Water Quality Issues of Irrigated Agricultural Runoff/Discharges San Joaquin River, Central Valley, California[1]

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Abstract

The Central Valley of California is one of the most productive agricultural areas in the world. The San Joaquin River, one of the largest rivers in the state, flows through the Central Valley and supports this agriculture by providing irrigation water and receiving agricultural discharges and runoff. However, the intensive agriculture is causing violations of state water quality standards and is contributing to the Clean Water Act § 303(d) listing of that waterbody; 8 of the 12 of the current standards/objectives violations there are due to pollutants from runoff/discharges from irrigated agriculture. To address this, the Central Valley Regional Water Quality Control Board has listed the following for TMDL development: selenium and boron (both naturally occurring in some Central Valley soils); salinity associated with soil leaching of salt accumulated from irrigated agriculture; diazinon and chlorpyrifos, organophosphorus pesticides used for agricultural pest control; oxygen-demanding substances that cause low DO in the Stockton Deep Water Ship Channel; legacy pesticides (e.g., DDT, dieldrin, toxaphene); unknown-caused aquatic life toxicity; and fecal coliforms (*E. coli*). TMDLs may also be needed for: aquatic plant nutrients (N and P) that cause excessive algae and aquatic weeds, which contribute to low DO in the Delta; currently-used pyrethroid-based pesticides; pH; TOC/DOC that lead to trihalomethane formation during domestic drinking water disinfection; excessive sediment associated with soil erosion; and toxicity of unknown cause. In order to meet the TMDL requirements over the next 10 to15 years, significant changes in irrigated agricultural practices will be required in the Central Valley.

Key words: San Joaquin River, San Joaquin Valley, TMDL, agricultural discharges, water quality impacts

Introduction

Upstream of Friant Dam/Millerton Lake near Fresno, California (see Figure 1) the San Joaquin River (SJR) is of high-quality, consisting primarily of rainfall and snowmelt from the Sierra Nevada mountains. Downstream of Friant Dam, the water quality of the San Joaquin River becomes highly impacted by agricultural and municipal discharges, stormwater runoff, and by diversions of water for agricultural irrigation and municipal use as it flows north past Vernalis, marking the beginning of the San Joaquin Delta. The federal Clean Water Act (CWA) requires that the Central Valley Regional Water Quality Control Board (CVRWQCB) list waterbodies that have constituents in concentrations that exceed the applicable water quality standards (objectives) (WQOs) as Clean Water Act Section 303(d) "impaired." Such a listing requires that the CVRWQCB develop Total Maximum Daily Loads (TMDL) to control the sources of the chemicals/conditions that cause the WQO violations. Table 1 presents a summary of the CVRWQCB/SWRCB/USEPA 2006 listing of SJR water quality impaired sections.

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Table 1

2006 CWA 303(d) List of Water Quality Limited ("Impaired") Reaches of San Joaquin River (SWRCB, June 2007)

Pollutant*/Stressor	River Reach (see key below)							Potential Sources (see key below)		
	FMP	MPB	BMS	MSM	MTR	TRS	SDB	Ag	SU	RE
DDT		X	X	X	X	X	X	X		
Group A Pesticides (legacy)		X	X	X	X	X	X	X		
EC/TDS		X	X	X				X		
Exotic Species	X								X	
Mercury			X	X	X	X	X			X
Unknown Toxicity		X	X	X	X				X	
						X	X	X		
Boron		X	X	X				X		
Toxaphene							X		X	
Selenium				X				X		

River Reach Designations
FMP - Friant Dam to Mendota Pool
MPB - Mendota Pool to Bear Creek
BMS - Bear Creek to Mud Slough
MSM - Mud Slough to Merced River
MTR - Merced River to Tuolumne River
TRS - Tuolumne River to Stanislaus River
SDB - Stanislaus River to Delta Boundary

Group A Pesticides	
aldrin	heptachlor epoxide
dieldrin	hexachlorocyclohexane
chlordane	(incl. lindane)
endrin	endosulfan
heptachlor	toxaphene

Source Designations
Ag - Agriculture
SU - Source unknown
RE - Resource Extraction

CWA - Clean Water Act
* Violates water quality objective

Table 2 lists the contaminants for which Section 303(d)-listing TMDLs exist, are pending, or may be established in the future for the SJR and Sacramento/San Joaquin River Delta, which is impacted by SJR-watershed-derived constituents.

This paper presents a summary of the water quality issues associated with each of the existing, pending, and potential future TMDLs for the SJR. It is based on a comprehensive report on these issues by Lee and Jones-Lee (2006a), which is available at http://www.gfredlee.com/SJR-Delta/sjr-WQIssues.pdf. Additional information and references that serve as background to this paper are available in the Lee and Jones-Lee report, and through the CVRWQCB website, http://www.waterboards.ca.gov/centralvalley/water_issues/tmdl/

Figure 1

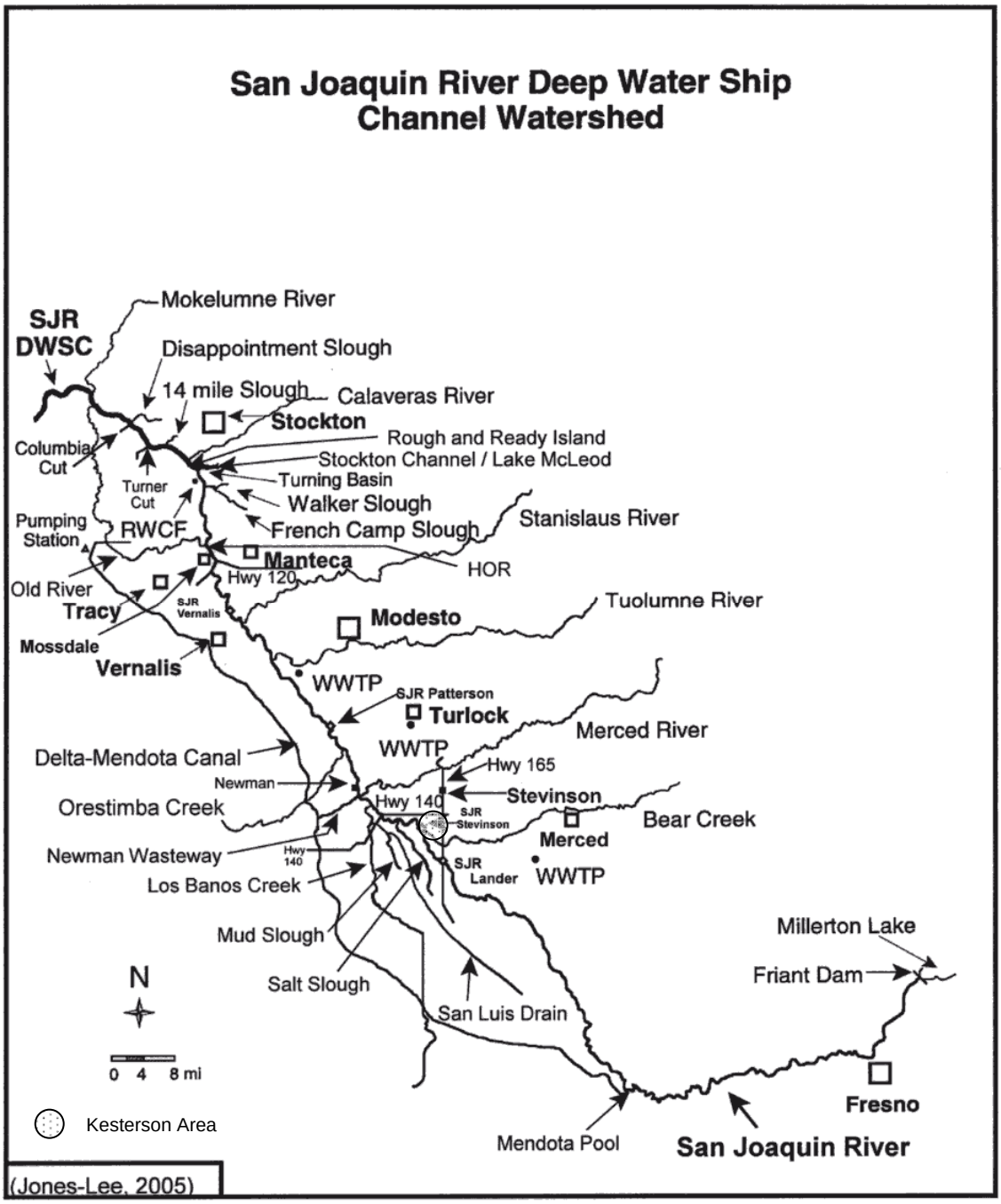
San Joaquin River Deep Water Ship Channel Watershed
Mokelumne River
SJR DWSC
Disappointment Slough
14 mile Slough
Calaveras River
Stockton
Rough and Ready Island
Columbia Cut
Stockton Channel / Lake McLeod
Turner Cut
Turning Basin
Walker Slough
Pumping Station
RWCF
French Camp Slough
Stanislaus River
Manteca
HOR
Hwy 120
Old River
Tracy
SJR Vernalis
Tuolumne River
Modesto
Mossdale
Vernalis
WWTP
SJR Patterson
Turlock
Merced River
Delta-Mendota Canal
WWTP
Hwy 165
Newman
Hwy 140
Stevinson
Orestimba Creek
SJR Stevinson
Bear Creek
Merced
Newman Wasteway
Hwy 140
SJR Lander
WWTP
Los Banos Creek
Mud Slough
Millerton Lake
Friant Dam
N
Salt Slough
San Luis Drain
0 4 8 mi
Fresno
Kesterson Area
Mendota Pool
San Joaquin River
(Jones-Lee, 2005)

Table 2. San Joaquin River Watershed TMDLs

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

Selenium

Malformations of waterfowl found in the Kesterson area were attributed to excessive selenium in the water. The selenium was determined to have been naturally occurring in the soils of the area but leached into the water through the irrigated agricultural practices in the Grasslands area located in the Mud and Salt Slough watersheds (see Figure 1). These findings caused the CVRWQCB to develop a TMDL to limit the concentrations of selenium discharged from this area. This is a phased TMDL; in 2009, additional restrictions on Grasslands-area selenium discharges will be implemented. The control of selenium to meet the 2009 TMDL requirements will likely significantly also affect the discharges of other constituents from the Grasslands area, such as salts and nutrients, as well as 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 which could lead to further restrictions on selenium discharges.

Salinity and Boron

The waters of the SJR and South Delta (west of the SJR between Stockton and Vernalis) have been found to contain sufficient concentrations of salinity (total salts) to be adverse to some irrigated agriculture. Boron concentrations in the SJR may also to be sufficient to be adverse to some irrigated agriculture. The salinity is derived from evapotranspiration from irrigated

agriculture and soil leaching; the boron is derived from leaching of the soils in the Grasslands area. The excessive concentrations of boron and salinity have caused the CVRWQCB to develop TMDLs 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 limitations on salinity in the SJR upstream of Vernalis. The CVRWQCB is in the process of developing that objective. The management of salinity discharges to the SJR, especially associated with meeting the potential, projected upstream salinity WQO, could significantly restrict the discharges of other pollutants and also the amount of irrigation return water that enters the SJR from Mud and Salt Sloughs.

OP Pesticides

Organophosphorus (OP)-based 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, however, significant deficiencies in the approach that the CVRWQCB is following in attempting to develop aquatic life toxicity control programs in the SJR watershed. These deficiencies include inadequate control of OP and other pesticide discharges from agricultural and urban areas in the SJR watershed, and inadequate monitoring for compliance with the TMDL for OP pesticides in the mainstem of the SJR. Also, the requirements adopted by the CVRWQCB for toxicity testing associated with National Pollutant Discharge Elimination System (NPDES) permitted urban stormwater discharges are inadequate to define the magnitude, frequency, and impacts of the discharges.

Oxygen-Demanding Substances

Nutrient discharges (nitrogen and phosphorus), primarily from irrigated agricultural tailwater and subsurface drain water discharges, cause the SJR upstream of the Stockton Deep Water Ship Channel (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, upon entering the DWSC at the Port of Stockton, the planktonic algae in the SJR die, decompose, and exert a significant oxygen demand. This oxygen demand contributes to violations of the DO WQO in the DWSC. Overall, the low-DO problem in the DWSC near the Port of Stockton results from the depth and flow characteristics created by the existence of the DWSC, and water diversions upstream of the DWSC, as well as the oxygen demand loads that develop on nutrients provided to the SJR upstream of Vernalis, and the discharge of ammonia to the SJR by the city of Stockton's domestic wastewater treatment plant. Additional information on the low-DO problem in the DWSC is provided in Lee and Jones-Lee (2003, 2004a).

The CVRWQCB has adopted a TMDL that 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 is giving the responsible parties (urban, Port of Stockton and agricultural interests) until 2009 to develop information that can be used to formulate a final TMDL to control the SJR DWSC DO WQO violations. Lee and Jones-Lee (2006a) discussed a number of the significant problems with the current CVRWQCB and California Federal Bay-Delta Program

(CALFED) approach. Those problems need to be addressed now so that the information will be available in 2009 for the formulation of the final TMDL.

Organochlorine "Legacy" Pesticides

Organochlorine-based pesticides (OCs), such as DDT, dieldrin, and toxaphene, were widely used on agricultural land in the Central Valley. Many of those pesticides are highly persistent in soils and aquatic sediments, and 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. Despite this ban, legacy pesticides are still being found in stormwater runoff from some agricultural lands in the SJR watershed in sufficient concentrations to accumulate to excessive levels in edible fish. Further, certain types of fish (such as catfish and bass) taken from Central Valley waterbodies contain excessive amounts of 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 CWA 303(d)-"impaired."

Lee and Jones-Lee (2002a) reviewed the information available on excessive bioaccumulation of organochlorine pesticides and PCBs in Central Valley waterbody fish. As they discussed, the accumulation of OCs in edible flesh of Central Valley fish has been well-established by fish tissue monitoring that has occurred over the past 20 years. Nevertheless, the CVRWQCB has not begun to develop TMDLs to control the excessive bioaccumulation of OCs in edible fish; the CVRWQCB and the funding agencies, such as CALFED, have given a low priority to addressing this problem. Because of the importance of this 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 studies needed to define current sources of OCs that are leading to the bioaccumulation of OC residues in edible fish. This is an environmental justice issue, since some minorities and economically disadvantaged individuals rely heavily on SJR fish as a source of food.

PCBs

Fish taken from some parts of the SJR and some of those 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, in electrical transformers, and for other purposes. While PCBs in aquatic systems are typically derived from industrial/commercial sources, there is a potential for some agricultural activities to also be a source. The bioaccumulation of PCBs in edible fish is of concern, because PCBs are suspected to be human carcinogens. PCBs are listed as needing a TMDL to control excessive bioaccumulation but, as with the other OCs, 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. Because the consumption of fish containing excessive dioxins/furans is a significant threat to human health, the US EPA included the SJR DWSC near the Port of Stockton on the CWA 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 area's being designated as a national Superfund site; 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 remove the Old Mormon Slough sediments, the US EPA has chosen to cover those sediments with clean sand in an attempt to prevent further bioaccumulation of dioxins/furans in edible fish of the area. While placement of the sand cover over the dioxins/furan-contaminated sediments in Old Mormon Slough will presumably constitute implementation of the TMDL, there are questions about the long-term reliability of this remediation approach. Of particular concern are its ability to prevent the bioaccumulation of dioxins/furans in edible fish for as long as the dioxins/furans are present in the sediments, and the adequacy of the proposed monitoring of the integrity of the sand cover.

Mercury

Mercury is a neurotoxin that is a threat primarily to fetuses and young children. In the environment, mercury in its various forms can be converted to methyl mercury at the sediment/water interface. It is the methyl mercury form that bioaccumulates in edible fish and poses a threat to young children and pregnant women who consume those fish. Some fish taken from the SJR and the South Delta have been found to contain excessive concentrations of mercury compared to US EPA and 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 CWA 303(d) impaired due to mercury. The mercury in the areas of concern is derived from former mercury mines in the Coast Range that discharge waters to the SJR tributaries, as well as from former gold mining activities in the Sierra where mercury that was used to help recover gold was lost to the soil and sediments of the area. That lost mercury continues to be transported to the SJR and its tributaries, owing in part to runoff of irrigation waters from agricultural lands.

The CVRWQCB is conducting studies to better define the approach that should be followed for controlling excessive mercury bioaccumulation in SJR and South Delta fish. An issue complicating the evaluation and management of mercury is that sulfate influences the rate of methyl mercury formation at the sediment/water interface; the SJR contains elevated concentrations of sulfate compared to the concentrations found in Delta waters derived from the Sacramento River. This could mean that the movement of SJR water, with its elevated sulfate levels, through the South Delta, could influence the bioaccumulation of mercury in edible fish in the South Delta.

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 rate of fish consumption. It is likely that in some areas of the SJR and Delta economically disadvantaged people and others are likely consuming more SJR/Delta fish than the national average. This could mean that the allowable concentrations of mercury in fish tissue need to be lower than the US EPA or state of California guidelines to order to protect those who eat more fish than the national average.

Sanitary Quality

The sanitary quality of water is assessed based on the presence of human pathogenic organisms derived from human and some animal fecal matter. While sanitary water quality standards for contact recreation (swimming, wading, etc.) have long been based on fecal coliforms, standards based on the bacterial indicator organism, *E. coli*, have been shown to be more reliable for protecting human health. Thus, in an effort to protect the quality of water for contact recreation, the US EPA is requiring that states adopt sanitary quality contact recreation standards based on *E. coli*. The CVRWQCB has adopted the *E. coli* standard recommended by the US EPA, although that objective has not yet been approved by the SWRCB. There is need for the SWRCB to approve the *E. coli* objective in order for it to be implemented 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 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 quality. There is need to more adequately evaluate the presence of *E. coli* in the SJR and South Delta waters, and to list those waters exceeding US EPA recommended limits for *E. coli* as CWA 303(d) impaired.

There is also concern about using waters with elevated pathogen-indicator organisms (such as *E. coli*) for domestic water supply. 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, including runoff from agricultural lands and urban areas, in order to protect domestic water supplies.

In addition to the concern about waterborne diseases caused by bacteria, such as typhoid fever, there is concern about human waterborne diseases caused by protozoans, such as *Giardia* and *Cryptosporidium*, as well as by enteric viruses. The *E. coli* standard does not adequately reflect the threat that those non-bacterial pathogens represent through exposure via contact recreation or domestic water supply. Ultimately, agricultural interests in the SJR watershed, including those responsible for runoff from irrigated lands and dairies, feedlots, and managed public and private wildlife refuges, will need to control at least *E. coli* as an indicator of human pathogens in stormwater runoff and tailwater discharges.

Toxicity of Unknown Cause

Toxicity tests on SJR and Delta waters using US EPA-recommended standard test procedures and organisms have shown the presence of aquatic life toxicity whose cause is unknown. Since the presence of aquatic life toxicity is a violation of the CVRWQCB Basin Plan, the CVRWQCB has listed 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 that toxicity, the CVRWQCB has developed a research program focusing on developing toxicity identification evaluations (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

Aquatic plant 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-caused water quality problems is accomplished through a Basin Plan narrative water quality objective for the control of "biostimulatory substances." The CVRWQCB has not developed specific guidelines on how to evaluate the presence of excessive amounts of biostimulatory substances in a waterbody. However, at the request of the CVRWQCB staff, Lee and Jones-Lee (2002b) provided guidance on an approach that can be used for implementation of the biostimulatory substance narrative water quality objective. Lee and Jones-Lee (2006b) provided additional discussion of relationships between nutrient concentrations and water quality impacts in the San Joaquin River and Delta. An appropriate approach involves site-specific evaluation, for each potentially impacted waterbody of concern, of the desired aquatic plant-related water quality, the nutrient loads to the waterbody to achieve those water quality characteristics, and the sources of nutrients that need to be controlled to achieve the desired nutrient load.

The CVRWQCB Agricultural Waiver water quality monitoring program requires that agricultural interests subject to regulation under this program, monitor nutrient concentrations at their monitoring locations beginning in the spring of 2006. Associated with that monitoring is the need to develop guidance on how the agricultural interests and the CVRWQCB staff should interpret the nutrient concentration data developed. The concentration data need to be interpreted based on guidance provided by the CVRWQCB for implementing the narrative water quality objective for biostimulatory substances. The proper implementation of that 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 of it. For example, 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 that nutrient evaluation and control programs for agricultural and urban runoff focus on available forms of phosphorus, rather than total phosphorus. Overall, if properly implemented, the Agricultural Waiver monitoring program could lead to the development of appropriate nutrient control programs for irrigated agriculture and urban sources in the SJR watershed and the Delta.

Aquatic Sediment Toxicity

Toxicity associated with aquatic sediments is becoming recognized as a potentially significant cause of aquatic life-related water quality impairment. Such 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 and other contaminants 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.

Decomposition of accumulations of dead algae can also contribute to sediment toxicity by creating low-oxygen or anoxic conditions in the sediment and at the sediment/water interface. Inadequate dissolved oxygen can be toxic to many forms of aquatic life. As discussed by Lee and Jones-Lee (2007) anoxic conditions lead to the accumulation of ammonia and hydrogen sulfide in the sediments, which are both toxic to aquatic life. At this time, regulatory agencies at the federal and state levels are largely ignoring the toxicity indirectly caused by nutrient discharges through their support of the growth of algae that die, settle, decay and cause anoxic conditions and lead to the accumulation of ammonia and hydrogen sulfide in sediments. These are the most important causes of sediment toxicity in some areas.

The SWRCB is currently developing sediment quality objectives that ultimately will be used to regulate the discharge to estuarine and marine waters and the Delta, of pollutants that accumulate in sediments and cause sediment toxicity. The SWRCB will also focus on 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. As discussed by Lee and Jones-Lee (2004b), it will be important that the chemical information be based not on total concentrations of chemicals (i.e., co-occurrence-based approaches), but rather 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 including the lower reach of the SJR. Ultimately this effort could significantly reduce the discharges of chemicals from the SJR watershed that accumulate in the SJR sediments downstream of Vernalis (i.e., within the Delta) that are adverse to the beneficial uses of the waters.

Some of the SJR DWSC sediments 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 on-land dredged sediment disposal areas, as well as on levees to enhance levee stability. The production of acid from these sediments is a result of the oxidation of iron and sulfur compounds in the sediments that 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. The acid production associated with exposure of DWSC sediments to oxygen is another consequence of SJR's watershed nutrients that lead to algal development and subsequently, to low DO and the associated accumulation of reduced forms of iron and sulfur in the sediments. There is need to more reliably evaluate how SJR DWSC sediments dredged from the navigation channel can be used for beneficial purposes, without adversely affecting 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 organisms. These heavy metals, derived from former mining activities in the Sierra Nevada Mountains, may not be adequately regulated by the current US EPA and state water quality criteria and objectives. This area needs further study.

Pyrethroid-Based 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, including in the SJR watershed. These pesticides accumulate in sediments following runoff events, where they also cause 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. 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 is of concern in water that is to be used for domestic water supply since TOC interacts with many types of disinfectants (such as chlorine and ozone/bromide) to produce disinfection byproducts. These byproducts are chloroform-like chemicals that are regulated as carcinogens in domestic water supplies. The waters exported from the Delta at the State Water Project (SWP) for domestic water supply use at times contain excessive concentrations of TOC compared to the US EPA's regulatory limit. This requires water utilities to practice additional water treatment at additional cost.

One of the major sources of TOC for the Delta is runoff from irrigated agriculture and discharges from wetland areas, including large wildlife refuges and hunting clubs, in the SJR watershed. Other sources include domestic and agricultural wastewaters, stormwater runoff, and organics derived from the peat soils characteristic of many of the Delta island agricultural areas. The cost of water treatment could be reduced if TOC were controlled at the various sources. This, however, 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 those waters for use as 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 various sources in the SJR watershed or 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; within a few years the it 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 of those waters at the water treatment facility. 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 those waters for groundwater recharge in aquifer storage and recovery (ASR) approaches. While waters containing elevated TOCs may be acceptable for use in treated domestic water supplies, they may be unsuitable for use in an ASR project because of adverse impacts on the aquifer characteristics. Potential ASR projects such as the one proposed by the city of Tracy based on Delta Mendota Canal water (derived from the South Delta) should treat the water to remove TOC before it is injected into the aquifer.

Suspended Sediment

Some agricultural lands on the west side of the SJR are subject to severe erosion. This causes runoff waters from these lands to contain high concentrations of suspended sediments, which in turn leads to highly turbid waters and shoaling/siltation at points at which 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 in areas 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, or 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. At this time the growth of algae in the SJR is light-limited. With a reduction in turbidity, there could be increased growth of algae, since surplus nutrients are available to support algal growth. Thus, the control of turbidity in the SJR could lead to increased planktonic algal growth in the SJR, which could in turn 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 those waters are toxic to the US EPA standard toxicity test alga (*Selenastrum capricornutum*). TIE studies have shown that at least part of that 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 by the CVRWQCB.

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, 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.

Unrecognized Pollutants

There is increasing concern about water quality problems caused by 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 from urban and agricultural sources. Pharmaceuticals and personal care products (PPCPs) are discharged to wastewater systems, the effluents from which enter surface and groundwaters. For example, pharmaceuticals and hormones that are used at CAFs (such as dairies, feedlots, etc.) and are discharged in agricultural wastewaters are unregulated, from a water quality impact perspective, but have the potential to be significantly adverse to aquatic life. In fact, adverse impacts of these chemicals on aquatic life are being found. There is need 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 domestic and agricultural wastewater discharges to surface waters in the Delta and SJR tributaries. Studies conducted at the University of California, Davis have demonstrated sublethal impacts of chemicals in SJR and Delta waters. There is need to better understand the water quality significance of those biomarker responses.

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 hunting clubs, and urban stormwater and wastewater discharges. Those impacts on the beneficial uses of SJR waters and the Delta are significantly affected 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 or defined. 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 to the SJR tributaries and the SJR, and all who derive benefits from using SJR watershed waters.

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