Summary of Water Quality Issues in the San Joaquin River and Stockton Deep Water Ship Channel

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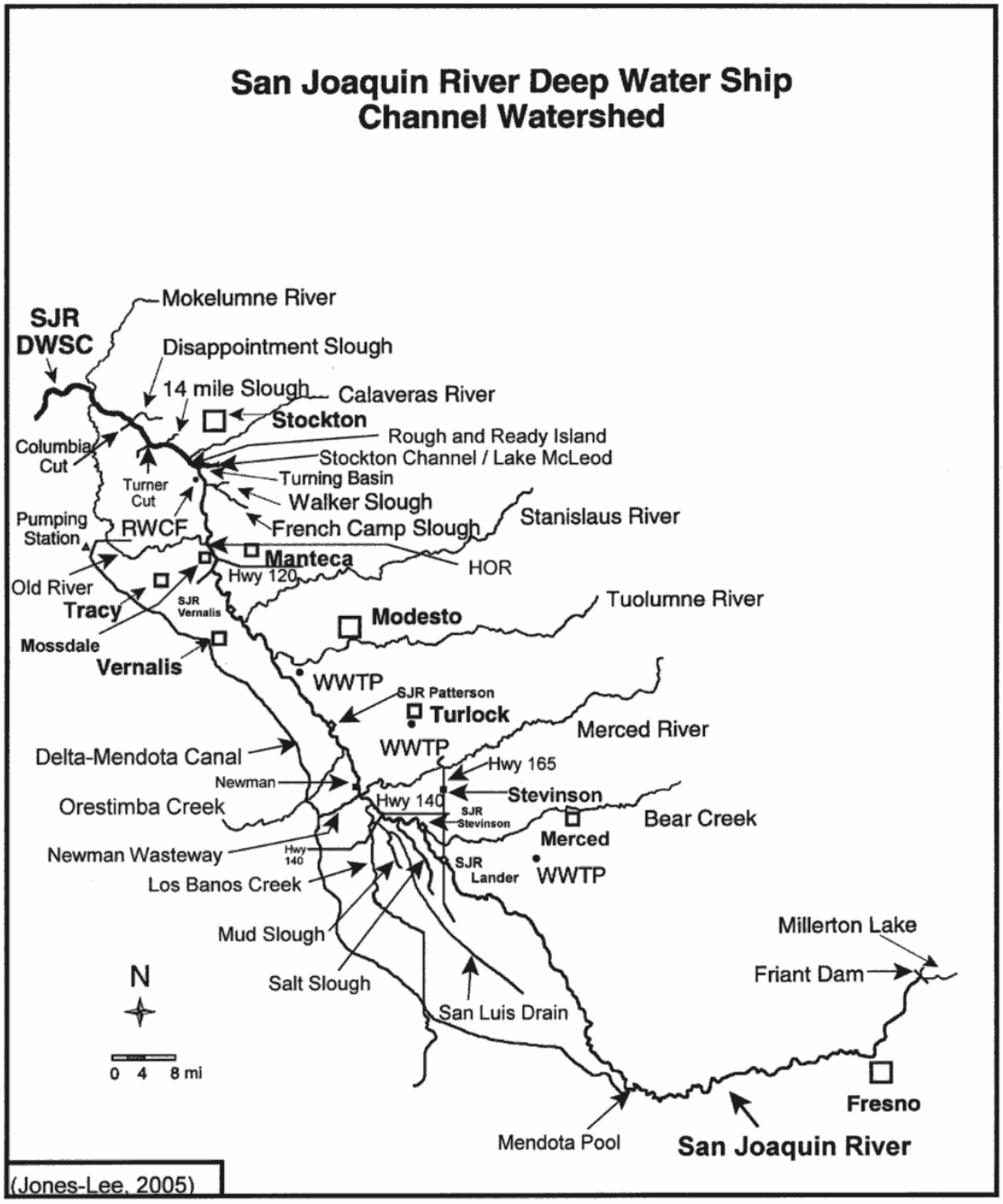
California's fertile Central Valley occupies the central portion of the northern two-thirds of the state; it encompasses the Sacramento Valley to the north and the San Joaquin Valley to the south. The San Joaquin River (SJR) is the major river draining the upper (north of Fresno) San Joaquin Valley. It originates with high-quality water in the Sierra Nevada and flows north through the Central Valley ultimately joining with the Sacramento River in the Sacramento-San Joaquin River Delta before discharging into upper San Francisco Bay (see Figure 1). In the early 1940s, the US Bureau of Reclamation (USBR) completed the construction of Friant Dam on the SJR near Fresno to support irrigated agriculture in the lower Central Valley. In most years Friant Dam diverts all the San Joaquin River water to irrigation in the Central Valley, leaving the river dry for approximately 120 miles downstream of Friant Dam to Highway 165. Among the significant impacts that the damming has had on SJR water quality, this diversion of SJR water eliminated a highly valuable Chinook salmon spawning area upstream between the dam and the confluence of the Merced River approximately 153 mi downstream.

Environmental groups led by the Natural Resources Defense Council (NRDC) won a court ruling that found that the diversion violates the CA Department of Fish and Game regulations and ordered that the USBR release sufficient water to the San Joaquin River to reestablish Chinook salmon reproduction in the river below Friant (Karlton, 2004). The SJR flow restoration settlement agreement was announced on September 13, 2006, between the Central Valley agricultural interests (Friant Water Users Authority [FWUA]), US Department of Interior and Commerce and the environmental groups (see http://www.fwua.org/settlement/settlement.html);
the implementation of the restoration of SJR flow is now awaiting funding from the US Congress. The settlement agreement ended an 18-year court battle. While returning water to the river is important to anadromous fish spawning, important also is the character of that water and the water quality issues faced as the flow is reestablished. For example, while Mud and Salt Sloughs (see Figure 1) contribute sufficient water to reestablish flow downstream of their confluence with the SJR, the quality of the SJR downstream of that confluence is drastically different from that upstream of Friant Dam.

SJR Water Quality Issues

Some of the most significant water quality problems in the SJR result from the fact that during the summer and fall many of the discharges to the SJR consist of irrigation return water that contains elevated concentrations of a variety of chemicals in amounts that cause violations of water quality standards (WQS) in the SJR. These and other chemicals in irrigation return water impair designated beneficial uses such as domestic water

Figure 1



supply, propagation of fish and other aquatic life, and recreation, and lead to fish containing excessive levels of mercury and pesticides, which is a threat to the health of those who use the fish as food. Exceedance of water quality standards is a violation of the Federal Clean Water Act and triggers the requirement that the Central Valley Regional Water Quality Control Board (CVRWQCB) develop a Total Maximum Daily

Load (TMDL) of pollutants to the SJR and its tributaries to eliminate the WQS violations. Lee and Jones-Lee (2006a,b,c) discussed water quality issues of the SJR, focusing on the TMDLs that the CVRWQCB has established for the SJR, as well as on other conditions and parameters that could become TMDLs (see Table 1). As discussed by Lee and Jones-Lee (2006a,b,c), eight of the existing 12 TMDLs are due to discharges from irrigated agriculture in the Central Valley. Six of the eight potential TMDLs are due to irrigated agricultural discharges in stormwater runoff and irrigation tailwater.

Table 1. San Joaquin River Watershed TMDLs
from Lee and Jones-Lee (2006a)

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

The mid to lower SJR receives flow from east-side rivers (Merced, Tuolumne, and Stanislaus Rivers) that, like the SJR, originate in the Sierra Nevada. En route, their high-quality mountain water also becomes somewhat polluted principally by irrigated agricultural runoff/discharges, although, except for pesticides, typically not to the same extent as the mainstem of the SJR. In addition, the SJR receives flow from west-side rivers, which, during the summer and fall are essentially irrigation return water and are typically of poor water quality.

Ultimately, over the next decade or so the CVRWQCB TMDL program will establish controls on the irrigated agriculture and other sources of pollutants that cause violations of water quality standards in the SJR and its tributaries. The CVRWQCB "Conditional Waiver of Waste Discharge Requirements for Discharges from Irrigated Lands" (Ag Waiver) program (http://www.waterboards.ca.gov/centralvalley/programs/irrigated_lands/irr-lands-disch-fact-sheet.pdf) requires that agricultural interests in the Central Valley monitor the water quality in waterbodies that receive large amounts of irrigated agricultural stormwater runoff and tailwater discharges. This monitoring will no doubt reveal additional violations of water quality standards being caused by agricultural activities that will need to be controlled by the dischargers.

In addition to enabling the restoration of the Chinook salmon spawning in the dry reach of the SJR, the court-ordered flow restoration will help reduce, by dilution, the magnitude of the violations of the water quality standards in the SJR, especially in the reach near Patterson, California. While this will reduce the amount of pollutant control that will need to be implemented by agricultural and other dischargers, Friant Dam flow releases alone will not result in elimination of WQS violations. There will be need for major control programs to be developed and implemented by agricultural interests to reduce discharges of pollutants in stormwater runoff and tailwater.

Delta Water Quality Issues

Water quality issues of the Sacramento-San Joaquin River Delta have been discussed in detail by Lee and Jones-Lee (2004a,b). The Delta has many of the same water quality problems that exist in the SJR. In addition, the Delta is polluted by chemicals derived from the Sacramento River, such as mercury, as well as from agricultural discharges within the Delta. The Delta also receives municipal wastewater discharges from Stockton, Sacramento, Tracy, and a new source, Mountain House and several communities that discharge to the SJR and its tributaries. One of the most significant water quality problem areas in the Delta is the SJR Stockton Deep Water Ship Channel (DWSC).

Stockton Deep Water Ship Channel

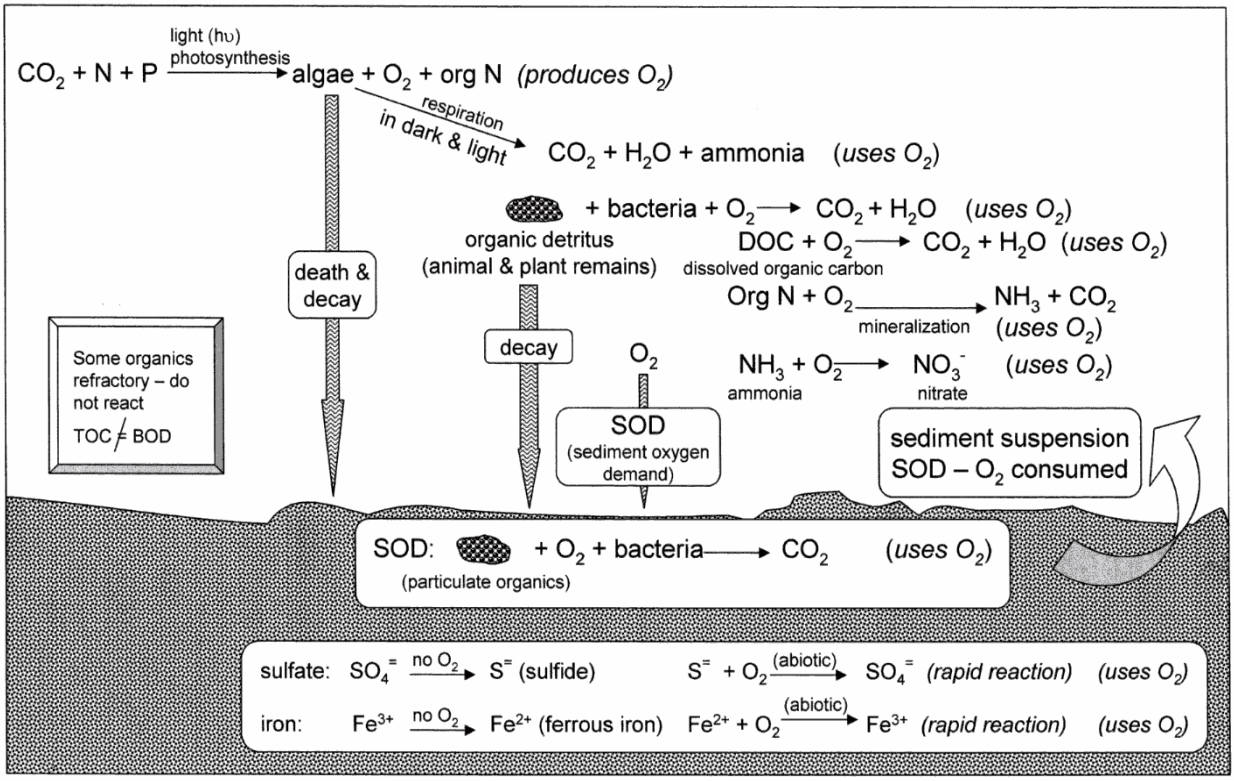
One of the most significant water quality problems in the Delta is the low dissolved oxygen (DO) problem in the DWSC near the Port of Stockton. The first seven miles of the SJR DWSC below the Port of Stockton experiences DO concentrations below the CVRWQCB DO WQS. The low-DO problem in the DWSC has been well-known since the late 1940s; however, it was not until the 1990s that action began to be taken to correct this problem. The CVRWQCB has established a TMDL to restore DO concentrations in the DWSC to levels above the WQS. The DO violations cause blockage and interruption of the fall-run Chinook salmon migration through the DWSC. This delays spawning in east-side SJR tributary rivers and impairs reproduction. The low-DO also causes fish kills and impairs rates of growth of fish that live in the DWSC.

Beginning in 1999, Drs. G. F. Lee and A. Jones-Lee served as technical advisors to the SJR DWSC TMDL Low-DO Steering Committee, and as the coordinating principal

investigators for the CALFED-supported $2-million project devoted to investigating the cause of the low-DO problem and the sources of constituents that create the oxygen demand in the DWSC. Lee and Jones-Lee (2003) developed a synthesis report and supplements on the nature of this problem and actions needed to control it. Additional information on this problem is available at http://www.gfredlee.com/psjriv2.htm, and the reports of the over a dozen investigators who participated in the CALFED-supported studies are available at http://www.sjrdotmdl.org/.

The SJR DWSC low-DO problem is due to oxygen demand derived largely from decomposition of algae that grow in the SJR upstream of the DWSC; the algae are supported by nutrients discharged by irrigated agriculture in the SJR watershed. High concentrations of planktonic algae grow in the 8 to 10-ft-deep SJR upstream of the DWSC. When that water enters the 35-ft-deep DWSC, the algae settle below the sunlight penetration zone (about 3 ft), die, and exert an oxygen demand as they decompose. Also contributing to the oxygen demand is the ammonia discharged by the city of Stockton in its domestic wastewaters near the Port of Stockton. Ammonia is converted to nitrate by nitrifying bacteria in the channel; this conversion uses large amounts of DO. The processes that affect dissolved oxygen in the DWSC are illustrated in Figure 2. Information on each of the processes shown in this figure is provided by Lee and Jones-Lee (2003).

Figure 2
Conceptual Model of DO Depletion Reactions
in the SJR DWSC



Lee and Jones-Lee (2003, 2004c) found that the frequency and magnitude of the low-DO problem in the DWSC are largely controlled by the diversion of SJR water upstream of DWSC at Mossdale, into the South Delta via Head of Old River, by the USBR Central Valley Project at Tracy pumping station, as well as the CA Department of Water Resources (DWR) State water project pumps at Banks that draw substantial amounts of the SJR water into the South Delta for export to the San Joaquin Valley, San Francisco Bay area and southern California. These withdrawals reduce the water flow through the DWSC and allow greater exertion of the oxygen demand there. Typically about 10,000 cfs to as much as 13,500 cfs of South Delta water, which consists of all of the SJR water and is mostly flow from the Sacramento River, is drawn through the Delta to the export pumps.

Normally at least 1,000 cfs of SJR flow is available upstream of Mossdale. When the water flow in the SJR through the DWSC is 1,500 cfs or greater, the residence time of oxygen-demanding material in the DWSC is less than one week and there are no DO problems there. When the flow through the critical reach (first seven miles) of the DWSC is less than about 100 cfs (which occurs when the export projects draw essentially all the SJR water into the South Delta), the residence time of the oxygen-demanding materials in the DWSC is over two weeks and there are severe low-DO problems. Overall, during periods of low SJR flows through the DWSC, a much greater part of the oxygen demand load to the SJR is exerted in the DWSC where it causes problems of fish kills, impaired fish growth, and blockage of salmon migration.

The California legislature originally made $40 million available to start to solve the DWSC low-DO problem. DWR is responsible for disbursement of these funds. The CVRWQCB has determined that one of the most promising approaches for eliminating the violations of the DO WQS is aeration of the channel. Studies are currently underway to evaluate approaches for channel aeration. The city of Stockton is spending over $70 million to nitrify (convert ammonia to nitrate) its domestic wastewaters prior to discharge. This will significantly reduce the magnitude of the oxygen demand added to the DWSC from that source, but it will not address the oxygen-demand load to the DWSC from algae. There will still be need for aeration and control of algal-related oxygen demand. As discussed by Lee and Jones-Lee (2003), studies need to be conducted to determine whether it is possible to control the discharge of nutrients to the SJR and its tributaries sufficiently to reduce the amount of algae-derived oxygen demand load to the DWSC.

A major reason for the low-DO problem in the DWSC is the channel's depth relative to that of the river. There are no low-DO problems in the SJR upstream of the DWSC even though the algal and oxygen loads are the same as those to the DWSC. The difference is that the SJR upstream of the DWSC is sufficiently shallow (8 to 10 ft) and sufficiently well-mixed top to bottom to allow the algae to gain sufficient light to live and reproduce. However, in the 35-ft-deep channel most of the water column is dark and the flow slows; algae settle to the lower, darker depths and die. This situation shifts some of the responsibility for the low-DO problem to those who use or benefit from the existence of the Port.

The CVRWQCB TMDL has established that the Port (channel), sources of upstream nutrients that support algal growth that leads to oxygen-demand load, the city of Stockton domestic wastewater discharge, and those who divert water from upstream of the DWSC all bear responsibility for the low-DO problems in the DWSC. In a joint administrative arrangement, each of those entities is assigned responsibility for solving this problem. The CVRWQCB TMDL for the DWSC
(http://www.waterboards.ca.gov/centralvalley/programs/tmdl/sjr_do/index.html),
which was adopted in 2005, has allowed those entities until December 2008 to conduct studies to evaluate the use of aeration, upstream oxygen demand source control, upstream water diversion, etc., to solve the SJR DWSC low-DO problem. The CVRWQCB will reconsider the TMDL by December 2009. For additional information on the CVRWQCB SJR DO TMDL, please contact Jennifer LaBay at jlabay@waterboards.ca.gov.

Overall

The implementation of the TMDLs and the Ag Waiver program will ultimately cause significant changes in irrigated agricultural discharges and water diversions from the SJR and the Delta in the Central Valley to adequately protect water quality.

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Drs. Lee and Jones-Lee have been full-time consultants through their firm G. Fred Lee & Associates since 1989 when they moved to El Macero (near Sacramento). This firm specializes in evaluating and managing the impacts of chemicals on water quality, advanced-level water supply water quality, water and waste water treatment, water pollution control, and solid and hazardous waste investigation and management. Drs. Lee and Jones-Lee have established a website, www.gfredlee.com, where they make available over 600 papers and reports developed from their research and consulting activities.

Dr. G. Fred Lee received his PhD degree in environmental engineering from Harvard University in 1960. For 30 years he taught university graduate-level environmental engineering courses and conducted research on water quality and solid waste management issues at several US universities including the University of Wisconsin, Madison; University of Texas at Dallas; Colorado State University; and the New Jersey Institute of Technology (NJIT) where he held the position of Distinguished Professor. During that period he conducted over $5 million in research and published over 500 papers and reports on his work. Dr. Anne Jones-Lee received her PhD degree in environmental sciences from the University of Texas at Dallas in 1978. For 11 years she held university graduate-level teaching and research positions at several universities including holding a tenured position in Civil and Environmental Engineering at NJIT.

Drs. Lee and Jones-Lee first began work on San Joaquin River and Delta water quality issues in 1989. Information on Drs. Lee and Jones-Lee's work on Sacramento-San Joaquin Delta and San Joaquin River water quality is available at http://www.members.aol.com/annejlee/Delta-SJR-exp.pdf. Copies of their publications on the Delta and SJR are available at http://www.gfredlee.com/psjriv2.htm.