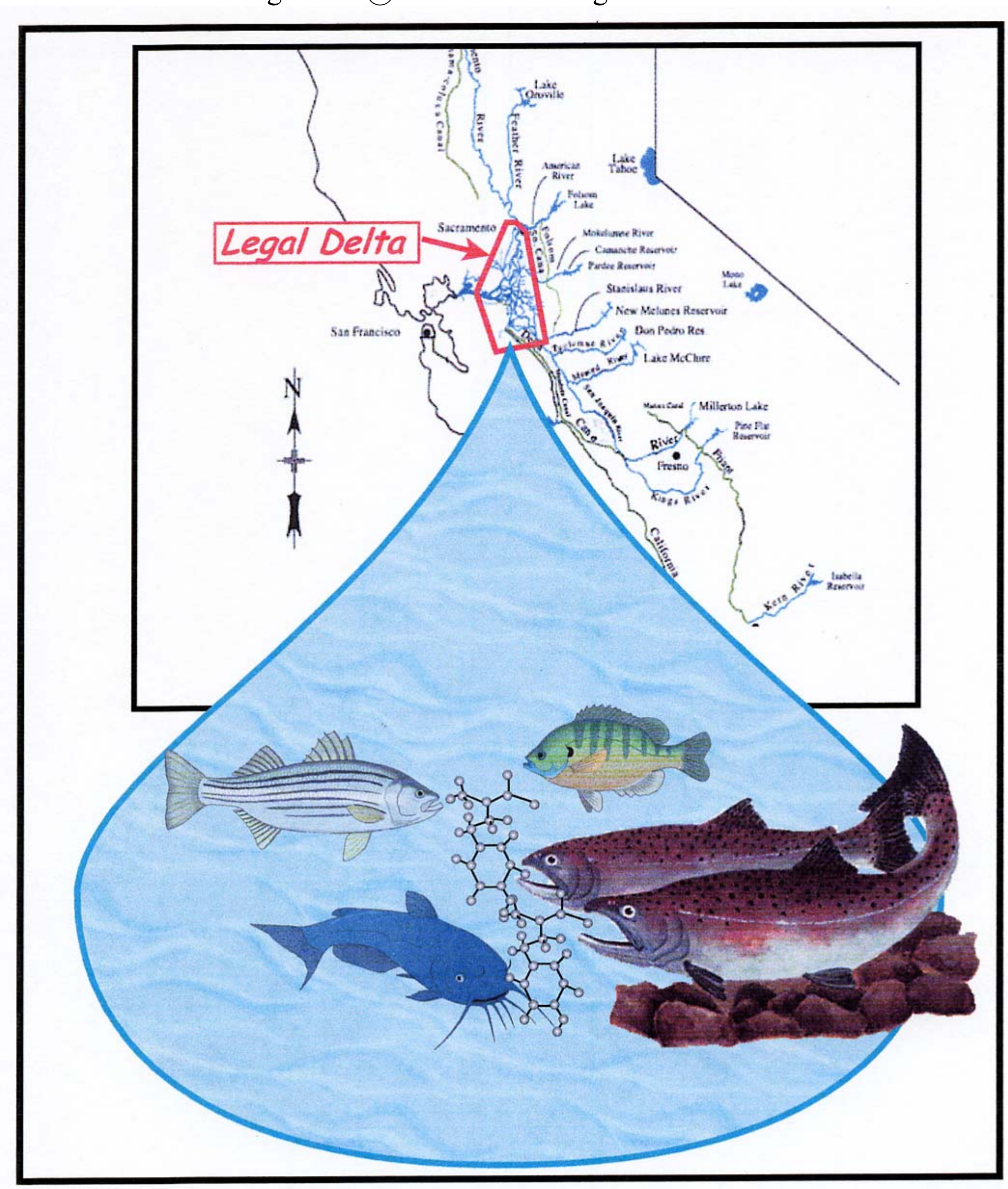
Overview of Sacramento-San Joaquin River Delta Water Quality Issues

G. Fred Lee, PhD, DEE   Anne Jones-Lee, PhD
G. Fred Lee & Associates
El Macero, California
gfredlee@aol.com   www.gfredlee.com



Adapted in part from images in SJRGA (2000)

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Background on Report Development and Source of Additional Information

This report was originally develop as,

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

Subsequently it was presented in part with updated information as,

Lee, G. F., and Jones-Lee, A., "Overview—Sacramento/San Joaquin Delta Water Quality," Presented at CA/NV AWWA Fall Conference, Sacramento, CA, PowerPoint Slides, G. Fred Lee & Associates, El Macero, CA, October (2007). http://www.gfredlee.com/SJR-Delta/DeltaWQCANVAWWAOct07.pdf

Drs, G. Fred Lee and Anne Jones-Lee have developed several other reviews on Delta water quality issues. These reviews are available on their website www.gfredlee.com at http://www.gfredlee.com/psjriv2.htm.

Also a comprehensive review of Delta water quality issues was presented in their Stormwater Runoff Water Quality Newsletter, Volume 10 Numbers 10 & 11, October 18, 2007 Topic: Water Resource and Quality Crisis Issues in Sacramento San Joaquin Delta, CA available at, http://www.gfredlee/Newsletter/swnewsV10N10-11.pdf

The 2003 *CWA 303 (d) list that was used as the basis for this report is no longer on the SWRCB website.. It has been updated at, http://search.ca.gov/search?q=303+&output=xml_no_dtd&site=ca_swrcb&client=ca_swrcb&proxystylesheet=ca_swrcb)* .

Updated information on the current 303 (d) list is available in, http://www.gfredlee.com/SJR-delta/DeltaWQCANVAWWAOct07.pdf

Over the past approximately 10 years we have served as a volunteer technical resource to William Jennings on Delta and Delta tributary water quality management issues. Through discussions with William Jennings (DeltaKeeper) we have gained considerable insight into Delta water quality problems and issues that need to be addressed to manage these problems. This report has been prepared in support of the DeltaKeeper's efforts to improve and protect the Sacramento-San Joaquin River Delta water quality-beneficial uses.

Appendix D presents a summary of our background and expertise, which serves 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 conferences and workshops, and make presentations on Delta water quality issues, which has served as a basis for much of the information presented in this report.

William Jennings, Chair of the California Sportfishing Protection Alliance (CalSPA), arranged for our financial support during 1999 through 2001 from CalSPA litigation settlements with the cities of Turlock and Manteca, to serve as a technical resource to the San Joaquin River Deep Water Ship Channel DO TMDL Steering Committee. DeltaKeeper (William Jennings) also provided support through making a DeltaKeeper boat, boat crew and staff biologist Kari Burr available to conduct sampling tours of the Central and South Delta during the summer 2003. William Jennings has served as a significant source of information that has stimulated the development of this report.

The city of Stockton provided financial support during 2000 and 2001 which enabled G. F. Lee to serve as Chair of the Technical Advisory Committee for the SJR DO TMDL Steering Committee. CALFED provided support for G. F. Lee to serve as the coordinating PI for the Low-DO Directed Action Project during 2001, 2002 and 2003. We wish to thank the SJR DO TMDL Steering Committee for support of our work on the SJR DO TMDL, which allowed us to expand our understanding of Delta water quality problems. We also wish to acknowledge the efforts of Dr. Chris Foe in helping to educate us on Delta water quality issues. We appreciate the assistance of John Herrick and Alex Hildebrand for information on South Delta characteristics, and Curtis Creel and other DWR staff on Delta flow information.

We thank Barbara Marcotte, Sam Harader and Donna Podger of the CBDA staff for their assistance as a source of information and for their support of our activities. CALFED/CBDA Science Program's workshops and seminars where discussions were presented on issues related to Delta water quality have been an important source of information that is included in this review.

A draft of this report on Delta Water Quality Issues was made available to over 200 individuals to provide an opportunity for review and comments. Appropriate comments were included in the final version. This report is planned to be a living report of Delta water quality issues, where we plan to release addenda as additional information is developed.

The 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.

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

Abstract

The Sacramento-San Joaquin River Delta is a unique and valuable resource and an integral part of California's water system. It is a tidal freshwater system, which receives runoff from over 40 percent of the State's area, including the Sacramento River and San Joaquin River watersheds. It covers 738,000 acres with hundreds of miles of interlaced waterways. Its land and waterways support communities, agriculture and recreation, and provide essential habitat for wildlife. The Delta also serves as a water supply source for about 23 million people in California. The legal Delta extends northward to just upstream of the city of Sacramento, eastward into the city of Stockton, southward to Vernalis, and westward to Chipps Island just downstream of Pittsburg (DWR, 1995).

Delta waters have been found to contain sufficient concentrations of various pollutants to be in violation of water quality objectives, and hence experience legal, as well as actual, impairments of beneficial uses. These violations of the US EPA Clean Water Act have led to the need to develop Total Maximum Daily Load (TMDL) programs in an effort to control the input of these pollutants from their sources, which include municipal, domestic, industrial and agricultural wastewater and stormwater.

For example, the water quality/beneficial use of Delta waters is impaired by excessive bioaccumulation in fish of organochlorine "legacy" pesticides (DDT, chlordane, dieldrin, etc.), PCBs, dioxins/furans, and mercury that is a threat to the health of those who use some types of Delta fish as food. Organophosphorus-based pesticides used in agriculture, such as diazinon and chlorpyrifos, are causing aquatic life toxicity to fish food organisms in the Delta. Further, pyrethroid-based pesticides are being found in aquatic sediments downstream of agricultural fields where these pesticides have been used. Some of those sediments have been found to be toxic to sediment organisms. Herbicides used to control roadside and other vegetation have been found to be present in Delta waters at sufficient concentrations to be toxic to algae. Also, Delta waters have been found to be toxic to aquatic life due to unidentified substances (i.e., exhibit toxicity of unknown cause). The current US EPA and California Department of Pesticide Regulation registration of pesticides does not ensure that following label restrictions for the use of a pesticide will prevent aquatic life toxicity in waters receiving runoff/discharges from areas of pesticide use.

An issue that is not being considered in regulating pesticides/herbicides in the Delta and elsewhere is the potential additive and synergistic toxicity of multiple pesticides and/or the interaction of pesticides with other chemicals in the water. Such interactions could cause adverse impacts to Delta aquatic life without there being an exceedance of current water quality objectives for the individual regulated pesticides.

Delta waters contain sufficient concentrations of total organic carbon (TOC) and nutrients (nitrogen and phosphorus compounds) to cause those water utilities that use Delta water as a domestic water supply source to have to provide additional treatment, at additional cost, to control excessive trihalomethanes (THMs) (carcinogens) in the treated waters. The nutrients in Delta waters stimulate algal growth which causes tastes and odors in the water supply.

The total salts (TDS/EC) in the San Joaquin River (SJR) as it enters the South Delta via Old River are at times in violation of the South Delta TDS/EC water quality objective (WQO). Several of the South Delta channels, such as Old River, Middle River and Grant Line Canal, have excessive levels of TDS/EC compared to water quality objectives. This situation has important and restrictive implications for South Delta agriculture. Further, the level of total salts in Delta waters restricts the ability of water management agencies to recharge domestic wastewaters to groundwater as part of wastewater reuse.

The nutrients in Delta waters cause excessive growths of water weeds such as water hyacinth that interfere with recreational use of Delta waters for boating, swimming, and water skiing. Further, the nutrients cause the growth of algae and aquatic weeds in Delta and Delta tributary waters that are used as agricultural water supply. Such growth requires the use of aquatic herbicides to prevent problems with water transport and the plugging of screens on irrigation canals and drip irrigation systems. There is concern about the toxicity of the aquatic herbicides to non-target aquatic life in the Delta and Delta tributary waters. The California State Water Resources Control Board (SWRCB) recently adopted a water quality order for a statewide general NPDES (National Pollutant Discharge and Elimination System) permit for the discharge of aquatic pesticides used for aquatic weed control. However, this permitting framework does not provide adequate protection of non-target organisms from toxicity caused by the aquatic pesticides alone or in combination with other chemicals in the water.

Excessive growth of algae in the San Joaquin River watershed waters and the South Delta channels also contribute to the problems of low dissolved oxygen in these waters. The decomposition of dead algae creates sufficient oxygen demand to cause or significantly contribute to violations of dissolved oxygen (DO) water quality objectives. At times the DO depletion is sufficient to cause fish kills. The export of South Delta water at the federal and state project pumps at Tracy and Banks greatly aggravates the low dissolved oxygen problem in the San Joaquin River (SJR) Deep Water Ship Channel (DWSC). Also, the export pumps at Tracy and Banks have altered the flow of South Delta channels so that low-DO problems and excessive salts are encountered in some of those channels as well. Another source of oxygen demand at times is the ammonia that is discharged in the city of Stockton domestic wastewater. This discharge to the SJR just upstream of the DWSC is a major source of oxygen demand that leads to low DO in the DWSC. The ammonia in the city of Stockton's wastewater discharges also has the potential to be toxic to aquatic life in the DWSC.

The fisheries and other aquatic life resources of the Delta have declined significantly over the past 20 years. This decline appears to be related to entrainment of fish at the export pumps and to the decline of fish food organisms (phytoplankton and zooplankton) in the Delta aquatic food web. The decline in phytoplankton in some parts of the Delta appears to be caused by the harvesting of algae by invasive species such as clams. The decline in zooplankton could be caused, in part, by aquatic life toxicity. The Delta water export projects may also contribute to these declines by drawing large amounts of low-nutrient Sacramento River water to the South Delta.

There is a lack of information on the significance of Delta sediments in causing aquatic life toxicity and contributing to excessive bioaccumulation of chemicals in edible organisms.

The SWRCB's current work toward development of sediment quality objectives should be expanded to cover Delta sediments, in accordance with the Bay Protection and Toxic Cleanup Program requirements.

The sanitary quality of Delta waters has been found to violate water quality objectives for contact recreation such as swimming, water skiing and wading. This means that those who have body contact with Delta waters are at increased risk of contracting disease. The sanitary quality of Delta waters is also of concern to the water utilities that use Delta waters as a water supply. The violations of the sanitary quality WQOs mean that without adequate treatment the use of Delta waters for domestic water supply poses a threat of disease for those who drink the water.

Heavy metals such as mercury, selenium, cadmium and nickel are potentially causing adverse impacts to Delta and San Francisco Bay organisms through food web bioaccumulation.

There is a variety of other potentially hazardous and deleterious chemicals discharged to Delta tributaries and the Delta channels. Several of the Delta tributaries are listed as 303(d) impaired due to heavy metals from former mining activities in the Delta watershed. Other hazardous and deleterious chemicals enter Delta tributaries and Delta channels via domestic and commercial wastewater discharges and stormwater runoff from Stockton, Tracy, Manteca, Sacramento, West Sacramento, etc., and from agricultural activities. These potentially hazardous and deleterious chemicals include pharmaceuticals and personal care products (PPCPs), pesticides, endocrine disruptors, etc., that have not been evaluated with respect to their impacts on Delta water beneficial uses. Further, current regulatory approaches do not adequately address the additive and synergistic impacts of multiple stressors on aquatic life and other beneficial uses of waterbodies.

There is also need for a more systematic and comprehensive approach to the examination of Delta waters and wastes discharged to the Delta for their implications for public health and aquatic life. The recent finding of perchlorate as a widespread water pollutant which is toxic to humans is an example of the inadequate approach for investigating potentially hazardous chemicals in water. Further, the finding of the polybrominated diphenyl ethers (PBDEs) (which bioaccumulate) as water contaminants in San Francisco Bay aquatic life demonstrates the inadequacy of the current approach for the protection of water quality. While both perchlorate and PBDEs have been in the aquatic environment for many years, they have only recently been discovered there.

The Delta water monitoring program associated with the State Water Resources Control Board (SWRCB) D-1641 water rights decision allowing Delta water export via the State Water Project (SWP) to Central and Southern California is substantially deficient compared to that which is needed to properly evaluate the impact of the water exports from the South Delta via the federal (Central Valley Project – CVP) and state export projects on Delta water quality-beneficial uses. Inadequate attention has been given to the water quality impacts of San Joaquin River water exports and the large amounts of Sacramento River water and its associated pollutants that are drawn to the South Delta by the federal project pumps at Tracy and the State Water Project pumps at Banks. The current water quality monitoring that focuses on TDS/EC is not an adequate surrogate for defining the full range of important Delta water quality problems.

There is an urgent need to significantly expand Delta water quality monitoring/evaluation to define the magnitude and extent of known and yet-to-be-defined water quality problems. This information is essential to developing water quality management programs to restore Delta water quality that has been degraded due to discharge of pollutants to the Delta channels, and the export of Delta waters by the federal and state projects. The funding for this program should be provided by the water exporters, those who discharge potential pollutants to the Delta and its tributaries, and those who use Delta aquatic resources. The current situation where decreasing funding is available for water quality monitoring is strongly contrary to protecting Delta water quality.

Summary of Existing Delta Water Quality Problems

This comprehensive review of the current understanding of Delta water quality issues has been developed in response to increased interest in Sacramento-San Joaquin River Delta water quality because of current South Delta water exports by the federal (Tracy) and state (Banks) water projects and proposed expanded Delta water exports by the State Water Project. This review discusses the currently recognized Delta water quality issues as assessed based on violations of Central Valley Regional Water Quality Control Board (CVRWQCB) Basin Plan water quality objectives (WQOs). These violations have resulted in the listing of Delta channels as US EPA Clean Water Act (CWA) 303(d) impaired. This means that chemicals and pathogen indicator organisms in Delta waters are at least legally impairing the beneficial uses of Delta waters. In accordance with the Clean Water Act, this listing requires that the CVRWQCB conduct TMDL programs to control the WQO violations.

As discussed below, in addition to the exceedances of WQOs, there are several known water quality problems – beneficial use impairments in Delta waters that are not listed by the CVRWQCB, State Water Resources Control Board (SWRCB) or US EPA as 303(d) impairments. These include excessive growth of aquatic weeds due to nutrients, TOC that leads to impairment of the use of Delta waters for domestic water supply, certain heavy metals that are toxic to aquatic life, and sediment accumulation that impairs the uses of Delta waters. These problems are primarily identified through the CVRWQCB Basin Plan "narrative" water quality objectives rather than by exceedances of numeric WQOs. There is need to conduct studies to implement the narrative water quality objectives for these and other constituents that are or potentially are causing beneficial use impairment.

This Delta water quality review also addresses deficiencies in current water quality monitoring programs that impede the ability to properly define the full range of Delta water quality problems-beneficial use impairments as well as to serve as the basis to begin to develop a TMDL program to control the WQO violations. This review also presents a summary of characteristics of current Delta water quality problems and suggests the approach that should be followed to control these problems. The current US EPA Clean Water Act and state of California water quality regulatory approach, which is based on defining violations of water quality standards/objectives and then developing a program to control those violations, fails to address the many thousands of chemicals that are present in urban and industrial wastewaters and stormwater runoff as well as discharges/runoff from agricultural areas, which can be adverse to the water quality-beneficial uses of waterbodies.

Periodically, significant environmental pollutants that have been in the environment for many years are discovered to represent a threat to water quality and/or public health. Two recent examples of this type of pollutant are perchlorate and the polybrominated diphenyl ethers (PBDEs). While these chemicals have been present in wastewaters and ambient waters for many years, they are now being recognized as widespread water pollutants. There are likely many other chemicals of this type which are a threat to water quality through adverse impacts to aquatic life or people who drink the water or who eat fish and other aquatic life derived from waterbodies, but which are not being adequately addressed in water quality evaluation and management programs. The issue of inadequate definition of water pollutants is discussed in more detail below.

Hazardous Chemicals in Edible Fish

A map of the Delta is presented in Figure S1. Various Delta channels/waterways are listed as CWA 303(d) impaired because of the excessive bioaccumulation in fish of mercury, organochlorine "legacy" pesticides (DDT, dieldrin, toxaphene, chlordane, etc.), PCBs, and, near Stockton, dioxins and furans. These organochlorine compounds can cause cancer and neurological damage in humans who eat Delta fish and other organisms that contain elevated levels. The organochlorine pesticides are called "legacy" pesticides because they had been used in agriculture and urban areas but have been banned for use for about 20 years because of their threat to human health. Since these chemicals are highly resistant to degradation in the environment, they are still present in soils and in water sediments downstream of areas where they were applied/used.

Even though excessive bioaccumulation of organochlorine compounds represents one of the most significant water quality problems in the Delta, at this time there are no funds available to the CVRWQCB or other agencies to evaluate the full extent of excessive bioaccumulation of the organochlorine chemicals that accumulate in Delta edible organisms. Further, no funds are available to define current sources of organochlorine hazardous chemicals or to begin to develop programs for control of the excessive bioaccumulation problem in Delta channels and near-Delta tributaries.

Also of concern is the excessive bioaccumulation of mercury in some types of Delta fish. Consuming mercury-contaminated fish can cause neurological damage in unborn and young children. The excessive bioaccumulation of mercury is also a threat to birds that feed on aquatic life. California Bay-Delta Authority (CBDA) is funding research to evaluate mercury bioaccumulation and its control in order to protect the CBDA Ecosystem Restoration Program's development of shallow water habitat to help restore Delta fisheries.

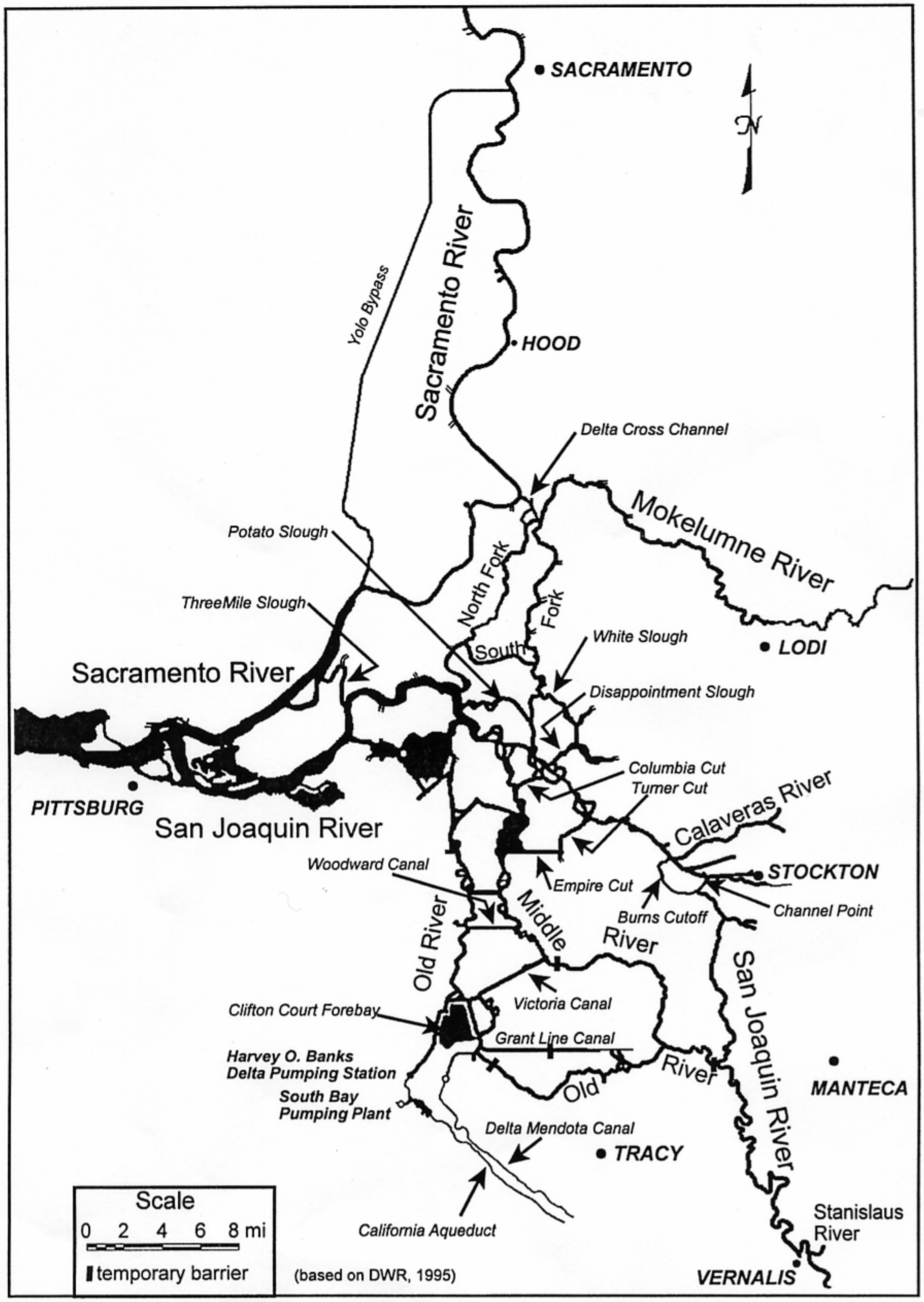
The chemicals that bioaccumulate to excessive levels in edible fish and other organisms tend to be associated with sediments. Therefore, work needs to be done to determine the role of Delta sediment-associated pollutants as a source of hazardous chemicals that bioaccumulate in edible organisms to levels that are a threat to the health of those who use Delta fish as food.

Overall, there are no funds available in CBDA or the State and Regional Water Boards to address several significant the human health problems of bioaccumulation of hazardous chemicals in Delta fish. This is a significant deficiency in the water pollution control programs in the Delta, Central Valley and California.

Toxicity of Currently Used Pesticides

With the banning of the organochlorine pesticides, new pesticides were developed to control agricultural and urban pests. Organophosphorus-based pesticides were developed and have been widely used in agriculture and in urban areas for about 20 years. The most commonly used organophosphorus pesticides are diazinon and chlorpyrifos. While the organophosphorus pesticides are less persistent in the environment than the organochlorine pesticides, they are

Figure S1
Map of the Delta



sufficiently persistent so that runoff from the areas where they have been applied can contain sufficient concentrations to be toxic to aquatic life in the receiving waters for this runoff.

Beginning in the late 1980s the CVRWQCB staff and University of California, Davis (UCD) faculty/staff found that diazinon and chlorpyrifos – two of the most commonly used organophosphorus pesticides – while not highly toxic to fish, are highly toxic to zooplankton (small water animals) that serve as food for young and small fish. This in turn can be detrimental to larger fish that are desirable to fishermen and are important to the Delta aquatic ecosystem. The CVRWQCB staff, with support of the UCD staff, found that waters in many areas of the Central Valley are toxic to zooplankton after organophosphorus pesticide application to agricultural and urban areas.

The presence of zooplankton toxicity in Central Valley waterbodies and Delta channels due to organophosphorus pesticides violates the CVRWQCB Basin Plan WQO controlling aquatic life toxicity. This has led to a CWA 303(d) listing for diazinon- and chlorpyrifos-caused aquatic life toxicity in the Delta channels. It is possible that this toxicity is in part responsible for the decline in the fisheries resources of the Delta. While the CVRWQCB is developing TMDLs to control organophosphorus pesticide toxicity in the Sacramento River and San Joaquin River watersheds, no work is being done to control the diazinon- and chlorpyrifos-caused toxicity in Delta channels. There are insufficient funds to enable the CVRWQCB to initiate work in this area.

With the reduced use of diazinon and chlorpyrifos, pyrethroid-based pesticides are being used increasingly in agricultural and urban areas. Some of these pesticides are as toxic or more toxic to zooplankton than the organophosphorus pesticides, and are also toxic to fish. One important difference between the organophosphorus and pyrethroid pesticides is that the pyrethroid pesticides tend to accumulate in aquatic sediments and are potentially toxic to sediment organisms. These sediment-associated organisms are important as fish food and to the aquatic ecosystem. At this time very little work is being done on investigating pyrethroid pesticide-caused water and sediment toxicity in the Central Valley and the Delta.

The current pesticide registration process used by the US EPA and the California Department of Pesticide Regulation (DPR) allows the use of pesticides that are highly toxic to aquatic organisms without evaluation of whether the pesticide can be present in stormwater runoff and irrigation water discharges at concentrations that are toxic to aquatic life in the receiving waters for the discharges/runoff. This is a significant deficiency in the federal and state of California pesticide registration process. Another deficiency in the current approach used for regulating pesticides is the failure to properly control aquatic life toxicity associated with additive or synergistic interactions among multiple pesticides in the water or between the pesticide and other chemicals in the water. It is well known that the toxicities of the organophosphorus pesticides diazinon and chlorpyrifos are additive. There is recent evidence that the combination of organophosphorus pesticides with triazine herbicides in water has a synergistic effect on aquatic life toxicity – i.e., the magnitude of the toxicity found is greater than the sum of the toxicities of the pesticide and herbicide. Additive or synergistic toxicity could lead to situations in which a pesticide could be present in concentrations below a water quality objective, yet be causing toxicity to aquatic life through interactions with other pesticides and/or other chemicals.

Sediment Toxicity

Organisms that live in or on aquatic sediments are important to the aquatic food web. A variety of chemicals can cause aquatic sediments to be toxic to aquatic organisms. While Delta sediments are known to contain several potential pollutants (heavy metals and organics) that have the potential to be toxic to aquatic life, there is limited information on the occurrence of toxicity in Delta sediments. This is an area that needs attention to determine where Delta sediments are toxic, and where toxic, the cause of the toxicity. This information is required to begin to remediate the polluted Delta sediments and to control the input of pollutants that accumulate in Delta sediments and cause the sediments to be toxic.

There is need to develop reliable sediment quality objectives to regulate real, significant water quality problems caused by sediment-associated pollutants. Recently the SWRCB staff responsible for developing sediment quality objectives has indicated that it has abandoned trying to use chemical concentration-based objectives in favor of a weight-of-evidence (WOE) approach. The WOE approach involves an integrated use of aquatic life toxicity, organism assemblage and appropriate chemical information to evaluate water quality impairment and causes, and remediation of the impairment. Sediment quality objectives should be based on biological effects, such as aquatic life toxicity, with the toxic substances properly identified through toxicity identification evaluations. Co-occurrence-based approaches, such as those that have been proposed in the past by the SWRCB staff, are well-known to be unreliable for this purpose. Adoption of a WOE approach by the SWRCB will be a significant advance toward properly regulating chemical pollutants in aquatic sediments. One of the major deficiencies of the current SWRCB sediment quality objectives development is the failure to include developing sediment quality objectives (SQOs) for Delta sediments, even though the Bay Protection and Toxic Cleanup Program (BPTCP) requires that SQOs be developed for Delta sediments.

Unknown-Caused Toxicity

Studies by the CVRWQCB staff, UCD Aquatic Toxicology Laboratory staff and others have found that many Central Valley waters, including the Delta, exhibit aquatic life toxicity for which the cause is unknown. The CVRWQCB staff, with support of others, has initiated a program to identify the cause of toxicity in such situations and develop management programs for this toxicity. A draft Strategy for Control of Toxicity of Unknown Cause is under development. This strategy will be used to support a proposal to CBDA to fund the implementation of a control program. Funding of this effort by CBDA would be in accord with the CALFED Record of Decision (ROD) which requires work to control the cause of unknown-caused toxicity in the Delta.

Heavy Metals

Several of the Delta tributaries are listed as 303(d) impaired due to heavy metals from former mining activities in the Delta watershed. Mercury from former Coast Range mercury mining operations and from gold mining operations in the Sierra-Nevada Mountains has been found to bioaccumulate in fish of the Delta and its tributaries. This accumulation is of sufficient magnitude to cause the fish to be hazardous to fetuses and young children when the contaminated fish are eaten by the mother or the child.

Selenium is another metal that is potentially causing water quality problems in the Delta. It bioaccumulates in the Delta food web and is potentially causing adverse impacts to certain higher trophic-level fish, notably sturgeon. This situation could cause even greater restrictions on the discharge of selenium to Delta tributaries in the San Joaquin River watershed than exist today.

There is a potential for food web accumulation of cadmium and nickel that is toxic to aquatic life. The bioaccumulation of these metals, as a cause of aquatic life toxicity, is not regulated under the current US EPA water quality criteria or CVRWQCB Basin Plan water quality objectives.

Some Delta sediments, such as in marinas, have been found to contain elevated concentrations of copper, possibly due to the use of copper in antifoulant paints on boat hulls.

In summary, past mining operations and current sources of heavy metals require that studies be conducted to determine the water quality significance of several heavy metals in Delta and Delta tributary water and sediments.

Drinking Water Quality Problems

From 10,000 to 13,000 cfs of Delta water is exported from the Central and South Delta for use for domestic water supplies in the San Francisco Bay area (Contra Costa and Santa Clara Water Districts) and Southern California (Metropolitan Water District of Southern California), and for agriculture in the Central Valley. About one-half of the exported water is used for domestic water supply. Delta water contains several constituents (TOC, bromide, nutrients and TDS/EC) that cause domestic water supply water quality problems that increase the cost of treatment. Of particular concern are the constituents – notably total organic carbon (TOC) and bromide – that form trihalomethanes (THMs) during water supply disinfection. THMs are chloroform and chloroform-like compounds that are regulated as carcinogens. The TOC is derived from runoff from agricultural and urban areas, wetlands, and Delta island peat soils; terrestrial plants and higher forms of aquatic plants. The bromide is derived from sea water intrusion into the Delta from San Francisco Bay.

The CBDA Drinking Water Subcommittee is developing a drinking water quality management strategy. The CVRWQCB is also reviewing drinking water quality problems in the Delta, associated with developing a Drinking Water Policy. There are major water quality management issues that will need to be addressed as part of developing a technically valid, cost-effective drinking water quality policy for the Delta, such as whether it is more appropriate to try to control TOC in agricultural runoff and urban stormwater and wastewater discharges at the source, or to treat the part of the export waters that are used for domestic water supply purposes to control the TOC/THM problem at the water treatment works.

The total salts (measured as total dissolved solids (TDS) and electrical conductivity (EC)) in Delta waters are of concern to the Southern California drinking water utilities, since elevated

TDS/EC in the water supply restricts the ability of water management agencies to recharge the treated wastewaters to groundwaters for future use as a domestic water supply.

Aquatic plant nutrients (nitrogen and phosphorus compounds) are derived from runoff and discharges from agricultural areas (including dairies and feedlots), wetlands discharges, urban wastewater discharges and stormwater runoff. The nutrients cause excessive growth of algae that cause tastes and odors in drinking water and decrease the length of filter runs for water utilities that use Delta waters as a water supply source. These water quality problems are controlled with increased water treatment at an increased cost. Efforts are being made by water utilities and regulatory agencies to control the constituents responsible for such impairments at their sources in the watershed. This could lead to significantly increased of cost of pollution control to agricultural and urban interests in the Delta watershed.

Impact of Salts on Agriculture in the South Delta

The San Joaquin River water that flows into the South Delta via Old River at times contains sufficient salts (TDS/EC) to cause violations of the CVRWQCB Basin Plan water quality objective for TDS/EC for the South Delta channels. The first phase of the currently proposed CVRWQCB Basin Plan Amendment to limit TDS discharges to the SJR upstream of Vernalis will not address this problem since the TDS/EC TMDL target that has been proposed by the CVRWQCB staff is the TDS/EC WQO for the South Delta channels. This means that South Delta irrigated agriculture tailwater discharges to the South Delta channels will at times cause violations of the WQO. These violations will be the result of the high salt loads to the Delta via the SJR that currently occur and are proposed to be allowed by the CVRWQCB as part of the initial phase of the San Joaquin River TDS/EC TMDL. There is need to control the TDS/EC discharges in the SJR watershed to a greater degree than that proposed by the CVRWQCB, so that the SJR waters that enter the South Delta will not be in violation of TDS/EC WQOs and will be suitable to South Delta agriculture that does not impair crop production and restrict tailwater discharges..

Nutrient Impact on Delta Aquatic Resources and Agricultural Water Supplies

Delta waters experience excessive growths of aquatic plants such as water hyacinth and *Egeria densa*. These water weeds interfere with recreational use of Delta waters for boating, swimming, water skiing, fishing, etc. The water weeds develop on nutrients added to Delta tributaries from urban, agricultural and wetlands sources in the Delta watershed, and from Delta island discharges. The California Department of Boating and Waterways spends several hundred thousand dollars per year to apply chemicals for controlling water weeds. There is concern about the potential toxic and other impacts of these chemicals on non-target organisms, such as fish food organisms, in the water column and sediments.

The excessive nutrients in Delta, Delta tributary and Delta export waters lead to the growth of sufficient algae and other aquatic plants to interfere with the transport of the waters in irrigation systems, including canals, by Delta watershed and in-Delta irrigation districts. The algae and water weeds plug irrigation system screens and drip-irrigation systems. Many irrigation districts treat these waters with herbicides to prevent aquatic plant growth in the irrigation water supply system. There is concern that the herbicides are toxic to non-target organisms and thereby impair aquatic life resources of the waters receiving the irrigation waters.

While, in the past, irrigation districts could apply aquatic herbicides without evaluating the potential for adverse impacts on non-target organisms, the SWRCB has been developing a permit system that could require monitoring of the treatment area for adverse impacts to aquatic resources in the area of treatment and downstream. However, the recently adopted Statewide General NPDES permit for application of aquatic herbicides falls short of providing adequate protection of non-target organisms from toxicity impacts of herbicides. It is essential that the NPDES permit covering aquatic herbicide application include comprehensive aquatic life toxicity testing and bioassessments to determine if the herbicides used and their transformation products, either alone or in combination with other chemicals in the water through additive or synergistic effects, are adverse to non-target organisms.

Low Dissolved Oxygen Problems

The nutrient-rich waters of the SJR upstream of the Deep Water Ship Channel (DWSC) lead to the development of sufficient algae in the SJR as it enters the DWSC to be a major contributor of oxygen demand that leads to the low-DO problem in the DWSC. The algae in the SJR do not cause low-DO water quality problems in the SJR upstream of the DWSC. However, the decomposition of algae that die in the DWSC is at times a major cause of oxygen depletion there which causes DO concentrations to fall below the WQO.

One of the recently documented problems caused by the export of South Delta water by the federal and state projects is the reduction of the flow of the SJR through the Deep Water Ship Channel near Stockton. The export pumping of South Delta water by the federal and state project pumps at Tracy and Banks causes most of the water in the SJR at Vernalis to be drawn into the South Delta via Old River, leaving little of the SJR flow to pass through the DWSC. This diversion of SJR flow into the South Delta is at times a major cause of severe low dissolved oxygen problems in the DWSC. If most of the SJR flow at Vernalis were allowed to pass through the DWSC before being exported to Central and Southern California, there would typically be sufficient flow to reduce/prevent the development of the low-DO problem in the DWSC.

The DeltaKeeper-supported studies conducted by the authors in the summer 2003 on South Delta channels showed severe DO depletion in Old River near the Tracy Boulevard bridge. At the time of the tour of this area on August 5, 2003, a fish kill had just occurred; many thousands of fish were seen floating on the water surface there. Data from DWR's continuous water quality monitoring station in the area of the fish kill showed that the DO there had been at or near zero for about six hours the previous night. Thus, the fish kill was likely due to low DO. A review of the DWR 2003 data obtained for Old River showed that there was a period of about six weeks beginning in late July when the DO in that channel was below the WQO. There were many days when the DO was less than 1.0 mg/L, compared to the 5 mg/L WQO. Similar situations have been recorded in that channel and some other South Delta channels over the past three years, and likely occurred before then as well. The severe low-DO problems in some of the South Delta channels are apparently the result of the decay of excessive algal growths.

The DeltaKeeper also supported two tours by the authors of Central Delta channels during the summer 2003 to investigate the mixing of Sacramento River water with San Joaquin River water that is present in the Deep Water Ship Channel. The SJR DWSC water enters the

Central Delta through Turner Cut and Columbia Cut where it mixes with Sacramento River water that is drawn to the South Delta via Middle River by the state and federal export projects. This mixing of Sacramento River water with SJR water in Turner Cut dilutes the oxygen demand, EC and other pollutants in the SJR DWSC waters, and thereby reduces the impact of introduction of SJR DWSC water into the Central Delta on Central Delta water quality. This is important because it means that the increased flow of the SJR through the DWSC which has been proposed as a means to help solve the low-DO problem will not in general have adverse impacts on Central Delta water quality. There may, however, be adverse impacts under certain flow and seasonal conditions. Specific studies need to be conducted to evaluate this situation.

Another major source of oxygen demand in the DWSC is the ammonia in the city of Stockton's domestic wastewater discharges. At times, the ammonia in the City's wastewater discharge to the SJR just upstream of the DWSC represents about 90 percent of the oxygen demand load to the DWSC. Under the revised CVRWQCB NPDES wastewater permit conditions designed to control ammonia toxicity to aquatic life, the city of Stockton's discharge of ammonia will need to be significantly reduced. This reduction will significantly reduce the oxygen demand load of Stockton's wastewater ammonia to the DWSC.

Delta fisheries have been declining over the past 20 years or so. Populations of lower trophic-level fish-food organisms (the zooplankton and phytoplankton that make up the lower level of the food web) have also declined one to two orders of magnitude since the 1980s. While the cause of this decline is not understood, it may be due in part to a decrease in algal populations in the Delta which could be caused by invasive species (Asian clams) that consume algae and zooplankton. Another potential cause of reduced algal growth in the Central Delta is the export pumps' drawing of large amounts of low-nutrient Sacramento River water through the Central Delta to the South Delta. Reductions in the algal input associated with nutrient control in the Delta watershed could lead to further reductions in the lower trophic-level food supply for zooplankton and larval and small fish. There is need to better understand the food web in the Delta to evaluate how manipulation of nutrients and algal loads to the Delta will impact Delta aquatic life resources.

Sediment Oxygen Demand

Studies of the bedded sediment oxygen demand (SOD) of the DWSC sediments have shown that it is not unusually high. It appears that the tidal currents cause the dead algae that would normally settle to the bottom and exert an SOD to be suspended in the water column near the bottom of the channel where the oxygen demand of the particulate matter (principally dead algae) is exerted.

Sanitary Quality of Delta Waters

The sanitary quality indicators in Delta waters have been found in some Delta waters to be in violation of water quality objectives for contact recreation, including swimming, water skiing, wading, etc. Studies on Delta waters have shown that they contain fecal coliforms at concentrations that have been associated with the presence of enteric (intestinal) pathogens (disease-causing organisms). As a result, those who have contact with some Delta waters are exposed to disease organisms that can cause a variety of enteric and other illnesses.

The sanitary quality of Delta waters is also of concern to the water utilities that use Delta waters as a water supply. The violations of the sanitary quality WQOs mean that the use of Delta waters for domestic water supply is a threat to cause diseases in those who drink the water without adequate treatment.

Sediment Accumulation

Some South Delta channels are experiencing shoaling (loss of water depth) due to the accumulation of sediment in the channels. The sediment accumulation is also detrimental to benthic (bottom-dwelling) organisms' habitat. The excessive sediments are apparently derived from erosion of agricultural lands in the watersheds of the westside tributaries of the San Joaquin River. Erosion in the San Joaquin River watershed also causes increased turbidity, which reduces light penetration and algal growth.

Managed Wetlands as a Source of Pollutants

The Delta watershed contains several federal and state wildlife refuges and private migratory waterfowl gun clubs. Many of these areas are managed to produce crops for wildlife. Runoff/discharges from managed wetlands contain several chemical constituents (TOC, salts and nutrients) that impair Delta water quality. As part of its agricultural waiver program, the CVRWQCB is requiring that the owners/managers of managed wetlands investigate the discharge of potential pollutants to Delta tributaries. This could lead to requirements for managing these discharges to protect Delta water quality.

Impact of Invasive Species

The Delta has been polluted by a variety of invasive species, such as the Asian clam, which are significantly adversely impacting the beneficial uses of Delta waters. It appears that the consumption of phytoplankton and zooplankton by this clam could be responsible for at least part of the decline in the lower trophic-level food web in the Delta.

Several types of aquatic plants (such as water hyacinth, *Elodea* and *Egeria densa*) are invasive plant species that are impairing the beneficial uses of Delta waters.

Impact of Export Projects on Chinook Salmon Home Stream Water Signal

The South Delta export projects that have changed the flow of Sacramento and San Joaquin River water through the Delta have also changed the transport of the home stream chemical signal which guides Chinook salmon to their spawning areas. Prior to the export projects, the San Joaquin River tributary home stream water chemical signal could be transported, during low-flow conditions, to San Francisco Bay, providing a home stream signal to fall-run Chinook salmon proceeding to their San Joaquin River tributary home stream. The export-project-caused drawing of large amounts of Sacramento River water to the South Delta has eliminated the San Joaquin River tributary home stream water signals from occurring in the Central and northern Delta, downstream of Columbia Cut. During the summer, fall and early winter the water in the San Joaquin River channel downstream of Columbia Cut is Sacramento River water, not San Joaquin River water. This means that when the fall-run Chinook salmon enter the Delta from San Francisco Bay during the fall and winter they have no home stream water signal to help them migrate through the Delta to their home stream waters.

Inadequate Water Quality Monitoring/Evaluation

As part of SWRCB water rights decision D-1641, several agencies, through the Interagency Ecological Program (IEP), conduct an Environmental Monitoring Program (EMP) that is to provide information on the impacts of Delta water exports to central and Southern California on Delta resources and water quality. A critical review of the IEP EMP shows that it falls short of adequately defining the full range of water quality impacts of the export of Delta water by the federal project (Central Valley Project – CVP) and state project (State Water Project – SWP). These exports are having major adverse impacts on DO concentrations in the SJR Deep Water Ship Channel and in several South Delta channels. They are also causing pollutants – such as mercury; organochlorine, organophosphorus and pyrethroid pesticides; and other pollutants such as TOC and heavy metals – that enter the Delta from tributary and in-Delta sources to be transported to areas of the Delta where they would not occur at the same concentrations if the South Delta exports did not occur.

The large amount of Sacramento River water that flows through the central Delta to the South Delta export pumps significantly changes the flow of water and pollutants in the Delta. For example, mercury present in Sacramento River water is transported to the central and South Delta via the Central Delta Old River and Middle River channels as a result of the export of South Delta water by the projects. This export changes the occurrence of mercury in Delta channels, which potentially impacts the excessive bioaccumulation of mercury in Delta fish. There has been essentially no evaluation of the impact of the export of South Delta waters at the Tracy and Banks pumps on a variety of Delta water quality problems. Particular attention should be given in an expanded monitoring/evaluation program to defining the full impact of the export of Delta waters by the federal and state projects.

There is need for a significant expansion of the water quality monitoring/evaluation program in the Delta. This expanded water quality monitoring should be focused on an evaluation of the current extent and magnitude of the 303(d) impairments in the currently listed Delta channels. Also, where the expanded monitoring/evaluation program shows a water quality use impairment, the sources of the pollutants responsible for the impairment should be defined. This information is essential to begin to develop a TMDL management program for the 303(d)-listed Delta channels.

The Clean Water Act of 1972 required that the US EPA develop a list of the Priority Pollutants and develop water quality criteria for them. The Agency was not given sufficient funding by Congress to accomplish this requirement, and therefore did not meet the congressionally established deadline. Litigation by an environmental group led to an agreement which established 129 Priority Pollutants. The list was developed by attorneys and was not peer-reviewed by the US EPA staff who were experts in this area or by professionals outside the Agency. It is recognized that the Priority Pollutant list did not and does not represent an appropriate listing of the wide variety of chemicals that are a threat to cause water pollution. It is also recognized that the currently regulated pollutants, such as the Priority Pollutants, represent a very small portion of the chemicals that are present in municipal, industrial and agricultural wastewaters and stormwater runoff that are a potential threat to water quality-beneficial uses of waterbodies. Unfortunately, however, the focus of water pollution control programs has been largely devoted to the Priority Pollutants, while ignoring many of the other chemicals used by urban populations, industry and agriculture that are a threat to cause water pollution. For example, more than 150 pesticides are used in the Central Valley, yet fewer than half a dozen receive any regulatory attention by the CVRWQCB. Even though there are significant problems with using the Priority Pollutant list as a primary list of hazardous chemicals of concern in the Delta and discharges to the Delta, there is inadequate monitoring of the Priority Pollutants in Delta waters.

There are more than 22 million organic and inorganic substances, with nearly 6 million commercially available. One hundred thousand of these are produced in large amounts. The current water quality regulatory approach addresses fewer than 200 of these chemicals. Another component of an expanded monitoring/evaluation program for the Delta should include a substantial program for searching for yet-unidentified water quality beneficial use impairments of Delta waters. Where found, the magnitude and extent of the impairment and the source of the pollutants should be defined. In addition to monitoring/evaluating potential water quality problems caused by conventional pollutants and Priority Pollutants, attention should be given to pharmaceuticals and personal care products (PPCPs) and endocrine disruptors that are present in domestic and other wastewaters and stormwater runoff that are discharged to the Delta and its tributaries, especially by the cities of Stockton, Tracy, Sacramento and West Sacramento. Also of potential concern are the wastewater discharges from Modesto, Merced and other San Joaquin River watershed municipalities and agricultural activities.

The PPCPs are a diverse group of chemicals, including human and veterinary drugs that are available over the counter and by prescription, food supplements, consumer chemicals such as fragrances and sunscreen agents, and the wastes from the manufacture of these and other materials. In general PPCPs and many other chemicals are not regulated with respect to causing water quality impairment. With increasing urban population and industrial activities in the Central Valley, there will be increasing significance of PPCPs and other pollutants derived from urban and industrial activities as a cause of water quality problems in the Delta. This is an area that needs attention in a Delta water quality monitoring/evaluation program. Additional information on PPCPs is available at www.epa.gov/nerlesd1/chemistry/pharma/index.htm.

Another significant deficiency in the current regulatory approach in defining water quality problems in the Delta and elsewhere is that chemical impacts are assessed based on individual chemicals without consideration of additive or synergistic effects. It is well established that the aquatic life toxicities of some combinations of pesticides are additive. Further, the toxicity of certain pesticide combinations show synergistic effects – i.e., the toxicity of a mixture of the pesticides is greater than the sum of the toxicities caused by the individual pesticides.

Another area that needs attention in an expanded water quality monitoring/evaluation program is the potential for various chemicals in domestic and commercial wastewater discharges and agricultural and urban stormwater runoff to be adverse to the migration of anadromous fish through the Delta to their home stream waters in the San Joaquin and Sacramento River watersheds. It is known that low concentrations, below those that are known to be toxic to fish and other forms of aquatic life, of a variety of chemicals – such as heavy metals, pesticides, PPCPs, etc. – can adversely impact the olfactory sensitivity and homing ability of anadromous fish such as Chinook salmon. There is need to determine if there are pollutants in Delta waters that are adverse to the homing of anadromous fish.

The funding for an expanded monitoring/evaluation program should be provided by the Delta water exporters, those who discharge wastewaters and contribute stormwater runoff to the Delta and its tributaries, and the users of Delta aquatic resources. The recent cuts in SWRCB water quality monitoring funding should be immediately reversed, and funding should be significantly expanded to cover defining current water quality problems, the sources of the constituents responsible for these problems, and the efficacy of water pollution control programs in controlling these problems, and to define yet-unidentified pollutants in the Delta and its tributaries.

The recently proposed CBDA Delta water exporters' "Delta Improvements Package" (DIP), in which additional Delta water would be exported to Central and Southern California by the State Water Project, is significantly deficient in defining the potential water quality impacts of additional Delta water exports. Before the proposed DIP is implemented with respect to increased Delta water exports, a comprehensive understanding of the current impacts of the existing exports should be developed. This information should then be used to predict the potential impacts of increased Delta water export, in order to provide a technically reliable basis upon which to establish appropriate mitigation measures for the Delta water quality problems caused by the export pumping of Delta water.

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Acronyms and Definitions

In this report, CALFED (California Federal Bay-Delta Program) is used to designate reports/activities prior to the 2003 reorganization and name change to the California Bay-Delta Authority (CBDA).

ac	acre
ac-ft	acre-feet
BOD	biochemical oxygen demand
BPTCP	Bay Protection & Toxic Cleanup Program
CALFED	California Federal Bay-Delta Program (former name of CBDA)
CBDA	California Bay-Delta Authority (formerly CALFED)
cf	cubic feet
cfs	cubic feet per second
CMARP	Comprehensive Monitoring, Assessment and Research Program
Corps/COE	US Army Corps of Engineers
CVP	Central Valley Project (Federal Project)
CVRWQCB	California Regional Water Quality Control Board, Central Valley Region (RWQCB)
CWA	Clean Water Act
DDT	dichlorodiphenyltrichloroethane (legacy pesticide)
DFG	California Department of Fish and Game
DHS	California Department of Health Services
DIP	Delta Improvements Package
DISC	Delta Issues Sub-Committee
DO	dissolved oxygen
DOC	dissolved organic carbon
DPR	California Department of Pesticide Regulation
DWQI	Delta Water Quality Issues (this report)
DWR	California Department of Water Resources
DWSC	Deep Water Ship Channel
EC	electrical conductivity
EMP	Environmental Monitoring Program
ft	feet
ft/sec	feet per second
g	grams
HOR	Head of Old River
IEP	Interagency Ecological Program
IMM	Iron Mountain Mine
lb/day	pounds per day
m^2	square meters
mgd	million gallons per day
mg/Kg	milligrams per kilogram
mg/L	milligrams per liter
mi	miles
MOU	Memorandum of Understanding
MRP	Monitoring Reporting Program

Acronyms (continued)

m/sec	meters per second
µg/L	micrograms per liter
µmhos/cm	micromhos (reciprocal ohms) per centimeter
µS/cm	microsiemens per centimeter
N	nitrogen
NPDES	National Pollutant Discharge Elimination System
O_2	oxygen
OCls	organochlorines, including organochlorine legacy pesticides (DDT, chlordane, dieldrin, toxaphene), PCBs and dioxins/furans
OEHHA	California Office of Environmental Health Hazard Assessment
OP	organophosphorus pesticide
OPP	US EPA Office of Pesticide Programs
P	phosphorus
PBDEs	polybrominated diphenyl ethers
PCBs	polychlorinated biphenyls
PPCPs	pharmaceuticals and personal care products
RMP	Regional Monitoring Program of San Francisco Bay and Estuary
ROD	Record of Decision
RRI	Rough and Ready Island (location of DWR continuous monitoring station)
RTAG	Regional Technical Assistance Group
SFEI	San Francisco Estuary Institute
SFEP	San Francisco Estuary Project
SJR	San Joaquin River
SOD	sediment oxygen demand
sq mi	square miles
SQO	sediment quality objective
storm sewer	Storm sewer is a separate storm drain that carries stormwater runoff from urban areas.
SWAMP	Statewide Ambient Monitoring Program
SWP	State Water Project (State Project)
SWRCB	State Water Resources Control Board
TDS	total dissolved solids
THMs	trihalomethanes
TIEs	toxicity identification evaluations
TMDL	total maximum daily load
TOC	total organic carbon
UCD	University of California, Davis
USBR	US Bureau of Reclamation
US EPA	US Environmental Protection Agency
USGS	US Geological Survey
UVM	ultrasound velocity meter
VAMP	Vernalis Adaptive Management Plan
WOE	weight of evidence
WQC	water quality criteria
WQO	water quality objective

Conversion Factors

To Convert	Multiply By	To Obtain
acres	4.35×10^4	sq. ft.
acre-feet	3.26×10^5	gallons
cu ft/sec	4.49×10^2	gallons/min
feet	3.048×10^1	cm
inches	2.54	cm
miles (statute)	5.28×10^3	ft
miles (statute)	1.609	km
pounds	4.54×10^2	grams
mgd	1.55	cfs

Sacramento-San Joaquin River Delta Water Quality Issues

Introduction

The Sacramento-San Joaquin River Delta is formed by the confluence of the Sacramento and San Joaquin Rivers. It is one of the most important sportfishing and recreational areas in the state of California, yet there is a relatively poor understanding of water quality issues associated with the Delta that could affect the recreational, fishing and other beneficial uses of the Delta. The authors have been involved in investigating and evaluating Sacramento-San Joaquin River Delta water quality issues since 1989. They have found that there is a significant lack of understanding and considerable misinformation on Delta water quality issues. Further, there is little work being done to control the current, well known water quality problems in the Delta. Presented below is a discussion of the water quality issues in the Delta that need to be more adequately defined, through an improved monitoring program, and managed, to restore and protect the beneficial uses of the Delta and its resources. A map of the Delta and its major waterways and tributaries is provided in Figure 1. The legal Delta extends on the north from just upstream of the city of Sacramento, on the east into the city of Stockton, on the south to Vernalis, and on the west to Chipps Island just downstream of Pittsburg (DWR, 1995).

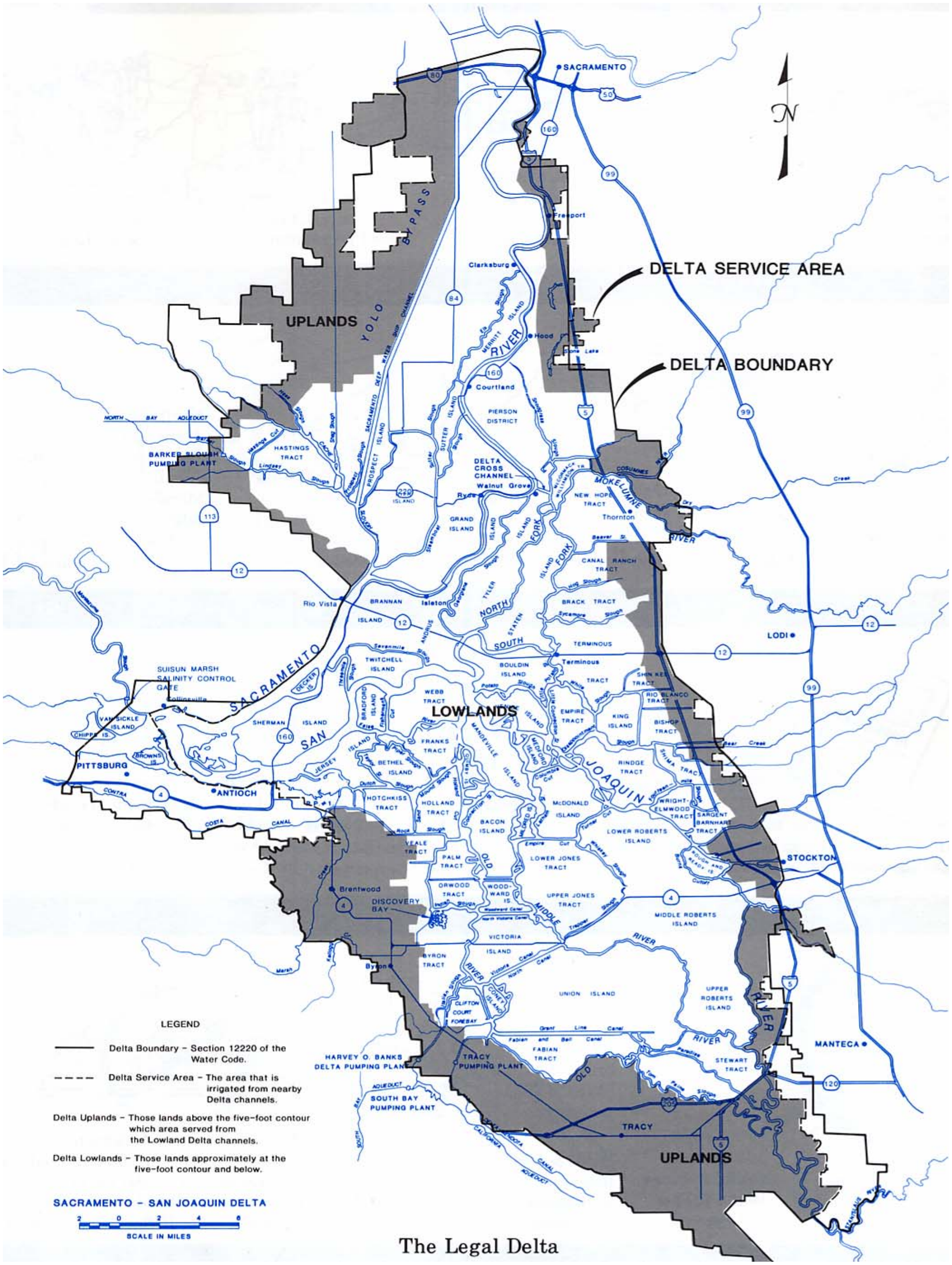
Delta Waterways and Channels 303(d) Listings

In July 2003 the US EPA (2003) Region 9 issued the final 2002 Clean Water Act (CWA) section 303(d) list of water quality limited ("impaired") segments of Central Valley Regional Water Quality Control Board (CVRWQCB) waterbodies. This listing is based on the recommendations of the CVRWQCB and the State Water Resources Control Board (SWRCB), with additions by the US EPA Region 9. The original list is based on information that was available in 2002 and is a source of information that should be used to evaluate some of the existing water quality problems in the Delta. However, it does not reflect all of the water quality problems, since it is dependent on there being a sufficient database of water quality monitoring on each of the Delta channels and tributaries to demonstrate that there have been violations of the CVRWQCB Basin Plan water quality objectives (WQOs) in the waterbody. As discussed below, there has been an inadequate monitoring program conducted on Delta channels and tributaries to determine the full extent of water quality objective violations that occur in the Delta. A summary of Delta waterbody and nearby tributary 303(d) listings as presented 2002 is presented below

Delta Waterways (eastern portion). Delta Waterways (eastern portion) is listed as impaired for chlorpyrifos from agriculture and urban runoff/storm sewers, DDT from agriculture, diazinon from agriculture and urban runoff/storm sewers, Group A pesticides from agriculture, mercury from resource extraction (mining), and unknown toxicity (source unknown). The Group A pesticides are the legacy pesticides that are no longer used, including aldrin, dieldrin, chlordane, endrin, heptachlor, heptachlor epoxide, hexachlorocyclohexane (including lindane), endosulfan and toxaphene. All resource extraction sources are abandoned mines.

Delta Waterways (Stockton Ship Channel). Delta Waterways (Stockton Ship Channel) is listed as impaired for chlorpyrifos from agriculture and urban runoff/storm sewers, DDT from agriculture, diazinon from agriculture and urban runoff/storm sewers, Group A pesticides from agriculture, mercury from resource extraction (mining), organic enrichment/low dissolved

Figure 1
Map of the Legal Delta



From Delta Atlas (DWR, 1995)

oxygen from municipal point sources and urban runoff/storm sewers, and unknown toxicity (source unknown).

Stockton Deep Water Channel, Upper (Port Turning Basin) is listed for dioxins from a point source, furans from contaminated sediments, pathogens from urban runoff/storm sewers and recreational and tourism activities (non-boating), and PCBs from an unidentified point source.

Mormon Slough, Commerce Street to Stockton Deep Water Channel, is listed on the 303(d) list as impaired due to organic enrichment/low dissolved oxygen from urban runoff/storm sewers, and pathogens from urban runoff/storm sewers and recreational and tourism activities (non-boating).

Mormon Slough (Stockton Diverting Canal to Commerce Street) is listed for pathogens from urban runoff/storm sewers and recreational and tourism activities (non-boating).

Delta Waterways (western portion). Delta Waterways (western portion) is listed as impaired for chlorpyrifos from agriculture and urban runoff/storm sewers, DDT from agriculture, diazinon from agriculture and urban runoff/storm sewers, electrical conductivity (EC/TDS) from agriculture, Group A pesticides from agriculture, mercury from resource extraction (mining), and unknown toxicity (source unknown). From the information available, the Delta Waterways (western portion) includes the South Delta waterway of Old River. Old River (San Joaquin River to Delta-Mendota Canal) is listed for low dissolved oxygen due to hydromodifications (altered flows) and source unknown.

Middle River (in the South Delta) is listed for low dissolved oxygen due to hydromodifications (altered flows) and source unknown.

CWA 303(d) Listings of near-Delta Tributaries. Listed below are waterbodies that are tributaries to the Delta, which have been listed as 303(d) impaired in the reach that discharges to the Delta. These tributaries, therefore, are likely adding listed and unlisted pollutants to the Delta.

<u>City of Stockton Channels</u>**.** Several of the city of Stockton channels that are connected to the main body of the Delta have their own listing for specific constituents. Five Mile Slough in the city of Stockton is listed for chlorpyrifos from urban runoff/storm sewers, and diazinon from agriculture and urban runoff/storm sewers. The agricultural source of diazinon for this waterbody is indicated as being from aerial deposition. Five Mile Slough is also listed for organic enrichment/low dissolved oxygen from urban runoff/storm sewers and pathogens from other urban runoff and recreational and tourism activities (non-boating).

Mosher Slough downstream of I-5 is listed for chlorpyrifos from urban runoff/storm sewers, diazinon from agriculture and urban runoff/storm sewers (the agricultural source of diazinon for this waterbody is indicated as being from aerial deposition), organic enrichment/low DO and pathogens from urban runoff/storm sewers. Mosher Slough upstream of I-5 is listed for pathogens due to urban runoff/storm sewers.

Smith Canal in the city of Stockton is listed for organic enrichment/low dissolved oxygen and organophosphorus pesticides from urban runoff/storm sewers, and pathogens from urban runoff/storm sewers and recreational and tourism activities (non-boating).

Walker Slough is listed for pathogens from urban runoff/storm sewers and recreational and tourism activities (non-boating).

San Joaquin River Upstream of the Delta. The San Joaquin River (Merced River to South Delta Boundary) is listed for boron, chlorpyrifos, DDT, diazinon, electrical conductivity and Group A pesticides from agriculture, mercury from resource extraction (mining), and unknown toxicity, source unknown. This is the same water that, a few miles downstream, enters the South Delta.

Calaveras River Upstream of the Delta. The Calaveras River, Lower, is listed for diazinon from urban runoff/storm sewers, organic enrichment/low dissolved oxygen from urban runoff/storm sewers, and pathogens from urban runoff/storm sewers and recreational and tourism activities (non-boating).

Mokelumne River Upstream of the Delta. The Mokelumne River, Lower, is listed for copper and zinc from resource extraction (mining).

Sacramento River Upstream of the Delta. The Sacramento River (Knights Landing to the Delta) is listed for diazinon from agriculture, mercury from resource extraction (mining), and unknown toxicity (source unknown).

It is apparent from the 303(d) listings that there are significant known water quality problems in the Delta that require that the CVRWQCB develop total maximum daily loads (TMDLs) to control the sources of the pollutants responsible for violations of the WQOs. Unfortunately, however, little or no work has been or is being done to control several of these water quality problems.

Excessive Bioaccumulation of Organochlorine Compounds in Delta and near-Delta Tributary Fish

Excessive bioaccumulation of hazardous chemicals, such as the organochlorine legacy pesticides, PCBs and dioxins (collectively referred to herein as "OCls") and mercury, in edible fish and other organisms is one of the most significant water quality problems of the Delta and its nearby associated tributaries. While CALFED (now California Bay-Delta Authority – CBDA) has been devoting considerable funds to addressing the mercury excessive bioaccumulation problem in the Delta and its tributaries, as discussed by Lee (2003a), no funds have been made available by CALFED/CBDA to begin to address the excessive bioaccumulation of the organochlorine hazardous chemicals in Delta and near-Delta tributary fish. This situation appears to be related to the fact that CALFED/CBDA funding for mercury excessive bioaccumulation is related to the concern of the CALFED/CBDA ecosystem restoration program (devoted to developing shallow water habitat) that the development of this program may be inhibited by the created shallow water habitat contributing to excessive bioaccumulation of mercury in edible fish of the Delta. Shallow water habitats have been found to be areas that convert various forms of mercury into methylmercury, which bioaccumulates in fish.

The excessive bioaccumulation of the OCls and mercury should be supported as a high priority, independent of any shallow water habitat issues, since this is a significant public health problem. It is also a significant environmental justice problem that is not being adequately addressed. Appendix A of this report presents information developed by Lee and Jones-Lee (2002a) on the current excessive bioaccumulation problem in the Delta, as well as a discussion (Lee, 2003a) of the need for funding for the development of a management program for control of excessive bioaccumulation of OCls in Delta and near-Delta tributary fish, as well as elsewhere in the Central Valley.

Excessive Bioaccumulation of Mercury

The excessive bioaccumulation of mercury in edible fish is one of the most significant water quality problems in the Delta. The California Office of Environmental Health Hazard Assessment (OEHHA, 2004a) has issued a mercury health advisory for consumption of Delta fish. Based on this advisory, the California Department of Fish and Game (DFG, 2004) has published the following in its Sport Fishing Regulations booklet:

> ***"San Francisco Bay and Delta Region***
> *Because of elevated levels of mercury, PCBs, and other chemicals, the following interim advisory has been issued. A final advisory will be issued when the data have been completely evaluated.*
> - *Adults should eat no more than two meals per month of San Francisco Bay sport fish, including sturgeon and striped bass caught in the delta. (One meal for a 150 pound adult is about eight ounces.)*
> - *Adults should not eat any striped bass over 35 inches.*
> - *Women who are pregnant or may become pregnant, nursing mothers, and children under age six should not eat more than one meal of fish per month. In addition, they should not eat any striped bass over 27 inches or any shark over 24 inches.*
> - *This advisory does not apply to salmon, anchovies, herring, and smelt caught in the bay; other sport fish caught in the delta or ocean; or commercial fish.*
> - *Richmond Harbor Channel area: In addition to the above advice, no one should eat any croakers, surfperches, bullheads, gobies or shellfish taken within the Richmond Harbor Channel area because of high levels of chemicals detected there."*

The excessive bioaccumulation of mercury in fish has caused the Delta to be listed as a Clean Water Act 303(d) impaired waterbody because of excessive bioaccumulation of mercury. Delta Waterways (eastern portion), Delta Waterways (Stockton Ship Channel), Delta Waterways (western portion), Sacramento River (Knights Landing to the Delta), and San Joaquin River (Merced River to South Delta Boundary) have all been specifically listed for mercury impairment.

According to Foe (pers. comm., 2004), with CALFED/CBDA support, a major research effort is being conducted on methylmercury production and cycling in the San Francisco Bay estuary (which includes the Delta) and its bioaccumulation in aquatic organisms. The results developed thus far are available for review at http://loer.tamug.tamu.edu/calfed/DraftReports.htm (CBDA, 2002). Key findings are the development of a total and methylmercury mass balance for the estuary (Task 1) and determination of mercury concentrations in forage and sport fish (Task 2).

Of major concern is that CALFED/CBDA has purchased and is restoring many thousands of acres of wetlands in the estuary. Wetlands are known from the CALFED/CBDA studies and the peer-reviewed literature to be efficient sites for the methylation of mercury. The Clean Water Act requires TMDLs to reduce aqueous and biotic methylmercury levels in listed waterbodies such as the estuary and the major rivers in the Central Valley. It is unclear how the Regional Board will be able to issue US EPA Clean Water Act 401 permits for creation of wetlands in listed waterbodies. CALFED/CBDA and others need to begin to invest funds to determine how to create marshes that minimize the production and export of methylmercury.

San Joaquin River Watershed 303(d) Listings

Lee and Jones-Lee (2002b) developed an invited review on the existing and potential water quality problems in the San Joaquin River watershed with emphasis on the existing 303(d) listings/TMDLs and the constituents that are present at concentrations that could cause further 303(d) listings of water quality impairments of the SJR and some of its tributaries. Table 1 lists the current TMDLs and the constituents that could possibly lead to additional TMDLs in the SJR watershed.

Table 1
San Joaquin River Watershed TMDLs

Current TMDLs
- Selenium
- Salinity, Total Dissolved Solids
- Boron
- OP Pesticides (Diazinon, Chlorpyrifos)
- Oxygen Demanding Substances (BOD, Ammonia, Organic N)

Pending
- Organochlorine Pesticides, (DDT, Chlordane, Dieldrin, Toxaphene, etc.)
- PCBs
- Mercury
- Unknown-Caused Toxicity
- Toxicity to Algae (Herbicides)

Potential Future
- Nutrients, Excessive Fertilization (Nitrogen and Phosphorus Compounds)
- High pH, Low DO caused by Excessive Fertilization (Photosynthesis)
- Alternative Pesticides to OP Pesticides
- Total Organic Carbon, Trihalomethanes in Domestic Water Supplies
- Excessive Sediment, Erosion, Turbidity
- Pathogen-Indicator Organisms, *E. Coli*
- Sediment Toxicity, Pesticides, Nutrients/Algae/Sediment Ammonia
- Temperature (?)
- Dioxins/Furans, Combustion Residues (?)

This situation is of importance to Delta water quality since the SJR at Vernalis and downstream is in the Delta. Further, the SJR is a major source of constituents that cause 303(d) listings in the southern and eastern Delta.

Lee and Jones-Lee (2002b) have presented the characteristics of each of the parameters listed in Table 1 with information on the technical basis for the listing of constituents in Table 1 as constituents that could be found in the future to be in violation of a CVRWQCB WQO.

CVRWQCB Assessment of Delta Water Quality Problem Research Needs

In February 2004, CBDA Science Program held a Contaminant Stressors Workshop, at which K. Landau, Assistance Executive Officer for the CVRWQCB, presented a review of Delta water quality issue research needs from the Regional Board's perspective. This review, "Priorities, Data Gaps, and Research Needs," is presented in Appendix B. According to Landau, the CVRWQCB staff find that the water quality problems with the greatest research needs in the Delta are associated with mercury, selenium, legacy pesticides, agricultural and urban use pesticides, endocrine disrupters, dissolved oxygen demand, unknown toxicity, total organic carbon and salt. Landau's discussion of Delta water quality problem research needs emphasizes defining the extent and magnitude of the problems, identifying the sources of contaminants, determining how these sources interact in the environment to cause problems, and evaluating potential practices or actions that can be implemented to address the problems. Landau (Appendix B) has provided additional information on the research needs for the water quality problems he listed.

Unrecognized Environmental Pollutants

Periodically, previously unrecognized significant environmental pollutants are being found in aquatic systems. Two recent examples of this type of situation are perchlorate and the polybrominated diphenyl ethers (PBDEs). With respect to perchlorate as a widespread water pollutant, Silva (2003) of the Santa Clara Valley Water District, has discussed the potential for highway safety flares to be a significant source of perchlorate (ClO_4^-) contamination to water, even when the flares are 100-percent burned. According to Silva,

> *"A single unburned 20-minute flare can potentially contaminate up to 2.2 acre-feet* [726,000 gallons] *of drinking water to just above the California Department of Health Services' current Action Level of 4 µg/L* [for perchlorate]*."*

Silva points out that, *"More than 40 metric tons of flares were used/burned in 2002 alone in Santa Clara County."* Silva also indicates that fully burned flares can leach up to almost 2,000 µg of perchlorate per flare. California's Office of Environmental Health Hazard Assessment (OEHHA, 2004b) has recently conducted an evaluation of the hazards of perchlorate in drinking water. The 4 µg/L action level for perchlorate in drinking water was based on the detection limit; it has been revised to 6 µg/L based on the recent OEHHA evaluation. An issue that needs to be considered is whether perchlorate is present in Delta waters, especially those near urban areas and major highways. At this time there is no monitoring of Delta waters for perchlorate. Without monitoring for perchlorate, it is not possible to know if this is a problem in some areas of the Delta.

Another widespread "new" pollutant has been recently discussed by Dr. K. Hooper (2003) of the Hazardous Materials Laboratory, Department of Toxic Substances Control, California EPA. In his abstract, he states,

> *"Over the past 25 years, tens of thousands of new chemicals (7 chemicals per day) are introduced into commerce after evaluation by USEPA. Few (100-200) of the 85,000 chemicals presently in commerce are regulated. We have reasons to believe that a much larger number than 200 adversely affect human health and the environment."*

As an example of unidentified hazardous chemicals in the environment, Hooper discussed finding PBDE (polybrominated diphenyl ether) in human breast milk and in San Francisco Bay seals. Archived human breast milk shows that this is a problem that has been occurring for over 20 years. According to McDonald (2003) of California Environmental Protection Agency, Office of Environmental Health Hazard Assessment,

> *"Approximately 75 million pounds of PBDEs are used each year in the U.S. as flame retardant additives for plastics in computers, televisions, appliances, building materials and vehicle parts; and foams for furniture. PBDEs migrate out of these products and into the environment, where they bioaccumulate. PBDEs are now ubiquitous in the environment and have been measured in indoor and outdoor air, house dust, food, streams and lakes, terrestrial and aquatic biota, and human tissues. Concentrations of PBDE measured in fish, marine mammals and people from the San Francisco Bay region are among the highest in the world, and these levels appear to be increasing with each passing year."*

PBDEs are similar to PCBs and are considered carcinogens. Some of the PBDEs are being banned in the US and in other countries.

PPCPs as Environmental Pollutants

At the CBDA Contaminant Stressors Workshop, Dr. Christian Daughton, Chief, Environmental Chemistry Branch, US EPA National Exposure Research Laboratory, made a presentation, "Ubiquitous Pollution from Health and Cosmetic Care: Significance, Concern, Solutions, Stewardship – Pollution from Personal Actions." This presentation covered information on pharmaceuticals and personal care products (PPCPs) as environmental pollutants. He also discussed the relationship between endocrine disrupters and PPCPs. (A copy of Daughton's presentation at the CBDA workshop is available from gfredlee@aol.com.)

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

According to Daughton (2004),

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

* * *

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

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

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

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

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

PPCPs may be particularly significant as a cause of water quality problems in the Delta, in the San Joaquin River near the city of Stockton's wastewater discharge, in Old River near the city of Tracy wastewater discharge, and in the Sacramento River near the Sacramento Regional County Sanitation District wastewater discharge and other communities such as West

Sacramento and Lodi. There is need to keep abreast of the latest developments in PPCP and endocrine disrupter research results, and apply these results to these areas of the Delta and near-Delta tributaries to ascertain whether significant water quality problems are being caused by these chemicals and other unrecognized pollutants.

The perchlorate, PBDE and PPCP situations are not atypical of what could be expected based on the approach that is normally used to define constituents of concern in water pollution control programs. As discussed by Kuivila (2000), there are approximately 150 pesticides used in the Central Valley that are a threat to cause water quality problems in the Delta. The CVRWQCB's current program to regulate pesticides considers only about half a dozen of these. Based on the vast arena of chemicals that are used in commerce, many of which could be present in aquatic systems through wastewater and stormwater runoff, it is likely that many other chemicals will be discovered in the future that are a threat to public health or aquatic ecosystems in the Delta. There is an obvious need to significantly expand the water quality monitoring program to specifically search for new, unrecognized water pollutants. As demonstrated by the perchlorate and PBDE situations, the current monitoring program, focusing on Priority Pollutants, is significantly deficient in properly defining constituents of concern with respect to impairing the beneficial uses of Delta waters.

Discussion of Delta Water Quality Problems

Presented below is a discussion of the major water quality problems in the Delta, their significance to the impairment of beneficial uses, and approaches that should be followed to address them.

Dissolved Oxygen. One of the most significant water quality problems in the Delta occurs in the first seven miles of the San Joaquin River (SJR) Deep Water Ship Channel (DWSC) below the Port of Stockton. In this reach of the Channel, dissolved oxygen (DO) concentrations can be 0 mg/L for extended periods of time. For at least 30 to 40 years there have been occurrences of DO concentrations below the water quality objective (WQO) which is 5 mg/L from December 1 through August 31, and 6 mg/L from September 1 through November 30. This situation has led to the CVRWQCB's listing this reach of the SJR DWSC as Clean Water Act 303(d) "impaired," which necessitates that the Regional Board develop a total maximum daily load (TMDL) of oxygen-demanding materials to control the DO WQO violations.

In 1999, with CALFED support, studies were initiated to define the causes of the low DO, the sources of constituents responsible and the factors influencing DO depletion in the DWSC. Lee and Jones-Lee (2000a) developed an "Issues" report, discussing many of the issues that need to be understood and addressed in order to begin to control the excessive DO depletion in the DWSC. In the spring of 2003, Lee and Jones-Lee (2003a) developed a Synthesis Report, which presents a summary and discusses the results of about four million dollars of principally CALFED-supported studies on the low-DO problem in the DWSC. It was found that the low-DO problem is the result of the development of the DWSC, where the SJR Channel was changed from 8 to 10 feet deep, to 35 feet deep, to accommodate ocean-going ships. This created a long, thin lake-like environment. Low flow conditions of the SJR through the DWSC leads to periods of several weeks to a month during which oxygen demand added to the DWSC at Channel Point (Port of Stockton) is exerted while traversing the first seven miles (critical reach) of the Channel.

One of the primary constituents responsible for the oxygen demand is the nutrients that develop into algae, which are discharged from agricultural sources in the headwaters of the San Joaquin River DWSC watershed from Mud and Salt Sloughs and the SJR at Lander Avenue (Highway 165). Another important source of oxygen demand for the DWSC is the city of Stockton's domestic wastewater discharge-associated ammonia. At times, especially under conditions of low SJR DWSC flow and high ammonia concentrations in the effluent, the City's oxygen demand load can represent on the order of 90 percent of the total oxygen demand load to the DWSC. However, under conditions of elevated flow and low effluent ammonia, the City's contribution of oxygen demand to the DWSC can be on the order of 15 percent of the total load.

As discussed by Lee and Jones-Lee (2003a) and Lee (2003b), coincident with fall stormwater runoff events the city of Stockton waterways (sloughs) experience fish kills which are associated with low dissolved oxygen in the sloughs. In November 2002 and August 2003, the DWSC at the Rough and Ready Island (RRI) monitoring station also experienced low DO following a rainfall runoff event. It appears, from the information available, that city of Stockton stormwater runoff has sufficient biochemical oxygen demand, as well as immediate oxygen demand, to cause low DO in the city of Stockton sloughs, which also may be impacting DO in the DWSC.

Another factor that greatly influences DO depletion in the DWSC is the flow of the SJR through the DWSC. Under low flow conditions of 100 cfs or so, the travel time for oxygen-demanding constituents, from the time they enter the DWSC at Channel Point until they reach Turner Cut seven miles downstream, can be on the order of 20 to 30 days. However, when the flows of the SJR through the DWSC are over about 1,500 cfs, the travel time between Channel Point and Turner Cut is a few days. In general during high flows, the DO water quality objective is not violated even though there are high oxygen demand loads added to the DWSC, because the amount of the demand that is exerted in the critical reach of the DWSC is small.

Ordinarily, higher flows in a river receiving an oxygen demand load will shift the point of maximum oxygen depletion (DO sag) further downstream. One of the unique aspects of the SJR DWSC low-DO problem is that higher flows do not cause the point of maximum DO depletion to shift downstream below Turner Cut. This arises from the situation where the state and federal project South Delta export pumps create a strong cross-Delta flow of the Sacramento River, which occurs to a considerable extent at Disappointment Slough/Columbia Cut and Turner Cut. The dilution of the residual SJR DWSC oxygen demand and its diversion into the Central Delta prevents DO problems from occurring in the SJR DWSC downstream of Turner Cut. Brown (2002) has provided information on the mixing of Sacramento River water with SJR DWSC water in the vicinity of Turner Cut and Columbia Cut.

From the information available now (see Gowdy and Grober, 2003), the solution of the low-DO problem in the SJR DWSC will be dependent on the use of aeration to add oxygen when needed, increased SJR DWSC flow, and, to the extent possible, reduction in the oxygen demand loads of nutrients/algae from upstream sources. As discussed by Lee (2003c) and Lee and Jones-Lee (2000a, 2003a), repeatedly over the period from 1999 through 2003, low SJR flows through the DWSC were accompanied by long hydraulic residence times in the first seven miles of the

DWSC below the Port of Stockton and severe DO depletion in the DWSC. The current practice of manipulating flows in the Delta and its tributaries without adequate regard to water quality impacts is strongly contrary to protecting the beneficial uses of the Delta's aquatic ecosystem. This issue is discussed further below in the Delta Improvements Package discussion.

Lee and Jones-Lee (2003a,b), as well as Lee (2003d) have presented the USGS-measured SJR DWSC flows for the period 1995 through September 2003. Figure 2 presents the complete 2003 SJR DWSC flow data. As shown in Figure 2, as well as in the previously reported data (Lee and Jones-Lee, 2003a), there are marked changes in the SJR DWSC flow over short periods of time. Many of the extreme low-flow events are associated with low DO in the SJR DWSC. As discussed by Lee and Jones-Lee (2003a,b) and Lee (2003d), the low flows of the SJR through the DWSC that have been occurring since at least 1995 are not the result of low flow of the SJR at Vernalis, but are related to the export of South Delta water by the state and federal projects and the associated manipulation of the current temporary South Delta barriers. Of particular concern is the Head of Old River (HOR) barrier. When it is present and operated so that most of the SJR Vernalis water is allowed to pass through the DWSC, there are few low-DO problems in the DWSC. It has also been found that the operation of the internal barriers within the South Delta (on Grant Line Canal, Middle River and Old River) influences the flow of the SJR through the DWSC. Based on barrier operation information provided by M. Holderman, Chief of the Temporary Barriers Project and Lower San Joaquin, Bay-Delta Office of the DWR, the removal of the South Delta internal barriers in the fall allows more SJR Vernalis water to pass into the South Delta at the Head of Old River. This in turn can even further aggravate the low-DO problem in the SJR DWSC.

<u>Impact of Vernalis Adaptive Management Program.</u> In 1999 the Vernalis Adaptive Management Program (VAMP) was initiated. This program was designed to assist the outmigration of juvenile salmon from the San Joaquin River eastside tributaries. Between about mid-April through mid-May, the operators of the water projects located on the eastside tributaries manage reservoir releases to provide a uniform flow of the San Joaquin River at Vernalis. At the same time, the Head of Old River barrier is closed so that the SJR flow at Vernalis primarily passes through the DWSC, rather than into the South Delta. The HOR culverts allow sufficient SJR Vernalis water to pass into the South Delta to protect South Delta channel water levels.

During VAMP operations in 2003 and projected for 2004, the SJR Vernalis flows were/are on the order of 3,200 cfs. Figure 2 shows the SJR DWSC flows during 2003, where the VAMP SJR DWSC flows during mid-April through mid-May were on the order of 2,500 to 2,700 cfs. During the 2003 VAMP, approximately 600 cfs of the 3,200 cfs VAMP flow at Vernalis passed through the Head of Old River barrier into the South Delta.

During 2003 VAMP, the state and federal projects averaged 1,446 cfs (SJRGA, 2004a). During the 2004 VAMP, the state and federal water projects will maintain an average pumping rate of 1,500 cfs (SJRGA, 2004b). As discussed elsewhere in this report, normally the combined export pumping by the state and federal projects is from 10,000 to 14,000 cfs. The greatly reduced export pumping during VAMP operations is designed to reduce the influence of the state and federal export projects' drawing of Sacramento River water and associated small fish to the South Delta.

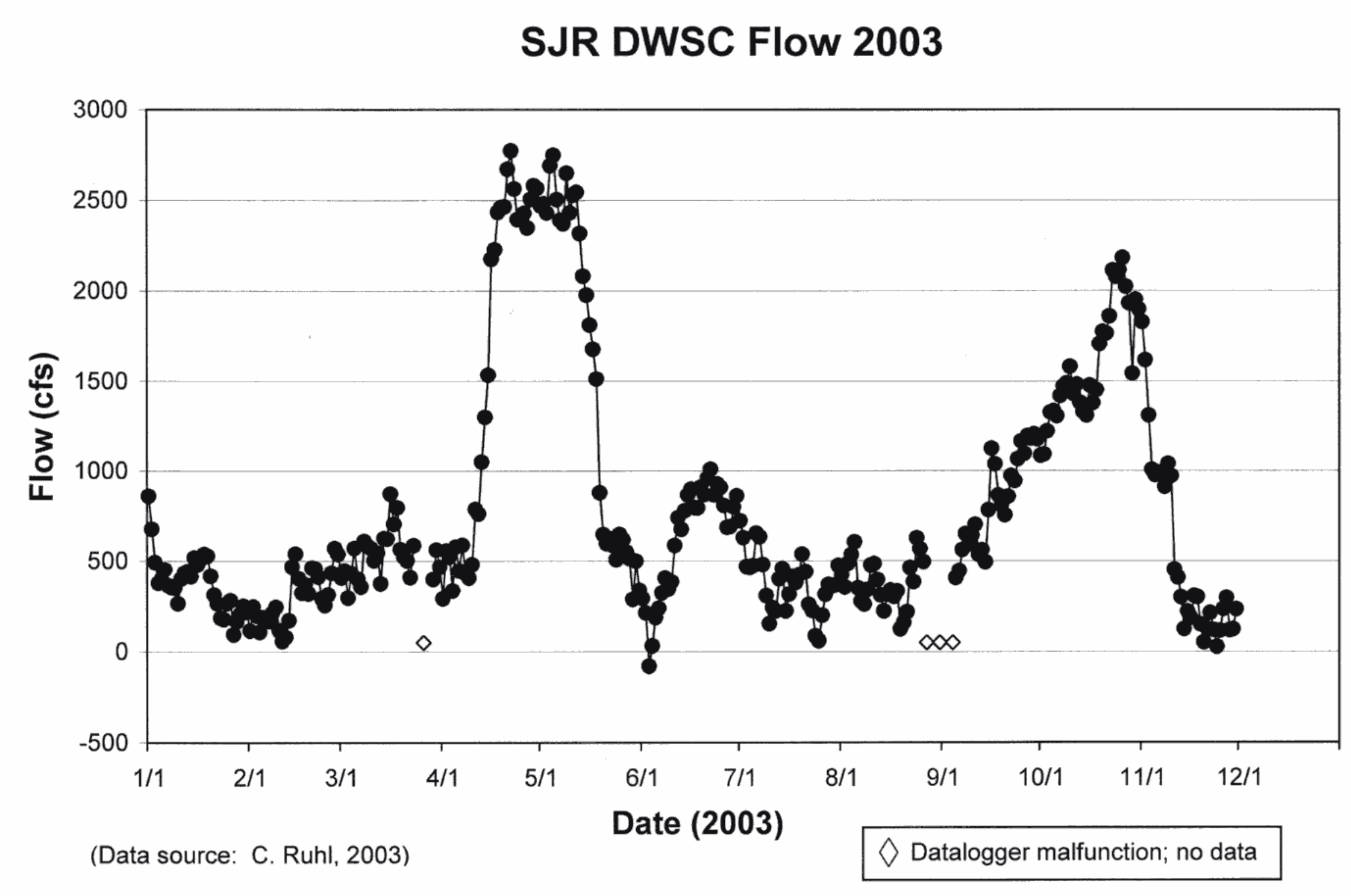

SJR DWSC Flow 2003
Flow (cfs)
3000
2500
2000
1500
1000
500
0
-500
1/1
2/1
3/1
4/1
5/1
6/1
7/1
8/1
9/1
10/1
11/1
12/1
Date (2003)
(Data source: C. Ruhl, 2003)
Datalogger malfunction; no data

Figure 2

During the VAMP flows, studies are conducted by fisheries biologists from the California Department of Fish and Game, US Fish and Wildlife Service and the San Joaquin River Group Authority on salmon smolt responses and survival. These studies are designed to evaluate the survival of salmon smolt outmigrating the San Joaquin River watershed in relationship to flow and export conditions with the Head of Old River barrier in place.

By June 1, 2003, with the removal of the HOR barrier, the South Delta export project pumps took all of the SJR flow at Vernalis into the South Delta, with the result that on one day there was a negative (upstream) flow of the SJR to the Head of Old River. There was a several-week period following 2003 VAMP where the SJR DWSC flows were less than 500 cfs (see Figure 2).

During the VAMP flows of the SJR through the DWSC, there are no low-DO problems in the DWSC. However, as discussed by Lee and Jones-Lee (2003a), after the cessation of VAMP flow, the SJR flow through the DWSC can be a few hundred cfs. This has been accompanied by low-DO problems in the DWSC. Concern has been expressed by A. Hildebrand (pers. comm., 2004) about VAMP's contributing to the low-DO problem in the DWSC. The release of large amounts of flow during VAMP from the eastside reservoirs potentially reduces the amount of flow that could be present in the SJR DWSC during the summer months. The issue of the impact of VAMP on SJR DWSC flows needs to be evaluated.

The San Joaquin River Group Authority provides annual VAMP reports. Further information on VAMP is available at their website, www.sjrg.org.

<u>Winter Low-DO Situations</u>. Studies by Lee and Jones-Lee (2003a) on the low-DO episode that occurred in January, February and March 2003 show that it was caused by the extremely low flow of the SJR through the DWSC, with flows less than 100 cfs. Since there was over 2,000 cfs of flow in the SJR at Vernalis, this situation was the result of those responsible for manipulating flows in the SJR DWSC watershed (Bureau of Reclamation, Department of Water Resources) drawing essentially all of the water in the SJR at Vernalis down Old River to the federal and state projects' export pumps. This led to extended periods of time with DO concentrations in the early morning hours at the Rough and Ready Island monitoring station of 0 mg/L. By late afternoon on some days, the DO might have been as high as 0.25 to 0.5 mg/L. Concentrations less than about 3 mg/L are known to be lethal to many fish. As discussed by Lee (2003d), a similar situation occurred in July 2003, where very low DO was found in the surface waters of the DWSC near Rough and Ready Island. This occurred when there was low flow in the SJR DWSC resulting from the federal and state projects export pumps' drawing SJR water into the South Delta.

<u>Sediment Oxygen Demand.</u> One of the issues of concern with respect to sources of oxygen demand is the impact of Delta sediment oxygen demand (SOD) on the oxygen resources of the Delta channels. The death and decay of algae frequently lead to an accumulation of dead algal cells in sediments. This can lead to both biotic (biochemical) and abiotic (chemical) reactions between the constituents in the sediments and the oxygen content in the sediments and overlying waters. The depletion of the DO content of the water column is manifested as sediment oxygen

demand. The abiotic sediment oxygen demand is due to the reduction of ferric iron to ferrous iron, sulfate to sulfide and manganese dioxide to manganous manganese. The ferrous iron and sulfide rapidly react with DO and therefore are an important source of oxygen demand in sediments and near-sediment overlying waters.

Studies by Litton (2003) on the SOD of the SJR DWSC near the Port of Stockton showed that the SOD of the DWSC was not unusually high considering the large amount of algal load to the DWSC. This situation is possibly due to the influence of tidal action on suspension of the bedded sediments. The tidal flow through the DWSC is on the order of 2,000 to about 4,000 cfs. The tidally influenced near-bottom currents in the DWSC are sufficient to suspend the settled sediments. There are elevated suspended solids in the near-bottom of the DWSC that are responsible for exertion of oxygen demand which impacts the DO concentrations in the water column. It appears that the normal SOD is manifested in the near-bottom DWSC water column rather than in the sediments or at the sediment water interface.

The zone of elevated suspended sediment near the DWSC sediment water interface is not due to density stratification. Salt (density) stratification does not occur in the central, eastern or southern Delta. It is limited to the northwestern Delta, where the Sacramento River enters the Delta near Chipps Island. Also, there is no permanent thermal stratification in the DWSC; however, there is temporary daily thermal stratification during the summer and fall that occurs on most days during the day but which is lost by late evening. With the cooling of the surface waters in late evening, much of the water column is mixed.

The Delta channel SOD may also be responsible for part of the low-DO conditions in the South Delta channels where DWR has found DO concentrations below the WQO. Of particular importance is the low-DO that occurs in Old River near the Tracy Boulevard bridge, which is discussed in this report.

<u>Managing Flows to Reduce Low-DO Problems</u>. As discussed by Lee (2003c,d) and Lee and Jones-Lee (2003a,b), a key aspect of an appropriate management approach for controlling the low-DO problem in the DWSC will be gaining control of the diversion of SJR flows at Vernalis down Old River to the federal and state projects' export pumps, as opposed to allowing these flows to proceed through the DWSC. To the extent that elimination of diversion of the SJR Vernalis water down Old River can be achieved to provide a minimum flow of 1,500 cfs through the DWSC, the magnitude of the low-DO problem in the DWSC can be significantly reduced. At this time, the CVRWQCB is initiating a Phase I TMDL designed to evaluate aeration and other approaches for controlling the low-DO problem. Lee (2003e) has reviewed various approaches that need to be evaluated with respect to solving the low-DO problem in the DWSC.

The South Delta currently has four temporary rock barriers that are installed each spring on South Delta channels and removed each fall. The export pumping of South Delta water by the federal and state projects exports water faster than it is replenished from the Central Delta and the San Joaquin River. This export used to lead to low water levels in South Delta channels. In order to address this problem, temporary rock barriers are constructed in order to maintain water levels in the South Delta. In accordance with the CALFED Record of Decision (ROD), these temporary rock barriers are to be replaced by permanent operable barriers by 2007. One of the potential approaches for gaining additional flow of the SJR through the DWSC suggested by Alex Hildebrand, involved reverse-flow low-head pumping of waters on the western side of the South Delta barriers into the South Delta. As part of the CALFED-supported 2001 Low-DO Directed Action Project, Rajbhandari et al. (2002) of DWR examined the feasibility of this approach as a means of supplementing the flow of the SJR into the DWSC. Lee and Jones-Lee (2003a) summarized the results of that study and concluded that it would be possible to reverse the flow of the South Delta from Old River into the SJR at the Head of Old River barrier through increasing the water levels in the South Delta through reverse-flow pumping over the western South Delta permanent barriers. This approach would introduce greater amounts of Sacramento River water into the South Delta than is occurring now, thereby improving South Delta water quality. Further, this approach would prevent low-quality water in the SJR at Vernalis from entering the South Delta. As discussed by Lee and Jones-Lee (2003a), there is, however, need to evaluate any potentially significant consequences of the reverse-flow low-head pumping over the permanent South Delta barriers on South Delta fisheries. Further, there may be need to obtain an NPDES discharge permit to pump South Delta water into the SJR.

Another approach for increasing the flow of the SJR through the DWSC is the recirculation of South Delta water through the Delta Mendota canal to allow the pumped water to flow into the SJR at the Newman Wasteway. This approach is possible since the federal project pumps at Tracy have excess pumping capacity during the summer months. This excess pumping capacity can be used to provide additional flow into the SJR that can then be allowed to pass into the DWSC before it is drawn to the export pumps in the South Delta. There are a number of biological/fisheries issues that need to be addressed/resolved before this approach can be approved, including the need for an NPDES permit to discharge Delta Mendota water into the SJR.

Another area where there is low DO in the Delta that is likely influenced by export project flow manipulations is the South Delta. Lee and Jones-Lee (2003a) reviewed the DWR monitoring data for the South Delta channel. They found that there are several South Delta channels (Old River, Grant Line Canal, and Middle River at some locations) where the dissolved oxygen at times can be below the water quality objective of 5 mg/L, and can be as low as 2 to 3 mg/L, especially in the early morning hours. On August 5, 2003, the senior author conducted a DeltaKeeper-supported tour of the South Delta channels. As reported by Lee et al. (2004a), during the tour they encountered a major fish kill in the Old River channel near where the Tracy Boulevard bridge crosses the channel. DWR maintains a water quality monitoring station near that location. The DO in the channel waters the night before was at or near 0 mg/L for several hours. The low DO likely caused the fish kill. The low DO was likely caused by excessive algal growth in the Old River channel, which, due to the limited flushing of that channel at that time, led to sufficient algal death and decay to lead to low DO.

<u>Low DO in the South and Central Delta</u>. Low DO in the South Delta channels is a significant water quality problem that deserves a high priority for defining the causes of the low DO, the role of flow manipulations in influencing low DO, and the sources of the oxygen-demanding constituents (which are likely the SJR watershed upstream of the Head of Old River split and local discharges from agricultural activities, as well as city of Tracy wastewaters). This situation is likely to change when CBDA (formerly CALFED) implements its Record of Decision (ROD)

commitment of installing operable barriers in the South Delta to replace the temporary barriers that are installed each year to help maintain water levels in South Delta channels, associated with the export pumping by the state and federal projects.

The Central Delta, Turner Cut and Columbia Cut are areas where there is a potential for low-DO problems at times. This can occur when elevated SJR flows through the DWSC bring large amounts of algae and ammonia into and through the critical reach of the DWSC under conditions where there is insufficient time in the critical reach for the algal-associated oxygen demand to be exerted and the ammonia to be nitrified. It is possible that low-DO situations may occur, especially along Turner Cut, under these conditions. During the summer 2003, Lee et al. (2004b) conducted two DeltaKeeper-supported tours of the Central Delta for the purpose of examining DO conditions in Turner Cut and Columbia Cut, as well as Old River and Middle River. These tours were conducted on July 17 and September 17, 2003. They showed that the SJR DWSC just upstream of Turner Cut had a high electrical conductivity (EC) which was not influenced by Sacramento River water. However, at Turner Cut on both occasions, the EC in Turner Cut channel was several hundred µmhos/cm (µS/cm) lower than the SJR DWSC water just upstream of Turner Cut. It was clear that Sacramento River water was being mixed with SJR DWSC water at Columbia Cut and Turner Cut, as a result of the state and federal projects' drawing Sacramento River water across the DWSC on its way to the export pumps.

There were no low-DO conditions found during these tours of the Central Delta. However, the tours were not conducted at times when the maximum likelihood for low-DO conditions would occur in Turner Cut or in its side channels, such as Whiskey Slough. Further studies of this situation are needed under conditions where there are greater oxygen demand loads to Turner Cut from the DWSC than occurred on the dates of the two tours.

As discussed below, pesticides, including herbicides, have been found in Central Valley waterbodies, including the Delta, at concentrations that are toxic to zooplankton and/or algae. This toxicity could influence the low-DO problem in the SJR DWSC.

Pesticide Toxicity. There are three types of pesticides of concern in potentially impacting water quality in the Delta. These include the organophosphorus (OP) pesticides such as diazinon and chlorpyrifos, as well as the carbamate pesticides, the pyrethroid pesticides and the organochlorine "legacy" pesticides. The CVRWQCB has listed Delta waterways (see above discussion) as impaired due to both the organophosphorus pesticides and the organochlorine pesticides. Pesticides are of concern because of their potential toxicity to various forms of aquatic life, which in turn can affect the aquatic ecosystem of the Delta, either directly through toxicity to aquatic life or indirectly through toxicity to zooplankton that serve as food for larval and juvenile fish. Some of the most severe pesticide-caused aquatic life toxicity occurs in Paradise Cut. This waterbody has no flow through it, and therefore limited dilution of the agricultural discharges of pesticides.

Recently, Spurlock (2004) reported on the current finding of chlorpyrifos in Central Valley waterbodies. According to Spurlock, *"Recent chlorpyrifos monitoring data were analyzed. In contrast to the previous analysis (Spurlock, 2002), these monitoring data reflect water quality in agriculturally-dominated waterways of the San Joaquin Valley, the Sacramento/San Joaquin Delta, and the Salinas River Basin under current use conditions throughout much of the year. The data demonstrate that chlorpyrifos has recently been observed in both rivers and tributaries of the San Joaquin Valley, the Sacramento/San Joaquin Delta, and Monterey County tributaries, frequently at levels that exceed DFG's WQC* [Department of Fish and Game's water quality criteria]*."*

One of the issues of particular concern is whether the OP pesticide toxicity to the zooplankter *Ceriodaphnia* measured in the laboratory represents toxicity that would be significantly adverse to larval or young fish. There are some who argue that, since the OP pesticide toxicity is restricted to certain types of zooplankton, toxicity to these types may not significantly affect fish populations, since there are other zooplankters that are not affected by OP pesticide toxicity which can serve as fish food. Werner et al. (2003a) reported that *Cladocerans* were found to be an important component of the diet of larval Chinook salmon. *Ceriodaphnia* is a *Cladoceran*. With respect to the impact of mixtures of pesticides on aquatic life, there is increasing evidence (Lydy, 2004) that mixtures of the triazine pesticides (herbicides) and the organophosphorus pesticides lead to an enhancement of toxicity.

There is also organophosphate pesticide toxicity associated with stormwater runoff from the city of Stockton into the Deep Water Ship Channel. As discussed by Lee and Jones-Lee (2001) and Lee and Jones-Lee (2002c), the water in the city of Stockton sloughs is toxic to zooplankton after each stormwater runoff event. This toxicity has been found to be caused primarily by diazinon used on urban properties, and also to some extent by chlorpyrifos.

With the termination of the use of diazinon and chlorpyrifos in urban areas because of the potential toxicity to children, there is increased use of the pyrethroid-based pesticides on home and commercial properties. At a CBDA salmon workshop, Inge Werner and Kai Eder, of the University of California, Davis, School of Veterinary Medicine, presented a discussion, "Sublethal Effects of Pesticides in Juvenile Chinook Salmon" (Werner and Eder, 2003), which included information on the relative 96-hour toxicities of diazinon, chlorpyrifos and esfenvalerate. Esfenvalerate is a pyrethroid-based pesticide. It is of interest to find that esfenvalerate has a 96-hour LC50 of about 0.25 µg/L to fathead minnow larvae, while diazinon's 96-hour LC50 toxicity to fathead minnow larvae is 6,000 µg/L and chlorpyrifos' is 331 µg/L. Similar toxicities were found for esfenvalerate to rainbow trout, with a 96-hour LC50 of 0.3 µg/L, while diazinon's 96-hour LC50 toxicity to rainbow trout is 400 µg/L and chlorpyrifos' is 9 µg/L. Esfenvalerate (and, for that matter, other pyrethroid-based pesticides) is much more toxic to fish than the OP pesticides diazinon and chlorpyrifos. With respect to toxicity to *Ceriodaphnia*, esfenvalerate's 96-hour LC50 is 0.28 µg/L, while diazinon's is 0.4 µg/L and chlorpyrifos' is 0.08 µg/L. Esfenvalerate is, therefore, also more toxic to *Ceriodaphnia* than diazinon.

While several of the pyrethroid-based pesticides are highly toxic to zooplankton and fish, it is unclear whether their strong sorption tendencies onto particulate matter reduce the magnitude of this toxicity sufficiently so that the amount of toxicity in the water column following a runoff event is small. However, this sorption can lead to the accumulation of the pyrethroid-based pesticides in sediments of the Stockton sloughs and the Deep Water Ship Channel, where there is a potential for aquatic life toxicity to benthic organisms. Weston et al. (2004) have found that sediments in some agricultural areas of the Central Valley contain pyrethroid-based pesticides and the sediments are toxic to benthic organisms. It is not clear, however, that this toxicity is due to the pyrethroid-based pesticides in the sediments. The current situation with respect to both water column and sediment toxicity in the city of Stockton sloughs and the Deep Water Ship Channel where the sloughs discharge needs to be investigated.

Another group of toxic chemicals that is of concern in the Delta is herbicides used in agricultural areas, as well as along roadways and other areas for weed control. Miller et al. (2002, 2003) reported finding diuron, a herbicide widely used along roads and in some agricultural areas, present in Central Valley waters at concentrations that are toxic to algae.

Lee (2003f) discussed the potential for the pesticide toxicity to zooplankton found within the SJR watershed and DWSC to possibly influence the DO depletion in the SJR DWSC. Toxicity to zooplankton could reduce the zooplankton grazing on algae and thereby increase the algae-caused oxygen demand load that enters the DWSC. Further, herbicide toxicity to algae upstream of Vernalis could reduce the amount of algae that enter the DWSC and thereby influence DO depletion in the DWSC. If the herbicide toxicity to algae was manifested near the DWSC, herbicides could increase the rate of death and decay of algae in the lower SJR and DWSC and thereby exacerbate the low-DO problem. The increased algae associated with pesticide toxicity to zooplankton and the decreased algae associated with herbicide toxicity to algae could be responsible for the patchiness of algae entering the DWSC and the DO "crashes" that occur at times (discussed by Lee and Jones-Lee, 2003a), where an abnormally high DO depletion will occur for a short period of time.

Lee and Jones-Lee (2004a) have discussed the deficiencies in the SWRCB's recent adoption of general aquatic herbicide NPDES permit. This permit does not require adequate monitoring of the waters that receive the herbicide to determine if its application leads to toxicity to non target organisms in the waters of the State. Since large amounts of aquatic herbicides are used in the Delta to control excessive growths of water hyacinth this could be an important issue impacting Delta water quality.

<u>Adequacy of US EPA and DPR Registration of Pesticides for Control of Environmental Impacts</u>. It is generally assumed by those not familiar with the US EPA Office of Pesticide Programs (OPP) and the California Department of Pesticide Regulation (DPR) that the pesticide registration process is designed to be protective of non-target organisms in the environment. However, a critical review of the US EPA OPP and California DPR registration processes shows that the use of registered pesticides in accordance with label restrictions can result in significant adverse impacts to non-target aquatic life.

Of particular concern with respect to water quality is that the US EPA OPP and California DPR do not restrict the use of pesticides that can be present in stormwater runoff or irrigation water discharges. However pesticides from those sources can be toxic to aquatic life in the receiving waters for the runoff/discharges. This situation is the origin of the widespread aquatic life toxicity that is occurring in California and other area surface waters due to the use of diazinon and chlorpyrifos in urban and agricultural areas. Jones-Lee and Lee (2000) and Lee (2001a) have recommended that regulatory agencies such as the CVRWQCB initiate a proactive approach for further evaluation of pesticide use in the Central Valley to determine if any of the 150 or so pesticides currently being used in this area are causing water column or sediment toxicity to aquatic life in the receiving waters for the runoff/discharges from the application areas. Further, as part of the proactive approach, with the beginning use of a new pesticide in an area, special-purpose studies should be conducted to determine if its use could cause aquatic life toxicity in the receiving waters for the runoff/discharges.

Organochlorine "Legacy" Pesticides. Lee and Jones-Lee (2002a) have reviewed the occurrence of excessive concentrations of the organochlorine "legacy" pesticides and PCBs in edible fish in the Central Valley. A summary of this information that is pertinent to the Delta and near-Delta tributaries is presented above and in Appendix A. The finding of excessive bioaccumulation of the OCls in Central Valley fish has led to the need to develop a TMDL to control the excessive bioaccumulation of these compounds in edible fish. The Lee and Jones-Lee (2002a) review also includes information on the approach that should be followed to define the relative significance of current runoff of OCls from areas where they have been applied, versus their presence in waterbody sediments, as a source of the OCls that are bioaccumulating in edible fish..

An area of increasing concern is the potential toxicity of mixtures of pesticides and other hazardous chemicals to aquatic life and human health. Carpenter et al. (2002) developed a review of this issue entitled, "Understanding the Human Health Effects of Chemical Mixtures." Additional information on this topic is provided in a book edited by Wilson and Suk (2002), entitled Biomarkers of Environmentally Associated Disease.

While the traditional approach for controlling excessive sediment-bound OCls is dredging of the sediments, increasing attention is being given to alternative approaches because of the high cost of dredging. One of the most promising is the addition of activated carbon to sediments, which would bind the OCls to the carbon particles, thereby preventing their uptake by benthic organisms. Luthy (2003) presented a review of his work on the use of activated carbon, in which he reported promising results for immobilizing organochlorine compounds in sediments. There is need to examine whether activated carbon addition to sediments could reduce bioaccumulation of OCls at various locations in the Delta and its tributaries, such as in city of Stockton Smith Canal Yosemite Lake sediments where, as discussed by Lee et al. (2002), PCBs and/or legacy pesticides are found in the sediments and are bioaccumulating to excessive levels in fish.

Sediment Toxicity. One of the issues that needs to be assessed for which there is little or no current information at this time is whether the sediments in various parts of the Delta are toxic to benthic and epibenthic organisms. Ogle et al. (2001) reported finding sediment toxicity in a number of the Delta channels in studies conducted in the mid-1990s. This work needs to be updated to evaluate the current situation. Also, further work needs to be done to define the cause of the toxicity, using sediment TIEs.

The US EPA (2000a) has developed a sediment toxicity test based on *Hyalella azteca,* which should be used to determine if there are sediments in the Delta that are toxic to benthic organisms. *Hyalella azteca* is an amphipod of moderate to high sensitivity to various types of pollutants. The finding of toxicity to *Hyalella* should be a trigger to conduct further studies to confirm that the toxicity is persistent (and, if not, its duration), the magnitude of the area that is toxic and whether there are gradients of toxicity which can identify "hot spots," whether the toxicity is accompanied by altered organism assemblages in the sediments of similar physical and chemical characteristics. Further, sediment TIE studies should be used to try to determine the chemical constituent(s) responsible for the toxicity. In time, following this approach, an understanding of the current situation with respect to sediment toxicity in the Delta will be obtained. Through ongoing periodic sampling of the sediments, it will be possible to determine whether the situation changes due to the introduction of new toxicants, such as a new or expanded-use pesticide that has not been used extensively, if at all, in the Delta and its tributaries.

Finlayson (pers. comm., 2004), as part of California Department of Fish and Game studies on water quality, has compiled Delta sediment toxicity data. These data are available from Finlayson on a CD ROM. This database also includes information on the chemical characteristics of the sediments in which toxicity measurements were made. Unfortunately, Finlayson included information on whether the concentrations of measured chemical parameters in the sediments exceeded the Long and Morgan co-occurrence-based so-called sediment quality guidelines. As discussed herein and by Lee and Jones-Lee (2002a), it is technically invalid to infer anything about the impact of a constituent in a sediment on beneficial uses of the waterbody on the basis of the concentration of a chemical constituent in sediment or whether that concentration exceeds or fails to exceed a co-occurrence-based sediment quality guideline. It has been known since the mid-1960s that the total concentration of a chemical in a sediment is not an indication of its potential impact on aquatic life or beneficial uses of the water.

Lee and Jones-Lee (2003c) presented a discussion of problems with the SWRCB's current efforts to develop sediment quality objectives (SQOs) as part of its complying with the state legislature's Bay Protection and Toxic Cleanup program's requirements for regulating contaminated sediments. They pointed out that the initial efforts of the SWRCB staff to develop chemical-specific numeric sediment quality objectives were not technically valid since they were based on a co-occurrence-based approach. As Lee and Jones-Lee discussed, a co-occurrence approach is not reliable for evaluating the water quality impacts of chemical constituents in sediments. Co-occurrence-based approaches for developing SQOs would lead to inappropriate regulation of the state's aquatic sediments. As a result of extensive comments it received on the unreliability of the initially proposed approach for developing SQOs, the SWRCB staff has recently indicated that a weight-of-evidence approach will now be used to develop SQOs for enclosed bays and estuaries of the state.

The SWRCB staff is still devoting considerable effort to trying to use the existing BPTCP database to relate the total concentration of a chemical in sediment and aquatic life toxicity. However, as Lee and Jones-Lee (2003c) discussed, the BPTCP database is significantly deficient in providing the information needed to properly relate sediment toxicity to a chemical(s) responsible for the toxicity, since toxicity identification evaluation (TIE) information was not collected in the BPTCP. There is no way to reliably evaluate the cause of the toxicity in the BPTCP studies without conducting TIE studies.

From a Delta water quality perspective, the SWRCB is not fulfilling the California legislature's requirements established in the BPTCP of developing sediment quality objectives for enclosed bays, estuaries and near-shore marine waters, including the Delta. The State Board staff and Board have indicated that they do not plan to develop sediment quality objectives for the Delta as part of their development of sediment quality objectives. If this current approach persists, the SWRCB will not fulfill the legislative requirements.

Finding sediment toxicity does not necessarily mean that the sediment is having a significant adverse impact on the overlying waters. As discussed by Lee and Jones-Lee (1996), many sediments are naturally toxic, due to low dissolved oxygen, and hydrogen sulfide and ammonia production arising from the decay of algae on or within the sediments. This decay leads to consumption of dissolved oxygen at the sediment-water interface and within the sediments. It is accompanied by a reduction of sulfate to sulfide and of ferric iron to ferrous iron. Also, any oxidized forms of manganese, such as MnO_2 are reduced to Mn^{2+}. Organic nitrogen is converted to ammonia, which in oxygen-free sediments remains in that form within the sediments, or slowly mixes, through sediment-water exchange reactions, into the overlying water column. The combination of low DO and ammonia causes many sediments to be unsuitable as habitat for a variety of forms of benthic and epibenthic organisms. However, the overlying waters in many eutrophic lakes where this situation is common produce outstanding warm water fisheries. This situation mandates that a proper evaluation be made of the water quality significance of sediment toxicity. This is why a combination of sediment toxicity, sediment TIEs to determine the cause of toxicity, and sediment organism assemblage information is essential to evaluating the significance of chemical constituents in aquatic sediments as they may impact the beneficial uses of the waterbody in which the sediments are located.

Lee and Jones-Lee (2002d) have recommended that a sediment quality triad involving a best-professional-judgment weight-of-evidence approach be used to evaluate sediment quality. As they discussed, it is important to properly use chemical information in this triad. Chemical concentration information should not be used in a co-occurrence-based approach like Long and Morgan's so-called "sediment quality guidelines," but rather should be evaluated through a TIE approach to identify the chemicals responsible for the toxicity. The sediment quality triad evaluation was advocated by a number of invited speakers at the Fifth International Symposium on Sediment Quality Assessment (SQA5) that was held in Chicago in October 2002 (Chapman, 2002; Burton et al., 2002). Those speakers and others, including DiToro (2002), discussed the inappropriateness of using co-occurrence-based sediment quality guidelines.

It is important, in evaluating the water quality significance of sediments, not to fall into the trap of trying to oversimplify the complexity of sediment - pollutant interactions. As discussed by Lee and Jones-Lee (2002a,d), there should be no attempt made to use chemical concentration-based sediment quality guidelines to judge excessive concentrations of constituents in sediments. Instead, a best-professional-judgment triad weight-of-evidence approach should be used.

Light Penetration and Turbidity/Color. Light penetration and, therefore, primary production in the Delta is limited by inorganic turbidity and/or color. The studies on the San Joaquin River Deep Water Ship Channel (Lee and Jones-Lee, 2003a) have shown that the light penetration in the San Joaquin River as it enters the Deep Water Ship Channel is severely limited by inorganic turbidity. Lee et al. (1995) conducted a survey of the world's literature of light penetration as measured by Secchi depth, where the focus of the results was on the Secchi depth that would occur based on light penetration's being inhibited only by phytoplankton. As phytoplankton numbers increase, light penetration (Secchi depth) decreases. It is possible to use the Lee et al. (1995) relationship to determine whether a waterbody has the light penetration expected based on the planktonic algal chlorophyll. Applying this approach to the San Joaquin River Deep Water Ship Channel and the Delta shows that the light penetration in the Deep Water Ship Channel and Delta is substantially less than what is predicted based on the planktonic algal chlorophyll. This decreased light penetration is due to erosion in the watershed, principally in the SJR westside tributary watersheds which transport large amounts of suspended sediment into the SJR and DWSC. Further, at times, there is sufficient release of highly colored water due to organics from the managed wetlands (refuges and duck clubs) in the Mud and Salt Slough watersheds to cause severe short-term decreases in light penetration. The inorganic turbidity and wetlands-derived color lead to lower DO than would be expected based on the photosynthesis that should be occurring by phytoplankton in the water column.

Also in the main part of the Delta the leaching of organics from peat soils on Delta islands introduces substantial amounts of color into the water. This in turn tends to lead to decreased phytoplankton growth. This may account in part for the deleterious growth of water hyacinth that occurs in some parts of the Delta, since hyacinth growth is on the surface of the water and therefore not inhibited by decreased light penetration. A review by Lee and Jones-Lee in the late 1980s and early 1990s (Lee and Jones, 1991a) showed that the planktonic algal chlorophyll present in the middle and south parts of the Delta near the export pumps is generally lower than would be expected based on the nutrient content of those waters. The reduced phytoplankton growth may also be due to a short hydraulic residence time between when nutrient-rich South Delta water mixes with nutrient-poor Sacramento River water that is drawn to the South Delta by the state and federal export projects.

Total Organic Carbon/Dissolved Organic Carbon. Total organic carbon (TOC) is an important water quality parameter for Delta waters, because those waters serve as a domestic water supply source for about 23 million people in California. TOC interacts with various disinfectants to produce trihalomethanes (THMs), which are low molecular weight organochlorine compounds like chloroform or chlorobromo compounds. THMs are regulated as carcinogens. This situation has caused the US EPA to propose to limit the TOC content of water supplies to about 2 mg/L.

TOC and dissolved organic carbon (DOC) have been measured in various Delta tributaries and at various locations in the Delta. From those studies it has been concluded that an appreciable part of the TOC that is exported from the Delta by the state and federal projects arises from the leaching of peat soils on Delta islands. The remainder is from sources upstream of the Delta. CBDA (2004a) discussed issues of TOC in Delta waters as it affects the use of those waters for domestic water supply purposes.

Recently Lee and Jones-Lee (2003d) introduced the concept of refractory and labile TOC in the Delta and its tributaries. Labile TOC is that part of the TOC measured concentration that will not persist from the point of measurement until it reaches a domestic water supply treatment works; i.e., it is the portion of the TOC that is degraded. Labile TOC is primarily composed of phytoplankton cells. As discussed by Lee and Jones-Lee (2003a), several investigators in the SJR DWSC low-DO studies have shown that there is a strong correlation between BOD and planktonic algal chlorophyll in the San Joaquin River and the DWSC. It is well established in the limnological literature (see Lee and Jones, 1991a) that the organic carbon in algal cells is largely mineralized during the decay of dead algal cells. The refractory (i.e., nondegradable) TOC is derived primarily from higher terrestrial and aquatic plants that contain lignin.

Recently, Dr. James T. Hollibaugh, Director of the School of Marine Programs at the University of Georgia, made a presentation at a CBDA luncheon seminar on work that he and his associates have done on the potential for shallow water habitat-developed vegetation to be a source of TOC that would contribute to the TOC problem for water utilities that utilize Delta waters as a water supply source. He reported that the TOC that develops in Delta shallow water habitat areas consists of refractory and labile (readily degradable) TOC. He concluded that the CBDA Ecosystem Restoration Program devoted to increasing shallow water habitat in the Delta as part of fisheries restoration will add refractory TOC to Delta waters. He indicated that, at this time, information is not available on the amount of TOC that would be exported from new shallow water habitat per unit area of new habitat. Without this information it is not possible to assess whether the creation of additional shallow water habitat in the Delta would represent a significant additional source of TOC compared to the existing concentrations.

From the studies that have been conducted on the SJR DWSC DO problems (Lee and Jones-Lee, 2003a), it is found that, at times, a substantial part of the TOC present in the San Joaquin River is in the form of algal cells. Depending on the flow of the SJR through the DWSC, much of the algae die and decompose in the first seven miles of the Deep Water Ship Channel below the Port of Stockton. Under elevated SJR DWSC flows above about 1,500 to 2,000 cfs, some of the algal cell TOC derived from San Joaquin River watershed sources is carried into the Central Delta via Turner Cut or Columbia Cut due to the cross-channel flow caused by the state and federal projects' export of water from the South Delta. This export creates a strong South Delta flow of Sacramento River water into the Central Delta, ultimately reaching the South Delta pumps.

Based on the studies by Lehman (2002), the death and decay of the planktonic algae that enter the DWSC from upstream SJR sources is compensated for by growth of algae in the DWSC. This means that even under conditions of low SJR DWSC flow, where much of the SJR DWSC watershed algae decompose in the first seven miles of the DWSC, there is still an appreciable planktonic algal chlorophyll load added to the Central Delta through Turner Cut and Columbia Cut.

Sacramento River water has low algal content and somewhat lower (although not insignificant) TOC, compared to San Joaquin River water. The fact that the planktonic algal chlorophyll at the Banks Pumping Station is normally found to be low compared to the SJR

DWSC TOC reflects the fact that the water pumped at Banks is primarily Sacramento River water. The high planktonic algal chlorophyll found in the San Joaquin River at Vernalis is either transported into the South Delta via Old River and then exported from the South Delta at the Tracy pumps, or is transported into the Central Delta via Turner Cut and Columbia Cut, where it is mixed with and diluted by the low planktonic algal chlorophyll water of the Sacramento River. It is expected that part of the planktonic algae that enter the Central Delta via Turner Cut and Columbia Cut will die and decompose in transport to the South Delta pumps at Tracy and Banks. It should be understood that much of the time, during the summer and fall, on the order of one-third to one-half of the water that is pumped by the Federal Project at Tracy is Sacramento River water and not San Joaquin River water.

As discussed in Lee and Jones-Lee (2003d), there are other sources of TOC for the Delta, such as urban stormwater runoff and domestic wastewaters, principally from the cities of Stockton and Sacramento and other communities in the Delta watershed. While wastewater discharges and stormwater runoff can cause elevated TOC in receiving waters, substantial parts of such TOC is labile and will not likely persist for a sufficient distance to reach a water supply treatment works in the Bay region or Southern California.

Woodard (2000) conducted a review of TOC concentrations and load data in Delta tributaries and at the export pumps. As discussed by Lee and Jones-Lee (2003d), it is important not to use the Woodard (2000) review of TOC data as an indication of sources of TOC that could affect water utilities that use Delta water as a water supply source. This is because Woodard's TOC data do not distinguish between the refractory and labile forms of TOC.

Lee and Jones-Lee (2003d) discuss the approach that should be followed to define the sources of labile and refractory TOC in Delta tributaries and within the Delta. They point to the importance of measuring not only TOC and DOC, but also planktonic algal chlorophyll *a*, pheophytin *a* and BOD in TOC source investigations.

In the late 1980s Delta Wetlands, Inc., proposed the development of in-Delta storage reservoirs. These reservoirs would be filled with water pumped from Delta channels during high flow periods and discharged back to Delta channels during the spring and summer. There is concern about the quality of water that would be discharged to the Delta channels. There have been several studies on this issue, the most comprehensive of which are the DWR studies conducted during the past year. These studies (DWR, 2004a) have investigated the potential for the peat soil of the Delta islands to release TOC that would contribute to the TOC problem for water utilities that use Delta waters as a water supply source. There is also a potential problem with adverse impacts of the Delta island storage reservoirs due to the conversion of the mercury in the island soils and in the waters added to the island reservoirs methylmercury and thereby contributing to the excessive mercury bioaccumulation problem that exists in the Delta. Since these islands have been used for agriculture, there may also be excessive bioaccumulation of legacy organochlorine pesticides derived from the soils when the soil-associated pesticides are mobilized in the waters added to these reservoirs. There is need for further studies to better define the water quality that will develop in the reservoirs and the impact of the discharge of the stored water on Delta channel water quality. CBDA (2003) has presented a discussion of these issues.

Algal Available Carbon Deficiency in the Central Delta. An issue that has emerged as important in managing Delta aquatic resources is the deficiency in available organic carbon to support the Delta aquatic food web. Jassby and Cloern (2000), Jassby et al. (2002), Jassby et al. (2003), Müller-Solger et al. (2002), Sobczak et al. (2002) have presented a series of papers on the importance of algal TOC added to the Delta as a component of the Delta aquatic food web. Jassby (pers. comm., 2003) has also supported the premise that algae are an important component of the aquatic food web in the Delta. As a result of their work, a different approach to managing the low-DO problem in the DWSC has evolved.

Lee (2003g) has suggested that rather than trying to reduce the algal oxygen demand load to the DWSC as one of the alternative approaches for solving the low-DO problem in the DWSC, it could be better to allow the algal load to the DWSC to pass into the Central Delta and thereby serve as a food source for the aquatic food web. As discussed herein, this can be accomplished by allowing the flows of the SJR through the DWSC to be above about 1,500 cfs. Under such flow conditions, the short residence time of the algal oxygen demand loads that enter the DWSC will transfer most of the algal oxygen demand loads to the Central Delta where they will not cause an oxygen demand problem and will serve as a source of assimilable carbon to the aquatic food web. Lee et al. (2004b) have investigated this situation and concluded that it would be rare that the addition of those algal oxygen demand loads to the Central Delta would lead to low-DO problems in that area. They suggested that any remaining oxygen depletion problems in the DWSC be controlled through aeration. The SJR upstream dischargers would still be held responsible for helping to pay for aeration to eliminate DO WQO violations that occur but that are not eliminated by the elevated flows of the SJR through the DWSC or the control of the city of Stockton ammonia loads.

One of the issues that needs to be considered is the benefit of nutrients to the Delta food web. Lee and Jones (1991b) have shown that there is a relationship between the normalized phosphorus loads to a waterbody and the fish biomass. The normalization is based on the Vollenweider approach of accounting for the waterbody's mean depth and hydraulic residence time. Lee and Jones-Lee (2004b) have discussed that the excessive nutrient loads to a waterbody which lead to high fish biomass tend to produce less desirable fish, such as carp.

Non-DO-Related Algal Impacts on Water Quality in the Delta. As discussed herein, algae are a major cause of low-DO problems in the Deep Water Ship Channel and in some South Delta channels. Excessively fertile waterbodies such as the Delta frequently experience blooms of bluegreen algae. This type of algae is notorious for causing water quality problems including floating algal scum, obnoxious tastes and odors in water supplies, airborne odors where the algal scum decomposes, and at times the production of toxins that kill animals and waterfowl. Further, bluegreen algae are known to a poor base to the food web since they are not readily grazed by zooplankton. Beginning in the 1960s most of the author's (Dr. G. F. Lee's) efforts devoted to excessive fertilization management were directed to waterbodies in which there were excessive growths of bluegreen algae. Lee (1971, 1973) published a comprehensive review of eutrophication which contains considerable information on bluegreen algae occurrence, water quality impact and control. For many waterbodies eutrophication (excessive fertilization) management focuses on the control of the excessive growth of bluegreen algae.

Until recently bluegreen algae were not the cause of water quality problems in the Delta. However, bluegreen algae have caused and continue to cause severe water quality problems in the city of Stockton Weber Point waterbody, McLeod Lake. This waterbody is connected to the Delta via a channel to the Port of Stockton. While this waterbody experiences Delta tides, it is a dead-end channel, where nutrients are derived from urban runoff. Stockton is devoting considerable effort toward controlling the impacts of bluegreen algae through aeration of the Weber Point waterbody to break up the algal scum (HDR, 2003).

Lehman and Waller (2003) have reported that,

> "*Blooms of the bluegreen algae* Microcystis aeruginosa *have occurred in the Delta from July through November since 1999 …. In 2002 these blooms occurred in the southern regions of the Delta in Middle and Old rivers and the lower San Joaquin River westward to Antioch."*

At about two-week intervals, as part of the DWR Delta D-1641 Compliance Monitoring, monitoring cruises are conducted along the SJR DWSC channel from about Prisoners Point to the Port of Stockton. The DWR (2003) September 24, 2003, and November 21, 2003, cruise reports state, "*Microcystis aeruginosa, a blue-green algae, was observed floating on or near the water surface from Station 1 (Prisoner's Point) to Station 8*." Station 8 is near Turner Cut. *Microcystis aeruginosa* is a classical bluegreen algae that is frequently associated with excessive fertilization of waterbodies.

While these water samples were taken from the SJR DWSC, the water in this channel at the time of the cruises in the late summer and fall is primarily a mixture of Sacramento River water with some Delta irrigation water returns. This is the result of the South Delta export pumping by the state and federal projects drawing all San Joaquin River water to the export pumps via Old River in the South Delta and through Turner Cut to the Central Delta/South Delta. As discussed in this report, typically the export pumping by the projects draws at least 8,000 cfs of Sacramento River water to the South Delta across the SJR DWSC downstream of Turner Cut and Columbia Cut.

Several members of the DWR Drinking Water staff made presentations on their studies at the California Lake Management Society (CALMS, 2003) annual meeting that was held in mid-November 2003. Information was provided at this meeting on the nature of the DWR Drinking Water monitoring program and some of the current water quality problems that are being experienced. The DWR presentations are posted at
http://wwwomwq.water.ca.gov/PublicationsPage/index.cfm.

At the California Lake Management Society annual meeting the DWR and the Santa Clara Valley Water District staff discussed problems with the growth of water weeds and algae in the Clifton Court Forebay and in San Luis Reservoir. San Luis Reservoir is located south of Clifton Court Forebay and is filled by California Aqueduct waters derived from the Banks Pumping Plant. Excessive growths of water weeds became a problem in Clifton Court Forebay beginning in 1994. There are 800 to 1,000 acres of water weeds in the Forebay. Also, weeds and attached algae are problems in the South Bay Aqueduct. According to the information provided, bluegreen algae are now developing in the Clifton Court Forebay which lead to excretion of taste- and odor-producing compounds. As far as is known, these algae are not developing to any significant extent in the northern, central or southern Delta. The tastes and odors produced by them can be a significant problem for water utilities that use Delta water as a water supply source.

This problem is not a new problem. The Metropolitan Water District of Southern California has experienced problems of this type, where algae develop in their water supply storage reservoirs that lead to taste and odor problems. These problems, in turn, lead to increased cost of treatment to control the tastes and odors. The algae that are causing tastes and odors are not the same type of algae that are contributed to the Central Delta through discharge of the SJR DWSC waters via Turner Cut and Columbia Cut. From the information available, it appears that those algae which make it through the DWSC die and decompose in the Central and South Delta. From the studies conducted in summer 2003 with DeltaKeeper's boat and staff support (Lee et al., 2004a,b), it appears that the algae in the DWSC that enter the Delta via Turner Cut and Columbia Cut do not lead to low-DO problems in the Central Delta. If there are problems of this type, they would be expected to be few and rare, and likely easily controlled. They would only occur under certain SJR DWSC flow regimes, and could be controlled through spot aeration in the Central Delta.

The excessive algae and weeds that develop in Clifton Court Forebay and San Luis Reservoir develop on nutrients (nitrogen and phosphorus compounds) primarily derived from the Sacramento River watershed and Delta island discharges. Both the San Joaquin River and the Sacramento River discharges to the Delta contain surplus nitrogen and phosphorus compared to the concentrations needed to limit algal growth rates. While the San Joaquin River at Mossdale and in the DWSC has a larger "surplus" algal available N and P than the Sacramento River, during the summer and fall essentially all of the SJR-derived surplus enters the South Delta and is exported by the federal water project at Tracy. Based on studies conducted in summer 2003 by Lee et al. (2004b) with DeltaKeeper support, DWR projects pumping records, DWR modeling of flows through the Central Delta and USGS flow measurements, the water and excess nutrients that enter Clifton Court Forebay and San Luis Reservoir are primarily derived from the Sacramento River watershed and from agricultural discharges to Middle River and Old River in the northern, central and southern Delta.

The US EPA, as part of a national program to develop chemical-specific numeric water quality criteria for nutrients (nitrogen and phosphorus compounds), has developed Regional Technical Assistance Groups (RTAGs) that work with US EPA Regional staff in developing nutrient criteria. Dr. G. F. Lee has been active since the 1960s in developing appropriate nutrient loads to waterbodies to protect the desired beneficial uses of the waterbody. He was an active participant in the US EPA Region 9 RTAG efforts to develop nutrient criteria for Central Valley waterbodies. Lee and Jones-Lee (2002e, 2004c) have discussed the problems with the approach that the US EPA (2000b) has adopted for developing the national default nutrient criteria, where they pointed out that this approach is not technically valid. This approach assumes that 25 percent of all waterbodies in an area contain excessive nitrogen and phosphorus. Adoption of the US EPA proposed national default nutrient criteria will result in overregulation of nutrients.

Lee and Jones-Lee (2004c) discussed the need to develop waterbody-specific nutrient criteria that consider the desirable nutrient-impacted water quality and the allowable nutrient loads/concentrations that can be added to the waterbody to achieve the desired level of algal and other aquatic plant productivity. Lee (2001b) has provided guidance on an approach for developing site-specific nutrient criteria for the Delta and Delta tributaries, as well as for the use of the Delta waters for domestic water supply purposes. This approach would involve the stakeholders and the regulatory agencies working together to develop a desired eutrophication-related water quality in the Delta tributaries, channels, and downstream water supply reservoirs. This evaluation would consider the desired amount of aquatic plants in each waterbody, considering their impacts on water quality beneficial uses and food web support. As part of this effort, studies would be conducted to determine the relationship between the nutrient loads/concentrations to and within a waterbody and the aquatic plant biomass-impacted water quality. Consideration would need to be given to the nutrients discharged from a waterbody on downstream waterbodies' eutrophication-related water quality.

Since domestic water utilities that use Delta water as a raw water source experience nutrient-related water quality problems such as algal caused tastes and odors, Lee (2001c) submitted a proposal to the CALFED Drinking Water Program to develop a framework for developing nutrient criteria for the Delta and water supply reservoirs that are filled with Delta water. CALFED was not interested in supporting this proposal, even though it was evaluated by several reviewers as a project that should be supported.

Sanitary Quality Issues. There are two aspects of sanitary quality in the Delta that need to be considered. One is the use of Delta water for domestic water supply purposes, such as by the Contra Costa Water District. The other is contact recreation, where those who use Delta water for recreational purposes incidentally ingest water, through swimming, boating, water skiing, etc. There are several types of organisms of concern with respect to causing human health problems associated with consumption of or contact with fecal contaminated waters.

Classical bacterial diseases are associated with the discharge of human fecal material to the water. These diseases range from gastroenteritis (upset stomach, diarrhea, vomiting, etc.) to severe diseases such as typhoid fever and cholera. There are also groups of bacteria that can cause a variety of "portal" diseases in the eyes, ears, nose and throat, such as staphylococcus and streptococcus. The sanitary quality of a water with respect to the group of enteric (intestinal) bacterial diseases is typically evaluated in terms of fecal indicator organisms of the coliform group. Since the 1940s, total coliforms, and then fecal coliforms, have been used as a measure of sanitary quality of a water, with respect to acquiring bacterial enteric diseases. While fecal coliforms are typically not pathogens, they are excreted in large numbers from human intestinal tracts and, therefore, are an indicator of fecal contamination of water. However, as discussed below, it has been well known for over 60 years that people can acquire diseases from waters that meet coliform standards.

Another group of intestinal disease organisms is protozoan (single-cell animal) parasites, such as amoebic dysentery. The protozoan intestinal parasites are of particular concern since they are cyst-forming organisms which are extremely resistant to death and decay. It has been known since the 1940s that the evaluation of the sanitary quality of a water based on coliforms is not a reliable indication of whether the water is safe with respect to enteric parasites. Waters can test free of fecal coliforms and still contain amoebic dysentery cysts and other protozoan parasites.

In recent years, the emphasis has shifted from amoebic dysentery to giardia and cryptosporidium. Both are protozoan parasites. Giardia became of importance through the finding that this organism inhabits the intestinal tracts of beavers and some other wild animals. It is for this reason that consuming what appears to be sparkling clear mountain stream water can lead to contracting giardia as a result of beavers defecating in the stream.

The protozoan intestinal parasite of greatest concern today is cryptosporidium. While it has been known for many years to be prevalent in water supplies, including those that meet the fecal coliform standards that have been used to judge the sanitary quality of drinking water, cryptosporidium gained national attention through the 1993 outbreak in Milwaukee, where 80 people died, and 400,000 people became ill through ingestion of the organism in drinking water. Ordinarily the ingestion of cryptosporidium may result in intestinal upset which will last for a couple of days. However, there are individuals with deficient immune systems (from AIDS, radiation therapy, etc.) who are extremely susceptible to severe illness, including death, caused by cryptosporidium.

The source of cryptosporidium can be human fecal waste, as well as some animal fecal waste, such as cattle. While for many enteric diseases, the parasitic organisms that inhabit the intestinal tract of animals are not pathogens for humans, there are situations, such as for some protozoan parasites, where there is the potential for fecal material discharged by animals to lead to human disease when consumed through a water supply or food.

The situation that developed in Milwaukee, where the municipal water supply was polluted by dairy wastes, brought to light what had been known since the 1940s – that the protozoan cyst pathogens are much more resistant to disinfection by chlorination than the coliforms. It is now well established that water supplies that meet the coliform drinking water standards, as well as the coliform-based contact recreation standards, can contain protozoan pathogens, such as cryptosporidium, at concentrations that are a threat to cause disease in people.

Another group of human pathogens of concern through drinking water supply or contact recreation is the viruses. There is a variety of human diseases caused by waterborne viruses. Their source is human fecal material. Generally, the viruses do not persist for long periods of time in water, although the persistence is sufficient so that they can cause human diseases. Viruses are a threat to cause disease in people through inadequately treated drinking water and through contact recreation. Viruses that can cause human disease also can be present in waters that meet the fecal coliform standard.

In the early 1990s, OEHHA conducted an environmental comparative risk project. The purpose of this project was to examine the human health and environmental risk associated with chemical and other stressors in the environment. This resulted in a report (OEHHA, 1994), which presented information on the comparative risk of various types of stressors to human health through water and air. Lee and Jones-Lee (1993) developed a section of this report devoted to a review of the comparative risk of pathogens to human health. They summarized the literature on this topic, pointing out that waterborne pathogens through drinking water, including waters that have been treated to meet the fecal coliform standard, represent a significant threat to cause disease in people through consumption of drinking water or contact recreation. From a comparative risk standpoint, humans in the US are far more likely to become ill and/or die from waterborne pathogens acquired through consumption of treated drinking water or contact recreation than from all of the highly regulated chemical stressors, such as the Priority Pollutants. This situation points to the inadequate regulation of water used for domestic water supply and contact recreation in protecting public health.

In an attempt to address the unreliability of the fecal coliform standard for protection of public health associated with contact recreation, in the 1980s the US EPA conducted several large-scale studies to examine the list of human diseases associated with contact recreation. This led to a recommendation that the fecal coliform standard be abandoned in favor of an *E. coli*, or fecal streptococcus, standard. It was found, through the US EPA studies, that there was a fairly direct relationship between *E. coli* concentrations in waters used for contact recreation, and intestinal illness. Based on this, the US EPA (1998) has adopted a policy that all states must adopt a contact recreation water quality standard based on *E. coli*. The CVRWQCB adopted this standard over a year ago and submitted it to the State Water Resources Control Board for review. Thus far the SWRCB has not acted on approval of this standard. One of the problems that has recently come to light is that Byappanahalli et al. (2002) have found that *E. coli* and *Enterococci* can reproduce in warm, moist soils. This finding could make the interpretation of an exceedance of an *E. coli* based contact recreation standard somewhat unreliable as an indicator of the potential for human enteric diseases.

As discussed in this report, the DeltaKeeper has focused part of its activities on evaluating sanitary quality of eastern and Central Delta waters. In general, it has been found that the sanitary quality of Delta waters based on *E. coli* is poor in the areas near Stockton and in areas near marinas and beaches. The water of the Delta outside of these areas meets the US EPA's suggested *E. coli* standard.

Unknown-Caused Toxicity. As discussed above, some of the Delta waterways are listed as impaired due to unknown-caused toxicity. Under the leadership of the Central Valley Regional Water Quality Control Board (originally Val Connor, now Karen Larsen), a group of scientists and engineers interested in this issue have developed a draft strategy for addressing the unknown-caused toxicity that occurs in Central Valley waterbodies. This strategy serves as the basis for developing a proposal to CBDA for Directed Action funding of its components. CBDA (CALFED, 2000) is committed, as part of its Record of Decision (ROD), to develop a program to control unknown-caused toxicity in Delta waters.

South Delta Salt Issues. The San Joaquin River as it enters the Delta and several Delta channels influenced by SJR waters contain excessive salts compared to the 700 µmhos/cm water quality objective for these waterbodies. The primary source for the excessive salts is the export of salts from agricultural areas, especially in the Mud and Salt Slough watersheds. These and other principally westside areas of the SJR watershed cause the SJR at Vernalis to be listed as 303(d) impaired because of excessive salts. Lee and Jones-Lee (2004d) and Lee et al (2004a) have recently reviewed the excessive salt situation in the SJR and South Delta. The total salt content of the waters is of concern because of its adverse impact on irrigated agriculture and the use of the water for domestic water supply. Montoya (DWR, 2004b) has recently reviewed the factors influencing the total salt content of the waters pumped by the state and federal projects. As discussed, the TDS/EC at the project pumping stations is influenced by a variety of factors, including the flow of the SJR, the amount of export pumping occurring, tide stage, position of South Delta barriers, etc.

A TMDL to control salt discharges to the level of the water quality objectives at Vernalis is being developed by the CVRWQCB. Since there are also excessive salts in several South Delta channels compared to the WQO for these waterbodies, there will be need to control salt discharges from SJR watershed sources so that the concentrations of salts in the SJR at Vernalis will not cause or contribute to violations of the EC water quality objective in South Delta channels.

As discussed by Lee et al. (2004a), Delta irrigated agriculture discharges EC in tailwater that is often three times that of the water taken from the channel. While the salt loads in the intake and discharge waters are on the average balanced, the concentrations in the tailwater discharges are greatly elevated due to the consumption of water by crop production. The net effect is to increase the salt concentration (EC) of Delta channels. If the waters taken by agriculture from a South Delta channel are already at the WQO of 700 µmhos/cm, the use of water from Delta channels by irrigated agriculture will lead to WQO violations when the tailwater is added back to the channels.

There is a major problem with the approach that the CVRWQCB has advocated to develop a Basin Plan amendment to begin to solve the violation of the salt (TDS, EC) water quality objective in the SJR watershed. The current focus of the TMDL is on meeting the salt WQO at Vernalis. This approach will not eliminate the violation of WQOs in the San Joaquin River upstream of Vernalis as well as in the South Delta. With respect to the latter, achieving the EC WQO at Vernalis will lead to continued EC WQO violations in the South Delta channels. As suggested by G. F. Lee at the CVRWQCB April 29, 2004, Salt and Boron TMDL workshop, the first step in this process should be to define TMDL goals for each reach of the SJR and its tributaries to meet the WQOs in all the waterbodies in the SJR watershed and in the South Delta. This will require that an understanding be developed of the EC that can be in the SJR at the Head of Old River and still allow irrigated agriculture to be practiced in the South Delta without causing violations of the summer irrigation season WQO of 700 µmhos/cm in South Delta channels at the location where the channel waters mix with irrigation tailwater.

As a possible approach for eliminating South Delta channel EC WQO violations, it has been suggested that the EC WQO for South Delta channels be raised from the current 700 µmhos/cm to a value that would allow South Delta irrigated agriculture tailwater discharges when the South Delta channels are at the WQO. It is unlikely that such an increase would be approved because of the adverse impact on crop production by irrigated agriculture. According to A. Hildebrand (pers. comm., 2004), *"In regard to water quality, there was extensive testimony that led to the need for a 700 µmhos/cm salinity standard to prevent losses in crop yield. The salinity was almost always better than 700 µmhos/cm pre CVP. Furthermore, even when the salinity standard is met at Vernalis it is not met downstream, particularly when flows are low and the salt load is high. Manteca, Tracy, Lathrop, and Mountain House wastewater enters the channel system. Furthermore, agricultural use of water necessarily concentrates whatever salt load is in the diverted water. The tributaries are not responsible for the salinity problem, but they aggravate the problem when they manipulate the time of flow from what it would be in the absence of VAMP."*

Depending on the operation of the permanent barriers that are to be installed in the South Delta by 2007, there is the potential to bring more low-salinity Sacramento River water into the South Delta and thereby reduce the EC in some, but not all, South Delta channels. This will not, however, eliminate the EC violations in some of the South Delta channels. From the information available, to eliminate these violations it will be necessary to reduce the EC concentrations of the SJR waters entering the South Delta at the Head of Old River below 700 µmhos/cm.

Heavy Metals. As discussed above, there is a major water quality problem in the Delta due to mercury. Lee (2003h) has presented a review of current and pending regulatory approaches for mercury in water and sediments. 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.

Brown et al. (2004) have discussed the potential for cadmium to be bioaccumulating in clams in the western Delta near Chipps Island to a sufficient extent to be potentially adverse to clam reproduction. Further, Thompson (1996) has found that diving ducks are gaining sufficient cadmium from eating clams to potentially adversely impact their reproduction.

Luoma (2004), at the 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. 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.

Former mining activities in the Delta watershed have resulted in large amounts of several heavy metals such as copper, zinc and cadmium being discharged to Delta tributaries which have then been transported to the Delta and have accumulated in Delta sediments. Of particular importance are the former discharges of the Iron Mountain Mine (IMM) near Shasta Lake to the upper Sacramento River. The US EPA (2004) has stated that its cleanup efforts at the Iron Mountain Mine

"… will lead to the control of over 95 percent of the copper, cadmium and zinc that historically discharged to the Sacramento River. Before Superfund cleanup actions, IMM discharged more than a ton per day of toxic metals into the Sacramento River."

While Keswick Reservoir will trap some of the particulate heavy metals from the IMM in its sediments, large amounts of the heavy metals that have been discharged to the Sacramento River from IMM and other mines are eventually transported to the Delta where they are to some extent deposited in Delta sediments.

According to A. Baillie (pers. comm., 2004) of the CVRWQCB, Delta marina sediments have been found to contain elevated copper concentrations compared to Delta channel sediments. Based on the Delta Dredging and Reuse database, Baillie reported that the average copper in marina sediments was 49.7 mg/Kg (dry weight) with a range of 5 to 300 mg/Kg. Delta river sediments had a mean copper concentration of 38 mg/Kg with a range of 1 to 90 mg/Kg. According to Dragun and Chiasson (1991) the USGS reported that the average copper in California soils was 49 mg/Kg with a range of 5 to 300 mg/Kg. It appears that Delta marina sediment copper is within the range of copper in California soils.

Baillie stated that some Delta marina sediments have also been found to contain tributyl tin (TBT). Both copper and TBT have been used in boat hull antifoulant paints. Copper is still being used for this purpose. Baillie also indicated that some Delta marina sediments are toxic to some aquatic life. It is not known whether the copper and other heavy metals in Delta sediments (including in marinas) is the cause of this toxicity. It will be necessary to conduct sediment toxicity tests and toxicity identification evaluations (TIEs) to determine which sediments are toxic and the cause of this toxicity. As discussed herein and by Lee and Jones-Lee (2002a,d), it is unreliable to try to use Long and Morgan ERLs and ERMs or MacDonald TELs (co-occurrence-based values) to determine the role of a constituent measured in sediments as the cause of sediment toxicity.

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 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 in Delta waterbodies, the heavy metals of potential concern in highway and street runoff will remain in nontoxic forms in Delta waters and sediments.

pH and Alkalinity. A review of the existing data for Delta channels shows that there are no excessive pH or extremely low alkalinity values in Delta waters. Even though there is marked algal photosynthesis in the surface waters of the San Joaquin River Deep Water Ship Channel that could cause elevated pH in the main channel in the late afternoon, which would violate the CVRWQCB Basin Plan objective, these problems have not been observed. There are situations, however, in some of the side channels, such as the Wine Slip in the Port of Stockton, where photosynthesis impacts diel pH sufficiently to cause violations. As discussed by Lee and Jones-Lee (2000a), Lee and Litton, in a study of the Port of Stockton Wine Slip conducted in August 1999, showed that pH values greater than 9 were experienced in late afternoon, which could be attributed to phytoplankton photosynthesis.

The CVRWQCB Basin Plan objective for maximum pH is 8.5. This value is considerably more restrictive than the US EPA Gold Book criterion of pH 9. Even a pH of 9 is not significantly adverse to a waterbody's fisheries, since many eutrophic waterbodies have excellent warm water fisheries and routinely have pH of 9.5 to 10 in the late afternoon.

The alkalinity levels in the San Joaquin River and in the Sacramento River are variable, depending on flow, but are sufficient to provide considerable pH buffering of Delta waters. This buffer capacity has not been recognized by the CVRWQCB as part of their permitting of the city of Stockton's wastewater discharges. Until recently, the Regional Board allowed the city of Stockton to add acid to its domestic wastewater effluent to a sufficient extent so that at times the pH in the effluent was on the order of 6. The purpose of the acid addition was to reduce the toxicity of ammonia present in the effluent. However, the acid was quickly neutralized in the San Joaquin River due to the buffering capacity of the water. The CVRWQCB no longer allows the city of Stockton to follow this approach.

Invasive Species. Cohen and Carlton (1995) have presented a comprehensive review of the occurrence and potential impacts of biological invasive species in San Francisco Bay and the Delta. Appendix C presents the Executive Summary from their report. They indicate that the San Francisco Estuary is recognized as the most invaded aquatic ecosystem in North America, with 212 introduced species (as of 1995). Since 1970, there has been at least one new species introduced every 24 weeks. They report that nonindigenous animals and plants in the Estuary have had a profound impact on the ecology of the system. One of the most important impacts is the introduced bivalves which, through filter feeding, are potentially altering the trophic dynamics of the Bay-Delta system. Cohen and Carlton point out that clams in the Suisun Bay area have the ability to filter essentially all of the water in the northern Estuary each day.

As discussed by Cloern et al. (2003), this filter-feeding (grazing) by clams appears to be having a significant adverse impact on the phytoplankton populations in the Suisun Bay area. The extent to which these impacts are occurring throughout the Delta is unknown and is an area that needs investigation. One of the major challenges of future water quality monitoring in the Delta is an assessment of the impacts of pollutants on the aquatic ecosystem, versus that of invasive species.

Biomarkers and Sublethal Effects

At a CBDA meeting in June 2003, Dr. Susan 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 one of its tributaries. She reported that a caged fish in Orestimba Creek (one of the westside tributaries to the San Joaquin River, which has 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. The 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 the experts 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 considerable periods 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. This presentation was based on a paper that is in press (Eder et al., 2003a,b; 2004).

Werner et al. (2003b) 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.

Delta Port and Navigation Channel Development

Ports that are used by ocean-going deep-draft ships have been developed in West Sacramento and Stockton. This development involved dredging channels from San Francisco Bay through to each of the ports. Since the dredged channels and associated port areas tend to accumulate sediments with a wide variety of potential pollutants, there is concern about maintenance dredging of these channels leading to the release of pollutants that are adverse to Delta water quality. Lee and Jones-Lee (2000b) and their associates have conducted extensive research on the water quality aspects of dredging in various waterbodies located throughout the

US and in some other countries. As they discuss, there is need to conduct comprehensive studies associated with each dredging project, especially those conducted in areas of poor water quality such as the Port of Stockton, to insure that the project does not cause significant adverse impacts to the beneficial uses of the waters in which the project is conducted, in areas where the dredged sediments are deposited and runoff/discharges from these areas, and in areas where dredged sediments are utilized for beneficial purposes, such as levee maintenance.

The CVRWQCB, as part of its permitting of dredging projects in the Delta, conducts comprehensive reviews of Delta channel maintenance projects for the purpose of working toward water quality protection associated with the dredging and dredged sediment disposal/utilization projects. While a wide variety of potential pollutants is investigated prior to and monitored associated with each dredging project, as discussed by Lee (2004a), there is the potential for unrecognized water quality impacts to be occurring by constituents that are not investigated/monitored under the current regulatory program. There is need to continue to expand the comprehensive nature of these dredging project investigations to include evaluation of previously unrecognized and new pollutants that have accumulated in the sediments that are dredged.

The Port of Stockton is in the process of proposing to greatly expand the number of ocean-going ships that use the Port. According to the draft EIR (ESA, 2003), for the expansion project, *"The total number of annual port calls would increase from 20 to 150 as a result of the Proposed Project."* This expansion has a number of potentially significant ramifications for Delta water quality. These include significantly increasing the suspension of sediments that occurs associated with ship traffic. To the extent that chemical constituents are released during sediment suspension, the increased ship traffic could aggravate existing water quality problems associated with ship traffic. There is also the potential for increased shoreline erosion associated with ship traffic, caused by the ship's wake. There is need for a more comprehensive investigation of the impact of ship traffic on Delta water quality.

The Port of Stockton has proposed to change the navigation depth of the DWSC from the current 35 feet to 40 feet. This would further aggravate the low-DO problem that exists in the DWSC near the Port of Stockton. As discussed by Lee and Jones-Lee (2003a), the development of the Port of Stockton and its associated deep water navigation channel is one of the primary causes of the low-DO problem in the SJR DWSC near the Port of Stockton. The DWSC in this region has converted the SJR from a fast-flowing river that has a depth of 10 to 15 feet to a slow-moving, long, thin lake, with a depth of 35 feet. This change in the physical characteristics of the channel greatly increases the hydraulic residence time of water in the channel beginning at the Port, with the result that oxygen-demanding materials, such as ammonia discharged by the city of Stockton wastewater treatment plant and algae that develop on nutrients derived primarily from agricultural sources in the SJR DWSC watershed, exert oxygen demand to a greater degree in the SJR DWSC than would occur if the dredged navigation channel to the Port of Stockton did not exist. Increasing the navigation depth of this channel to 40 feet will further aggravate this situation.

The Corps of Engineers was required to mitigate the impact of the increased channel depth on the oxygen demand assimilative capacity associated with the past deepening of the channel from 30 feet to 35 feet that occurred in the late 1980s by installing an aeration device located at the Port of Stockton near Channel Point. A critical review of the approach that the Corps of Engineers was allowed to adopt with respect to evaluation of whether the aerator design would mitigate for the decreased oxygen demand assimilative capacity of the DWSC, and the required operation of this aerator, shows that the aerator is not achieving design specifications. This issue has been addressed by Brown (Jones & Stokes, 2003). Further and most importantly, the Corps' current approach for operating the aerator does not require the Corps to operate the aerator whenever the oxygen concentrations in the DWSC near the Port of Stockton are below the water quality objective for this reach of the Channel.

As discussed by Lee and Jones-Lee (2003a), there have been several periods over the last couple of years when the dissolved oxygen concentrations in the DWSC just downstream of the Port of Stockton were at or near zero mg/L. Associated with these periods were fish kills. However, in accordance with the current operations plan for the aerator adopted as part of mitigation for increasing the channel depth from 30 feet to 35 feet, the aerator was not operated during all times that the DO was below the water quality objective. Lee (2003i) has discussed the need to change the characteristics and operations of the aerator so that it more appropriately mitigates for the deepening of the channel that took place in the late 1980s from 30 feet to 35 feet. Further, associated with any additional deepening of the channel, such as that proposed by the Port of Stockton, more appropriate review of mitigation measures as they may impact the oxygen demand assimilative capacity of the SJR DWSC should be conducted than occurred for the late 1980s deepening of the channel.

Another aspect of increased ship traffic is the potential water quality impacts of ships discharging their ballast water at the Port of Stockton. Ballast water is notorious as a means of transporting invasive species to areas where they would not ordinarily be found. Further, since the ballast water for ocean-going ships that reach the Port of Stockton is likely marine water with a high salt content, the increased shipping could introduce substantial salt into the Port of Stockton area and thereby increase the TDS of the San Joaquin River water at the Port. Further, depending on the source of the ballast water and whether mid-ocean exchange of the ballast water from that which was acquired at the original port of embarkation has occurred, there is a potential for the introduction of a wide variety of chemical pollutants and pathogens into the Port of Stockton associated with the increased number of ships utilizing the Port.

Thermal Discharges

The pollution of Delta waters by thermal discharges is an issue that is not being adequately addressed. Part of the problem is that the California Thermal Plan is badly out of date and needs to be updated to more properly reflect current knowledge on how elevated temperatures impact aquatic life. All discharges that contain elevated temperatures in Delta waters should be investigated to determine if excessive thermal discharges are occurring that are detrimental to Delta aquatic life.

Impact of Urbanization on Delta Water Quality

The rapid urbanization of the Delta watershed is bringing ever-increasing amounts of potential pollutants into the Delta and its tributaries. In addition to urban stormwater runoff being a source of pesticide-caused aquatic life toxicity and oxygen demand, it is also a source of a wide variety of potential pollutants, such as heavy metals (including lead, cadmium, copper and zinc), petroleum hydrocarbons (including PAHs), dioxins, total suspended solids, etc. The Center for Watershed Protection (CWP, 2003) has recently issued a report, "Impacts of Impervious Cover on Aquatic Systems." This report provides information on the impacts of urbanization of areas on urban stream hydrology and stream aquatic life habitat, and includes information on the chemical characteristics of urban streams. Lee and Jones-Lee (2004e) have recently developed a review of urban stream water quality in which they discuss issues that need to be considered in evaluating the water quality impacts and the control of chemical constituents and pathogen indicator organisms.

Jones-Lee (2004) publishes a *Stormwater Runoff Water Quality Science/Engineering Newsletter* that discusses urban and rural stormwater runoff water quality issues. This *Newsletter* is in its seventh year of publication. It is distributed by email periodically at no cost to over 8,000 individuals. Past issues of this *Newsletter* are available at www.gfredlee.com. This *Newsletter* discusses the characteristics of urban stormwater runoff and the significant problems that exist today in regulating urban area stormwater runoff water quality impacts. Lee and Jones-Lee (2003e) have recently discussed these problems relative to urban stormwater runoff impacts to port and harbor water quality, and presented a recommended approach for evaluating and managing the water quality impacts of urban area and highway stormwater runoff-associated constituents.

The current regulatory approach at the federal and state level is not effective in defining and managing the real, significant water quality impacts of urban stormwater runoff-associated potential pollutants on receiving water quality. Jones-Lee and Lee (1998) have recommended that the current NPDES monitoring of stormwater runoff from urban areas and highways, in which a suite of potential pollutants is monitored in the runoff for a couple of storms each year, be changed to an Evaluation Monitoring approach. The current monitoring approach is patterned after typical wastewater discharge monitoring, in order to evaluate compliance with the NPDES permit conditions and water quality standards.

As discussed by Jones-Lee and Lee (1998) and Lee and Jones-Lee (2003e), the characteristics of urban stormwater runoff, where elevated concentrations of largely particulate (non-toxic, non-available) constituents are discharged over short periods of time, make the use of an exceedance of US EPA worst-case-based water quality criteria and state standards based on these criteria unreliable for evaluating water quality impacts. Rather than continuing to monitor discharge chemical characteristics, which are now well established, Jones-Lee and Lee (1998) recommend that the monitoring be shifted to studies of the receiving waters for the runoff, to determine the adverse impacts of the runoff-associated constituents on the beneficial uses of these waters. This approach will lead to the development of reliable wet-weather standards that can be used to more appropriately regulate the water quality impacts of urban area and highway stormwater runoff than the water quality standards that are being used today.

According to a May 5, 2004, editorial in the *Sacramento Bee*, 45,000 acres of Delta farmlands have been converted to urban areas in the last 10 years. Further, with the population of the Central Valley – and especially the Delta watershed – expected to increase significantly in the next decade or so, there will be substantial increases in the amount of stormwater runoff discharged to Delta tributaries and directly to the Delta. The current estimated urban population in the San Joaquin River watershed is approximately two million. Lee and Jones-Lee (2000a) report that the SJR watershed urban population is rapidly expanding with a rate of growth of 2 percent/yr and expected to double to about 4 million people by 2040. Increased attention needs to be given to evaluating the water quality impacts of Delta watershed urban stormwater runoff on Delta water quality-beneficial uses. This evaluation will require studies that specifically focus on the fate, transport and impacts of urban area and highway stormwater runoff on Delta tributaries and Delta waters. Particular attention should be given to stormwater runoff water quality impacts from Stockton, the greater Sacramento metropolitan area and upstream San Joaquin River watershed municipalities.

An issue of concern is the current stormwater management practice for Modesto's stormwater runoff, of discharging parts of it into dry wells without regard to whether this practice is causing groundwater pollution. Lee et al. (1998) and Taylor and Lee (1998) have provided information on the potential for infiltration of urban area and highway stormwater runoff-associated constituents to cause groundwater pollution. The current Modesto practice of infiltrating stormwater could – as a result of the investigations of the impacts of this practice, which are now being required by the CVRWQCB – be curtailed and result in even greater urban area stormwater potential pollutant loads to the San Joaquin River.

The recent SFEI Regional Monitoring for Trace Substances Annual Meeting included a discussion of the effects of the urbanization of the San Francisco Bay watershed on pollutant loadings to the Bay, by Davis et al. (2004). They conclude that, *"Urbanized portions of Bay Area watersheds are significant sources of most priority contaminants, including PCBs, mercury, copper, organochlorine pesticides, dioxins, diazinon, PAHs, and PBDEs."* In a presentation at the SFEI 2004 conference, Oros (2004) presented an expanded discussion of the current knowledge on the occurrence and sources of PAHs in the San Francisco Bay Estuary. A similar presentation was made by Yee (2004) for dioxins in the Bay sediments and aquatic life. Background information on Oros' presentation has been provided by Oros and Ross (2004). The Oros and Yee studies have shown that urban areas are significant sources of these potential pollutants. Based on the information provided, it is likely that similar kinds of problems, caused by PAHs, PCBs, PBDEs, organochlorine legacy pesticides and mercury, are occurring in waterbodies in the greater Sacramento area and the San Joaquin River Deep Water Ship Channel near Stockton. Both of these areas need to be specifically targeted for detailed studies on PAH, PCB and dioxin occurrence in water and sediments and for PCBs, PBDEs and dioxins in fish.

Impact of Export Projects on Chinook Salmon Home Stream Water Signal

At a CBDA Chinook/Steelhead Restoration workshop held in July 2003 several presentations were made on the lack of a well-defined genetic makeup of the Chinook salmon that return to San Joaquin River tributaries. This situation is related to the fish straying from their home stream water. It was pointed out that in other areas the Chinook salmon that return to a particular home stream normally have a well-defined genetic structure. It appears that something is causing the Chinook salmon that spawn in the SJR watershed tributaries to have problems finding their home stream for spawning. The South Delta export projects that have changed the flow of Sacramento and San Joaquin River water through the Delta have changed the transport of the home stream chemical signal for spawning of Chinook salmon. Prior to the export projects, the San Joaquin River tributary home stream water chemical signal which guides the fish to their spawning areas could be transported, during low-flow conditions, to San Francisco Bay, and thereby provide a home stream signal to fall-run Chinook salmon proceeding to their San Joaquin River tributary home stream. Lee and Jones-Lee (2003f) have discussed that the export-project-caused drawing of large amounts of Sacramento River water to the South Delta has eliminated any San Joaquin River tributary home stream water signals from occurring in the Central and northern Delta, downstream of Columbia Cut. The waters in the San Joaquin River channel downstream of Columbia Cut during the summer, fall and early winter are Sacramento River water, and not San Joaquin River water. This means that the fall-run Chinook salmon, upon entering the Delta from San Francisco Bay during the fall and winter have no home stream water signal to help them migrate through the Delta to their home stream waters. The consequences of this situation on the restoration of the Chinook salmon fishery need to be evaluated.

Delta Improvements Package

In the summer of 2003 the agencies/entities responsible for managing water exports from the Delta held a meeting in Napa, California, to discuss the implementation of the expanded exports of Delta water called for in the CALFED (2000) Record of Decision. The results of this meeting became known as the "Napa Agreement." Over the fall and early winter this has evolved into what is now called the Delta Improvements Package (DIP). Quinn (2004) of the Metropolitan Water District of Southern California presented a review of the "Delta Improvements Package: A 2004 CALFED Priority" at the January 2004 CBDA Drinking Water Subcommittee meeting. One of the components of the proposed Delta Improvements Package is additional monitoring of selected parameters (TOC and salt) of interest to those who export Delta waters for municipal and agricultural purposes, as well as Delta agricultural interests, especially the South Delta agricultural interests.

In February 2004 the CBDA (2004b) released the proposed Delta Improvements Package. Table 2 presents a listing of the components of the proposed DIP. In May 2004 CBDA (2004c) released for public comment a Draft Memorandum of Understanding (MOU) Regarding CALFED Bay Delta Program Activities in the Delta. In response to the request for comments on this draft MOU, Lee and Jones-Lee (2004d) provided an overall assessment and detailed comments on the proposed DIP and draft MOU covering its implementation.

> ***"Overall Assessment of the DIP***
>
> *It is our assessment that the California Bay-Delta Authority is not in a position to reliably pursue adopting and implementing the currently proposed Delta Improvements Package. The information base upon which to develop adequate reviews of the potential water quality impacts of increasing the Harvey O. Banks pumping station's flow to 8,500 cfs does not exist. Figure 1 presents a plot of the Department of Water Resources (DWR) measured flow at the Banks pumping station for the period 2001 through 2003. As shown, increasing the Banks pumping station flows to 8,500 cfs, as proposed in the DIP interim implementation, will, at times, represent a significant additional export of Delta water by the State Water Project.*

Table 2
Components of the Delta Improvements Package (DIP)

SUMMARY OF STATUS OF
ACTIVITIES UNDER CONSIDERATION[1]

WATER SUPPLY RELIABILITY

Increase State Water Project (SWP) Pumping Capacity to 8,500 cfs

Implement SWP/CVP Integration Plan

- The SWP will convey CVP refuge water at the Banks Pumping Plant
- The CVP will provide water to assist DWR in meeting the SWP's water quality responsibility
- Water made available by Sacramento Valley water users pursuant to an Agreement known as "Phase 8" of the Bay-Delta water rights hearings by the State Water Resources Control Board (SWRCB) will be shared by the CVP and SWP

Design and Construct CVP/SWP Aqueduct Intertie

Operations Criteria and Plan Update

ENVIRONMENTAL WATER ACCOUNT

Continue the Environmental Water Account (EWA)

- Fixed Assets – Capital Assets and Water Purchases
- Variable Operational Assets
  - SWP Pumping of (b)(2)/ERP Upstream Releases
  - EWA Use of SWP Excess Capacity
  - Export/Inflow Ratio Flexibility
- Water Management Tools and Agreements
- EWA Debt Carryover and Source Shifting
- Wet/Dry Year Exchanges
- Storage

ESA COMPLIANCE AND ECOSYSTEM RESTORATION

Water project ESA consultation requirements

Update of CALFED ROD programmatic ESA consultation – EWA and ERP

WATER QUALITY

In-Delta Salinity Projects

- Old River and Rock Slough Water Quality Improvement Projects
- Develop Strategy for Franks Tract
- Delta Cross Channel Reoperation
- Through Delta Facility
- Install Permanent Operable Barriers

In-Delta Dissolved Oxygen Projects

- Dissolved Oxygen Implementation Strategy

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[1] From CBDA, February (2004b)
http://calwater.ca.gov/DeltaImprovements/DIP/DIP_CBDA_staff_report_Att_A_2-11-04.pdf

Table 2 (continued)

San Joaquin River Salinity
Basin Plan Amendment to Implement a Total Maximum Daily Load (TMDL) for Salinity
Implementation of Source Control Measures
San Joaquin River/CVP Recirculation Feasibility Study

SCIENCE
Environmental Water Account Technical Reviews
South Delta Hydrodynamics and Fish Investigations
Delta Smelt Fish Facility Survival
Addressing Critical Information Gaps and Uncertainties Regarding Water Operations and Biological Resources

RELATED ACTIONS
Trinity River
Freeport Regional Water Project

We have critically examined the current information base on the impacts of the State and federal export projects on Delta water quality. Our findings are presented in the DWQI report. It is found that CALFED, DWR, USBR and the State Water Resources Control Board (SWRCB) have not adequately and reliably evaluated the water quality impacts of the current exports of Delta water by the State and Federal export projects. Significantly increasing the amount of export, as proposed in the DIP, should not take place until an adequate evaluation of the current impacts of the export projects on Delta water quality has been conducted. Further, this evaluation of the current impacts should be conducted in such a way as to serve as a technical base for predicting the magnitude of the additional adverse impacts that will occur through increasing the Banks pumping station flows to a more consistent 8,500 cfs than has been occurring in the recent past. This information can then be used to develop appropriate mitigation measures to address the adverse impacts of further exports of Delta water through the State Water Project as proposed in the DIP."

(Figure 1 is presented in the Lee and Jones-Lee (2004d) comments on the MOU and proposed DIP.)

Lee and Jones-Lee (2004d) provided detailed comments on the deficiencies in information upon which to evaluate the water quality impacts of increasing Delta water exports on the water quality within the Delta. Of particular concern are the impacts of the current and proposed expanded exports on the transport and fate of pollutants added to the Delta from tributary and in-Delta sources. As they point out, the export projects have totally changed the flow of water through the Delta and therefore the impacts of pollutants in Delta waters on water quality-beneficial uses of the Delta.

Delta Water Quality Monitoring Programs

The key to reliably managing water quality in the Delta is a comprehensive water quality monitoring and evaluation program. There are several water quality monitoring programs being conducted in the Delta and its nearby tributaries. In general, these programs have specific objectives related to managing Delta resources. The most comprehensive of these programs is the Interagency Ecological Program (IEP) Environmental Monitoring Program (EMP). On March 25, 2003, Stephen Verigin of the Department of Water Resources (DWR) and Susan Ramos of the US Bureau of Reclamation (USBR) submitted a revised Delta water quality monitoring program to Celeste Cantú, Executive Director of the State Water Resources Control Board (available at http://iep.water.ca.gov/emp/EMP_Review_Final.html). This monitoring program is being conducted as part of implementing the State Water Resources Control Board's Water Rights Decision 1641 covering the export of water from the Delta by the state and federal projects. As stated in the cover letter for this submission,

> *"D-1641 specifies three goals for this monitoring program: (1) to ensure compliance with Bay-Delta water quality objectives; (2) to identify meaningful changes in any significant water quality parameters potentially related to operation of the State Water Project (SWP) or the Central Valley Project (CVP); and (3) to reveal trends in ecological changes potentially related to SWP/CVP operations. Condition 11 (e) requires DWR/USBR to evaluate the EMP and report their conclusions to the Executive Director of the State Water Resources Control Board every three years."*

The 2001-2002 Review of the Environmental Monitoring Program states that,

> *"The Environmental Monitoring Program (EMP) was initiated in 1971 and now monitors water quality and phytoplankton, zooplankton, and benthos abundance and distribution in the upper San Francisco Estuary."*

According to the report, the monitoring elements consist of

- *"'Continuous Recorder' monitoring of water temperature, electrical conductivity (EC), or dissolved oxygen,*
- *Continuous 'Multiparameter' monitoring,*
- *Discrete (monthly) physical and chemical water quality monitoring,*
- *Discrete (monthly) phytoplankton monitoring,*
- *Discrete (monthly) zooplankton monitoring, and*
- *Discrete (monthly) benthos monitoring.*

> *EMP monitoring is currently conducted at 22 of the 42 stations listed in D-1641, Table 5."*

The footnotes to Table 5 Water Quality Compliance and Baseline Monitoring list the following as the current parameters that are monitored:

- *"Continuous recording (every 15 minutes) of water temperatures, electrical conductivity (EC), and/or dissolved oxygen. For municipal and industrial intake chloride objectives, EC can be monitored and converted to chloride concentration.*
- *Continuous multi-parameter monitoring (recording every 1 to 15 minutes with telemetry capabilities) includes the following variables: water temperature, EC, pH, dissolved oxygen, turbidity, chlorophyll fluorescence, tidal elevation, and meteorological data (air temperature, wind speed and direction, solar radiation).*

- *Discrete physical/chemical monitoring is conducted near-monthly on alternating spring and neap tides and includes the following variables: macronutrients (inorganic forms of nitrogen, phosphorus, and silicon), total suspended solids, total dissolved solids, total, particulate and dissolved organic nitrogen and carbon, chlorophyll* a*, pH, dissolved oxygen (DO), EC (specific conductance), turbidity, Secchi depth, and water temperature. In addition, on-board continuous recording is conducted intermittently for the following variables: water temperature, dissolved oxygen, electrical conductivity, turbidity, and chlorophyll* a *fluorescence.*
- *Near-monthly discrete sampling on alternating spring and neap tides for phytoplankton enumeration or algal pigment analysis.*
- *Near-monthly tow or pump sampling for zooplankton, mysids, and amphipods.*
- *In 2003 and 2004, replicated benthos and sediment grab samples are taken quarterly (every three months) and during special studies; more frequent monitoring sampling resumes in 2005."*

There is also a monitoring program for fish in the Delta. However, it is not integrated with the EMP program.

Several years ago, those responsible for organizing the Interagency Ecological Program (IEP) monitoring terminated the pesticide monitoring. This is unfortunate. What should have been done was to shift the monitoring for organochlorine pesticides, from the water column to fish tissue. This is a much more reliable approach for determining whether there are excessive concentrations of organochlorine pesticides than attempting to measure these pesticides in the water column.

Dr. G. Fred Lee was part of an external advisory panel for the 2001-2002 review of the Environmental Monitoring Program, which served as a basis for the DWR/USBR (2003) submission to the SWRCB. As part of this effort it was found that those responsible for developing the D-1641 water quality monitoring program for the Delta assumed a narrow scope for the potential impacts of the export of Delta waters on Delta water quality compared to the water quality monitoring program that is needed to fully evaluate the impacts of the export projects on Delta water quality beneficial uses.

The state and federal export projects, which typically export about 10,000 to as much as 13,000 cfs of Delta water, significantly alter the impacts on Delta waters of a variety of pollutants, such as mercury, organochlorine pesticides, PCBs, organophosphorus and other pesticides, herbicides, aquatic plant nutrients, etc. As one example of this, the export of South Delta water by the two projects, which causes at least 8,000 cfs of Sacramento River water to be drawn through the Central Delta to the South Delta export pumps, carries mercury into regions of the Delta where it would not otherwise exist at the concentrations found, if the export projects did not occur. The same applies with respect to altering the location and impacts of a number of other constituents that are on the CVRWQCB 303(d) list of constituents causing impaired water quality in the Delta. Because of the limited scope that the DWR, USBR and SWRCB have assumed for potential impacts of the state and federal export projects, there has been no proper evaluation of the full range of water quality impacts of the export of Delta water by the state and federal projects.

One of the most striking examples of an impact of the state and federal export projects on Delta water quality occurs in the first seven miles of the Deep Water Ship Channel (DWSC) near Stockton. As documented by Lee and Jones-Lee (2003a,b) and Lee (2003c,d), the state and federal South Delta water export projects at times cause most (essentially all) of the San Joaquin River water at Vernalis to flow down Old River into the South Delta to the federal export project pump at Tracy. As discussed by Lee and Jones-Lee (2003a), this causes the hydraulic residence time (travel time) of water in the DWSC critical reach (between Channel Point and Turner Cut) to be increased from a few days to several weeks, to as much as a month. This, in turn, leads to much greater DO depletion in the DWSC than would occur if the San Joaquin River water at Vernalis were allowed to pass through the San Joaquin River DWSC. Lee and Jones-Lee, as part of developing the Issues Report (Lee and Jones-Lee, 2000a), found, through a review of the existing water quality data on the DO in the DWSC, that there was a direct relationship between low DO in the Channel and low flows of the SJR through the Channel. Further work on this issue by Lee and Jones-Lee is presented in the Synthesis Report (Lee and Jones-Lee, 2003a). Additional discussion of the low-DO problem in the SJR DWSC is presented herein. The low-DO problem in the DWSC is now recognized to be, in part, due to the export pumping of San Joaquin River Vernalis water that enters the South Delta via Old River.

A project proposal for continuation of the SJR DO TMDL monitoring program on the San Joaquin River and its tributaries was submitted to CALFED/CBDA by the agricultural interests in the SJR DWSC watershed. CBDA has approved this monitoring program with some modifications. Several individuals (Foe and Lee) have been critical of this program in providing the additional data needed to more adequately characterize the upstream discharges and their impacts on the low-DO problem in the DWSC. Their comments on the deficiencies in the proposed monitoring program are available from the SJR DO TMDL website (www.sjrtmdl.org). Those responsible for organizing this program chose not to correct the deficiencies in this program pointed out by Foe and Lee, and submitted it for approval by CALFED/CBDA. Lee and Jones-Lee (2003a) have commented on the continuing significant deficiencies in the proposal submitted to CALFED/CBDA for additional monitoring upstream of the SJR DWSC. Lee has provided additional comments (Lee, 2003j) on deficiencies in this monitoring program. CBDA chose to ignore many of these deficiencies and has approved the monitoring program for funding, with some changes that address, in part, some of the deficiencies raised by Foe and Lee. There are still significant problems with it, however, in providing the data needed to properly characterize upstream oxygen demand loads as they may impact DO in the DWSC.

DWR Drinking Water Quality Program. The California Department of Water Resources (DWR) has a domestic water supply water quality monitoring program devoted to monitoring certain locations in the Delta. Information on this program is available from the DWR website (http://wq.water.ca.gov/mwq). The program includes monitoring for the following parameters at the Harvey O. Banks Pumping Plant:

- Electrical conductivity
- Chlorophyll fluorescence
- Water temperature
- UV 254

- pH
- Turbidity

These data are located at http://cdec.water.ca.gov/cgi-progs/staMeta?station_id=HBP. The DWR water quality monitoring at Banks also includes periodic monitoring for a suite of potential toxicants (such as low molecular weight organic compounds, herbicides, pesticides, heavy metals, PCBs, etc.) of concern for use of the water as a domestic water supply. These data are available at http://wdl.water.ca.gov/wq/gst/wq_report_details_gst_asp. These monitoring data show that several potential toxicants with respect to use of the water for domestic water supply purposes are below critical concentrations for this use. They may not, however, be below critical concentrations for the impact of some of these constituents on aquatic-life-related beneficial uses of Delta waters. In addition, other DWR water quality data for other locations are available from http://www.wq.water.ca.gov/owq/Data/wqdata.htm.

DWR is now providing weekly water quality reports. Information on obtaining these reports is available from rich@water.ca.gov. Real Time Data and Forecasting Project Water Quality Weekly Reports are available for the Sacramento River and San Joaquin River precipitation, flow and electrical conductivity; flow, electrical conductivity and total organic carbon for in-Delta stations; chlorophyll fluorescence, turbidity and temperature on the South Bay Aqueduct; chlorophyll fluorescence, turbidity and UVA on the California Aqueduct; and information on Delta operations.

One of the problems with the DWR drinking water monitoring program (and, for that matter, other DWR monitoring programs) is that chlorophyll fluorescence is measured at a number of locations; however, the measurements are made in such a way that they cannot be translated to planktonic algal chlorophyll concentrations – i.e., the fluorometer measurements are not calibrated in terms of µg/L of chlorophyll *a*. This means that the chlorophyll data generated in this program are of little or no utility in examining the overall planktonic algal chlorophyll situation in the Delta. It is not possible to compare applicable chlorophyll measurements made using reliable analytical methods with the DWR data. This is a particularly significant deficiency, since one of the areas that needs attention in the Delta is a better understanding of phytoplankton growth dynamics and biomass. Without reliable, comparable planktonic algal chlorophyll data at various locations, it is not possible to use the existing DWR monitoring data as part of this evaluation.

Since there are a number of factors that influence chlorophyll measurements by fluorescence, it is extremely important that any fluorometric measurements of chlorophyll be frequently calibrated against water samples obtained from the same waters in which fluorescence measurements are made, which are extracted using the standard acetone extraction procedure for measuring planktonic algal chlorophyll (Standard Methods – APHA et al., 1998).

DWR South Delta Water Quality Monitoring. DWR maintains a set of monitoring stations in the South Delta associated with evaluating the operations of the South Delta temporary barriers. Lee and Jones-Lee (2003a) provide a summary of the characteristics of the monitoring and the data obtained from this monitoring program. As discussed herein, there are severe low-DO problems and excessive total salts in several of the South Delta channels.

DeltaKeeper Monitoring. The DeltaKeeper is conducting a monitoring program of the sanitary quality of selected areas in the Delta, such as near marinas, beaches, etc. The DeltaKeeper, in cooperation with local agencies, has established the Delta Issues Subcommittee (DISC), which is an interagency task force spearheaded by DeltaKeeper as part of their Delta Pathogen Project. The following agencies participate in this group: San Joaquin County Environmental Health Department, San Joaquin County Public Works Department, San Joaquin County Public Health Services, California Department of Health Services, and DeltaKeeper. Meetings are held approximately once every two months.

The purpose of the DISC is to provide outreach and education on public health issues associated with contact recreation in the Sacramento-San Joaquin River Delta. Its strategy is to combine resources and ideas and act in unison to produce and disseminate multilingual educational materials. Thus far, the San Joaquin County Environmental Health Department has produced a two-page laminated health advisory for recreational water use, and DeltaKeeper has distributed the notice to local marinas for posting. The next goal of the DISC is to post local waterways with warning/health advisory signs indicating that contact recreation water quality standards have not been met, and outlining precautionary steps for those who make contact with the water.

The DeltaKeeper also monitors dissolved oxygen in the city of Stockton sloughs that serve as drainage ways for city of Stockton stormwater runoff to the Delta. These sloughs have periodic fish kills associated with stormwater runoff events, which are caused by low DO and possibly other factors. Some of these data have been incorporated into the Lee and Jones-Lee (2003a) SJR DWSC Synthesis Report as part of the discussion of the impacts of city of Stockton stormwater runoff on the SJR DWSC low-DO problem. This issue has been discussed in another section of this report.

The DeltaKeeper has also been responsible for gaining funding for other water quality monitoring programs in the Delta, including the studies that were conducted by the San Francisco Estuary Institute (SFEI) on excessive bioaccumulation of organochlorine pesticides and PCBs in Delta fish. It also obtained funding from CALFED for a continuation of the monitoring program that the CVRWQCB staff had been conducting on the aquatic life toxicity of city of Stockton stormwater runoff to its sloughs. The CVRWQCB and DeltaKeeper data were written up by Lee and Jones-Lee (2001). These data cover the period from 1994 through 2000 and show that stormwater runoff from the city of Stockton was consistently toxic to *Ceriodaphnia*. This toxicity was due to diazinon and chlorpyrifos used on residential and commercial properties. The Mosher Slough and Five Mile Slough data from this study were used by Lee and Jones-Lee (2002c) as the basis for developing a draft TMDL technical report for the CVRWQCB.

City of Stockton. The city of Stockton conducts several water quality monitoring programs associated with its NPDES permits for domestic wastewater discharges and stormwater runoff. The stormwater runoff data are reported to the CVRWQCB in the annual NPDES permit report. In addition, as part of its NPDES MRP Order No. R5-2002-0083, the City conducts a monitoring program as part of its wastewater discharge impact evaluation on the SJR DWSC. The city conducts monitoring at eight stations, from the San Joaquin River at Bowman Road to just north of Turner Cut on the DWSC. A variety of conventional wastewater pollutants is monitored at each location at weekly, monthly and quarterly intervals, depending on the parameter and season.

City of Tracy. The city of Tracy also discharges wastewaters to Old River in the South Delta under an NPDES permit. Monitoring of the characteristics of these wastewaters is required by the CVRWQCB as part of this permit. The city of Tracy wastewater monitoring data are made available to the CVRWQCB in NPDES monitoring reports. The city of Tracy's wastewater discharge occurs to Old River just downstream of where Old River confluences with the San Joaquin River. The average monthly flow of the City's wastewater discharge is 8.1 mgd, which translates to 12 cfs (Kummer, pers. comm., 2003). Additional information on the characteristics of city of Tracy wastewaters is available in the Lee et al. (2004a) South Delta Tour report.

Special-Purpose Studies. There have been a number of special-purpose studies of a limited duration that have provided considerable data on Delta water quality issues. One of the most important of these is the CALFED-sponsored studies on the low-DO problem in the DWSC. A total of approximately four million dollars over a four-year period has been devoted to obtaining data and analysis on the occurrence, magnitude, extent and duration of dissolved oxygen concentrations less than the water quality objective in the DWSC between Channel Point and Columbia Cut. These studies have included detailed monitoring of many of the tributaries and the mainstem of the San Joaquin River to define the sources of oxygen demand and the factors influencing its transport to the DWSC. Approximately 20 reports have been generated by various investigators presenting the results of these studies. These are available from the SJR DO TMDL website (http://www.sjrtmdl.org). A summary and synthesis of the information obtained from these studies is presented in the Synthesis Report by Lee and Jones-Lee (2003a). Essentially all of the data generated as part of the CALFED-supported studies have been posted on the IEP database (http://iep.water.ca.gov/data.html).

Flow Monitoring. One of the key components of the monitoring that is being done in the Delta is the monitoring of flow of the various channels and SJR DWSC. This flow monitoring is difficult because of the tidal influence on flows in the Delta. The USGS UVM station (Garwood) located on the SJR just upstream of the DWSC is a key station, providing measurements of San Joaquin River flow through the DWSC. The USGS monitoring station at Vernalis is also a key station, providing measurements of total SJR flow into the Delta. Other flow measurements by DWR and the USGS are important in defining the total fluxes of various constituents of concern that impact Delta water quality. The flow data are available from the USGS and DWR websites.

SFEI. The San Francisco Estuary Institute has been conducting a monitoring program of San Francisco Bay for a number of years, which focuses on providing information related to the water quality characteristics of the Bay. In some years the SFEI monitoring studies have included monitoring stations located in the Delta. The SFEI data are available from the SFEI website (http://www.sfei.org).

Agricultural Waiver Monitoring. In July 2003 the CVRWQCB (2003) adopted Order No. R5-2003-0826, which included a requirement for a comprehensive monitoring program of agricultural discharges to Central Valley waterbodies. This monitoring program is applicable to agricultural discharges to Delta channels. The agricultural waiver monitoring program, if implemented as currently required, will eventually provide considerable additional data on the water quality characteristics of agricultural discharges to the Delta channels and their impacts on the beneficial uses of these channels. The objectives of this program are:

"a. Assess the impacts of waste discharges from irrigated lands to surface water;
b. Determine the degree of implementation of management practices to reduce discharge of specific wastes that impact water quality;
c. Determine the effectiveness of management practices and strategies to reduce discharges of wastes that impact water quality;
d. Determine concentration and load of waste in these discharges to surface waters; and
e. Evaluate compliance with existing narrative and numeric water quality objectives to determine if additional implementation of management practices are necessary to improve and/or protect water quality."

Lee has provided detailed comments on the deficiencies of the CVRWQCB (2003) agricultural waiver monitoring program (Lee, 2003j, 2004b; Lee and Jones-Lee, 2003g). Key deficiencies in this program were discussed in a *Stormwater Runoff Water Quality Science/Engineering Newsletter Volume* 6-10 (Jones-Lee, 2003). This Newsletter is available from www.gfredlee.com.

The Central Valley Regional Water Quality Control Board (CVRWQCB, 2003) has established, as part of Order No. R5-2003-0826, the following table (Table 3) as the minimum requirements for the constituents to be monitored by the agricultural watershed Coalition Groups. Each monitoring group or individual is to develop a Monitoring Reporting Program (MRP):

> *"The MRP Plan must include a sufficient number of monitoring sites and surface water flow monitoring for each location to allow calculation of the load discharged for every parameter monitored. Method detection limits and practical quantitation limits shall be reported. All peaks detected on chromatograms shall be reported, including those which cannot be quantified and/or specifically identified. The Coalition Group shall use US EPA approved methods, provided the method can achieve method detection limits equal to or lower than analytical method quantitation limits specified in this Order. At a minimum, the MRP Plan must clearly demonstrate (1) compliance with requirement of all phases of monitoring as described in this MRP; (2) sufficient number of monitoring sites based on acreages and watershed characteristics, flow monitoring, and frequency of sample collection to allow for the calculation of load discharged for every waste parameter monitored; and (3) the use of proper sampling techniques and laboratory procedures to ensure a sample is representative of the site and is performed in the laboratory using approved methodologies."*
>
> * * *
>
> *"Bioassessment monitoring protocols are at the developing phase, and there are no Basin Plan requirements or standards addressing the results of bioassessment monitoring. Coalition Groups are encouraged to conduct Bioassessments to collect data*

Table 3 Constituents to be Monitored[2]

Constituents	Quantitation Limit	Reporting Unit	Monitoring Phase
General Parameters			
Flow	N/A	cfs (ft^3/sec)	1, 2 & 3
pH	N/A	pH units	1, 2 & 3
Electrical Conductivity	N/A	µmhos/cm	1, 2 & 3
Dissolved Oxygen	N/A	mg O_2/L	1, 2 & 3
Temperature	N/A	Degrees Celsius	1, 2 & 3
Color	N/A	ADMI	1, 2 & 3
Turbidity	N/A	NTUs	1, 2 & 3
Total Dissolved Solids	N/A	mg/L	1, 2 & 3
Total Organic Carbon	N/A	mg/L	1, 2 & 3
Drinking Water			
E. coli	(b)	MPN	1
Total Organic Carbon	(b)	mg/L	1
Chloroform*	(b)	µg/L	1
Bromoform*	(b)	µg/L	1
Dibromochloromethane*	(b)	µg/L	1
Bromodichlormethane*	(b)	µg/L	1
Toxicity Tests			
Water Column Toxicity	-	-	1
Sediment Toxicity	-	-	1
Pesticides (a)			
Carbamates	(b)	µg/L	2
Organochlorines	(b)	µg/L	2
Organophosphorus	(b)	µg/L	2
Pyrethroids	(b)	µg/L	2
Herbicides	(b)	µg/L	2
Metals (a)			
Cadmium	(b)	µg/L	2
Copper	(b)	µg/L	2
Lead	(b)	µg/L	2
Nickel	(b)	µg/L	2
Zinc	(b)	µg/L	2
Selenium	(b)	µg/L	2
Arsenic	(b)	µg/L	2
Boron	(b)	µg/L	2
Nutrients (a)			
Total Kjeldahl Nitrogen	(b)	mg/L	2
Phosphorus	(b)	µg/L	2
Potassium	(b)	µg/L	2

a. In addition to Toxicity Investigation Evaluations (TIEs), sites identified as toxic in the initial screen shall be re-sampled to estimate the duration of the toxicant in the waterbody. Additional samples upstream of the original site should also be collected to determine the potential source(s) of the toxicant in the watershed.
b. Quantitation limits must be lower than LC50 or other applicable federal or state toxic or risk limits.
* Deleted from the required monitoring by the SWRCB, February 2004.

[2] Adapted from CVRWQCB (2003)

that may be used as reference sites and provide information for scientific and policy decision making in the future. Bioassessments may serve monitoring needs through three primary functions: (1) screening or initial assessment of conditions; (2) characterization of impairment and diagnosis; and (3) trend monitoring to evaluate improvements through the implementation of management practices. Bioassessment data from all wadeable impaired waterbodies may serve as an excellent benchmark for measuring both current biological conditions and success of management practices."

Lee and Jones-Lee (2003g) discussed that a number of the monitoring parameters and the then-proposed approaches listed in Table 3 will lead to inadequate, unreliable, and in some cases, uninterpretable data on the characteristics of stormwater runoff and tailwater/subsurface drain water discharges from irrigated agricultural areas in the Central Valley. In order to use the funds spent on agricultural waiver water quality monitoring in a technically valid, cost-effective manner, Lee and Jones-Lee concluded that it is essential that revisions be made in the monitoring program parameters to work toward achieving reliable, meaningful data. Under the current regulatory agricultural waiver monitoring requirements, agricultural interests discharging to Delta channels must have defined the monitoring programs that they propose to use, by April 1, 2004. Many of the agricultural interests in the Central Valley failed to meet this deadline.

According to the CVRWQCB (2003) Order,

"The MRP Plan shall describe a phased monitoring approach and provide documentation to support the proposed monitoring program. The program shall not consist of more than three phases. Phase 1 monitoring shall, at a minimum, include analyses of physical parameters [labeled "General Parameters" in the above adaptation of Table 1]*, drinking water constituents, pesticide use evaluation, and toxicity testing. Phase 2 monitoring includes chemical analyses of constituents that were identified in toxicity testing in phase one that may include pesticides, metals, inorganic constituents and nutrients and, additional monitoring site in the watershed. Phase 3 monitoring includes management practice effectiveness and implementation tracking and additional water quality monitoring sites in the upper portions of the watershed."*

It was anticipated that the Phase 1 monitoring would begin in the spring 2004. Phase 2 monitoring is to begin no later than two years after the initiation of Phase 1, and Phase 3 will commence no later than two years after the initiation of Phase 2. Therefore, if implemented as proposed by the CVRWQCB, it will likely be three to four years before comprehensive data on discharges to Delta channels from Delta island agricultural activities will be available for Phase 2 parameters, which are the parameters of greatest interest in defining water quality issues.

Lee (2004b), in his comments to the SWRCB on the deficiencies in the CVRWQCB Order and the State Board staff's recommendations with respect to supporting this Order, pointed out that the proposed minimum monitoring program set forth in the Order will not achieve the Order's objectives defined above. These issues are discussed in detail in Lee (2004b). The State Board staff and Board chose to ignore these deficiencies, with the result that, unless the situation is changed, significant amounts of data will be generated as part of the agricultural waiver monitoring program that will be of little value in evaluating the water quality impacts of agricultural runoff/discharges to the Delta channels on channel water quality-beneficial uses.

An example of the significant deficiencies in the CVRWQCB (2003) Order is the approach that is recommended for monitoring for excessive fertilization problems arising from nutrient discharges from irrigated agriculture in the Central Valley. The minimum recommended monitoring program does not include monitoring for nitrate. Nitrate is the most common form of nitrogen in irrigated agricultural discharges that can lead to excessive fertilization of the receiving waters. Without monitoring for nitrate, it is not possible to evaluate the potential for irrigated agriculture to discharge excessive amounts of nitrogen compounds in stormwater runoff, tailwater and subsurface drain water discharges.

Other significant deficiencies in providing key data to properly evaluate the impact of pesticides, metals, organics and nutrients in agricultural stormwater runoff and tailwater discharges will not begin to become available until Phase 2 is initiated more than two years after Phase 1 is initiated. Since in many areas of the Central Valley, Phase 1 will not be initiated this year because of the failure of agricultural interests to submit their monitoring plans by the April 1 deadline, it will be three or more years before key data will be available on the characteristics of agricultural runoff/discharges.

Another problem with the proposed agricultural waiver monitoring is that there is no requirement for bioassessment monitoring of the impacts of agricultural discharges/stormwater runoff on macroinvertebrates in the waterbodies receiving this runoff. Further, there is no requirement for monitoring the tributary headwaters for agricultural drains and other small waterbodies that directly receive agricultural runoff/discharges. In addition, there are inadequate requirements for monitoring flow at the locations where the discharges occur. Without adequate flow measurements it will not be possible to estimate the loads of agriculturally derived pollutants that are being carried by various waterbodies.

During the summer 2003, on behalf of the CVRWQCB, the University of California, Davis, Aquatic Toxicology Laboratory conducted a monitoring program of selected agricultural drains and other waterbodies in the Central Valley that are likely to be impacted by agricultural runoff/discharges. It was found that several of the monitoring locations showed aquatic life toxicity in the water column and/or sediments, and concentrations of TOC and some other pollutants that are adverse to the beneficial uses of waterbodies.

SWAMP. The State Water Resources Control Board, in cooperation with the Central Valley Regional Water Quality Control Board, is developing a Statewide Ambient Monitoring Program (SWAMP). At this time the details of this program for the Central Valley have not been finalized. From the information available, it appears that there will be limited monitoring conducted in the Delta and near-Delta tributaries that would help better define the current water quality conditions in these waterbodies. Additional information on the SWAMP is available at http://www.swrcb.ca.gov/swamp.

DFG. The California Department of Fish and Game (DFG) conducts a fish monitoring program in the Delta and its tributaries. Associated with this program are physical and chemical data on the characteristics of the waters. These data are available from the IEP database. According to Finlayson (pers. comm., 2004), DFG does not conduct any routine water quality monitoring in the Delta.

Corps of Engineers Dredging of the SJR DWSC. Associated with obtaining permits for maintenance of navigation depth of the Deep Water Ship Channel, the US Army Corps of Engineers and public and private entities, such as the Port of Stockton and marina owners, must obtain CVRWQCB permits to dredge. These permits contain requirements for monitoring of the dredging projects. The data generated in these projects are made available to the CVRWQCB as project reports.

Other CALFED/CBDA Projects. CALFED/CBDA supports a number of individual research projects, which include collection of data on water quality characteristics of the Delta. The various CALFED/CBDA projects and their reports are made available through the CBDA website (http://calwater.ca.gov). Also, summaries of many of these projects are provided in the CBDA nearly annual Science Program reviews, where abstracts of the projects are presented.

San Francisco Bay-Delta Estuary Project (SFEP). The US EPA and several state of California agencies are active in the San Francisco Bay-Delta Estuary Project. According to the project's website,

> *"The S.F. Estuary Project is one of over 20 Estuary Projects established by the National Estuary Program to protect and improve the water quality and natural resources of estuaries nationwide.*
>
> *We were formed in 1987 as a cooperative federal/state/local program to promote effective management of the San Francisco Bay-Delta Estuary. In addition to spearheading and participating in a wide variety of projects, the Estuary Project also serves as a clearinghouse for information on the Bay-Delta ecosystem, including such topics as wetlands, wildlife, aquatic resources and land use."*

The SFEP holds biennial State of the Estuary conferences, in which the various investigators conducting studies on the estuary present summaries of their work. Abstracts of these projects are available in the books of abstracts for the State of the Estuary Conferences; the most recent report available is from October 2003. A description of the overall characteristics of this project is available from the SFEP website (http://www.abag.ca.gov/bayarea/sfep/).

Expanded CALFED/CBDA Science Program Delta Water Quality Activities. The CALFED/CBDA Science Program held a workshop on February 4-5, 2004, devoted to Contaminant Stressors in the Bay-Delta Watershed. Information on this workshop includes the following:

> *"**Contaminant Stressors in the Bay-Delta Watershed***
> *Populations of fish and other critical species in the Bay-Delta are in decline. Chemical contaminants are one of several key stressors on ecosystem health outlined by the CALFED Ecosystem Restoration Program Plan (ERPP, July 2000). Most metrics and*

indicators of xenobiotic effects focus on the level of the individual, however, cause-effect links to higher trophic orders (population, community, ecosystem) are poorly understood. How anthropogenic contaminants affect the recovery of populations is a critical unknown for ecosystem restoration. A major goal of the CBDA Science Program is to use the best available science to fill the gaps that critical unknowns leave in our understanding of ecosystem processes in the Bay-Delta."

(http://calwater.ca.gov/Programs/Science/adobe_pdf/Contaminant_Stressors_Public_Notice_2-4-5-03.pdf)

CBDA has posted a link to presenters and supplemental materials from this workshop at http://198.31.87.66/pdf/ContaminantStressorsSuppMat.pdf.

CMARP. The CALFED (2000) Bay-Delta Program August 28, 2000, Record of Decision, on page 75 states,

"The Science Program will be developed and directed by an interim lead scientist, who will also serve in the role of lead scientist during the initial years of program implementation. Implementation of the CALFED Science Program includes implementation of the Comprehensive Monitoring, Assessment and Research Program (CMARP), now under the direction of the interim lead scientist. The Science Program also has primary responsibility to establish the role of adaptive management in program implementation, implement strategies to reduce uncertainties that impede successful accomplishment of CALFED goals, provide programmatic review of overall implementation of mitigation measures and integrate the CALFED Science Program with existing/related agency science programs."

The CALFED/CBDA website contains the Comprehensive Monitoring, Assessment and Research Program (CMARP, 1999) report at http://calwater.ca.gov/programs/science/cmarp/contents.html. This report introduction states as "CALFED mission and principles,"

*"The mission of the CALFED Bay-Delta Program is to develop a long-term comprehensive plan that will restore ecological health and improve water management for beneficial uses of the Bay-Delta system. The CALFED Mission Statement is supported by a set of **Primary Objectives** and **Solution Principles**, as cited in the Executive Summary of the CALFED Bay-Delta Program Programmatic EIS/EIR, March 1998.*

*The **Primary Objectives** are:*

- *Water Quality – Provide good water quality for all beneficial uses.*
- *…"*

The CMARP report represents the collective efforts of a number of Delta experts. The report includes Chapter 4- Part C. Water Quality. This Chapter states, *"The CALFED Bay-Delta Program's goal for water quality is to improve the quality of water of the Sacramento-San Joaquin Delta Estuary for all beneficial uses; including domestic, industrial, agricultural, recreation, and aquatic habitat. Providing good water quality for agricultural and industrial uses includes lowering mineral, nutrient, and metal concentrations in water such that the water is nontoxic and can be reused. The goal for drinking water quality is to reduce pathogens, nutrients, turbidity, and toxic substances in source waters to the Delta through watershed protection measures. In addition, bromide and organic carbon levels would be low enough to meet drinking water regulations. Good water quality for recreational use involves reduction of disease-causing organisms in the water and reduction in nuisance algal blooms."*

* * *

"The water-quality-monitoring program scope includes baseline, trend, effectiveness, compliance/mitigation and operations monitoring. The program addresses the programmatic water-quality actions outlined in the CALFED Phase II Report (11/98) (Table 4-2)."

"The goal of the water-quality-monitoring plan is to monitor water quality and associated physical and environmental variables to document the effects of CALFED Stage 1 actions on water quality and on the ecosystem (Table 4-3). A monitoring network will be established to evaluate the success of proposed CALFED Water-Quality Program Plan actions, to address or verify identified water-quality problems, and to assess trends, loads, and sources of important water-quality constituents. The major question, 'Is Delta water quality improving?', will be addressed through this monitoring program."

CMARP Chapter 4 Part C Water Quality lists in Table 4-2, **Water Quality Program Actions**,

Drinking Water,
Pesticides,
Organochlorine Pesticides,
Trace Metals,
Mercury,
Salinity,
Selenium,
Turbidity and Sedimentation,
Low Dissolved Oxygen and
Toxicity of Unknown Origin.

Table 4-3 lists as the **Water-Quality Monitoring Objectives**,

"1. Assess effects of CALFED activities (including Ecosystem Restoration, Storage and Conveyance, Water Transfers, Water Use Efficiency, Watershed Management Coordination, and Levee System Integrity Programs) on water quality
2. Determine sources, loads, and trends of water-quality constituents of concern
3. Assess system productivity of Bay/Delta waters
4. Monitor water and sediment quality as necessary to comply with CALFED actions

5. *Provide continuing data on water-quality constituents of concern, such as bromide, that may indicate the need for further CALFED actions to improve water quality.*
6. *Assess ecological and human-health related to water and sediment quality, including monitoring contaminant concentrations in biota."*

The CMARP report contains, as an appendix, the November 2, 1998, "Contaminants Monitoring in the Bay-Delta" report. This 23-page report was prepared by a workgroup consisting of experts from the San Francisco Estuary Institute, private aquatic life toxicity testing laboratories, representatives of the Central Valley and San Francisco Regional Water Quality Control Boards, the Department of Pesticide Regulation and the USGS. This appendix includes the following statements:

> ***"Goals and Objectives***
> *Water Quality is one of CALFED's Common Programs. The goal of the Water Quality Program is to improve the quality of the waters of the Sacramento-San Joaquin Delta Estuary for all beneficial uses. Because species dependent on the Bay and Delta are affected by upstream water quality conditions in some areas, the scope of the Water Quality Program also includes watershed actions to reduce water quality impacts on species dependent on the Delta (CALFED 1998a).*
>
> *The specific CALFED goals and objectives addressed in this section are (CALFED 1998b):*
>
> - *Provide good Delta water quality for recreational use; Reduce health risks associated with consuming fish.*
> - *Provide improved Delta water quality for environmental needs; Reduce concentrations of pesticide residues, hydrocarbons, heavy metals, and other pollutants in water and sediments.*
>
> *The CALFED Water Quality Technical Team (WQTT) has produced a Water Quality Program Plan that lists actions to improve water quality (CALFED 1998a). Monitoring will be needed to evaluate whether those actions are successful. Since many of the actions have not begun, monitoring cannot yet be designed. However, the monitoring recommendations included in this section provide for the determination of baseline conditions, and can be expanded in space or time to be used when needed."*

This appendix includes discussion of the need for monitoring and research for a variety of known and potential pollutants in Delta waters, including trace elements (primarily metals), organochlorines (PCBs, dioxins and hexachlorocyclohexanes), polycyclic aromatic hydrocarbons (PAHs), pesticides and synthetic biocides, bivalve and fish tissue parameters, aquatic toxicity tests, sediment toxicity tests, exposure indicators (biomarkers, histopathology and physiology), as well as monitoring for system productivity for fish, phytoplankton, zooplankton and benthos.

The current CALFED's (now CBDA's) program for water quality monitoring, evaluation and management is falling far short of achieving the ROD commitment, since little of the

CMARP water quality monitoring program has been initiated since it was first formulated in 1998. This is a significant deficiency in CBDA's current water quality management program.

Recently, Patrick Wright, Director of the CBDA program, indicated that the CBDA agencies are conducting a review of the potential for an expanded water quality program in the Delta. The details of this proposed expanded program are not yet available. They could include substantial additional water quality monitoring in the Delta. In order for this program to be effective and produce needed and reliable results, it will be extremely important that a key component of the program include detailed review of past and current water quality data that exist on the Delta and near-Delta tributaries.

Overall. Even though there has been and continues to be considerable water quality monitoring in the Delta and its tributaries, there is still inadequate monitoring to provide the information needed to develop management programs for many of the constituents which cause the 303(d) listing of Delta channels as impaired. Further, the current 303(d) listing is likely limited compared to what would be needed based on a comprehensive, in-depth monitoring of the Delta channels.

Need for Expansion of the Delta Water Quality Monitoring/Evaluation Program

There is need to significantly expand the water quality monitoring/evaluation program for the Delta. This is a significantly neglected area. While there is an Interagency Ecological Program (IEP) monitoring program, it is not focused on water quality and is largely conducted with limited regard to providing information pertinent to water quality assessment. The current Delta water quality monitoring program needs to be expanded so that the focus is on an assessment of beneficial use impairment, rather than the current approach of monitoring algae, zooplankton, fish and sediment organisms. There is a variety of factors, such as invasive species, that can influence phytoplankton, zooplankton and benthic organism populations, which cause the IEP EMP to fail to provide the information needed on the impacts of chemical stressors on Delta aquatic-life-related beneficial uses.

As discussed above, the Delta and tributaries near the Delta have been found to be impaired under the Clean Water Act section 303(d). The monitoring program that is needed should specifically focus on assessing the current status of the impairment for each of the 303(d) listings. Particular reference should be given to whether the impairment, which is generally based on excessive concentrations of a chemical constituent, is a "real" impairment, or represents the application of worst-case-based water quality criteria/standards to Delta waters. Further, the monitoring program should specifically address the magnitude, area and duration of the impairment. With respect to duration, is it a pulse-type duration associated with and following pesticide application, or is the impairment year-round? This information can then be used to prioritize the second phase of the monitoring.

The second phase should be devoted to defining the constituents responsible, if not already defined (such as for toxicity), and the sources of these pollutants. The monitoring results can lead to the information base needed to begin to implement the TMDL that is needed to control the exceedance of an appropriately developed water quality standard/objective.

If it is found that the impairment represents an "administrative" impairment related to using worst-case generic water quality objectives rather than site-specific objectives that are appropriate for the Delta waters of concern, then work with the CVRWQCB should be initiated to develop the site-specific objectives that will be protective without spending large amounts of funds for constituent control that will have little or no impact on the beneficial uses of the waterbody in question.

The monitoring program should include both the water column and sediments. It should be integrated with the agricultural waiver monitoring program that is being developed. The application of that program to the Delta still must be defined. Once that is done, the deficiencies in that monitoring program in defining the amounts of potential pollutants in runoff/discharges from agricultural lands, as well as the amounts of pollutants entering the Delta from tributary sources, need to be investigated. Ultimately, the agricultural waiver program should include developing an understanding of the how the pesticides, fertilizers and other constituents added to agricultural lands and those that are discharged from agricultural lands in the form of tailwater or subsurface drain water impact water quality. Lee (2003j, 2004b) discussed the deficiencies in the current agricultural waiver monitoring program that was adopted by the CVRWQCB in July 2003. His recommendations should be incorporated into the agricultural waiver monitoring program that is being developed by Delta agriculture, in order to improve the utility of the data that are to be generated.

The monitoring should focus on measuring not only chemical constituents that are, at some times and locations, pollutants (i.e., impair beneficial uses of the waterbody), but also aquatic life toxicity in the water column and/or sediments. Further, the bioaccumulation of known hazardous chemicals, such as the organochlorine "legacy" pesticides (DDT, chlordane, dieldrin, toxaphene, etc.), PCBs, dioxins and furans, should be measured. Substantial monitoring funds should be available for toxicity identification evaluations (TIEs) to identify the cause of toxicity in the water column or sediment, wherever it is found. Lee and Jones-Lee (2002f) have developed a comprehensive discussion of the approach that should be used to conduct water quality monitoring programs in the Central Valley for nonpoint source discharges/runoff.

Unfortunately, there is no monitoring of the amount of water hyacinth and *Egeria densa* that develops in the Delta. This is a significant deficiency in the current Delta water quality monitoring program that should be immediately corrected, since this is one of the most significant water quality problems in the Delta. The magnitude of this problem can be judged by the fact that the California Boating and Waterways conducts extensive water hyacinth control through herbicide addition.

Over the past 10 years there has been comprehensive water quality monitoring of San Francisco Bay and its associated estuary. This effort was conducted under what is known as the Regional Monitoring Program (RMP). The San Francisco Estuary Institute held its annual conference on May 4, 2004, at which the results of the past year's RMP, as well as an overview review of the past five years' RMP were presented and discussed. This review and other information on this program is (or will shortly be) available from the SFEI website, www.sfei.org.

The focus of the RMP has been on those constituents that are causing the Bay to be on the 303(d) list, with emphasis on those constituents which are bioaccumulating to excessive levels in edible organisms, such as mercury, organochlorine legacy pesticides, PCBs and dioxins. Taberski (2004) has presented a review of the value of the RMP in helping the San Francisco Bay Regional Water Quality Control Board develop the kinds of information needed to begin to manage the water quality impacts of the constituents that cause the Bay to be on the 303(d) list. While aggressive monitoring/evaluation programs are being conducted in the San Francisco Bay area for mercury, PCBs, dioxins, PAHs, organochlorine legacy pesticides, aquatic life toxicity, etc., except for mercury, essentially no work is being done in the Delta to address these constituents which are a cause of Delta waters to be listed as 303(d) impaired. A similar kind of program to the San Francisco Bay RMP needs to be developed for the Delta to address the known water quality impairments that are occurring in Delta channels. Davis (pers. comm., 2004) has indicated that SFEI (2004) is developing a report that discusses the development and organization of the RMP. Davis indicated that he may be contacted for information on the availability of this report (jay@sfei.org).

Availability of Funding for Monitoring. In addition to the water quality monitoring programs' in the Delta having been deficient for many years, the current and especially the future situation is likely to be even bleaker because funding decreases are occurring associated with the current state of California budget shortfall. There is need to restore and greatly expand the funding available for Delta water quality monitoring.

While some take the position that it is the responsibility of the Central Valley Regional Water Quality Control Board to conduct monitoring of Delta water quality, this approach is not viable, since the Regional Board does not and will not likely have the funds to undertake this effort. As a result, it will be necessary for CBDA and those responsible for discharges/runoff to acquire the funds to fund this monitoring.

CALFED/CBDA's Activities in Addressing Water Quality Problems in the Delta

When CALFED first became active, there was a major effort to develop a water quality management program in the Delta and its tributaries. The consulting firm that had the initial contract to support CALFED activities assigned the responsibility for developing these programs to an individual(s) with limited understanding and experience in water quality issues. This person(s) made significant errors in evaluating water quality in the Delta, such as claiming that there were major heavy metal problems in the Delta due to stormwater runoff from urban areas that necessitated the collection and treatment of all urban stormwater runoff to remove heavy metals. Eventually, as a result of comments made by various individuals, including the senior author, on the unreliability of the proposed water quality management program, that effort was terminated and replaced by a new effort involving committees of interested experts advising CALFED on the water quality problems that exist in the Delta and its tributaries. This led to the development of a Water Quality Program Plan (CALFED, 1998). While this approach had considerable technical merit, CALFED management did not follow through, and all of the effort made by many individuals was lost several years ago. Since then, CALFED/CBDA's water quality management program has been essentially restricted to a major effort devoted to mercury and the low-DO problem in the first seven miles of the Deep Water Ship Channel below the Port of Stockton. There has been no effort devoted to many of the other well-documented water quality problems that exist in the Delta, such as those associated with the previous 303(d) list and the 2002 303(d) list of impaired Delta channels. CBDA needs to significantly expand its water quality investigation and management program to address the known water quality problems and to conduct studies to determine if there are other as yet undefined problems that are impairing the beneficial uses of Delta waters.

Delta Water Quality Research Needs

Presented in this report and for some issues discussed below is a summary of the areas of Delta water quality-related research needed to better define the known and potential water quality problems that are impacting the beneficial uses of Delta waters. The information gained from such research would be an important step in developing a technically valid, cost-effective program to manage Delta water quality. Additional information on each of the areas summarized below is provided in the above discussion.

Organochlorine Pesticides, PCBs and Dioxins. The finding of excessive bioaccumulation of the organochlorine legacy pesticides (such as DDT, chlordane, dieldrin, toxaphene, etc.), PCBs and dioxins in Delta and near-Delta tributary fish mandates that a substantial research effort be initiated on the current degree and extent of excessive bioaccumulation of OCls in edible Delta fish. Also the amount of these chemicals entering the Delta from tributary, agricultural, urban and wastewater sources needs to be defined. Studies need to be conducted on the role of Delta sediments as a source of OCls that are bioaccumulating to excessive levels in Delta channel fish. US EPA aquatic organism bioaccumulation testing should be conducted to determine whether the organochlorines are present in sediments at sufficient concentrations of bioavailable forms to bioaccumulate to excessive levels in Delta fish. Where this occurs studies need to be conducted to develop biota sediment accumulation factors which can be used to relate sediment concentrations to edible and other organism tissue residues. This approach is discussed in Lee and Jones-Lee (2002a).

It will also be important to determine whether the organochlorines are adverse to aquatic life. Particular attention should be given to dioxins in the vicinity of the Port of Stockton. It is now well-established that very low levels of dioxins can be adverse to fish and other aquatic life, below those concentrations that are known to cause cancer in people. The research on the organochlorines should include not only water column effects, but also benthic organism effects.

Where toxic hot spots are found in Delta and near-Delta tributary sediments of the OCls that are significant sources for excessive bioaccumulation in edible organisms, studies need to be done to determine if the addition of activated carbon is a potential remediation approach for controlling the bioavailability of sediment-associated OCls.

Currently Used Pesticides/Herbicides. Work needs to be done on the occurrence and water quality significance of the various pesticides/herbicides used in the Delta and in Delta tributaries, with respect to their potential to be adverse to aquatic life and other beneficial uses of Delta waters. Through DPR reporting, each of the pesticides/herbicides used in the Delta should be investigated to determine whether it is present in runoff/discharges from the areas of use in agricultural and urban areas at sufficient concentrations to be toxic or otherwise deleterious to various forms of aquatic life. Consideration should be given not only to toxicity in the water column but also to sediment toxicity and other adverse impacts cause by the currently used pesticides. Further, this should be an ongoing program, where if a new pesticide/herbicide is used in the Delta or near-Delta tributaries, studies would be conducted to determine whether its initial use is adverse to aquatic life and other beneficial uses of Delta waters. This effort should include the herbicides used for aquatic weed control, where studies independent of those conducted by those applying the herbicides are conducted to determine whether there are adverse water quality impacts caused by the use of the herbicides for aquatic weed control within the Delta and near-Delta waters.

Heavy Metals. Work needs to be done to define whether heavy metals are causing water quality problems-impairment of the beneficial uses for aquatic life, etc., in the Delta or near-Delta tributaries. Of particular concern is the potential for food web accumulation of cadmium or nickel, where concentrations of metals below the water quality objective can result in adverse effects to host organisms and higher trophic level organisms through accumulation of tissue residues of the metal. Further work needs to be done on whether selenium additions to the Delta are adverse to Delta aquatic life.

Impacts of the State and Federal Export Projects on Delta Water Quality. The state and federal export projects have the potential to cause significant adverse impacts on the water quality beneficial uses of the Delta. As discussed herein, the work that has been done under D-1641 to evaluate these impacts is deficient compared to that which is needed to define the impacts of Delta export projects on Delta water quality. A team of independent experts should work together to properly evaluate the potential adverse impacts of Delta water exports. Where this team finds potential problems with a particular type of pollutant, such as an organochlorine pesticide, mercury, currently used pesticides, heavy metal inputs from tributaries, etc., studies should be conducted to evaluate how the movement of water in the Delta caused by the export projects impacts the effects of these constituents on Delta water quality.

Phytoplankton Primary Production within the Delta. An assessment should be made of the factors controlling phytoplankton primary production within the Delta. Particular emphasis should be given to why, based on the nutrient content of Delta waters, there is not more primary production. It has been found that Delta waters, when allowed to stand, such as in a water supply reservoir, will produce substantial crops of phytoplankton. What is the role of light limitation due to inorganic turbidity and color on primary production? Is the export of water from the Delta creating insufficient time in Delta waters during the summer and fall months for the phytoplankton to develop before the water is exported from the Delta via the export pumps? What is the role of the export projects' drawing large amounts of low-nutrient Sacramento River water through the Delta in the limitation of algal production? Another area of concern is whether invasive species are significantly controlling phytoplankton biomass through harvesting of phytoplankton.

Another research area is an evaluation of the importance of phytoplankton derived from the San Joaquin River watershed as a source of assimilable organic carbon for the Delta food web. There is need to better understand the food web in the Delta and especially what controls the lowest trophic level biomass. Of concern is whether reducing the algal loads to the Central Delta would be detrimental to the food web.

Biomarkers, PPCPs, Endocrine Disrupters, Etc. A substantial research effort should be initiated on the occurrence of sublethal effects of various types of chemicals, such as PPCPs, endocrine disrupters and low levels of pesticides (at concentrations below those that are acutely toxic to aquatic life) on Delta water quality. Particular attention should be given to waters near the cities of Stockton and Tracy and downstream of the Sacramento Regional County Sanitation District discharges to the Delta, as well as other upstream communities that discharge wastewaters to Delta tributaries. Consideration should also be given to any discharges/runoff from dairies and other animal husbandry facilities as a source of PPCPs.

Delta Sediments. A comprehensive program of investigating the toxicity of Delta sediments should be initiated, using a variety of sensitive test organisms. Where toxicity is found, sediment-based toxicity investigation evaluations should be conducted to determine the cause of the toxicity and the sources of the constituents responsible for the toxicity. This work should include the development of biological effects-based sediment quality objectives for Delta sediments. Total chemical concentrations or co-occurrence-based sediment quality objectives should not be used in the Delta or other waterbodies that are tributary to the Delta (or, for that matter, elsewhere) as a basis for evaluating sediment quality, because of the unreliability of total concentrations in predicting bioavailable/toxic forms of potential pollutants.

Organism Assemblages. Surveys of Delta sediment benthic and epibenthic organisms should be conducted to determine where altered organism assemblages are occurring, compared to what would be expected based on an unimpacted sediment population.

Total and Dissolved Organic Carbon. Studies need to be conducted on the sources of total and dissolved organic carbon for the Delta from tributaries and within the Delta from aquatic vegetation. The organic carbon should be investigated in terms of the total labile and refractory carbon that can adversely impact domestic water supply water quality. Particular attention needs to be given to urban wastewater and stormwater runoff as a source of refractory TOC that can impact domestic water supply water quality. Studies need to be conducted on the potential for controlling refractory TOC from the various sources, including agricultural runoff, urban and industrial land runoff, wastewaters, etc. An evaluation needs to be made of the cost of controlling excess TOC in water utilities' raw water at the source, compared to the cost of controlling it at the water treatment works.

Pathogens. The monitoring that the DeltaKeeper has been doing in the eastern and Central Delta needs to be expanded to all parts of the Delta, to determine where pathogen indicator organisms, such as *E. coli*, are present at concentrations which are indicative of a public health threat for contact recreation in the waters of that area. In those areas where there are consistent violations of the *E. coli* water quality standard, there is need to conduct further studies to determine the specific sources of *E. coli* that are responsible for the violations.

Nutrients. Investigations need to be conducted to determine the degree of nutrient control needed from the Delta watershed and within the Delta to achieve desired water quality from the perspective of domestic water supply and aquatic weed growth, especially hyacinth and *Egeria densa* within the Delta.

Salts. There is need to determine the appropriate salt loads to the Delta from the San Joaquin River watershed, to protect the use of Delta waters for domestic water supply and the associated recharge of groundwaters from the wastewaters based on a Delta water supply, as well as to protect irrigated agriculture in the Delta.

Dissolved Oxygen. There is need to do further work on the relationship between various oxygen demand sources for the Deep Water Ship Channel, with particular reference to the interrelationship between the oxygen demand loads from the city of Stockton's domestic wastewaters, the city of Stockton's stormwater runoff, and the planktonic algae from the San Joaquin River watershed, to the DO depletion associated with the flow of the SJR through the DWSC. There is need to understand the impact of significantly reducing the flow of the SJR into the South Delta via Old River on water quality in the South Delta.

There is also need to understand the origin of the low DO that occurs in Old River near the Tracy Boulevard bridge, and what can be done to control it, as well as the low DO that occurs in Middle River within the South Delta.

There is need to investigate the potential occurrence of low DO in the Central Delta, especially Turner Cut and Whiskey Slough, under worst-case conditions of oxygen demand loads from the DWSC.

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Appendix A
Review of Excessive Bioaccumulation of
Organochlorine Pesticides and PCBs in Delta and Delta Tributary Fish

The following section is from the Lee and Jones-Lee (2002) report of excessive bioaccumulation of OCls in edible fish taken from the Delta and near-Delta tributaries. As discussed in this report, the data on the concentrations of legacy pesticides and PCBs in fish taken from some of the tributaries to the Delta indicate the current areas where excessive bioaccumulation of OCls has occurred and are useful in indicating the potential sources of these chemicals for the Delta, as well as for fish that may migrate into the Delta. The data presented in the following section uses the Office of Environmental Health Hazard Assessment (OEHHA) screening values to judge excessive concentrations of the legacy pesticides and PCBs in Delta and near-Delta tributary fish. The references for the following section are listed in the references for the main body of the report.

OEHHA Fish Tissue Criteria. Table 1 presents the US EPA and OEHHA fish tissue screening values for evaluation of excessive bioaccumulation of selected chemicals.

Table 1
US EPA and OEHHA Fish Tissue Screening Values

CHEMICAL	US EPA Value[1] (µg/kg wet weight)	OEHHA Value[2] (µg/kg wet weight)
Chlordane[3]	80	30
Total DDT[4]	300	100
Dieldrin	7	2
Total endosulfan[5]	60,000	20,000
Endrin	3000	1000
Heptachlor epoxide	10	4
γ-hexachlorocyclohexane (lindane)	80	30
Toxaphene	100	30
PCBs[6]	10	20
Dioxin TEQ[7]	0.7 ppt	0.3 ppt

Source: SARWQCB (2000)

1: USEPA SVs (US EPA, 1995) for carcinogens were calculated for a 70 kg adult using a cancer risk of 1x10-5. SVs for non-cancer effects were calculated for a 70 kg adult and exposure at the RfD (hazard quotient of 1). A fish consumption value of 6.5 g/day was used in both cases.

2: California OEHHA (1999) SVs (CLS-SVs) specifically for this study were calculated according to US EPA guidance (US EPA, 1995). CLS-SVs for carcinogens were calculated for a 70 kg adult using a cancer risk of 1x10-5. CLS-SVs for non-cancer effects were calculated for a 70 kg adult and exposure at the RfD (hazard quotient of 1). A fish consumption value of 21 g/day was used in both cases

3: Sum of alpha and gamma chlordane, cis- and trans-nonachlor and oxychlordane.

4: Sum of othro and para DDTs, DDDs and DDEs.

5: Sum of endosulfan I and II.

6: Expressed as the sum of Aroclor 1248, 1254 and 1260.

7: Expressed as the sum of TEQs for dibenzodioxin and dibenzofuran compounds which have an adopted TEF.

The values listed in Table 1 are based on an upper-bound estimated cancer risk of one additional cancer in a population of 100,000 people who consume, on the average, 6.5 g/day (about 1 meal/month) of the fish containing the screening value concentration over their lifetime. Additional information on critical concentrations of OCls in fish tissue is provided by Brodberg and Pollock (1999) and US EPA (1997).

The screening values listed in Table 1, when adjusted for appropriate consumption rates for people who use fish from the listed waterbodies as a regular part of their diet, are the recommended screening values that should be used as management goals in an OCl bioaccumulation management plan for a cancer risk of 10^{-5}.

Lee and Jones-Lee (2002) have discussed a significant problem with past excessive bioaccumulation studies associated with the detection limits used to measure the concentrations of the OCls in fish and other organism tissue. As they discuss, many of the previous studies have used analytical methods that did not have adequate sensitivity to measure the OCls at concentrations that are recognized as a potential threat to human health. This has resulted in substantial parts of the existing fish tissue OCl database not being adequate to determine whether there were excessive OCl concentrations in edible fish tissue, compared to the OEHHA screening values.

Excessive OCl Bioaccumulation in Delta Fish/Clams. There are two major sources of data on OCl bioaccumulation in the Delta and near-Delta tributaries. One of these is the study conducted by the San Francisco Estuary Institute (SFEI), with Jay Davis as the lead scientist (Davis et al., 2000). The planning and reporting of the data collected in this 1998 study was a joint effort between Dr. Chris Foe of the CVRWQCB, William Jennings (the DeltaKeeper) and Jay Davis of SFEI. The funding for this study was provided by the DeltaKeeper. The other major source of OCl excessive bioaccumulation data is the SWRCB's Toxic Substances Monitoring Program (TSMP) (SWRCB/TSMP, 2002). While that program provided substantial historical data, little recent OCl data have been gathered by the TSMP on the Delta since the funds available to the CVRWQCB have been devoted primarily to measuring mercury bioaccumulation in Central Valley fish. A summary of the data obtained on the OCl concentrations in fish taken from the Delta and near-Delta tributaries is presented below.

<u>Port of Stockton Turning Basin.</u> In 1998, largemouth bass and white catfish were collected by DeltaKeeper/SFEI from the Port of Stockton Turning Basin. Total DDT and total chlordane were present at concentrations below the OEHHA screening values in the largemouth bass sample. The white catfish sample contained total DDT above the OEHHA screening value. Total chlordane was not present in the white catfish at an excessive level. Dieldrin and toxaphene analyses were conducted with methods that did not have an adequate detection limit to determine if there were exceedances of the OEHHA screening value. However, total PCBs were present above the OEHHA screening value in several of the largemouth bass taken from the Port of Stockton Turning Basin.

White catfish and largemouth bass were collected from "Stockton Deep Water Channel" in 1986 and 1990. The only OCl measured with adequate detection limits was total DDT. It was found that total DDT was less than the OEHHA screening value in these fish.

Port of Stockton near Mormon Slough. DeltaKeeper/SFEI sampled *Corbicula fluminea* (freshwater clam) from the Port of Stockton near Mormon Slough in 1998. Mormon Slough enters the canal that connects McLeod Lake with the Turning Basin. Mormon Slough is of interest, since this is the area of the McCormick & Baxter Superfund site (US EPA, 2002), which has discharged sufficient PCBs and dioxins to cause the San Joaquin County Department of Health to post this area for excessive PCBs and dioxins in fish. Total DDT was less than the OEHHA screening value in fish taken from this area. Dieldrin and total PCBs were above the OEHHA screening values. The other OCls were not measured with adequate detection limits.

Smith Canal. Smith Canal is a freshwater tidal slough, located within the city of Stockton. It is one of the primary waterway conveyance systems of city of Stockton stormwater runoff. DeltaKeeper/SFEI sampled Smith Canal white catfish and largemouth bass at Yosemite Lake in 1998. Yosemite Lake is at the head of Smith Canal. It receives City storm sewer discharges. Total DDT and total chlordane were less than the OEHHA screening value in both kinds of fish. However, total PCBs were above the OEHHA screening value in both white catfish and largemouth bass taken from Smith Canal at Yosemite Lake. Dieldrin and toxaphene analyses were conducted with methods that did not have an adequate detection limit to determine if there were exceedances of the OEHHA screening value. As a followup to the finding of excessive PCBs in some Smith Canal fish, Lee et al. (2002), with DeltaKeeper and CVRWQCB support, conducted studies on Smith Canal sediments and found that the sediments in the Yosemite Lake area of Smith Canal contained elevated PCBs that were available for biouptake.

San Joaquin River near Turner Cut. In 1998, DeltaKeeper/SFEI sampled largemouth bass and white catfish from the San Joaquin River "around Turner Cut." This location is about seven miles downstream of the Port of Stockton Turning Basin within the Deep Water Ship Channel. Total DDT, total chlordane and total PCBs were all below OEHHA screening values in both types of fish analyzed. Again, inadequate detection limits were used for dieldrin and toxaphene.

White Slough downstream from Disappointment Slough. White Slough is on the eastern part of the mid-Delta. In 1998, DeltaKeeper/SFEI sampled largemouth bass and black bullhead at White Slough downstream from Disappointment Slough. Total DDT and total PCBs were less than the OEHHA screening values. Dieldrin, chlordane, and toxaphene were not measured with sufficiently sensitive analytical methods to determine if there were exceedances of the OEHHA screening values.

San Joaquin River at Potato Slough. In 1998, DeltaKeeper/SFEI sampled largemouth bass and white catfish from San Joaquin River at Potato Slough, which is between Disappointment Slough and Point Antioch. Total DDT and total chlordane were below OEHHA screening values for both types of fish. Total PCBs were found above the OEHHA screening value in the white catfish sample. Inadequate sensitivity was used in the PCB analysis of the largemouth bass sample. Dieldrin and toxaphene analyses were conducted with methods that did not have an adequate detection limit to determine if there were exceedances of the OEHHA screening value.

Lee (2003a) had reported that, except during high flood-flow conditions that occur in the spring, the water in the San Joaquin River Deep Water Ship Channel and its associated tributaries downstream of Disappointment Slough/Columbia Cut is predominantly Sacramento River water.

The state and federal export project pumps at Tracy and Banks cause all San Joaquin River water present in the Deep Water Ship Channel at Turner Cut to be drawn down to the South Delta via Turner Cut and Columbia Cut and Middle River. Therefore, the legacy pesticide/PCB content of the San Joaquin River Deep Water Ship Channel beginning at Turner Cut and downstream is influenced to a considerable extent by Sacramento River water and local sources.

San Joaquin River off Point Antioch. DeltaKeeper/SFEI collected largemouth bass in 1998 from the San Joaquin River off Point Antioch near the fishing pier. There were no exceedances of any of the OCls measured. The same problems occurred with this DeltaKeeper/SFEI study for detection limits for dieldrin, chlordane, and toxaphene. As discussed above, the San Joaquin River channel below Disappointment Slough is, during the summer, fall and early winter, primarily a mixture of Sacramento River water and releases from Delta islands. It would only be under high San Joaquin River flows, such as during the late winter/spring, that any significant amount of San Joaquin River water would reach Point Antioch.

Sycamore Slough near Mokelumne River. In 1998, DeltaKeeper/SFEI sampled largemouth bass and black bullhead from Sycamore Slough at Mokelumne River. One largemouth bass taken from this location had dieldrin above the OEHHA screening value. Total DDT was below the OEHHA screening value, while the analyses for the rest of the OCls were conducted with insufficiently sensitive analytical methods.

Mokelumne River between Beaver and Hog Sloughs. In 1998, DeltaKeeper/SFEI sampled largemouth bass and black bullhead from the Mokelumne River between Beaver and Hog Sloughs. Total DDT and total PCBs were less than the OEHHA screening values. Dieldrin, chlordane, and toxaphene were analyzed with insufficiently sensitive analytical methods to determine if there were exceedances of the OEHHA screening values.

Mokelumne River near Woodbridge. Various organisms were sampled from the Mokelumne River at Woodbridge in 1978-1981. Asiatic clam was the only organism that contained DDT above the OEHHA screening value in 1978. Total DDT was not above the OEHHA screening value in the 1979-1980 sampling for Asiatic clam and largemouth bass. Almost all other OCls at that sampling time and location were analyzed with insufficiently sensitive analytical methods.

In 1992, the USGS sampled Asiatic clam taken from the Mokelumne River near Woodbridge. The concentrations of total DDT were below the OEHHA screening value. The detection limits used for dieldrin, chlordane, toxaphene and total PCBs were inadequate to detect these chemicals at the screening value.

Middle River at Bullfrog. Middle River runs north to south through the middle of the Delta. It connects to the San Joaquin River Channel in the north and to Old River in the south. In 1998, DeltaKeeper/SFEI sampled largemouth bass and white catfish from Middle River at Bullfrog. Total DDT and total PCBs were less than the OEHHA screening values. The analytical methods used for dieldrin, chlordane and toxaphene were not sufficiently sensitive to determine if there were exceedances of the OEHHA screening values.

Old River. Old River connects to the San Joaquin River downstream of Vernalis. At times, appreciable San Joaquin River water is diverted into the South Delta via Old River. White catfish from Old River were sampled by DeltaKeeper/SFEI in 1998. Total DDT and total PCBs were found above the OEHHA screening value. Total chlordane was less then the screening value. Dieldrin and toxaphene were not measured with sufficiently sensitive analytical methods to determine if there were exceedances of the OEHHA screening values. Old River/Tracy fish were also sampled by the TSMP in the mid-1980s. Channel catfish collected in 1984 had excessive DDT concentrations. Total chlordane was less than the OEHHA screening value in channel catfish. The other fish sampled in the 1980s (golden shiner and redear sunfish) had total DDT below the OEHHA screening values. All of the other OCls measured in the fish taken from Old River in the 1980s were analyzed with insufficiently sensitive analytical methods.

Paradise Cut. Paradise Cut is an area of intensive agricultural drainage, located in the South Delta. It is a dead-end slough which connects to Old River. Carp, catfish and largemouth bass from Paradise Cut were obtained by the TSMP in the mid- to late 1980s. Excessive concentrations of DDT, dieldrin, chlordane, toxaphene, and PCBs were found in these fish. Largemouth bass were sampled by DeltaKeeper/SFEI from Paradise Cut in 1998. These fish did not contain total DDT, total chlordane and total PCBs above the OEHHA screening values. Insufficiently sensitive analytical procedures were used for dieldrin and toxaphene. In 1998, white catfish were also sampled by DeltaKeeper/SFEI from Paradise Cut and were found to have excessive total DDT above the OEHHA screening value.

Old River at Central Valley Project Pumps. White catfish were collected from Old River near the Central Valley Project pumps (Tracy) in 1998. While total DDT and toxaphene were above the OEHHA screening value, total chlordane was found to be at concentrations below the OEHHA screening value. Dieldrin and PCBs were not measured with sufficiently sensitive analytical methods to determine if there were exceedances above the OEHHA screening values.

O'Neill Forebay/California Aqueduct. In the early 1980s, the TSMP collected striped bass and white catfish from the O'Neill Forebay/California Aqueduct. Total DDT was found in all of these fish above the OEHHA screening value. Total chlordane was found at concentrations less than the OEHHA screening value. All but one of these fish had dieldrin above the OEHHA screening value. One of the fish had total PCBs above the OEHHA screening value. The other fish were analyzed with inadequate sensitivity to measure PCBs at screening-value concentrations. Also, some of the fish were analyzed for dieldrin and toxaphene with analytical methods that were not sufficiently sensitive.

Near-Delta Tributaries. It is of interest to examine the OCl bioaccumulation data for fish taken from near-Delta tributaries. This information could be an indication of fish with excessive OCls that have moved out of the Delta or could move into the Delta. Further, near-Delta tributaries that contain fish with excessive OCls could be an ongoing source of OCls that bioaccumulate to excessive levels in Delta fish.

Sacramento River at Mile 44. The Sacramento River at Mile 44 station was not sampled as part of the State Water Resources Control Board's TSMP from 1978 through the 1980s. It has been sampled from 1997 through 2000 by the Sacramento River Watershed Program (SRWP) (LWA, 2003). All but one set of white catfish, largemouth bass, Sacramento sucker and pike minnow obtained during 15 sampling events from 1997 through 2000 had a total DDT less than the OEHHA screening value for an allowable limit for the chemical in edible fish tissue. The white catfish sample collected in 1998 had a total DDT above the screening value. The dieldrin data, presented in Figure 1, show a couple of white catfish samples with concentrations above the OEHHA screening value. Most of the values were reported as less than the detection limit, which was below the screening value. Chlordane concentrations were below the OEHHA screening value. Toxaphene was not measured.

Figure 2 presents the total PCBs found in various types of fish taken from the Sacramento River at Mile 44 during the period 1997 through 2000. The Sacramento River downstream of Sacramento is part of the Delta, according to its legal definition. There were a number of white catfish, largemouth bass and Sacramento sucker with concentrations of total PCBs above the OEHHA screening value.

<u>Sacramento River at Hood.</u> Sacramento River at Hood station is located downstream of the city of Sacramento. This station is one of the primary monitoring stations for OCl bioaccumulation in fish in the lower Sacramento River. Figure 3 presents the total DDT concentrations found in fish from this location for the period 1978 through 1998. As shown, there are many values over the years with concentrations of total DDT in white catfish above the OEHHA screening value. Figure 4 shows that, in 1998, dieldrin was present above the OEHHA screening value in white catfish and largemouth bass taken from the Sacramento River at Hood. Some of the white catfish taken from this location in 1998 had excessive concentrations of total chlordane (Figure 5) and toxaphene (Figure 6). Total PCBs (Figure 7) in white catfish and largemouth bass taken from the Sacramento River at Hood station in 1998 had concentrations above OEHHA screening values.

<u>Cache and Putah Creeks.</u> Cache Creek and Putah Creek are important lower Sacramento River tributaries. They discharge to the Yolo Bypass. Historically, in 1978 through 1981, the concentrations of the OCls measured in the fish and other organisms taken from these creeks did not exceed OEHHA screening values.

TSMP data from 1999 show that sucker taken from Putah Creek had a DDT concentration below OEHHA screening values. However, largemouth bass had excessive DDT. In largemouth bass taken in 1999, chlordane was measured at a concentration below the OEHHA screening value. Inadequate detection limits were used for chlordane measured in the sucker. Both sucker and largemouth bass analytical methods had insufficient sensitivity for measurements of dieldrin. Largemouth bass were just under the OEHHA screening value for PCBs. Analytical methods used on the sucker had inadequate detection limits for chlordane, toxaphene and PCBs. In largemouth bass samples taken in 1999, chlordane and toxaphene were not measured with sufficiently sensitive analytical methods to determine if there were exceedances of the OEHHA screening values.

In 1995, the USGS sampled Sacramento sucker from Cache Creek at Guinda. Dieldrin, toxaphene, and total PCBs were less than the detection limits, which were above the OEHHA screening values. They found that total DDT and total chlordane were less than the OEHHA

Figure 1

Concentrations of Dieldrin in Aquatic Organisms
Sacramento River at Mile 44 1997 - 2000

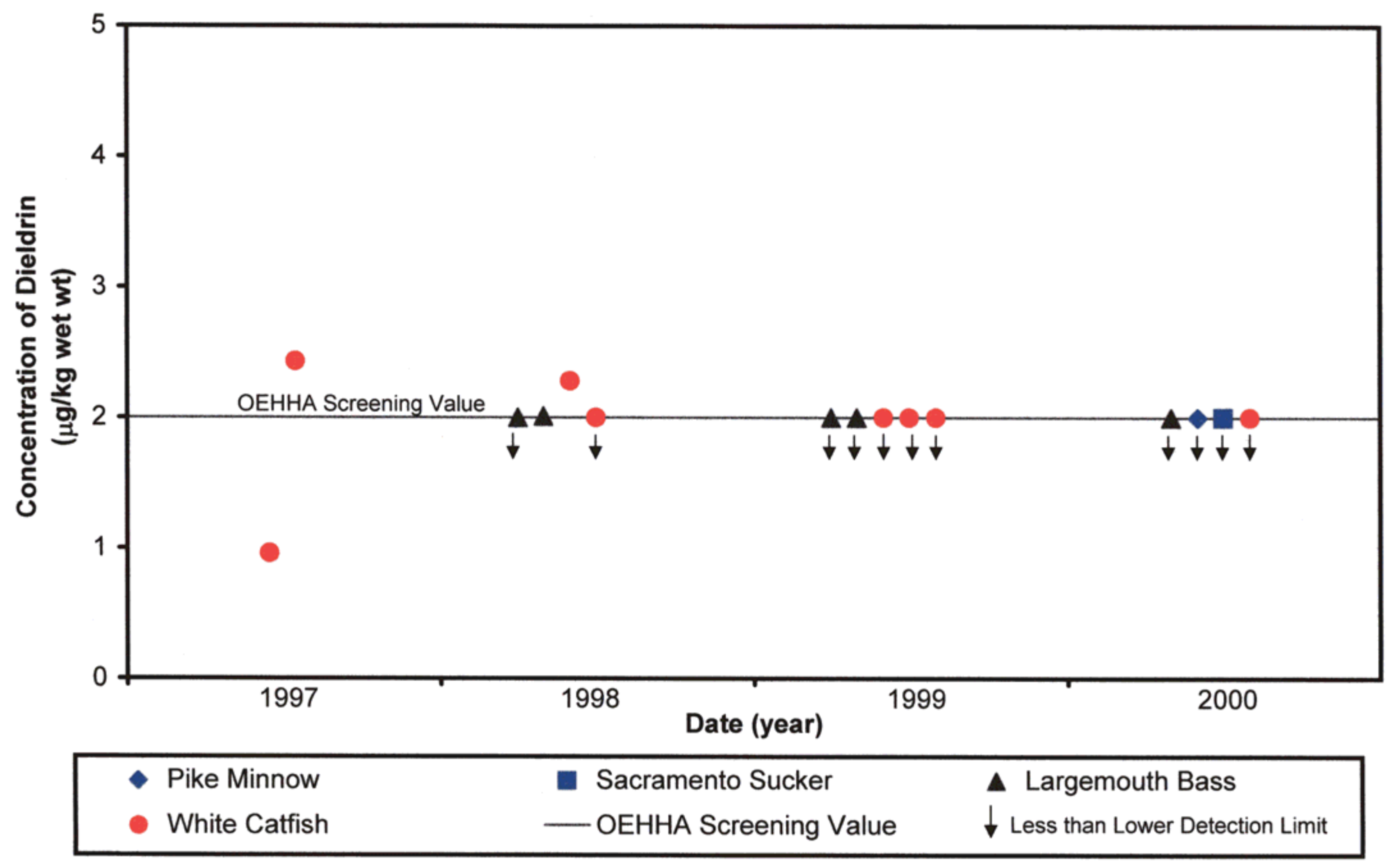


Figure 2

Concentrations of Total PCBs in Aquatic Organisms
Sacramento River at Mile 44 1997 - 2000

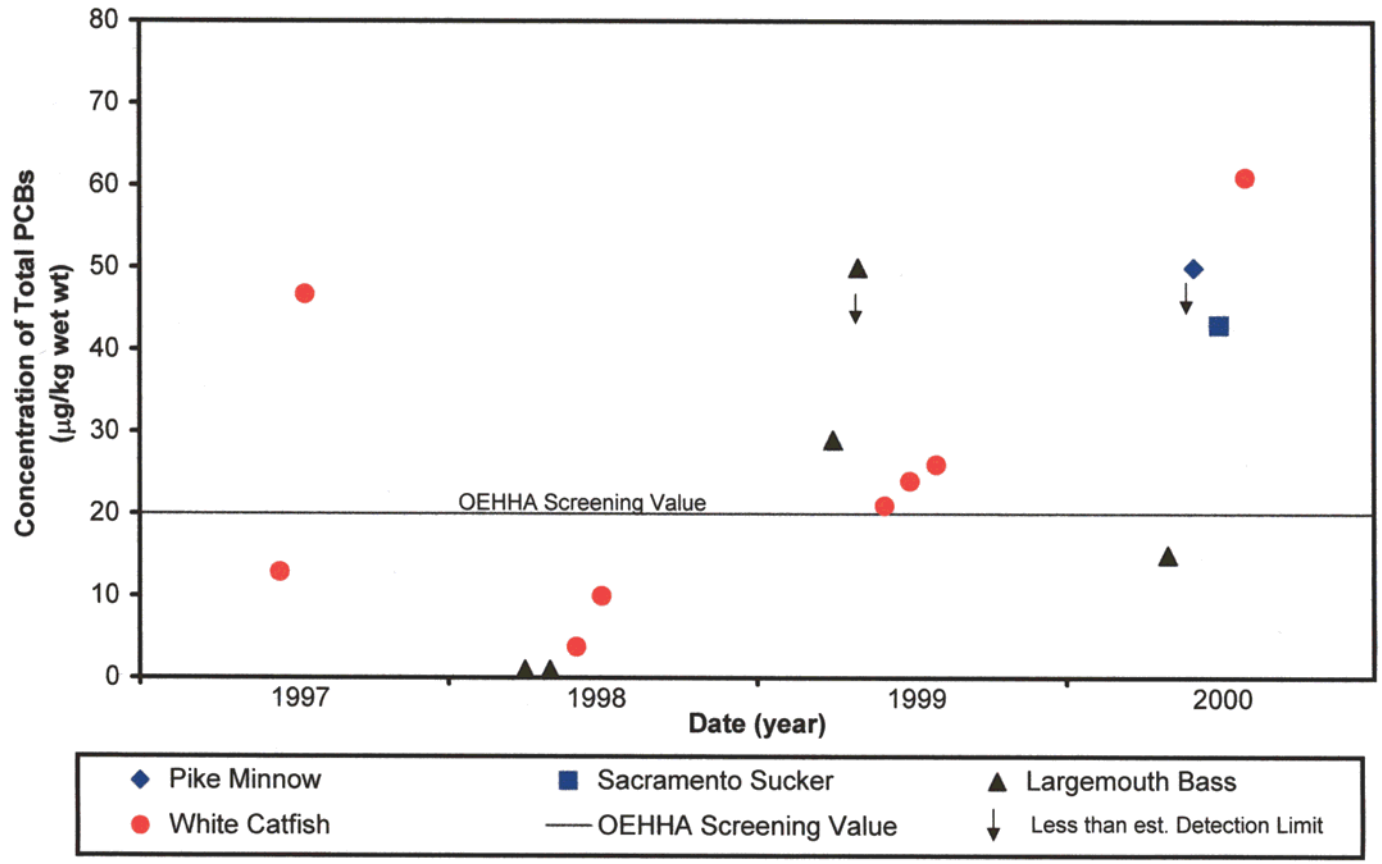


Figure 3

Concentrations of Total DDT in Aquatic Organisms Sacramento River at Hood 1978 - 2000

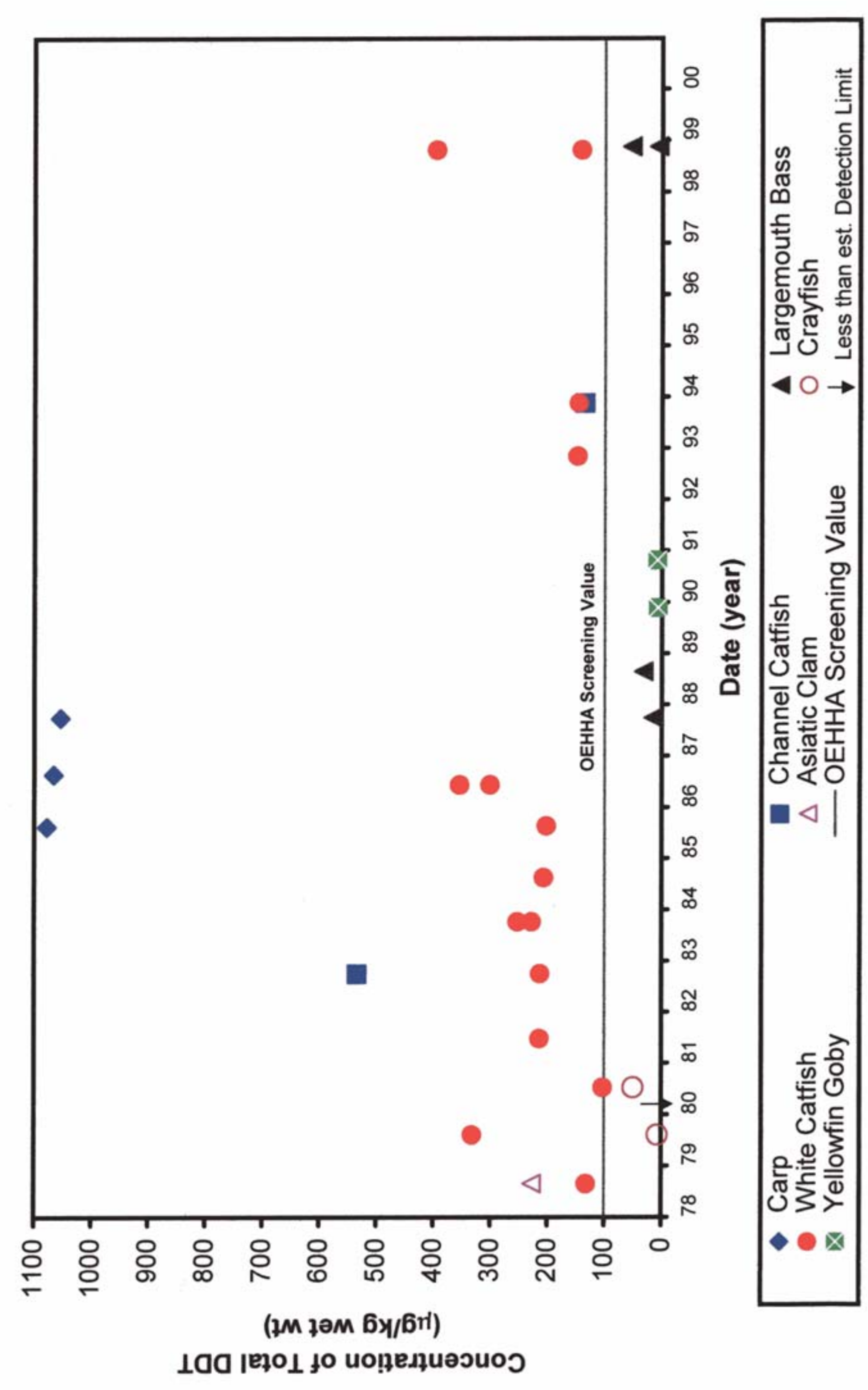
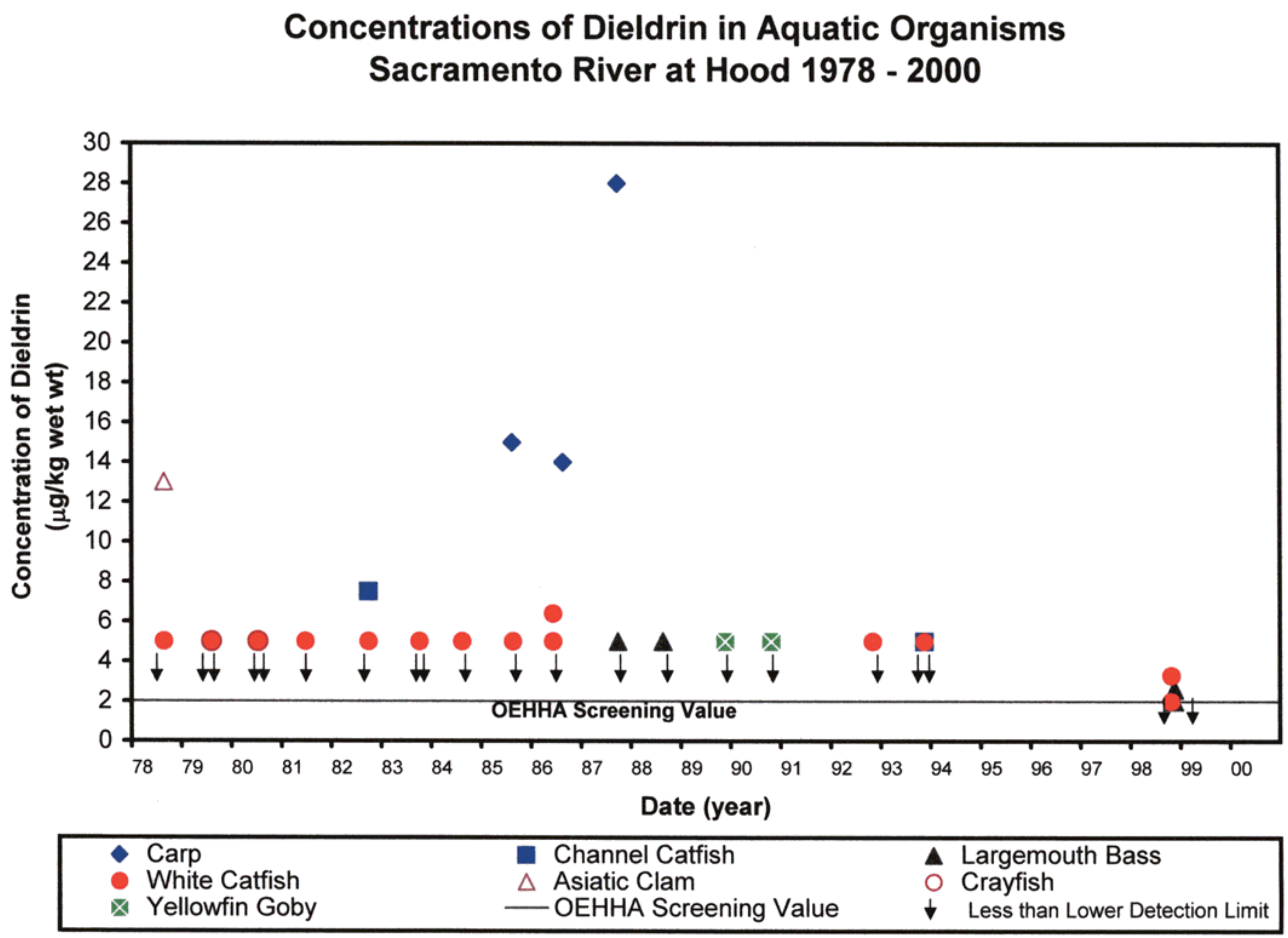


Figure 4



Concentrations of Dieldrin in Aquatic Organisms
Sacramento River at Hood 1978 - 2000
Concentration of Dieldrin (µg/kg wet wt)
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
OEHHA Screening Value
78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00
Date (year)
Carp
White Catfish
Yellowfin Goby
Channel Catfish
Asiatic Clam
OEHHA Screening Value
Largemouth Bass
Crayfish
Less than Lower Detection Limit

Figure 5

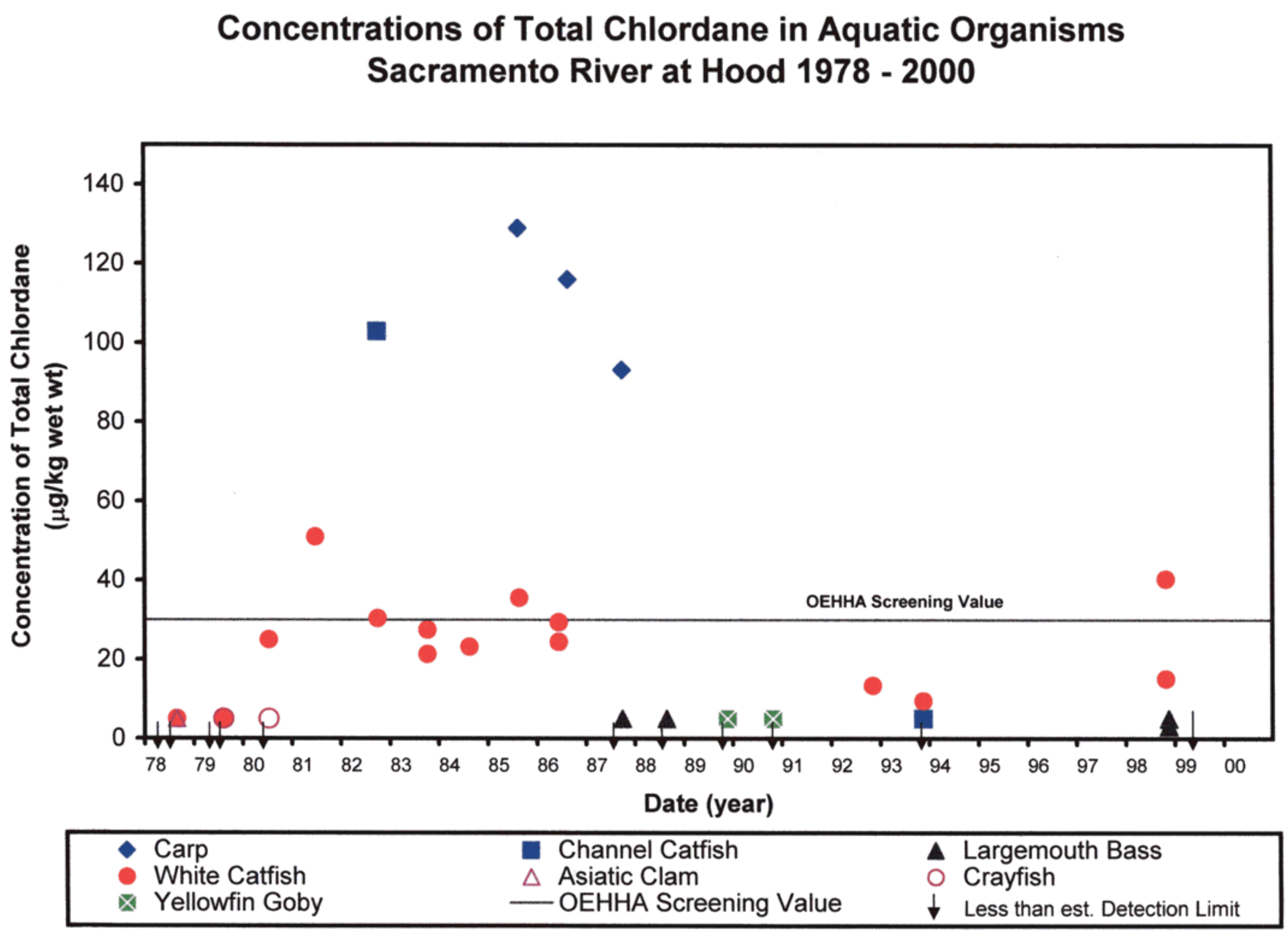

Concentrations of Total Chlordane in Aquatic Organisms
Sacramento River at Hood 1978 - 2000
Concentration of Total Chlordane
(µg/kg wet wt)
140
120
100
80
60
40
20
0
OEHHA Screening Value
78
79
80
81
82
83
84
85
86
87
88
89
90
91
92
93
94
95
96
97
98
99
00
Date (year)
Carp
White Catfish
Yellowfin Goby
Channel Catfish
Asiatic Clam
OEHHA Screening Value
Largemouth Bass
Crayfish
Less than est. Detection Limit

Figure 6

Concentrations of Toxaphene in Aquatic Organisms
Sacramento River at Hood 1978 - 2000

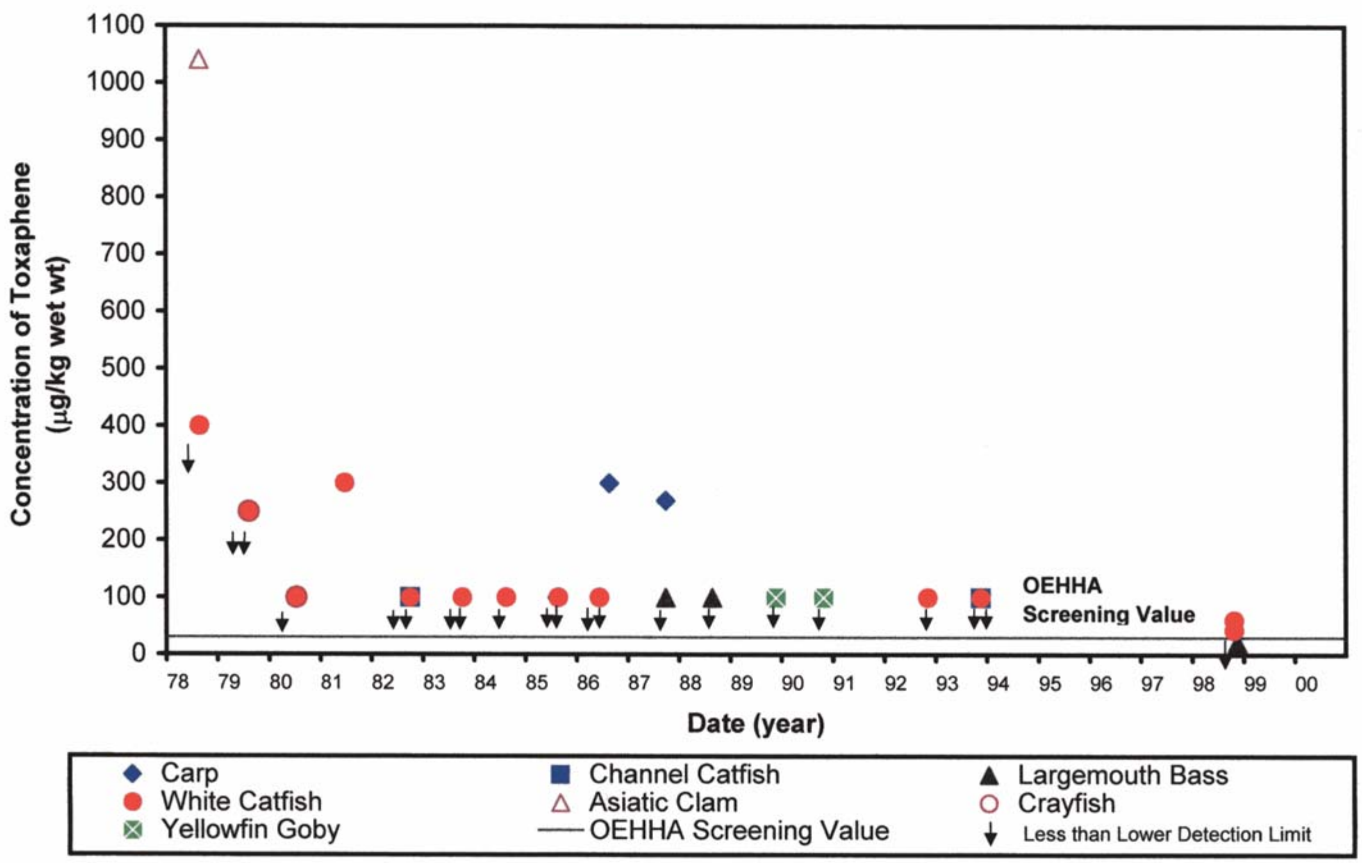
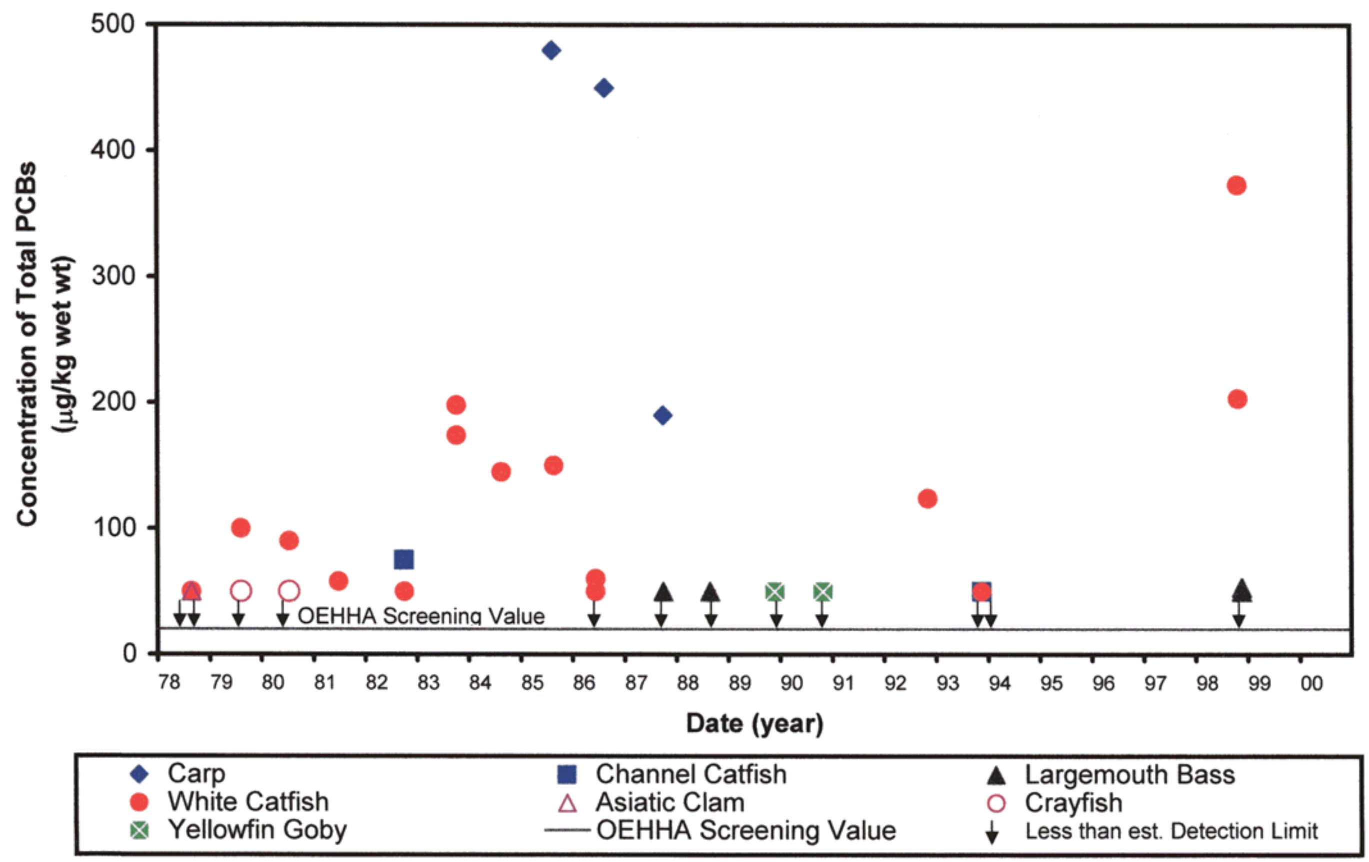


Figure 7

Concentrations of Total PCBs in Aquatic Organisms Sacramento River at Hood 1978 - 2000



screening values. Overall, it can be concluded that, at this time, based on the limited sampling that has been done, except for DDT in Putah Creek, neither Cache nor Putah Creek fish have been found to contain excessive concentrations of OCls. However, a number of the OCls of particular concern, such as chlordane that is discharged from the University of California, Davis (UCD), Department of Energy (DOE) national LEHR Superfund Site, located on the UCD campus, have not been measured with sufficiently sensitive analytical methods. A review of the inadequacy of the studies that have been conducted thus far by UCD and DOE for the UCD/DOE LEHR Superfund site is provided in reports by Lee, which are available on the DSCSOC website, http://members.aol.com/dscsoc/ dscsoc.htm. Chlordane has been found to be discharged to Cache Creek from the LEHR site at concentrations above the US EPA water quality criterion that could bioaccumulate to excessive levels in Putah Creek fish.

Cache Slough. As part of the Sacramento River Watershed Program, Cache Slough fish were sampled in 1998, 1999 and 2000. In 1998, largemouth bass had measurements of DDT, chlordane, and PCBs below the OEHHA screening values. However, dieldrin exceeded the OEHHA screening value. Toxaphene was not measured. White catfish and largemouth bass were sampled from Cache Slough in 1999 and 2000. Largemouth bass were analyzed with inadequate detection limits for chlordane and PCBs, while the white catfish had concentrations of chlordane and PCBs below the OEHHA screening values. DDT concentrations were below the OEHHA screening values in both sets of fish sampled. Dieldrin was not measured with sufficiently sensitive analytical methods to determine if there were exceedances of the OEHHA screening values.

Sacramento River at Rio Vista. DeltaKeeper/SFEI sampled *Corbicula fluminea* from the Sacramento River at Rio Vista in 1998. They found that the total DDT and total PCBs were less than the screening values. Dieldrin, chlordane, and toxaphene analyses were conducted with methods that did not have an adequate detection limit to determine if there were exceedances of the OEHHA screening value.

Potential Future 303(d) Listings for Excessive OCl Bioaccumulation. While some of the Delta channels and near-Delta tributaries are listed on the 2002 303(d) list for excessive bioaccumulation of OCls, as discussed above, there are data from these areas for waterbodies which show excessive OCl bioaccumulation that has not caused the waterbody segment of concern to be listed on the current 303(d) list. It is possible that with the development of the updated list, additional Delta channels and near-Delta tributaries will be added to the Clean Water Act 303(d) list of OCl-impaired waterbodies. However, this situation is somewhat in doubt, since the approach that is being discussed at the SWRCB for establishing new 303(d) listings requires a substantial database to justify such listings, which in most instances is beyond the database available.

The problem with the State Board's proposed approach for establishing new 303(d) listings is that it is valid only if there are substantial monitoring funds and an appropriate monitoring program to investigate the waterbodies that have been found to have some fish with excessive bioaccumulation of OCls, to determine if there is a significant public health problem associated with eating fish from these waterbodies.

Under the current financial crisis that exists in California, the funds to properly implement the proposed approach for establishing new 303(d) listings may not be available. This could mean that the public who eat fish from these areas could be exposed to excessive concentrations of OCls without there being an appropriate regulatory program to evaluate the threat to their health. As discussed by Lee (2003b), there is an urgent need for funding of sufficient magnitude to determine the current status of OCl bioaccumulation in Delta channel and near-Delta tributary fish. The magnitude of this funding should be such that it will be possible to determine whether OEHHA should list a particular waterbody with a fish consumption advisory for having one or more OCls in edible fish tissue that are a threat to those who use the fish as food. The current situation, where there are a few fish taken in the past half a dozen years or so which show exceedances of OEHHA screening values for some OCls, should not be perpetuated.

There is also need to clearly define the fish consumption rates for those who are using Delta and near-Delta fish as a substantial part of their diet. It is believed that there are individuals who are subsistence fishermen in the Delta and near-Delta tributaries, who are consuming greater amounts of fish than are assumed by OEHHA in establishing its screening values. This situation could cause the screening values used for these waterbodies to have to be significantly lowered to protect the health of the subsistence fishermen in the area in order to avoid situations such as commonly occurred in the past, where a substantial amount of fish tissue analysis has been conducted with inadequate analytical methods. The regulatory agencies and the public should determine the appropriate screening value to protect the subsistence fishermen and then use analytical methods that will determine the concentrations of the OCls below these screening values.

Currently, there is a Delta Watershed Fish Project being conducted, which has a Local Advisory Group. The focus of this group's activities is on education of those who consume fish from the Delta on the potential hazards of these fish with respect to mercury. This group's activities need to be expanded to include the threat caused by organochlorine legacy pesticides and PCBs. Further, there is need to expand the work of Shilling (2003) on Background Information for a Central Valley Fish Consumption Study, which included some data on fish consumption in the Delta, to better define fish consumption rates in the Delta. There is also need to expand the work that is being done in the Sacramento River watershed by Alyce Ujihara and Sun H. Lee of the California Department of Health Services, Environmental Health Investigation Branch, to include assessing fish consumption rates in the Delta.

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Need for Funding to Support Studies to Control Excessive Bioaccumulation of Organochlorine "Legacy" Pesticides, PCBs and Dioxins in Edible Fish in the Central Valley of California[3]

G. Fred Lee, PhD, PE, DEE
G. Fred Lee & Associates
27298 E. El Macero Drive, El Macero, CA 95618
Ph: (530)753-9630 Fx: (530)753-9956 Em: gfredlee@aol.com
www.gfredlee.com
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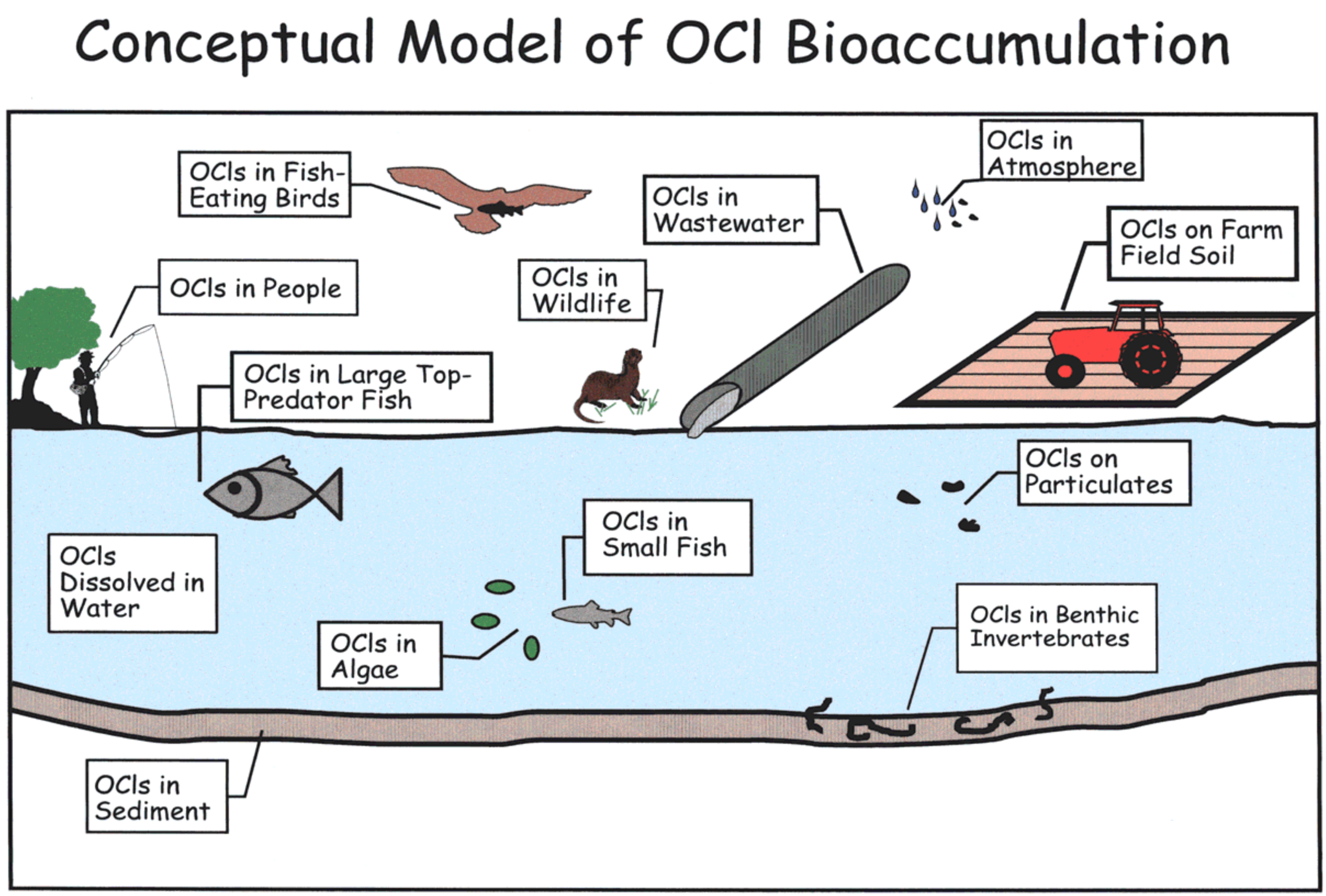
One of the most significant water quality problems that exist in the mainstems of the Sacramento and San Joaquin Rivers and many of their tributaries, as well as the Delta, is the excessive bioaccumulation of organochlorine "legacy" pesticides (DDT, dieldrin, chlordane, toxaphene), PCBs and possibly dioxins/furans. The excessive bioaccumulation of these organochlorines (OCls) causes many of the more desirable fish (such as largemouth bass, white catfish, etc.) to contain sufficient concentrations of these pesticides and/or PCBs so that their use as food represents a threat to cause cancer in those who eat them. This is an environmental justice problem, since the individuals who are most likely impacted to the greatest extent are those who must, because of economic reasons, use local fish as a major source of food in their diet.

Figure 1 shows the nature of the excessive bioaccumulation problem in Central Valley fish and other edible aquatic life. Basically, the problem is a food web accumulation problem, where the OCls are taken up by lower-trophic-level organisms, which ultimately results in elevated concentrations in fish and other organism tissue. Each of the waterbodies of concern has received in the past (and may receive, to some extent, today) sufficient concentrations of one or more OCls to lead to concentrations of these chemicals in some of the waterbodies' fish to be above the California Office of Environmental Health Hazard Assessment (OEHHA) guidelines for the use of the fish as food because of the potential for those who use these fish to acquire cancer.

The former use of one or more of the OCls (except dioxins/furans) in each of the waterbodies' watersheds for agricultural and/or urban purposes has led to stormwater runoff transport and, in some instances, wastewater discharges of the OCl(s) to a sufficient extent to lead to bioaccumulation to excessive levels in some of the edible fish in the waterbodies receiving the runoff/discharges. With respect to dioxins and furans, they may have been discharged to the waterbody or its tributary from former municipal and/or industrial wastewater discharges as well as in stormwater runoff from highways and streets and/or runoff/discharges from areas where low-temperature burning has taken place. They may also have been contaminants in the herbicide 2,4,5-T and could be derived from areas where this herbicide has been used.

[3] Reference as Lee, G. F., "Need for Funding to Support Studies to Control Excessive Bioaccumulation of Organochlorine "Legacy" Pesticides, PCBs and Dioxins in Edible Fish in the Central Valley of California," Report of G. Fred Lee & Associates, El Macero, CA, July (2003).

Figure 1


Conceptual Model of OCl Bioaccumulation
OCls in Fish-Eating Birds
OCls in People
OCls in Large Top-Predator Fish
OCls in Wildlife
OCls in Wastewater
OCls in Atmosphere
OCls on Farm Field Soil
OCls on Particulates
OCls in Small Fish
OCls Dissolved in Water
OCls in Algae
OCls in Benthic Invertebrates
OCls in Sediment

The Central Valley Regional Water Quality Control Board (CVRWQCB) has identified 11 waterbodies in the Central Valley, including the Sacramento and San Joaquin Rivers and the Delta, as well as a number of tributaries, as having excessive concentrations of the organochlorines in edible fish. This has resulted in these waterbodies being listed as Clean Water Act 303(d) "impaired" waterbodies. This listing results in the need for the CVRWQCB to develop a total maximum daily load (TMDL) to control the excessive bioaccumulation of the organochlorines in edible fish.

These waterbodies include the Delta Waterways, Lower American River, Colusa Basin Drain, Lower Feather River, Lower Merced River, Natomas East Main Drain, San Joaquin River, Lower Stanislaus River, Stockton Deep Water Ship Channel, Lower Tuolumne River and Lower Kings River. These waterbodies are listed on the federal Clean Water Act's 303(d) list as "impaired" for organochlorine (OCl) compounds including "Group A" pesticides (such as toxaphene, chlordane, dieldrin, aldrin, endrin, heptachlor, heptachlor epoxide, hexachlorocyclohexane [including lindane], and endosulfan), DDT, DDE, DDD, and the non-pesticides polychlorinated biphenyls (PCBs) and dioxins/furans. The water quality problem caused by these chemicals is excessive bioaccumulation of one or more of the OCls in edible fish tissue compared to public health screening values established to protect humans from an increased risk of cancer associated with using the fish as food.

Table 10 from Lee and Jones-Lee (2002) (see attached) lists the Central Valley waterbodies that have been found to contain fish and other edible aquatic life with excessive OCls compared to OEHHA public health guidance for the use of fish as food. As shown, there are several other Central Valley waterbodies that have been found to contain excessive OCls that are not on the CVRWQCB 303(d) list of impaired waterbodies. The Central Valley waterbody OCl fish excessive bioaccumulation problem is likely much larger than indicated based on the 303(d) listing and the information presented in Table 10, since there have not been sufficient funds to conduct comprehensive surveys of Central Valley fish to fully define the extent of this problem.

In discussing this matter with the CVRWQCB staff (Jerry Bruns and others), it is found that the CVRWQCB does not have funds to develop the information needed to begin to address this problem, with the result that one of the most significant water quality problems in the Central Valley, which is directly affecting human health, is not being addressed.

This spring, it was decided that it would be appropriate for the DeltaKeeper to submit a proposal to try to gain funding to start the process of developing the information needed to effectively manage the excessive bioaccumulation of OCl chemicals in edible fish. Based on a review of the potential to gain funding under the SWRCB March 2003 Consolidated Request for Concept Proposals, this excessive bioaccumulation problem of the organochlorines is not eligible for support in any of the many tens of millions of dollars that the legislature has appropriated for studies. The Consolidated Request for Concept Proposals issued in March 2003 by the State Water Resources Control Board covers the California Bay-Delta Authority (CALFED), the US EPA, the California

Coastal Commission and the California Resources Agency. Grants would be made available through funding from Proposition 13, Federal Clean Water Act section 319, and Proposition 50. Based on discussions with CVRWQCB staff responsible for review of Concept Proposal submissions, none of these sources of funds could be used to address the excessive bioaccumulation of OCls.

About two years ago it was determined, with the concurrence of the Central Valley Regional Water Quality Control Board staff responsible for administration of a 319(h) project that had been awarded to the DeltaKeeper, that the project funds should be devoted to conducting a pilot study to determine whether the sediments in Smith Canal, a city of Stockton urban waterway, are the source of the PCBs that have been found in edible fish taken from Smith Canal. The situation is that the DeltaKeeper made settlement funds available to San Francisco Estuary Institute (SFEI) to do a survey of excessive bioaccumulation of organochlorine compounds in Central Valley fish. One of the locations where studies were conducted was in Smith Canal. The fish taken from Smith Canal were found to have some of the highest PCBs of any location in the Central Valley. Smith Canal at that time, and even today, is not on the CVRWQCB list of impaired waterbodies that have excessive bioaccumulation of PCBs. This situation exists for a number of other waterbodies in the Central Valley, where the current 11 waterbodies that are listed could readily be expanded to a much larger number, based on excessive bioaccumulation of organochlorines in edible fish.

The DeltaKeeper 319(h) project resulted in a report,

> Lee, G. F., Jones-Lee, A., and Ogle, R. S., "Preliminary Assessment of the Bioaccumulation of PCBs and Organochlorine Pesticides in *Lumbriculus variegatus* from City of Stockton Smith Canal Sediments, and Toxicity of City of Stockton Smith Canal Sediments to *Hyalella azteca*," Report to the DeltaKeeper and the Central Valley Regional Water Quality Control Board, G. Fred Lee & Associates, El Macero, CA, July (2002),

which demonstrated, using benthic organism uptake studies, that the PCBs in Smith Canal sediments are, at least in part, bioavailable, even though the sediments have a high organic carbon content. Organic carbon in sediments tends to reduce bioavailability of chemicals like the organochlorines. This was the first time that the US EPA's sediment bioaccumulation testing procedure had been used in the Central Valley. It is clear that there is need to conduct a large-scale sediment testing program using this approach to determine the location of the sediments in Central Valley waterbodies from which the organochlorines are being derived that are bioaccumulating to excessive levels in edible fish.

In the summer of 2000, Lee and Jones-Lee submitted a proposal to CALFED to develop the information that is needed to begin to define the sources of the organochlorines that are bioaccumulating to excessive levels in Central Valley waterbody fish. The reviews on the proposal indicated that one of the reasons it was not supported by CALFED was that it is devoted to a human health issue, rather than an ecological issue. As it turns out, there is no funding within CALFED, outside of the Drinking Water Program, for human health issues. The excessive bioaccumulation of organochlorines is not a drinking water problem. There were also questions by one of the reviewers about the practicality of defining sources of the organochlorines that are bioaccumulating to excessive levels, since this has not been undertaken in the Central Valley. However, as I pointed out, I have been working on organochlorine excessive bioaccumulation issues since the 1960s in other parts of the US, and I know from my experience and the literature that it is possible to define sources and to manage these sources.

At the May 6, 2003, CVRWQCB meeting, Board member Christopher Cabaldon indicated to the Board that the CALFED Environmental Justice Subcommittee had concluded that the excessive bioaccumulation of mercury in Delta and Delta tributary fish is an environmental justice issue, since the excessive bioaccumulation of mercury in edible fish is a threat to human health. Last winter, after I had completed a comprehensive review of the excessive OCl bioaccumulation problem for the CVRWQCB/SWRCB (see below), I contacted Sam Luoma, who directs the CALFED Science Program, indicating that the excessive OCl bioaccumulation problem is a well documented problem that is of significance to human health to people throughout the Central Valley who use Delta and its tributary fish as food. This is clearly an environmental justice issue. I pointed out that, as far as I could tell, there was no CALFED funding for this issue since this is a human health issue as opposed to an ecological issue. Dr. Luoma stated that he agreed that there was no funding to address this problem within CALFED, and that this is an environmental justice issue, but that the CALFED Environmental Justice Subcommittee has no funds to support work in this area.

Beginning about a year ago, the Central Valley Regional Water Quality Control Board, through funding from the State Water Resources Control Board and the US EPA, made funds available to the California Water Institute at California State University, Fresno, which provided support for Dr. Jones-Lee and me to develop a comprehensive report on the organochlorine excessive bioaccumulation issues. This report,

> Lee, G. F. and Jones-Lee, A., "Organochlorine Pesticide, PCB and Dioxin/Furan Excessive Bioaccumulation Management Guidance," California Water Institute Report TP 02-06 to the California Water Resources Control Board/Central Valley Regional Water Quality Control Board, 170 pp, California State University Fresno, Fresno, CA, December (2002)
> (http://www.gfredlee.com/OClTMDLRpt12-11-02.pdf),

was completed in December 2002. It provides detailed information on the current state of knowledge on excessive bioaccumulation of organochlorines in edible fish (see Table 10). Further, it defines the areas of needed study in order to begin to manage the problem. The principal issues of concern are those of the relative significance of aquatic sediments versus land runoff from agricultural and other areas as a source of organochlorines that are bioaccumulating to excessive levels. It is expected that aquatic sediments are the primary source; however, work in the early 1990s by the US Geological Survey showed that, at least in some areas, the "legacy" pesticides are still being discharged by agricultural lands at concentrations which could represent a significant source of organochlorines for excessive bioaccumulation in fish. Studies need to be conducted to determine, where excessive organochlorine bioaccumulation is found, whether the current terrestrial land runoff sources are a significant source for the excessive bioaccumulation.

Further, funds are needed to better define where excessive bioaccumulation is occurring. For example, an area of particular concern is excessive bioaccumulation of PCBs in the Sacramento River near Sacramento. This area, according to the data available, has excessive PCBs. It is not listed as a 303(d) "impaired" waterbody due to excessive PCB bioaccumulation. The Regional Board staff feels that there is need for additional studies to confirm the data; however, there are no funds available to do these studies. Lee and Jones-Lee conclude that there are sufficient data now to justify listing the Sacramento River near Sacramento as impaired due to excessive PCB bioaccumulation in fish. This approach would warn the public that many of the more desirable fish taken from the Sacramento River near Sacramento can contain excessive PCBs and, therefore, should not be consumed. It would also establish the need for studies to define the sources of these PCBs.

Recommended Approach for Establishing the OCl Management Program[4]

Lee and Jones-Lee (2002) have discussed a recommended approach for developing management programs for organochlorine pesticides and PCBs. The recommended approach for establishing the legacy pesticide, PCB and dioxin/furan excessive bioaccumulation management program is to first obtain sufficient funding so that a comprehensive study can be conducted on current OCl concentrations in edible fish from the 303(d) listed waterbodies. Particular attention should be given to sampling from various locations within the waterbodies to see if there are areas where fish and other organisms (such as clams) have higher concentrations.

At the same time that sampling is conducted for fish, samples of sediment from various locations in the listed waterbodies should also be taken and analyzed for OCls of concern. It would be highly desirable, although it may not be possible during the initial study, to do the sediment bioaccumulation evaluation using *Lumbriculus variegatus* (the oligochaete), following procedures similar to those used in the Smith Canal sediment PCB study (Lee et al., 2002).

For each of the listed waterbodies an advisory panel should be appointed to plan, implement and report on the needed studies. Suggested members of this panel include the CVRWQCB staff, DPR staff, county agriculture commissioners, CALFED, agricultural interests, Farm Bureau, county RCDs, irrigation districts, Department of Fish and Game and environmental groups. The results of this monitoring program could take several years to establish current degrees of excessive bioaccumulation for the OCls. This approach would also provide information that is needed to develop a site-specific sediment biota accumulation factor for each listed waterbody or parts thereof.

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[2] From Lee and Jones-Lee (2002)

For some of the listed waterbodies − possibly most − there would be need to determine the external loads of OCls associated with summer irrigation season tailwater discharges and winter stormwater runoff. If substantial loads are found of excessive bioaccumulation at the point where the tributary discharges to the waterbody, then forensic studies would need to be conducted to determine the origin of these loads within the waterbody's watershed.

Ultimately, from studies of this type, it should be possible to determine whether current external loads of OCls represent a significant source of OCls that are bioaccumulating to excessive levels. This information could then be used to determine whether there is need to establish a control program from watershed sources of OCls for waterbodies that currently have excessive bioaccumulation of one or more OCls in one or more types of fish.

A list of specific topic areas of further study for OCl bioaccumulation management program development includes the following:

- Determine, for each of the listed waterbodies, as well as other Central Valley waterbodies, the current degree of edible fish tissue OCl residues. These residues should be compared to OEHHA screening values which have been adjusted for local fish consumption rates. This information is essential to defining the waterbodies within the Central Valley where OCls have bioaccumulated to excessive levels in edible fish.
- Determine for each of the listed waterbodies whether stormwater runoff and/or irrigation tailwater discharges and/or domestic and industrial wastewater discharges are currently contributing sufficient concentrations of the OCl(s) of concern in the waterbody to be contributing to the excessive bioaccumulation of this OCl(s) in edible fish tissue.
- Conduct a quantitative assessment of the current atmospheric loads of the OCls for several of the listed waterbodies to evaluate the potential significance of this source.
- Determine the concentrations of the OCls of concern in the listed waterbodies and the bioavailability of the sediment-associated OCl residues for food web accumulation that leads to excessive edible tissue residues.
- Determine the extent of edible fish tissue contamination by dioxins and furans within the Central Valley waterbodies. Where excessive concentrations are found in edible fish tissue, determine likely sources of the dioxins and furans that are bioaccumulating to excessive levels.
- Since the allowable OCl tissue residue for edible fish is dependent on local waterbody fish consumption rates, it is recommended that, as part of developing the management program for the OCl-listed waterbodies, representative fish consumption rates for each listed waterbody be developed.
- It is recommended that studies of the type conducted by USGS NAWQA in the early to mid-1990s be conducted again to verify that the continued transport of several organochlorine pesticides from agricultural and urban areas at potentially significant concentrations is occurring.

- There is need for studies to determine for each OCl-listed waterbody whether current transport of the OCls to the waterbody significantly contributes to the bioavailable OCl residues within the waterbody that lead to excessive bioaccumulation in edible organism tissue.
- Special-purpose studies need to be conducted using aquatic organism incubation to determine if domestic wastewaters are a significant source of OCls for certain Central Valley waterbodies.
- Studies should be conducted to determine if the bioaccumulation by the freshwater clam *Corbicula fluminea* could be used to evaluate the bioaccumulation that may be occurring in edible fish.
- All fish tissue analyses for the OCls should be conducted with an analytical method detection limit that is at least slightly below the OEHHA human health screening value.
- The fish samples that are currently stored frozen, taken from Smith Canal and a number of other locations, should be analyzed for OCl content in edible tissue.
- It is recommended that systematic studies of fish tissue OCl concentrations for the fish types of concern at a particular location be conducted to examine the variability in OCl composition at about the same time and location. This information is essential to understanding whether the apparent changes in OCl composition over time are related to real changes or simply reflect the variability of the data.
- It is also recommended that all OCl measurements of fish tissue include measurements of the lipid content. This information may be useful to normalize the OCl bioaccumulation based on fish edible tissue lipid content.

Additional information on these recommended studies is available in the Lee and Jones-Lee (2002) report.

The fact that none of the Consolidated funding sources have funds that could be used to support the needed organochlorine studies is a major gap in the approach that is being used today by the US EPA, CALFED, the State Water Resources Control Board and the Regional Water Quality Control Boards, where one of the most (if not the most) important water quality problems that affects human health in the Central Valley is not eligible for funding to develop the information base needed to begin to define the full magnitude of this problem, the sources of the organochlorines that are leading to excessive bioaccumulation, and approaches that could be used to potentially control the problem. It is for this reason that I recommend that the DeltaKeeper join with other environmental groups and request that the legislature provide funding to specifically address support for work on this topic. Another option would be to submit proposals to one or more foundations for support.

Discussion of Recent OCl Organism Tissue Data[5]

This section presents an overview discussion of the OCl fish and other aquatic organism recent (post-1997) data relative to exceedance of the OEHHA standard fish consumption screening values. As indicated, these values are based on a 21 g/day fish consumption rate, which translates to about 1 meal/week. They are based on an upper-bound cancer risk of one additional cancer in 100,000 people who consume fish at this rate over their lifetime. It is expected that there will be some individuals for some Central Valley Waterbodies who will consume fish from a listed Waterbody at a greater rate than the rate OEHHA used.

Table 10 presents a summary of all of the OCl aquatic organism tissue residue data that have been collected since 1997 compared to the OEHHA screening values. All data collected from 1997-2001 is, for the purposes of this report, termed "recent" data.

An "x" for an OCl and a location indicates that there are some recent OCl fish tissue or *Corbicula fluminea* (clam) data, where the concentrations of the OCl were above the OEHHA screening value. In situations where some fish had concentrations above the OEHHA screening value and others did not, an "x" was used to indicate that an exceedance of the value has recently occurred in at least one sampling of organisms at the location since 1997. An "o" means that there have been recent data collected with adequate analytical method sensitivity, which have shown that the concentrations of the OCl are below the OEHHA screening value. A "--" means that there have been no measurements made for this OCl at this location. A "?" indicates that the analytical methods used for the recent data have not had adequate sensitivity to determine the OCl at the OEHHA screening value. An "o?" indicates that the concentration of the OCl was just below the OEHHA screening value. An "x?" indicates that the concentration of the OCl in aquatic life tissue collected prior to 1997 was above the OEHHA screening value, but this OCl has not been measured at all, or with adequate sensitivity since 1997. An "*" indicates that organochlorine pesticides have been found in the water column at potentially significant concentrations; however, no data are available on the bioaccumulation of the OCls for this waterbody.

Based on past studies, the primary OCls of concern for excessive bioaccumulation in the Sacramento and San Joaquin River watersheds and the Delta are DDT, dieldrin, chlordane, toxaphene and PCBs. These are referred to herein as the primary OCls of concern.

Some of the past and recent studies have involved the use of analytical methods for certain of the OCls that did not have sufficient sensitivity to detect the OCl in fish tissue samples at the OEHHA screening values. Usually DDT and/or PCBs have been analyzed with sufficient sensitivity to detect exceedances. Unless previous studies showed exceedances of a certain OCl and there is no recent confirming data, the waterbody is not listed as a high priority for future studies.

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5 From Lee and Jones-Lee (2002)

Table 10
Summary of Central Valley Waterbodies with Excessive OCl Residues
Based on 1997 - 2000 Organism Tissue Data and OEHHA Screening Values

Location	Total DDT	Dieldrin	Total Chlordane	Total Toxaphene	Total PCBs
San Joaquin River Watershed					
San Joaquin River at Highway 99	o	o	o	o	o
San Joaquin River at Lander Avenue	o	x	o	o	o
Mud Slough	x	x	?	x	x
Salt Slough	x?	x?	?	x?	?
Merced River	x	x	o	x	x
San Joaquin River at Crow’s Landing	o	o	o	o	o
Orestimba Creek	x?	x?	?	x?	?
Spanish Grant Drain	x?	?	?	x?	x?
Olive Avenue Drain*	--	--	--	--	--
Turlock Irrigation District, Lateral #5	o	?	?	?	?
Del Puerto Creek	x?	?	?	?	?
Ingram Creek*	--	--	--	--	--
Hospital Creek*	--	--	--	--	--
Lower Tuolumne River	x	x	o	x	x
Stanislaus River	x	x?	?	x?	x
San Joaquin River at Vernalis	x	x	x	x	x
San Joaquin River “at Bowman Road”	x	?	o	?	x
San Joaquin River at Mossdale	x?	?	?	?	?
San Joaquin River “at Highway 4”	x	?	o	?	o
Sacramento River Watershed					
McCloud River	o	o	o	o	o
Clear Creek	o	o	o	o	o
Sacramento River at Keswick	o	?	o	--	x
Sacramento River at Bend Bridge, near Hamilton City	o	o	o	o	o
Mill Creek	o	o	o	o	o
Deer Creek	o	o	o	o	o
Big Chico Creek	o	o	o	o	o
Sacramento River at Colusa	o	?	o	--	x
Sutter Bypass	x?	x?	x?	x?	x?
Feather River near Nicolaus/Hwy 99	o	o	o	o	x
Feather River at Forbestown	--	--	--	--	x?
Yuba River	x?	?	?	?	?
East Canal near Nicolaus	x?	x?	?	?	?
Sacramento Slough	o	x	o	--	x
Colusa Basin Drain	x	x	x?	x?	o
Sacramento River at Veteran’s Bridge	o	?	o	--	x
Natomas East Main Drain	o	?	o	?	x

Table 10 (Cont.)					
Sacramento River Watershed (Cont.)	**Total DDT**	**Dieldrin**	**Total Chlordane**	**Total Toxaphene**	**Total PCBs**
Arcade Creek	o	x?	x?	?	?
American River at Discovery Park	o	x	o	?	x
American River at Watt Avenue	x?	x?	x?	--	x?
American River at J Street	o	?	o	--	x
Sacramento River at Mile 44	x	x	o	--	x
Sacramento River at Hood	x	x	x	x	x
Cache Creek	o	?	?	?	o
Putah Creek	x	?	o	?	o?
Cache Slough	o	x	o	--	o
Sacramento River at Rio Vista	o	?	?	?	o
Delta					
Port of Stockton Turning Basin	x	?	o	?	x
Port of Stockton near Mormon Slough	o	x	?	?	x
Smith Canal	o	?	o	?	x
San Joaquin River around Turner Cut	o	?	o	?	o
White Slough downstream from Disappointment Slough	o	?	?	?	o
San Joaquin River at Potato Slough	o	?	o	?	x
San Joaquin River off Point Antioch	o	?	?	?	o
Sycamore Slough near Mokelumne River	o	x	?	?	?
Mokelumne River between Beaver and Hog Sloughs	o	?	?	?	o
Middle River at Bullfrog	o	?	?	?	o
Old River	x	?	o	?	x
Paradise Cut	x	?	o	?	o
Old River at Central Valley Pump	x	?	o	x	?
O'Neill Forebay/California Aqueduct	x?	?	x?	?	x?
Tulare Lake Basin					
King's River	o	?	o	?	o
Kern River	o?	?	?	?	--

x At least one fish sample taken in the late 1990s or 2000 was above the OEHHA screening value.
o None of the fish samples taken in the late 1990s or 2000 were above the OEHHA screening value.
? The analytical methods used were not sufficiently sensitive to measure the OCl at the OEHHA screening value.
o? The concentrations of an OCl were just below the OEHHA screening value.
x? The concentration of an OCl was above the screening value in the past but either has not been recently analyzed or the recent analytical methods used did not have sufficient sensitivity.
-- No measurements were made for this OCl.
* Organochlorine pesticides have been found in the water column at potentially significant concentrations. No data are available on the bioaccumulation of the OCls for this waterbody.

San Joaquin River Watershed. The uppermost point where fish have been recently collected and OCls have been measured with adequate sensitivity in the San Joaquin River watershed was at the San Joaquin River at Highway 99. The largemouth bass collected in 2000 did not show exceedances of the OEHHA screening value at this location for each of the primary OCls of concern. Further down the SJR at Lander Avenue, only dieldrin in white catfish collected in 1998 was above the OEHHA screening value. DDT, chlordane, toxaphene and PCBs were all below the OEHHA screening value.

Mud and Salt Sloughs are tributaries of the San Joaquin River that enter the River below Lander Avenue but above the Merced River. White catfish taken from Mud Slough in 1998 had concentrations of total DDT, dieldrin, toxaphene and total PCBs above OEHHA screening values. There have been no recent fish tissue data collected from Salt Slough. However, older data showed exceedances of total DDT, dieldrin and toxaphene.

Channel catfish and largemouth bass were collected from the Merced River at the Hatfield St. Recreation Area in 1998. These fish contained excessive concentrations of total DDT, dieldrin, chlordane, toxaphene and total PCBs above the OEHHA screening values. Future studies should include samples taken at several locations at and above the Hatfield St. Recreation Area.

The San Joaquin River at Crow's Landing receives the upstream discharges of Mud Slough, Salt Slough and the Merced River. The recent largemouth bass data collected at this location did not show exceedances for any of the OCls. It appears that Mud Slough, Salt Slough, and the Merced River, as well as the SJR at Lander Avenue, while having fish that show excessive OCls, are not contributing OCls to the San Joaquin River at sufficient concentrations to cause fish taken near Crow's Landing to have excessive OCls.

The westside tributaries to the SJR (Orestimba Creek, Spanish Grant Drain, Del Puerto Creek, Olive Avenue Drain, Ingram Creek and Hospital Creek) are major sources of OCls for the San Joaquin River. These waterbodies were found in the early 1990s to contain measurable concentrations of several of the OCls of concern in the water column that could bioaccumulate to excessive levels in aquatic organisms. There are no recent data on OCl concentrations in aquatic organisms taken from the westside tributaries. This is an area that should be a high priority for further study.

The mid- to lower eastside tributaries (Stanislaus River and Tuolumne River) of the San Joaquin River contain fish with excessive concentrations of several OCls. These tributaries are potentially contributing certain OCls to the San Joaquin River to cause fish taken from the San Joaquin River at Vernalis to show exceedances of the primary OCls of concern.

Fish taken recently from the San Joaquin River at Bowman Road and Highway 4 have had exceedances of one or more OCls. There has been no recent sampling of fish from the San Joaquin River at Mossdale. It would be expected, however, that they would also have an exceedance of total DDT.

Overall, with respect to the San Joaquin River watershed, the eastside and westside tributaries of the SJR contain fish with exceedances of one or more OCls. It also appears that these tributaries are discharging sufficient concentrations of some OCls to cause the fish taken from the San Joaquin River at Vernalis to contain excessive DDT, dieldrin, chlordane, toxaphene and PCBs.

Sacramento River Watershed. The Sacramento River and its tributaries above the Colusa Basin Drain (except at Keswick for PCBs), have been found, through recent fish collection, to have fish with OCls at less than the OEHHA screening value. While a 1997 sampling showed that there was an exceedance of PCBs in rainbow trout collected in the Sacramento River at Keswick, the subsequent samplings did not show this problem.

The Colusa Basin Drain is a main agricultural drain in the Central Sacramento Valley. Carp taken from the drain have been found to contain excessive DDT and dieldrin. White catfish did not contain excessive OCls. Previously, excessive chlordane and toxaphene have been found; however, there are no recently collected data with adequate sensitivity to ascertain the current situation with regard to toxaphene and chlordane in Colusa Basin Drain fish. The fish from this drain have recently been found to contain PCBs below the OEHHA screening value.

The recent white catfish and largemouth bass samplings from the Feather River near Nicolaus/Highway 99 have shown no exceedances of organochlorine pesticides. However, PCBs were found in pike minnow from the Feather River near Nicolaus/Highway 99 in excess of the OEHHA screening value.

In 1980, a variety of types of fish from the Feather River at Forbestown did show exceedances of PCBs. These exceedances relate to the use of PCB oils for road dust control. There has been no followup on this situation. It is suggested that this should be followed up to determine the current situation.

White catfish taken from the Sacramento Slough in 2000 contained excessive dieldrin and PCBs. Largemouth bass did not have excessive dieldrin, but did have excessive PCBs. DDT and chlordane were less than OEHHA screening values.

Sacramento River at Veteran's Bridge had excessive PCBs in white catfish.

Natomas East Main Drain white catfish and largemouth bass contained excessive PCBs.

Recently sampled largemouth bass from the American River had exceedances of PCBs, while excessive dieldrin was found in pike minnow.

Sacramento River at Mile 44 had excessive DDT, dieldrin and PCBs in white catfish and excessive DDT and PCBs in largemouth bass.

Sacramento River at Hood had white catfish and largemouth bass showing exceedances of all of the primary OCls of concern.

Excessive DDT was found in largemouth bass obtained from Putah Creek.

Largemouth bass from Cache Slough had exceedances of dieldrin.

Delta. The Port of Stockton Turning Basin had excessive PCBs and DDT in largemouth bass.

Dieldrin and PCBs were found in *Corbicula fluminea* sampled from the Port of Stockton near Mormon Slough.

Largemouth bass and white catfish taken from the Smith Canal at Yosemite Lake contained excessive PCBs.

The San Joaquin River below Turner Cut and the Central Delta have not recently been found to contain excessive OCls (DDT and PCBs) in fish.

Sycamore Slough near Mokelumne River had an exceedance of dieldrin found in largemouth bass.

White catfish taken from Old River at several locations have been found to contain excessive DDT and, at one location, PCBs. Excessive DDT was found in largemouth bass from Paradise Cut.

Tulare Lake Basin. No problems were encountered with excessive OCls in recently sampled King's River fish.

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Appendix B

Priorities, Data Gaps, and Research Needs[6]

Kenneth D. Landau, Assistant Executive Officer
Central Valley Regional Water Quality Control Board

CALFED and the Regional Board have worked together over the past several years to develop approaches for addressing water quality problems that impact Delta watershed beneficial uses. The priority problems that are included in the ROD and other CALFED documents are consistent with Regional Board priorities. Regional Board staff is working with various federal, state and local agencies: discharger groups; watershed groups and other stakeholders to address contaminants of concern.

All the contaminants we are working on cause widespread impairments, but research and information is needed, in most cases,

- to define the extent and magnitude of the problems,
- to identify the sources of contaminants,
- to determine how these sources interact in the environment to cause problems and
- to evaluate potential practices or actions that can be implemented to address the problems.

The priority issues the Regional Board is facing with regard to contaminant issues are:

- mercury,
- selenium,
- legacy pesticides,
- agricultural and urban use pesticides,
- endocrine disrupters,
- dissolved oxygen demand,
- unknown toxicity,
- total organic carbon. and
- salt

I will be discussing the data gaps and research needs that must be filled to effectively address these problems.

Mercury – The Regional Board has identified sites throughout the Central Valley Region that are impacted because of elevated levels of mercury in fish. This includes the Delta, Cache Creek, Sacramento River and many lakes and reservoirs. We have been working

[6] Presentation at California Bay-Delta Authority Workshop, "Contaminant Stressors in the Bay-Delta Watershed" – Policy & Management Session, February 4, 2004.

with CALFED and others over the past several years to address the mercury problem in the Delta and key tributaries. Our efforts have focused on:

- identification of the sources of mercury,
- determining the factors that influence mercury uptake in organisms, and
- identification of preliminary actions to address the problems.

More work is still needed in all these areas. In addition, more information is needed on the distribution of fish with elevated levels of mercury in their tissue. We need to know where the hot spots are and why fish in those areas contain higher levels of mercury than in other places. We also need to know who is eating the fish and develop a system for alerting the public to the health risks.

Selenium –sources, controls and treatment measures for selenium-affected waterbodies tributary to the Delta are well understood. Regulations and control programs are in place, or are being developed, to implement solutions for these remaining impairments. There are, however, continuing selenium bioaccumulation problems in the Bay. Research is needed to determine whether Central Valley selenium contributes to problems in the Bay, and whether additional water quality objectives or control measures are needed to protect the Bay.

Legacy Pesticides – such as DDT and other organochlorines were banned from use over 25 years ago because of their highly toxic and bioaccumulative nature. Studies show that the amount of these pesticides present in the environment and in fish tissue is declining. However, levels in fish from many water bodies are still too high. In order to address the problem, we need to know where these pesticides have accumulated and at what rate they are degrading. Then we will need to determine whether we can rely on the natural rate of decline to address the problem or whether we should takes steps to accelerate it. In addition, there are some sites in the watershed that appear to be receiving inputs of essentially undegraded pesticides. We need to collect information to identify the sources of this material.

Agricultural and Urban Use Pesticides –impair many waterbodies in the Central Valley. The extent and magnitude of the problems and the sources of the pesticides are not well defined. The effectiveness of alternative management practices and other actions in keeping pesticides out of Delta waters and tributaries to the Delta have not been fully evaluated. Some of this information may be developed through TMDLs and the irrigated agricultural waiver program. However, determining the impacts of the mix of pesticides entering Delta waters from the different sources will continue to be a challenge. In addition, more information is needed on sediment toxicity. There is evidence that pyrethroid insecticides, which are coming into wider use as organo phosphate pesticides are being phased out, have the potential to cause widespread sediment toxicity.

Endocrine Disrupting Chemicals –are present in the environment at high enough concentrations to effect resident aquatic life. Sources of these chemicals include pharmaceuticals present in wastewater treatment plant effluent and pesticides in agricultural return flows and runoff. The Pesticide Action Network reports that over 2 million pounds of suspected endocrine disrupting pesticides are applied in California every year. Little is known about the levels of these chemicals present in Central Valley waterways and what their effects on aquatic life are.

Dissolved Oxygen Depletion – in the Stockton Deep Water Ship Channel effectively forms a barrier to fish migration in the San Joaquin near Stockton for weeks at a time in the spring and fall. Progress has been made in identifying the causes of the problem related to loading. Additional work, however, needs to be done to confirm the sources of loads and the linkage of causes to sources in the upper watershed. Additional data and research is also needed to determine the appropriate concentrations of dissolved oxygen needed to protect beneficial uses in various Delta waterways. Specifically, issues need to be resolved regarding averaging periods and where and how objectives are applied in the water column.

Unknown Toxicity – The Regional Board has employed toxicity testing to assess Central Valley water quality since the late 1980's. Toxicity from pesticides in urban and agricultural runoff, metals in abandoned mine drainage, and pathogens have been identified and programs to remove the toxicity have been established. Yet the cause and source of many instances of toxicity were never identified.

As such many Central Valley waterbodies are considered impaired due to "unknown toxicity". The major questions that need to be answered include:

- is the historic toxicity continuing today?
- if so, what is the cause and how can the problem be addressed?

In order to answer these questions, more extensive toxicity monitoring and research to develop advanced toxicity identification evaluation and chemical analysis tools needs to be conducted.

Total Organic Carbon – is a constituent of concern for drinking water uses because it causes the formation of carcinogenic disinfection byproducts when the water is chlorinated at the drinking water treatment plant. TOC also is a necessary component of the food web. The Regional Board must consider both drinking water and ecosystem beneficial uses when establishing objectives for constituents of concern. Research is needed to determine the levels of TOC allowable in source water to meet drinking water limits for Disinfection By Products while ensuring that ecosystem needs for TOC are still met.

Salt – Salinity is a major problem in the San Joaquin River, impacting agricultural and municipal use of water in the San Joaquin River and the Delta. Although salinity at these concentrations is not directly an ecological impact, potential control measures could involve changes in water management at the farm and regional level, which could impact flows and water quality of ecological significance. A major challenge is understanding the interrelations of these various control efforts so that improvements in one area do not exacerbate problems in another area.

Appendix C

BIOLOGICAL STUDY

NONINDIGENOUS AQUATIC SPECIES IN A UNITED STATES ESTUARY:

A CASE STUDY OF THE BIOLOGICAL INVASIONS OF THE SAN FRANCISCO BAY AND DELTA

Andrew N. Cohen[1]
Energy and Resources Group
University of California at Berkeley
Berkeley California 94720

James T. Carlton
Maritime Studies Program
Williams College - Mystic Seaport
Mystic, Connecticut

A Report for the

UNITED STATES FISH AND WILDLIFE SERVICE[2]
WASHINGTON, D. C.
December 1995

Copies may be obtained:

U.S. Fish & Wildlife Service
Division of Fish and Wildlife Management Assistance
4401 N. Fairfax Dr., Room 840
Arlington, VA 22203
(703) 358-2025
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National Technical Information Service
Springfield, VA 22161
(800) 553-6847 or (703)487-4650
Report No. PB96-166525
Cost: $49.00 plus $4.00 shipping

1 Current address: San Francisco Estuary Institute, 180 Richmond Field Station, 1325 South 46th Street, Richmond, CA 94804.

2 Funding provided to authors through Connecticut Sea Grant Program (National Oceanic and Atmospheric Administration Grant No. 36RG0467).

Executive Summary

1. THE SAN FRANCISCO BAY AND DELTA REGION IS A HIGHLY INVADED ECOSYSTEM

   - The San Francisco Estuary can now be recognized as the most invaded aquatic ecosystem in North America. Now recognized in the Estuary are 212 introduced species: 69 percent of these are invertebrates, 15 percent are fish and other vertebrates, 12 percent are vascular plants and 4 percent are protists.

   - In the period since 1850, the San Francisco Bay and Delta region has been invaded by an average of one new species every 36 weeks. Since 1970, the rate has been at least one new species every 24 weeks: the first collection records of over 50 non-native species in the Estuary since 1970 thus appear to reflect a significant new pulse of invasions.

   - In addition to the 212 recognized introductions, 123 species are considered as cryptogenic (not clearly native or introduced), and the total number of cryptogenic taxa in the Estuary might well be twice that. Thus simply reporting the documented introductions and assuming that all other species in a region are native—as virtually all previous studies have done—severely underestimates the impact of marine and aquatic invasions on a region's biota.

     Nonindigenous aquatic animals and plants have had a profound impact on the ecology of this region. No shallow water habitat now remains uninvaded by exotic species and, in some regions, it is difficult to find any native species in abundance. In some regions of the Bay, 100% of the common species are introduced, creating "introduced communities." In locations ranging from freshwater sites in the Delta, through Suisun and San Pablo Bays and the shallower parts of the Central Bay to the South Bay, introduced species account for the majority of the species diversity.

2. A VAST AMOUNT OF ENERGY NOW PASSES THROUGH AND IS UTILIZED BY THE NONINDIGENOUS BIOTA OF THE ESTUARY. IN THE 1990s, INTRODUCED SPECIES DOMINATE MANY OF THE ESTUARY'S FOOD WEBS.

   - The major bloom-creating, dominant phytoplankton species are cryptogenic. Because of the poor state of taxonomic and biogeographic knowledge, it remains possible that many of the Estuary's major primary producers that provide the phytoplankton-derived energy for zooplankton and filter feeders, are in fact introduced.

   - Introduced species are abundant and dominant throughout the benthic and fouling communities of San Francisco Bay. These include 10 species of introduced bivalves, most of which are abundant to extremely abundant. Introduced filter-feeding polychaete worms and crustaceans may occur by the thousands per square meter. On sublittoral hard substrates, the Mediterranean mussel *Mytilus galloprovincialis* is abundant, while float fouling communities support large populations of introduced filter feeders, including bryozoans, sponges and seasquirts. The holistic role of the entire nonindigenous filter-feeding guild—including clams, mussels, bryozoans, barnacles, seasquirts, spionid worms, serpulid worms, sponges, hydroids, and sea anemones—in altering and controlling the trophic dynamics of the Bay-Delta system remains unknown. The potential role of just one species, the Atlantic ribbed marsh mussel *Arcuatula demissa,* as a biogeochemical agent in the economy of Bay salt marshes is striking.

- Introduced clams are capable of filtering the entire volume of the South Bay and the northern estuarine regions (Suisun Bay) once a day; indeed, it now appears that the primary mechanism controlling phytoplankton biomass during summer and fall in South San Francisco Bay is "grazing" (filter feeding) by the introduced Japanese clams *Venerupis* and *Musculista* and the Atlantic clam *Gemma*. This remarkable process has a significant impact on the standing phytoplankton stock in the South Bay, and since this plankton is now utilized almost entirely by introduced filter feeders, passing the energy through a non-native benthic fraction of the biota may have fundamentally altered the energy available for native biota.

- Drought year control of phytoplankton by introduced clams—resulting in the failure of the summer diatom bloom to appear in the northern reach of the Estuary—is a remarkable phenomenon. The introduced Atlantic soft-shell clams *(Mya)* alone were estimated to be capable at times of filtering all of the phytoplankton from the water column on the order of once per day. Phytoplankton blooms occurred only during higher flow years, when the populations of *Mya* and other introduced benthic filter feeders retreated downstream to saltier parts of the Estuary.

- Phytoplankton populations in the northern reaches of the Estuary may now be continuously and permanently controlled by introduced clams. Arriving by ballast water and first collected in the Estuary in 1986, by 1988 the Asian clam *Potamocorbula* reached and has since sustained average densities exceeding 2,000/m^2. Since the appearance of *Potamocorbula,* the summer diatom bloom has disappeared, presumably because of increased filter feeding by this new invasion. The *Potamocorbula* population in the northern reaches of the Estuary can filter the entire water column over the channels more than once per day and over the shallows almost 13 times per day, a rate of filtration which exceeds the phytoplankton's specific growth rate and approaches or exceeds the bacterioplankton's specific growth rate.

- Further, the Asian clam *Potamocorbula* feeds at multiple levels in the food chain, consuming bacterioplankton, phytoplankton, and zooplankton (copepods), and so may substantially reduce copepod populations both by depletion of the copepods' phytoplankton food source and by direct predation. In turn, under such conditions, the copepod-eating native opossum shrimp *Neomysis* may suffer a near-complete collapse in the northern reach. It was during one such pattern that mysid-eating juvenile striped bass suffered their lowest recorded abundance. This example and the linkages between introduced and native species may provide a direct and remarkable example of the potential impact of an introduced species on the Estuary's food webs.

- As with the guild of filter feeders, the overall picture of the impact of introduced surfacedwelling and shallow-burrowing grazers and deposit feeders in the Estuary is incompletely known. The Atlantic mudsnail *Ilyanassa* is likely playing a significant—if not the most important—role in altering the diversity, abundance, size distribution, and recruitment of many species on the intertidal mudflats of San Francisco Bay.

- The arrival and establishment in 1989-90 of the Atlantic green crab *Carcinus maenas* in San Francisco Bay signals a new level of trophic change and alteration. The green crab is a food and habitat generalist, capable of eating an extraordinarily wide variety of animals and plants, and capable of inhabiting marshes, rocky substrates, and fouling communities. European, South African, and recent Californian studies indicate a broad and striking potential for this crab to significantly alter the distribution, density, and abundance of prey species, and thus *to* profoundly alter community structure in the Bay.

- Nearly 30 species of introduced marine, brackish and freshwater fish are now important carnivores throughout the Bay and Delta. Eastern and central American fish — carp, mosquitofish, catfish, green sunfish, bluegills, inland silverside, largemouth and smallmouth bass, and striped bass—are among the most significant predators, competitors, and habitat disturbers throughout the brackish and freshwater reaches of the Delta, with often concomitant impacts on native fish communities. The introduced crayfish *Procambaras* and *Pacifastacus* may play an important role, when dense, in regulating their prey plant and animal populations.

- Native waterfowl in the Estuary consume some introduced aquatic plants (such as brass buttons) and native shorebirds feed extensively on introduced benthic invertebrates.

3. INTRODUCED SPECIES MAY BE CAUSING PROFOUND STRUCTURAL CHANGES TO SOME OF THE ESTUARY'S HABITATS.

- The Atlantic salt marsh cordgrass *Spartina alterniflora,* which has converted 100s of acres of mudflats in Willapa Bay, Washington, into grass islands, has become locally abundant in San Francisco Bay, and is competing with the native cordgrass. *Spartina alterniflora* has broad potential for ecosystem alteration. Its larger and more rigid stems, greater stem density, and higher root densities may decrease habitat for native wetland animals and infauna. Dense stands of *S. alterniflora* may cause changes in sediment dynamics, decreases in benthic algal production because of lower light levels below the cordgrass canopy, and loss of shorebird feeding habitat through colonization of mudflats.

- The Australian-New Zealand boring isopod *Sphaeroma quoyanum* creates characteristic *"Sphaeroma* topography" on many Bay shores, with many linear meters of fringing mud banks riddled with its half-centimeter diameter holes. This isopod may arguably play a major, if not the chief, role in erosion of intertidal soft rock terraces along the shore of San Pablo Bay, due to their boring activity that weakens the rock and facilitates its removal by wave action. *Sphaeroma* has been burrowing into Bay shores for over a century, and it thus may be that in certain regions the land/water margin has retreated by a distance of at least several meters due to this isopod's boring activities.

4. WHILE NO INTRODUCTION IN THE ESTUARY HAS UNAMBIGUOUSLY CAUSED THE EXTINCTION OF A NATIVE SPECIES, INTRODUCTIONS HAVE LED TO THE COMPLETE HABITAT OR REGIONAL EXTIRPATION OF SPECIES, HAVE CONTRIBUTED TO THE GLOBAL EXTINCTION OF A CALIFORNIA FRESHWATER FISH, AND ARE NOW STRONGLY CONTRIBUTING TO THE FURTHER DEMISE OF ENDANGERED MARSH BIRDS AND MAMMALS.

    - Introduced freshwater and anadromous fish have been directly implicated in the regional reduction and extinction, and the global extinction, of four native California fish. The bluegill, green sunfish, largemouth bass, striped bass, and black bass, through predation and through competition for food and breeding sites, have all been associated with the regional elimination of the native Sacramento perch from the Delta. The introduced inland silversides may be a significant predator on the larvae and eggs of the native Delta smelt. Expansion of the introduced smallmouth bass has been associated with the decline in the native hardhead. Predation by largemouth bass, smallmouth black bass and striped bass may have been a major factor in the global extinction of the thicktail chub in California.

    - The situation of the California clapper rail may serve as a model to assess how an endangered species may be affected by biological invasions. The rail suffers predation by introduced Norway rats and red fox; it may both feed on and be killed by introduced mussels; and it may find refuge in introduced cordgrass, although this same cordgrass may compete with native cordgrass, perhaps preferred by the rail. Other potential model study systems include introduced crayfish and their displacement of native crayfish; introduced gobies and their relationship to the tidewater goby; and the combined role that introduced green sunfish, bluegill, largemouth bass, and American bullfrog may have played in the dramatic decline of native red-legged and yellow-legged frogs.

5. THOUGH THE ECONOMIC IMPACTS OF INTRODUCED ORGANISMS IN THE SAN FRANCISCO ESTUARY ARE SUBSTANTIAL, THEY ARE POORLY QUANTIFIED.

    - Although some of the fish intentionally introduced into the Estuary by government agencies supported substantial commercial food fisheries, these fisheries all declined after a time and are now closed. The signal crayfish, *Pacifastacus,* from Oregon, whose exact means of introduction is unclear, supports the Estuary's only remaining commercial food fishery based on an introduced species.

    - The striped bass sport fishery has resulted in a substantial transfer of funds from anglers to those who supply anglers' needs, variously estimated, between 1962 and 1992, between $7 million and $45 million per year. However, striped bass populations and the striped bass sport fishery have declined dramatically in recent years.

    - Government introductions of organisms for sport fishing, as forage fish and for biocontrol have frequently not produced the intended benefits, and have sometimes had harmful "side effects," such as reducing the populations of economically important species.

- Few nonindigenous organisms that were introduced to the Estuary by other than government intent have produced economic benefits. The clams *Mya* and *Venerupis*, accidentally introduced with Atlantic oysters, have supported commercial harvesting in the Bay or elsewhere on the Pacific coast, and a small amount of recreational harvesting in the Bay (though these clams may have, to some extent, replaced edible native clams); the Asian clam *CorbicuIa* is commercially harvested for food and bait in California on a small scale; the Asian yellowfin goby is commercially harvested for bait; muskrat are trapped for furs; and the South African marsh plant brass buttons provides food for waterfowl. There do not appear to be any other significant economic benefits that derive from nongovernmental or accidental introductions to the Estuary.

- A single introduced organism, the shipworm *Teredo navalis*, caused $615 million (in 1992 dollars) of structural damage to maritime facilities in 3 years in the early part of the 20th century.

- The economic impacts of hull fouling and other ship fouling are clearly very large, but are not documented or quantified for the Estuary. Most of the fouling incurred in the Estuary is due to nonindigenous species. Indirect impacts due to the use of toxic anti-fouling coatings may also be substantial.

- Waterway fouling by introduced water hyacinth has become a problem in the Delta over the last fifteen years, with other introduced plants beginning to add to the problem in recent years. Hyacinth fouling has had significant economic impacts, including interference with navigation.

- Perhaps the greatest economic impacts may derive from the destabilizing of the Estuary's biota due to the introduction and establishment of an average of one new species every 24 weeks. This phenomenal rate of species additions has contributed to the failure of water users and regulatory agencies to manage the Estuary so as to sustain healthy populations of anadromous and native fish, resulting in increasing limitations and threats of limitations on water diversions, wastewater discharges, channel dredging, levee maintenance, construction and other economic activities in and near the Estuary, with implications for the whole of California's economy.

RESEARCH NEEDS

Much remains unknown in terms of the phenomena, patterns, and processes of invasions in the Bay and Delta, and thus large gaps remain in the knowledge needed to establish effective management plans. The following are examples of important research needs and directions:

1. EXPERIMENTAL ECOLOGY OF INVASIONS

Only a few of the hundreds of invaders in the Estuary have been the subject of quantitative experimental studies elucidating their roles in the Estuary’s ecosystem and their impacts on native biota. Such studies should receive the highest priority.

2. REGIONAL SHIPPING STUDY

Urgently required is a San Francisco Bay Shipping Study which both updates the 1991 data base available and expands that data base to all Bay and Delta ports. A biological and ecological study of the nature of ballast water biota arriving in the Bay/Delta system is urgently required. Equally pressing is a study of the fouling organisms entering the Estuary on ships' hulls and in ships' seachests, in order to assess whether this mechanism is now becoming of increasing importance and in order to more adequately define the unique role of ballast water. A Regional Shipping Study would provide critical data for management plans.

3. INTRAREGIONAL HUMAN-MEDIATED DISPERSAL VECTORS

Studies are required on the mechanisms and the temporal and spatial scales of the distribution of introduced species by human vectors after they have become established. Such studies will be of particular value in light of any future introductions of nuisance aquatic pests.

4. STUDY OF THE BAITWORM AND LOBSTER SHIPPING INDUSTRIES

This study has identified a major, unregulated vector for exotic species invasions in the Bay: the constant release of invertebrate-laden seaweeds from New England in association with bait worm (and lobster) importation. In addition a new trade in exotic bait has commenced, centered around the importation of living Vietnamese nereid worms, and both the worms and their substrate deserve detailed study. These studies are urgently needed to address the attendant precautionary management issues at hand.

5. MOLECULAR GENETIC STUDIES OF INVADERS

The application of modern molecular genetic techniques has already revealed the cryptic presence of previously unrecognized invaders in the Bay: the Atlantic clam *Macoma petalum,* the Mediterranean mussel *Mytilus galloprovincialis,* and the Japanese jellyfish *Amelia "aurita."* Molecular genetic studies of the Bay's new green crab (*Carcinus*) population may be of critical value in resolving the crab's geographic origins and thus the mechanism that brought it to California. Molecular genetic studies of worms of the genus *Glycera* and *Nereis* in the Bay may clarify if New England populations have or are becoming established in the region as a result of ongoing inoculations via the bait worm industry. Molecular analysis of other invasions will doubtless reveal, as with *Macoma* and *Mytilus*, a number of heretofore unrecognized species.

6. INCREASED UTILIZATION OF EXOTIC SPECIES

Fishery, bait, and other utilization studies should be conducted on developing or enlarging the scope of fisheries for introduced bivalves (such as *Mya, Venerupis,* and *Corbicula),* edible aquatic plants, smaller edible fish (such as *Acanthogobius),* and crabs (*Carcinus* and *Eriocheir).*

7. POTENTIAL ZEBRA MUSSEL INVASION

Studies are needed on the potential distribution, abundance and impacts of zebra mussels (*Dreissena polymorpha* and/or *D. bugensis*) in California, to support efforts to control their introduction and to design facilities (such as water intakes and fish screens) that will continue to function adequately should the mussels become established.

8. ECONOMIC IMPACTS OF WOOD BORERS AND FOULING ORGANISMS

The economic impacts of wood-boring organisms (shipworms and gribbles) and of fouling organisms (on commercial vessels, on recreational craft, in ports and marinas, and in water conduits) are clearly very large in the San Francisco Estuary, but remain largely undocumented and entirely unquantified. A modern economic study of this phenomenon, including the economic costs and ecological impacts of control measures now in place or forecast, is critically needed.

9. ECONOMIC, ECOLOGICAL AND GEOLOGICAL IMPACTS OF BIOERODING NONINDIGENOUS SPECIES

Largely qualitative data suggest that the economic, ecological, and geological impacts of the guild of burrowing organisms that have been historically and newly introduced have been or are forecast to potentially be extensive in the Estuary. Experimental, quantitative studies on the impacts of burrowing and bioeroding crustaceans and muskrats in the Estuary are clearly now needed to assess the extent of changes that have occurred or are now occurring, and to form the basis for predicting future alterations in the absence of control measures.

10. POST INVASION CONTROL MECHANISMS

While primary attention must be paid to preventing future invasions, studies should begin on examining the broad suite of potential post invasion control mechanisms, including biocontrol, physical containment, eradication, and related strategies. A Regional Control Mechanisms Workshop for past and anticipated invasions could set the foundation for future research directions.

Appendix D
Drs. G. Fred Lee and Anne Jones-Lee's Background
Pertinent to Assessment of Delta Water Quality

Dr. G. Fred Lee is President of G. Fred Lee & Associates, which consists of Drs. G. Fred Lee and Dr. Anne Jones-Lee (Vice President) as the principals in the firm. This discussion of Delta water quality is based on G. Fred Lee's academic background and professional experience, which includes a BA degree from San Jose State College in environmental health sciences 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 and, for a several-year period, 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-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.

Overall, Dr. Lee is highly familiar with how water quality criteria have been developed, their strengths and weaknesses, and, most importantly, their proper application in water quality management programs. He and Dr. Jones-Lee published an invited paper, "Appropriate Use of Numeric Chemical Water Quality Criteria," discussing how the US EPA criteria and state water quality standards based on these criteria should be implemented, considering the approach for their development and their appropriate use to regulate constituents in ambient waters from various sources.

In 1989, Dr Lee retired from university teaching and research and expanded his 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, 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 490 papers and reports covering work they have done in their various areas of activity. One of these areas is Delta water quality.

Dr Lee's international work as a water quality adviser included serving as the US representative to the Organization of Economic Cooperation and Development (OECD) eutrophication studies. This was a 22-country, 200-waterbody, 50-million-dollar effort that was conducted in the 1970s, relating nutrient loads to eutrophication response for waterbodies located in western Europe, North America, Japan and Australia. Dr. Jones-Lee and Dr. Lee have been advisers to Spain on developing water quality management programs for Spain's approximately 800 reservoirs, the USSR on developing water quality management programs for the Volga River Basin, Italy on developing management approaches for excessive fertilization of the Adriatic coast between Venice and Rimini, Israel (Sea of Galilee), Jordan on surface (King Talal Reservoir) and groundwater quality protection, Tunisia on its coastal marine waters, Japan on Seto Inland Sea water quality management issues, South Africa on managing water quality in reservoirs, Egypt on managing pesticide residues as they can impact water quality in the Nile River, the Netherlands on water quality management in the new waterbody then proposed to be created behind the Delta Works which was to be filled with Rhine River water, France on managing excessive fertilization of freshwater waterbodies, and Norway on lake water quality. Dr. Lee has also been adviser to the US-Canadian International Joint Commission for the Great Lakes, where he served on a number of advisory panels for investigating and managing Great Lakes water quality issues. His international work has included studies in Antarctica on nutrient load eutrophication response for an Antarctic lake. The best way to become familiar with Dr. Jones-Lee and Dr. Lee's current activities is through their website, www.gfredlee.com, which lists the papers and reports that they have developed since they have been full-time consultants.

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. He is familiar with the various attempts by members of the CALFED administration to develop a credible water quality management program.

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. With respect to the Sacramento River, he worked with the Central Valley Regional Water Quality Control Board (CVRWQCB) staff in helping to develop the Sacramento River Watershed Program, with particular emphasis on the monitoring aspects of this program. Beginning in the 1990s he began to work with William Jennings (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. Through support provided from litigation settlements between the DeltaKeeper and various communities, where by mutual agreement part of the funds in the settlement were made available for Dr. Lee to support the Steering Committee for the San Joaquin River low-DO TMDL, beginning in 1999 Dr. Lee worked closely with the SJR DO TMDL Steering Committee as well as the Regional 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

A group of researchers submitted a proposal to CALFED in June 2000 that was a miscellaneous, unprioritized request for funds to support a group of projects that were, to some extent, related to the low-DO problem. CALFED did not support this proposal. Dr. Lee was asked by the Steering Committee to assume the leadership for developing the revised Directed

Action proposal to CALFED. With support from the DeltaKeeper through litigation settlements, 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 are developing a synthesis report supplement that presents a review of the various studies that they have conducted over the past year that are pertinent to investigating and managing Delta water quality issues.

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