries in good condition violates California Fish and Game Code §5937. Judge Karlton established a February 2006 date for a hearing to consider the "remedy" for this violation, including the flows needed to restore the upper SJR fisheries and bring the operation of Friant Dam into compliance with the law. During the summer and early fall of most years, the SJR at the confluence with the Merced River largely consists of irrigation return (tailwater) flow. This results in the water in the SJR being of poor quality, with several known water quality objective (WQO) violations.

Since the magnitude of the corrective actions that will be needed to address these water quality problems will be dependent on the flow of the SJR, the releases of water from Friant Dam to restore fisheries will have ancillary effects on these water quality issues. Without increased flows from Friant Dam, a number of costly and arguably extreme control measures will be required to meet current and likely future WQOs. For the urban and agricultural interests affected by these measures, releases from Friant will be beneficial by helping to provide for less onerous pollutant control programs.

A key issue that will need to be addressed is the need, through permit conditions and/or other Water Rights mechanisms, for the Bureau of Reclamation to ensure that any new releases from Friant Dam to the SJR for the purpose of meeting instream flow needs for fisheries will be allowed to persist (i.e., not be diverted) throughout the SJR to at least Turner Cut in the Stockton Deep Water Ship Channel.

In accordance with Clean Water Act requirements, exceedance of a WQO means that action must be taken to eliminate the WQO violation. Since the quality of water in Millerton Lake is high, release of water from Friant Dam to the SJR channel that is allowed to pass all the way to the Delta and SJR Deep Water Ship Channel will dilute the concentrations of the pollutants in SJR water that are causing WQO violations. Reductions in the concentrations of pollutants by Friant releases to the SJR channel will reduce the cost of pollutant control programs that public agencies (including the USBR), municipalities and agricultural interests will have to fund to comply with Clean Water Act requirements. This is one of the substantial benefits of restoring releases of Friant Dam water to the SJR.

Overall Assessment

The water quality in the SJR in the Central Valley floor is significantly degraded due to runoff/discharges from irrigated agriculture, other agricultural activities (such as dairies and feed lots), municipalities and other sources. Of greatest concern are nutrients (nitrogen and phosphorus compounds), pesticides/insecticides, herbicides, heavy metals, suspended solids, PCBs, pathogens, and TOC. In addition there is aquatic life toxicity of unknown cause. These pollutants and conditions such as water diversions cause adverse impacts to aquatic life; low DO in channels; excessive bioaccumulation of organochlorine legacy pesticides, PCBs, dioxins and mercury in fish and other aquatic life; threat of disease though contact recreation; development of carcinogens in disinfected drinking water; adverse impacts on irrigated agriculture through excessive salinity; blocking of Chinook salmon homing for spawning; turbid water and sediment accumulation; excessive aquatic weed growths; toxicity to algae; adverse impacts on the recharge of waters as part of enhanced groundwater recharge; and other yet to be identified impacts. Further, pollutants derived from the SJR could be contributing to the pelagic organism decline that has been found in the Delta.

Some of the chemicals that are adversely impacting water quality in the SJR and Delta have been listed by the CVRWQCB/SWRCB/USEPA as a cause of CWA 303(d) impairments that will require the development of TMDLs to control pollutant discharges. Insufficient funds have been made available to the regulatory agencies to develop the information needed for the CVRWQCB to begin to work on all the pollutants/waterbodies for which TMDLs have been scheduled. Further, there are a number of other water quality problems (impairments of beneficial uses) in the SJR, its tributaries, and the Delta that are known but have not yet been designated as CWA 303(d) impaired waterbodies for which there is need to initiate the TMDL process. The water pollution control programs in the Central Valley, like other programs in other locations, are grossly underfunded compared to the magnitude of the known water quality problems.

Many of the known and yet to be recognized water quality problems are impacted by SWRCB Water Rights approved water diversions in the SJR watershed, SJR and the Delta, which impact the magnitude and location of the water quality impacts of pollutants. There has been no requirement for the holders of Water Rights that permit water diversions to reliably determine the impact of the water diversions/flow manipulations on water quality.

The water diversions/exports from the Delta are causing increased sea water intrusion into the Delta which contributes disinfection byproducts (bromide) into the South Delta and apparently into the SJR through the CVP. These exports are also bringing large amounts of low nutrient/algae Sacramento River water into the upper and mid-Delta, thereby reducing the primary production in these areas. Also, these exports are causing a loss of the Chinook salmon SJR Sierra home stream water chemical signal in the northern and western Delta. This can contribute to increased “straying” of Chinook salmon, which could result in less effective spawning associated with altered timing of reaching a suitable spawning area. These CVP and SWP exports are causing low water levels in the South Delta channels, which interferes with pumping of Delta water from some channels for South Delta irrigated agriculture. Further, these exports are causing several water quality problems in South Delta channels such as DO WQO violations through reduced water movement in some channels.

One of the most significant water diversions in the SJR watershed is associated with the USBR Friant Dam project, where the Bureau diverts all the SJR Sierra water to the Central Valley for irrigation. This dries up the SJR between Friant Dam and Lander Avenue; it also causes the SJR water where Mud and Salt Sloughs enter the SJR to consist of irrigated agriculture wastewaters (subsurface drain and tail waters) and drainage from public and private wildlife refuges and private gun clubs wetland areas. During the summer and fall these wastewaters and drainage are of poor quality and cause major water quality problems in the SJR and downstream all the way into the Delta. The court order to require the USBR to provide sufficient flows from Friant Dam to the SJR channel to restore the fisheries of the SJR in the area that is currently dried up by diversions could be a major factor in improving the SJR water quality.

In addition to known pollutants, there are a large number of chemicals discharged by agricultural and urban areas in stormwater runoff and wastewaters that are not monitored and evaluated for potential adverse impacts to the beneficial uses of the SJR and the Delta. The current water quality monitoring/evaluation in the SJR, its tributaries and the Delta as impacted by SJR-derived pollutants is highly deficient to begin to define the pollutants that are adversely impacting SJR and Delta water quality, to identify sources of pollutants, and to evaluate the impact of pollutant control programs. Without greatly increased funding, the water pollution control programs for the SJR and Delta will largely be of limited success in restoring these waterbodies to unimpaired beneficial uses. Funds to support this monitoring, evaluation and management program should be derived from all who discharge wastewaters and stormwater runoff, including irrigated agriculture, to the SJR tributaries and the SJR, and all who derive benefits from using SJR watershed waters.

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Appendix A

REVIEW PANEL REPORT[1]

(19 Dec 2005)

San Francisco Estuary Sacramento-San Joaquin Delta
Interagency Ecological Program on Pelagic Organism Decline

Submitted by: Mark D. Bertness (Brown University), Stephen M. Bollens (Washington State University Vancouver), James H. Cowan, Jr. (Louisiana State University), Ronald T. Kneib (University of Georgia Marine Institute), Parker MacCready (University of Washington), Russell A. Moll (California Sea Grant College Program), Paul E. Smith (Scripps Institution of Oceanography), Andrew R. Solow (Woods Hole Oceanographic Institution), Robert B. Spies (Applied Marine Sciences)

Executive Summary

The review panel recognizes that addressing the issue of pelagic organism decline (POD) in the managed ecosystem and human-dominated watershed of the upper San Francisco Estuary (Sacramento-San Joaquin Delta) is a formidable challenge. We commend the Interagency Environmental Program (IEP) managers and scientists for seeking ways of balancing the needs for human use of the area's water resources with the survival requirements of other components of the ecosystem. The suite of problems in the Bay-Delta is of immense importance to California. Working under constant political scrutiny and demand for "instant results" the IEP has maintained a high-quality program that includes an invaluable long-term data set. The passion of the IEP employees for their program and the effort invested to make it succeed were very evident to the review team. When confronted with demands for more answers and political quick fixes to a deteriorating environment, the IEP produced a thoughtful and skilled response with a more elaborate research program that will hopefully reveal the underpinnings of the ecological disaster confronting the Bay-Delta. The review panel praises the IEP for a job well done and hope that our observations, comments and suggestions will be of assistance to the scientists and managers who are attempting to seek novel solutions to complex problems of critical resource management through this worthy program.

The IEP, together with the coordinating efforts of the California Bay-Delta Authority (CBDA), represents a unique collaboration of federal and state entities charged with the immense task of developing an understanding of the structure and functioning of the Bay-Delta ecosystem. Such a unique collaboration affords many opportunities and yet demands a high level of effort to make the IEP succeed. Such aspects as a well-developed management structure, regular management meetings, frequent informal communications and a clear reporting structure are the hallmarks of a good management approach. Each component of the IEP has an identified leader(s) and a clear set of management objectives that collectively point toward a thoughtful study program. The review panel commends the IEP for taking the necessary steps to make program management

[1] excerpts from POD Review Panel, "San Francisco Estuary Sacramento-San Joaquin Delta Interagency Ecological Program on Pelagic Organism Decline," Report to CA Bay Delta Authority Science Program, Sacramento, CA, December 19 (2005).
http://science.calwater.ca.gov/pdf/workshops/POD/IEP_POD_Panel_Review_Final_010606_v2.pdf

succeed. Further, we have the impression that management of the IEP is intended to serve the needs of the study program and not vice versa – a very healthy approach.

The review panel identified several strengths and weaknesses of the current program. These are summarized below and followed by summary recommendations. Subsequent portions of the report expand on these points and provide additional details and comments on specific projects.

Strengths:
- The program has developed a very substantial historical data base on important populations of pelagic and benthic organisms for the upper estuary and Delta. This provides the primary means for detection of changes in the ecosystem and is an essential source of insights into the possible causes for long-term decline of pelagic organisms.
- The management of the IEP appears to be working well and addresses many of the issues one could expect with such a complex collaboration.
- The research effort has been guided by a conceptual model approach with the potential to allow ideas to evolve as the information base is augmented.

Weaknesses:
- The program relies too heavily on local perspectives and resources for problem analysis, research and solutions. This can give rise to a culture of common assumptions that impedes exploration of alternative possibilities.
- The step-like decline in abundance of delta smelt and other pelagic species in 2001 has been interpreted as a recent shift in environmental or biological conditions, and is driving much of the recent research effort. However, the evidence is not convincing and the interpretation is open to question.
- Interest in understanding and presumably reversing the long-term decline in pelagic organism abundance in the Bay-Delta does not appear to be associated with specific restoration targets.
- Key pieces of basic information appear to be lacking on the habitat requirements and early life stages of pelagic species of interest. For example, there is very little information on where the eggs of delta smelt can be found in the system. Likewise, there are few reliable estimates of vital rates (e.g. stage-specific growth and mortality rates) required to adequately model spatially-explicit population dynamics of pelagic species under different scenarios.
- The data analyses and dynamic models lack the sophistication to match the complexity of the dynamics in the hydrological and population/community dynamics of the Bay-Delta system.

Recommendations:
- The IEP should consider a revision to its management structure to make better use of key academic partners in program decision-making. This should be done in a manner that avoids conflicts of interest yet provides a mechanism for input to management decisions from members of the academic community who are most knowledgeable about the Bay-Delta system. Seeking annual input from a small group of external advisors is one means of addressing this issue.
- The IEP is advised to make use of peer review at all possible opportunities in awarding and reviewing of contracts and grants. While recognizing that many high-quality studies have been supported in the past through these contracts and grants, the review panel recommends

this step to assure that the best possible science remains a primary criterion of present and future work in the Bay-Delta.

- While it is recognized that conducting much of the research on this ecosystem is an explicit role of the resource agencies that constitute the IEP, extra-governmental assistance is needed in portions of the program. For example, external expertise may be sought to incorporate a strong spatially-explicit perspective into sampling protocols as well as in hypothesis development and testing. An open solicitation of proposals could be a valuable means of capitalizing on additional externally available expertise in these areas, particularly from within the academic community.
- Key information gaps involving the natural history and population dynamics should be filled for species of special concern. Spawning habitat of delta smelt should be identified and data from the most successful population abundance surveys should be placed within the context of dynamic stage-structured population models. For example, the number and fecundity of adults caught in the Kodiak trawl allows a prediction of larvae at 3-, 6-, 9- and 12-mm size classes. A direct survey of eggs in natural spawning substrata would improve these estimates immensely. This could proceed to an escapement- and evasion-corrected sample of juveniles from the Fall Midwater Trawl survey. Existing index data are adequate to design this approach. The inter-stage rates then become the first draft estimates of a list of population vital rates for a model that will not tolerate ambiguity in a closed population like the delta smelt.
- Use of the DSM2 hydrodynamic model should be phased out in favor of a 3-D numerical modeling system. With regard to the biological components of the system, the habitat-quality monitoring program should be improved and expanded to recognize species-specific ontogenetic requirements with in the structure of the landscape at multiple spatial scales. There should be targeted studies to elucidate critical habitat requirements of key species of concern. These recommendations are intended to provide a better foundation for future ecosystem modeling.

Comments on Contaminants studies

There is a paucity of historical data on contaminants and their potential effects in the Delta region of the San Francisco Estuary due to both the resistance of some government agencies to more actively investigate them and in the long held belief of many agency biologists that the existing problems in the Delta were due to other factors. So, turning belatedly to contaminants as a potential major factor in the decline of fish populations raises formidable challenges both from lack of historical data and construction of imaginative approaches to answering the obvious but difficult questions. Due to lack of attention, the thinking about these problems has not matured too far in many quarters. For example, there is an undue reliance on short-term survival bioassays, which were developed for regulatory tools in water quality management with no guarantees that they do indeed identify low-level chronic effects over multiple generations. These assay results may or may not be relevant to long-term toxicity, but there is a significant chance that any toxic problems from long-term, low-level exposures will not be manifest in or linked to such assay results. It is evident that some of the UC Davis biologists have taken seriously the possibility that long-term, sub-lethal effects are having effects and have produced some excellent studies and publications in this area. Most of these studies have included histopathological analyses with an emphasis on parsing the findings between toxic impacts and amounts of storage products available (e.g., glycogen) for various energetic demands. The histopathology findings will be useful only if they point to the life stage and mode of impairment caused by contaminants. Other studies can then be designed to measure changes in survival, fitness, growth and reproduction, as appropriate.

Looking for alterations in survival, fitness, growth and reproduction of delta fish species due to low-level exposures to biologically active mixtures of contaminants is the most productive approach to this potential aspect of the problem. This top-down approach will also yield data that can, in theory, be linked to other data needed by population modelers and possibly show where other factors can interact with contaminants, a possibility that we need to anticipate. The challenge is to link what has or can be done on alterations of normal biochemistry, physiology and anatomy to their ultimate contributions (positive or negative) to the population trajectories.

ANALYSES OF EXISTING DATA

Toxic and other harmful effects of *Microcystis aeruginosa* blooms – The occurrence of *Microcystis* and other harmful algal blooms (HAB) may be more symptomatic of changes in turbidity/light levels or nutrient inputs with the Delta system. Blooms do not appear to be sufficiently widespread to be a feasible explanation for either the long-term or recent step-declines in pelagic fishes. Though worthy of pursuit as part of monitoring the larger system-wide changes that continue to occur in the Delta, HAB may be considered an additional symptomatic response to environmental stressors associated with human uses within the watershed. Studies of *Microcystis* should be completed as planned but if expanded in the future should be aimed at providing information applicable to the control of HABs in the system, with less emphasis on their effects on other components of the biological community, which can reasonably assumed to be negative. An additional useful perspective is to view *Microcystis* toxins as one a number of stressors that fish populations may face.

Use and toxicity of pyrethroid pesticides - It appears that pyrethroid insecticides are increasingly finding their way into the Delta from urban development and agricultural activities in the Sacramento-San Joaquin watershed. One might expect the toxic effects of these compounds to manifest in the primary prey communities (small crustaceans) of pelagic fishes before they reach levels that are sufficiently toxic to cause direct mortality of fishes. As these compounds represent only one group of contaminants that are expected to affect the biological communities of the Delta in the future, it may be less important to describe their specific effects in the system than to seek ways of reducing contaminant inputs to the Delta. However, given the known sensitivity of fish and invertebrates to pyrethroids and their increasing use in the watershed, this would be a good time to rapidly determine whether pyrethroid concentrations are involved in, or can be ruled out as, playing a major role in the recent POD. Without chemical measurements at key points in the environment where these compounds are suspected of having effects little progress can be made. Expanded, integrated chemical measurements of pyrethroids may be necessary to resolve their potential role in toxic effects as well as to raise awareness of other chemicals that my be having effects.

Use and toxicity of aquatic herbicides – One question that did seem to be considered with respect to aquatic herbicides is whether or not submerged aquatic vegetation (SAV) is providing a positive or negative habitat function for the early life stages of pelagic fishes. Is it worth considering the potential effects of herbicide use on spawning habitat of delta smelt or other species of interest? Spawning habitat and spawning substrata used by delta smelt in the Sacramento-San Joaquin delta region is unknown and a significant information gap in the life history of this species (see p. 13 and p. 59 in Bennett 2005, San Francisco Estuary and Watershed Science 3(2):1-71). If either shallow subtidal or intertidal vegetation play a role as spawning habitat for this species, it could provide a link between essential fish habitat and the application of aquatic herbicides, even if there are no lethal direct effects of the herbicides or the carrier compounds (e.g. surfactants) on the fishes.

Analysis/summary of recent changes in delta water operations – The emphasis on characterizing recent changes in water project operations in an attempt to account for an apparent step-change in pelagic fish abundance is understandable in terms of political pressure to do something now. However, if POD cannot be understood from an historical perspective, it would seem there is little chance of identifying a specific cause(s) for what is only the last portion of the variation in the record of fish abundance.

There are many reasons to be concerned about a focus on a time period that is too narrow, not the least of which is that conditions are likely to change in the near-term as well as long-term future. Also, some fish numbers are already low and it will be difficult to identify subsequent real changes in abundance – either up or down. The panel was surprised by the lack of data from certain sources that should have been readily available (e.g. fish losses due to impingement and entrainment associated with the operation of power plants in the Delta). It is important to obtain this information and compare it to the historical record of fish abundance based on independent surveys.

It would be useful to relate salvage densities to regional abundance indices because there is no a priori reason to expect the water diversion activities to operate in a density-dependent manner on pelagic organisms (i.e. salvage capture should be proportional to the size of the population). Independent collections of fishes in the net survey stations nearest the water diversion operations should be consistent with the salvage measures of fish abundance. If this is not true, then one both) is inadequately representing the status of the fish populations.

NEW STUDIES

Liver histopathology and general pathobiology (starvation disease, and toxic exposure) for pelagic fishes – This study examined pelagic fishes for lesions which could be due to either starvation, disease or exposure to toxic chemicals, but the findings have limited applicability because there is no identified path to link its findings to POD. Further, examining just a few sections of liver could miss significant lesions. More importantly, previous studies have identified other organ systems that are sensitive to the effects of contaminants (nervous system, reproductive system, respiratory system, i.e., gills, excretory system) and none of these were systematically examined. The authors did note that some gonads exhibited intersex conditions in 5-10% of the species examined, a finding of potential significance.

This study may characterize the general effects of environmental stressors on morbidity in pelagic fishes, but what can the findings contribute to a solution? Stressors acting on early life stages would be missed because the affected individuals likely died and are no longer in the population to present their condition. Furthermore, 'the general conclusion of the pathological reports was that findings were not out of the ordinary for wild fish populations.' Based on the results in hand the only conclusion may be that the pelagic fishes are under stress(es) and this in itself is not a great discovery. A multivariate analysis of the histopathology results with other variables might shed some insight into the stresses that impact the livers of these fishes.

The approaches to understanding the population-level effects of contaminants are much broader than histopathology. For example, one could relate growth and reproduction to contaminant concentrations in tissues, use alternative biomarkers, measure effects of experimental exposures to complex mixtures of contaminants, include much more environmental chemistry, etc. Then there is the real potential for interactive effects of contaminants with disease, food limitation, HABs, etc. There appears to be no compelling reason to continue this work beyond completion of the 2005 sample analyses. Broader based creative approaches are needed to assess the potential role of contaminants in population trajectories. Some of the current work on striped bass shows real evidence of a broader based approach beyond what was done in summer of 2005.

Field survey of *Microcystis aeruginosa* bloom biomass toxicity – Harmful algal blooms have affected fish populations in many estuaries undergoing eutrophication. Whether increased nutrient or light availability have been the principal factor(s) in the apparent expansion of *Microcystis* populations in the Delta remains to be seen. The research to date on *Microcystis* in the Delta has focused on identifying areas where the species is most abundant and in measuring the presence of microcystins in the food web below the level of fishes. It may be more important in considering the continued development of this area of research to establish a connection between *Microcystis* and pelagic fishes in the system. Is there any evidence of an association between fish kills and blooms of *Microcystis* or other potential HABs in the Delta? Historically, *Microcystis* blooms have not been identified as an issue in connection with historical POD. However, the IEP is encouraged to look into remote sensing techniques to develop a more cost effective way to assess the distribution of *Microcystis*. The collection of spot samples can continue to serve as the source of information to evaluate toxicity. Because there seems to be little doubt as to the toxic nature of *Microcystis* a suggestion is to place more emphasis on aerial distributions and bloom status (rapidly growing versus senescent) rather than toxicity testing. Unless a link can be established between *Microcystis* and pelagic fish population dynamics, continued research in this area may be more pertinent to the development of an ecosystem-level model of the estuary than to the search for the underlying causes of POD.

Acute and chronic invertebrate and fish toxicity tests -- There appeared to be little evidence of toxic effects of ambient levels of microcystins in Delta fishes. Although other compounds entering the system may be having negative effects on fishes and/or their primary prey resources either now or in the near future, it is unclear that this area of research will be strongly connected to the current or historical decline in pelagic fish abundance. Short-term assay results may not be linked to any underlying chronic toxicity affecting pelagic fish populations in the estuary. The findings of this study indicated some effects on certain crustaceans (e.g. amphipod, H.

azteca and copepod, P. forbesi) within portions of the watershed, but no significant toxicity to fishes and other crustaceans (e.g. cladoceran, C. dubia). The review panel recommends completing toxicity tests as proposed in the 2005 Synthesis Report and 2006-2007 work plan. However, a broader based approach to potential long-term low-level effects of contaminants on these populations is needed.

Appendix B

Drs. G. Fred Lee and Anne Jones-Lee's Background
Pertinent to Assessment of San Joaquin River and Delta Water Quality

Dr. G. Fred Lee is President of G. Fred Lee & Associates, which consists of Dr. G. Fred Lee and Dr. Anne Jones-Lee (Vice President) as the principals in the firm. This discussion of San Joaquin River and Delta water quality is based on G. Fred Lee's academic background and professional experience, which includes a BA degree in environmental health sciences from San Jose State College in 1955, a Master of Science in Public Health focusing on water quality issues from the University of North Carolina in 1957 and a PhD in environmental engineering/ environmental science from Harvard University in 1960. Beginning in 1960 for a period of 30 years he held university graduate-level professorial teaching and research positions at several major US universities, including the University of Wisconsin, Madison, the University of Texas system and Colorado State University. In 1989 he retired from university teaching and research as a Distinguished Professor of Civil and Environmental Engineering at the New Jersey Institute of Technology, where he also held the position of Director of the Site Assessment and Remediation division of a multi-university hazardous waste research center. For a several-year period, he also held the position of Director of the Water Quality Program for the State of New Jersey Sea Grant Program. During his 30-year university teaching and research career he conducted in excess of five million dollars of research and published over 500 papers and reports on these efforts.

Dr. Anne Jones-Lee was a university professor for a period of 11 years in environmental engineering and environmental sciences. She has a BS degree in biology from Southern Methodist University and obtained a PhD in Environmental Sciences in 1978 from the University of Texas at Dallas, focusing on water quality evaluation and management. At the New Jersey Institute of Technology she held the position of Associate Professor of Civil and Environmental Engineering with tenure. She and Dr. Lee have worked together as a team since the mid-1970s.

Dr. Lee's areas of expertise include work on fate, effects and impacts of chemical constituents and pathogens on various aspects of water quality as it relates to the beneficial uses of waterbodies. He has frequently served as an adviser to local, state, national and international governmental agencies and other entities on a variety of aspects of water quality, including water quality criteria and standards development and their appropriate implementation. This activity included serving as an invited peer reviewer for the National Academies of Science and Engineering "Blue Book" of water quality criteria in 1972, a member of the American Fisheries Society Water Quality Committee that reviewed the US EPA's "Red Book" water quality criteria of 1976, and a US EPA invited peer reviewer in the early 1980s for the approach that the Agency then proposed and finally adopted for developing water quality criteria for protection of aquatic life. This is the same criteria development approach that is in existence today. Further, Dr. Lee was involved as a US EPA invited peer reviewer for several criteria documents. His work on water quality issues is somewhat unusual, in that, in addition to having a strong background in the chemical and biological sciences pertinent to water quality evaluation, he also has an engineering background in developing control programs for chemical constituents in point and nonpoint source discharges.

In 1989, Dr. Lee retired from university teaching and research and expanded the part-time consulting activities that he conducted while a university professor into a full-time activity. While living in New Jersey he became involved in three different consulting jobs in California, one of which was concerned with Delta water quality issues. Another was concerned with Lake Tahoe water quality, and the third was on behalf of the Metropolitan Water District of Southern California, on groundwater quality protection in the San Gabriel Basin. It was at that time that Dr. Anne Jones-Lee and he moved from New Jersey to El Macero, which is adjacent to Davis, California, about 11 miles from Sacramento. Since 1989 they have maintained a two-person specialty consulting firm, working on water supply water quality, water and wastewater treatment, water pollution control for both fresh and marine surface waters, and solid and hazardous waste impact evaluation and management, with particular emphasis on groundwater quality protection. They have continued to be active in publishing the results of their studies, where in the last 15 years they have added another 600 papers and reports covering work they have done in their various areas of activity. One of these areas is San Joaquin River and Delta water quality.

Dr. Lee's initial work on Delta water quality occurred in the summer of 1989, where he was asked to be a consultant to Delta Wetlands on water quality issues associated with the development of in-Delta storage reservoirs. As part of this effort he became familiar with Delta water quality issues. Dr. Lee's work on Delta water quality issues has included participating in various CALFED (now California Bay-Delta Authority – CBDA) committees, subcommittees, working groups, etc., concerned with water quality issues in the Delta and its tributaries.

Beginning in the mid-1990s Dr. Lee became involved in the details of water quality issues in both the Sacramento and San Joaquin River watersheds. Beginning in the 1990s he began to work with William Jennings (formerly the DeltaKeeper) as a volunteer technical adviser to help the DeltaKeeper focus its activities on technically correct positions on water quality management. This approach has provided Dr. Lee with an opportunity to become involved in a variety of areas that are of particular significance to the DeltaKeeper's efforts to improve the quality of science and protection/enhancement of water quality of the Delta and its tributaries. Dr. Lee's work with the DeltaKeeper included addressing such issues as managing aquatic life toxicity in the Central Valley and Delta due to pesticide runoff/discharges from agricultural and urban areas, reviewing and managing excessive bioaccumulation of organochlorine legacy pesticides and PCBs in Central Valley waterbodies and the Delta, review of the potential environmental impacts of aquatic pesticides used for aquatic weed control in the Central Valley and Delta, impact of flow management in and from the South Delta on water quality, and providing guidance on environmental aspects of dredging and dredged sediment management in the Delta.

One of Dr. Lee's major areas of work has been on the San Joaquin River Deep Water Ship Channel low-DO problem. Beginning in 1999, Dr. Lee worked closely with the SJR DO TMDL Steering Committee as well as the Central Valley Regional Water Quality Control Board staff in helping to formulate and implement higher quality science and engineering in the San Joaquin

River low-DO TMDL program. This included Dr. Lee being awarded a contract with the CVRWQCB, to develop an "Issues" report of the issues that need to be addressed as part of formulating a TMDL to control the low-DO problem in the San Joaquin River DWSC. This Issues report is available as

Lee, G. F. and Jones-Lee, A., "Issues in Developing the San Joaquin River Deep Water Ship Channel DO TMDL," Report to Central Valley Regional Water Quality Board, Sacramento, CA, August (2000). http://www.gfredlee.com/sjrpt081600.pdf

Dr. Lee worked closely with the Central Valley Regional Water Quality Control Board lead staff (Dr. Chris Foe) in developing a coherent two-million-dollar proposal, which was funded by CALFED. Dr. Lee served as the coordinating PI for 12 projects that were conducted under this proposal. This work resulted in a synthesis report,

Lee, G. F. and Jones-Lee, A., "Synthesis and Discussion of Findings on the Causes and Factors Influencing Low DO in the San Joaquin River Deep Water Ship Channel Near Stockton, CA: Including 2002 Data," Report Submitted to SJR DO TMDL Steering Committee and CALFED Bay-Delta Program, G. Fred Lee & Associates, El Macero, CA, March (2003). http://www.gfredlee.com/SynthesisRpt3-21-03.pdf

This report presents a summary/synthesis of approximately four years and four million dollars of studies on the SJR DWSC low-DO problem. Since completion of the synthesis report in March 2003, Drs. Lee and Jones-Lee have continued to be active in Delta water quality issues. They have developed a series of reports on these issues that are available from their website, www.gfredlee.com, in the San Joaquin River Watershed section. They have developed a synthesis report supplement that presents a review of the various studies that they have conducted over the past two years that are pertinent to investigating and managing Delta water quality issues. This work has included a detailed review of San Joaquin River water quality.

Further information on Drs. Lee and Jones-Lee's experience pertinent to assessment of Delta and San Joaquin River water quality issues is available on their website, www.gfredlee.com, or upon request.