Synopsis of CWEMF Delta
Nutrient Water Quality Modeling Workshop

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Presented below is a synopsis of the California Water and Environmental Modeling Forum (CWEMF) "Delta Nutrient Water Quality Modeling Workshop" that was held on March 25, 2008 in Sacramento, California. That workshop, attended by about 115 individuals, was designed to provide an overview of the current nutrient-related water quality issues and problems (based on impairment of beneficial uses) in the Sacramento San Joaquin Delta. It also focused on the current ability to model the relationships between nutrient (nitrogen and phosphorus) loads/concentrations and nutrient-related water quality problems. CWEMF has posted the PowerPoint slides for most of the workshop presentations on its website,
http://www.cwemf.org/workshops/NutrientLoadWrkshp.pdf, in the Workshop section.

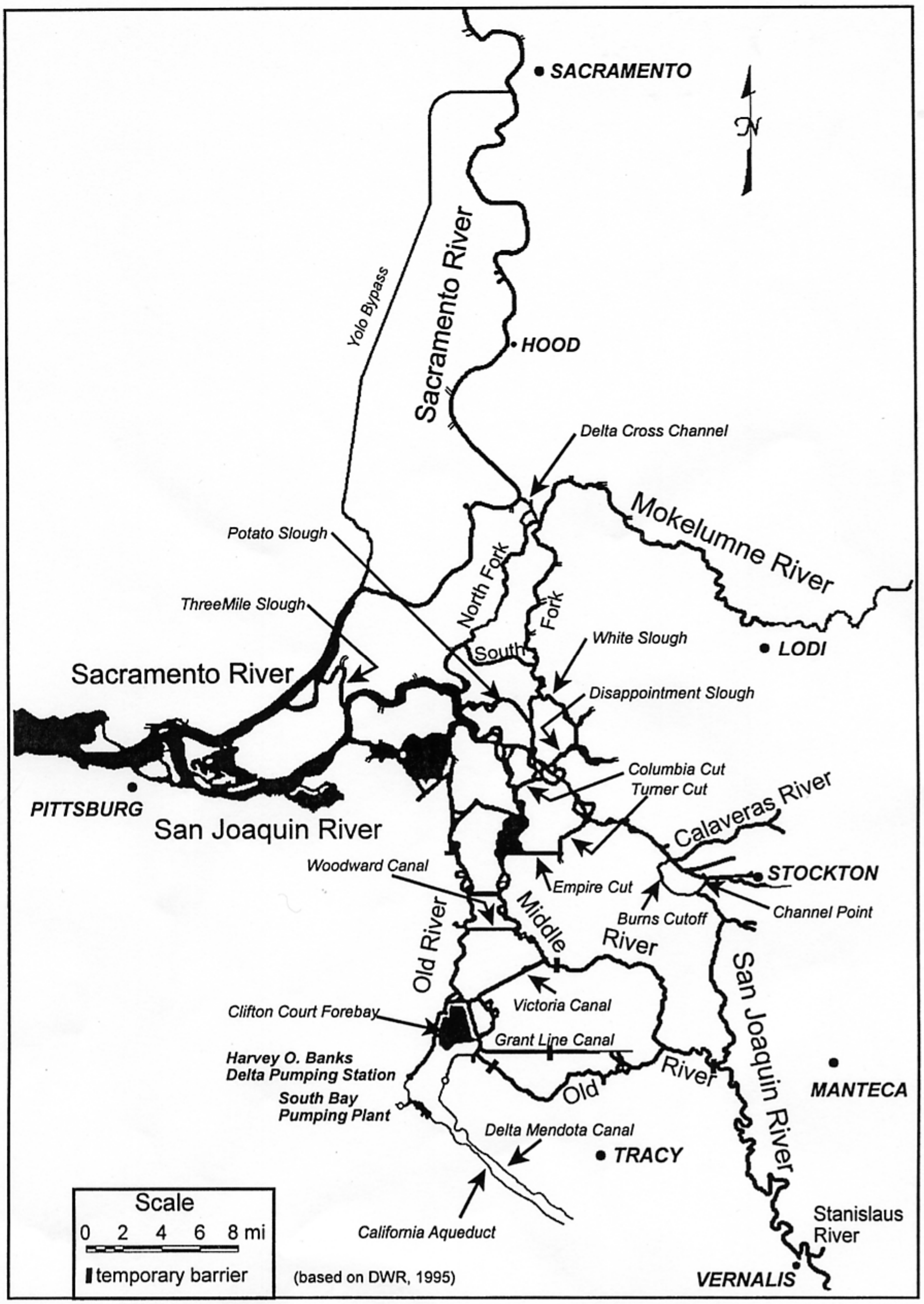
In this write-up Dr. G. Fred Lee, conference organizer, reviews key issues discussed by the speakers, and provides additional information from the literature on issues that are pertinent to the topics covered by the speakers. For greatest clarity, it is recommended that these comments be reviewed along-side the PowerPoint slides for the presentations. While the focus of the workshop and these comments is Sacramento San Joaquin Delta nutrient-related water quality problems, this discussion includes information that has applicability to investigating and managing nutrient-related water quality problems in other waterbodies as well.

The Delta

As shown in Figure 1, the Sacramento San Joaquin Delta is formed by the confluence of the Sacramento and San Joaquin Rivers, and discharges to the Pacific Ocean through San Francisco Bay. It is a freshwater, tidal system. The Sacramento and San Joaquin Rivers and the Delta are the major surface waters in California, and provide domestic water supply for more than 23-million people and water for several million acres of irrigated agriculture. The waters in the rivers and the Delta are highly managed through storage reservoirs and diversions to enhance domestic and agricultural water supply for many areas of the state. They also provide important recreational areas, and support anadramous and other fish. As discussed at the workshop, the water quality in the Delta is severely deteriorated due to nutrients discharged from irrigated agriculture and municipalities. While the excessive fertilization of the Delta is well-known and long-standing, these problems have not yet been adequately addressed by state or federal regulatory agencies. This workshop was intended to draw attention to these problems and their significance.

Background information on the Delta and its characteristics is provided in the California Department of Water Resources "Delta Atlas"

Figure 1 Map of the Delta


SACRAMENTO
N
Yolo Bypass
Sacramento River
HOOD
Delta Cross Channel
Mokelumne River
Potato Slough
North Fork
South Fork
ThreeMile Slough
White Slough
LODI
Sacramento River
Disappointment Slough
Columbia Cut
Turner Cut
PITTSBURG
San Joaquin River
Calaveras River
STOCKTON
Woodward Canal
Empire Cut
Burns Cutoff
Channel Point
Middle River
Old River
Victoria Canal
Clifton Court Forebay
Grant Line Canal
Harvey O. Banks Delta Pumping Station
Old River
San Joaquin River
MANTECA
South Bay Pumping Plant
Delta Mendota Canal
TRACY
Scale
0 2 4 6 8 mi
temporary barrier
California Aqueduct
(based on DWR, 1995)
Stanislaus River
VERNALIS

(http://baydeltaoffice.water.ca.gov/DeltaAtlas/index.cfm). Newsletter Volume 10 nos. 10&11 (http://www.members.aol.com/LFandWQ/swnews101011.pdf) provides background information on resource management issues and water quality management issues in the Delta.

Workshop Introduction

Rich Satkowski, Executive Director of CWEMF Sacramento, CA (cwemf@cwemf.org) opened the workshop by providing information on CWEMF and background to the workshop. Background information on CWEMF is available at, http://www.cwemf.org.

Dr. G. Fred Lee, President of G. Fred Lee & Associates (gfredlee@aol.com), reviewed the topics to be covered in the workshop, pointing out that the primary purpose of the workshop was to provide a introduction to the occurrence, magnitude, and water quality significance of the nutrient (nitrogen and phosphorus compounds)-caused water quality problems in the Delta and water supply reservoirs that receive Delta waters. The major nutrient-related water quality problems in the Delta considered are domestic drinking water taste and odors and toxicity, excessive growths of water weeds such as water hyacinth and egeria, and the low dissolved oxygen (DO) that occurs in the San Joaquin River (SJR) Deep Water Ship Channel (DWSC) near the Port of Stockton.

In addition, a brief introduction was presented on how changes in the phosphorus loads in the Sacramento River impacted the phosphorus concentrations and phytoplankton concentrations in the Delta. A summary of a conceptual model for nutrient sources for the Delta was presented at the workshop. The final session of the workshop was devoted to a brief review of the regulatory issues for controlling the water quality problems caused by nutrients.
Background information on the development of the workshop is available at,

> Lee, G. F., and Jones-Lee, A., "Delta Nutrient Water Quality Modeling Workshop — Background Information," Report of G. Fred Lee & Associates, El Macero, CA, September (2007).
> http://www.members.aol.com/GFLEnviroQual/NutrWorkshopRev4.pdf

Newsletter NL 11-2 (http://www.members.aol.com/LFandWQ/swnews1102.pdf) also provides additional background information on Delta nutrient water quality issues that are pertinent to the March 25 Workshop and potential followup workshops.

In his introductory remarks on the organization of the workshop, Dr. Lee mentioned that the initial workshop would not address the issue of the role of nutrients as the base of the phytoplankton-based food web in the Delta. While that issue would be important in the development of a nutrient management program for the Delta, it was beyond the scope of the present workshop. In his review of the current phytoplankton biomass in the Delta, Dr. A. Jassby indicated that fish production in the Delta is limited by algal (primary production) biomass.

> Jassby, A., "Phytoplankton Biomass and production in the Delta and Suisun Bay: Current Conditions and Trends," IEP Newsletter **19**(2):51-56 Spring (2006).
> http://iep.water.ca.gov/report/newsletter/2006_newsletters/IEPNewsletter_spring2006final5.pdf

Lee pointed out that reducing the nutrient loads, especially the phosphorus loads, to the Delta would be in the direction reducing primary production in the Delta, which could, in turn, have detrimental impacts on Delta fish production. The relationship between nutrient loads to waterbodies located in various areas of the world and their associated fish production was discussed by Lee and Jones-Lee in,

> Lee, G. F. and Jones, R. A., "Effects of Eutrophication on Fisheries," Reviews in Aquatic Sciences 5:287-305, CRC Press, Boca Raton, FL (1991)
> http://www.gfredlee.com/fisheu.html

A slide of the primary relationship of nutrients and fish production developed by Lee and Jones-Lee was included in Dr. Lee's PowerPoint slides. This and several other Delta nutrient water quality issues, such as those listed in Dr. Lee's slide on possible follow on workshops, could be covered in more detail in follow-on workshops. A list of potential follow-on workshops is discussed below.

Flow Patterns in the Delta

Tara Smith, Chief of the Delta Modeling Bay-Delta Office of the California Department of Water Resources, Sacramento, CA (tara@water.ca.gov) discussed the flow patterns of the Sacramento River and San Joaquin River through the Delta. Ms Smith's PowerPoint slides were not included in those posted by CWEMF because they incorporated animated particle tracking slides to show how water from the tributary rivers flows through the Delta.

The patterns of flow of the Delta water and the associated nutrients are of importance since the San Joaquin River has lower flows but higher concentrations of nutrients than the Sacramento River. Except during the Vernalis Adaptive Management Program (VAMP) from April 15 through May 15, when the Head of Old River barrier is typically in place and the USBR and DWR export projects are operating at low or no export rates, the San Joaquin River flow is typically restricted to the South Delta prior to being exported by the two export projects. Information on VAMP is available at http://www.delta.dfg.ca.gov/jfmp/vamp.asp.

Following the completion of their SJR DWSC low-DO synthesis report discussed below, Drs. Lee and Jones-Lee conducted several special-purpose studies, with the support of the DeltaKeeper (William Jennings), on the flow of the SJR and Sacramento Rivers as it enters the Delta and moves through the Delta channels to the USBR and DWR Delta water export projects at Tracy and Banks as well discharges to San Francisco Bay. Their reports on that work provide important information on how SJR water and associated potential pollutants are transported through the Delta.

> Lee, G. F.; Jones-Lee, A. and Burr, K., "Results of the August 5, 2003, Tour of the South Delta Channels," Report of G. Fred Lee & Associates, El Macero, CA (2004).
> http://www.members.aol.com/duklee2307/South-Delta-Tour.pdf

> Lee, G. F.; Jones-Lee, A. and Burr, K., "Summary of Results from the July 17, 2003, and September 17, 2003, Tours of the Central Delta Channels," Report of G. Fred Lee & Associates, El Macero, CA (2004).
> http://www.members.aol.com/duklee2307/Central-Delta-Tours.pdf

Subsequent to Lee and Jones-Lee's work, Monsen et al. published their findings regarding the effects of the flow diversions from the Delta.

Monsen, N., Cloern, J., and Burau, J., “Effects of Flow Diversions on Water and Habitat Quality: Examples from California’s Highly Manipulated Sacramento–San Joaquin Delta,” San Francisco Estuary & Watershed Science, Vol. 5, Issue 3, Article 2, July (2007) http://repositories.cdlib.org/jmie/sfews/vol5/iss3/art2

The Sacramento River flow through the Delta is primarily controlled by the drawing of river water by the South Delta export project pumps, which have, in the past, drawn as much as about 13,000 cfs. Substantial Sacramento River water is drawn from its channel to those pumps via the Delta Cross Channel when its gates are open, and through Old River and Middle River channels in the Central Delta. Information on the Delta Cross Channel is available at http://baydeltaoffice.water.ca.gov/ndelta/TDF/. The CALFED Science Program Workshop, “A Two-Part Discussion on Delta Conveyance Modeling in Support of the Delta Vision Blue Ribbon Task Force Workshop 1: Modeling Approaches” that was held on April 3, 2008 also provides information on some of the issues pertinent to the flow of water through Delta Channels. That workshop was webcast and is archived at, http://www.visualwebcaster.com/event.asp?regd=y&id=46840.

Drinking Water Quality of the Delta Waters

Dr. Jeff Janik, Limnologist with the California Department of Water Resources, Sacramento, CA (jjanik@water.ca.gov) and **Dr. Rich Losee** of the Metropolitan Water District of Southern California Water Quality Laboratory, LaVerne, CA (rlosee@mwdh2o.com) described the nutrient-related water quality problems in Delta waters, the California Aqueduct, and Southern California water supply reservoirs that receive Delta waters. They described how, at times, the algae that grow in those waters cause severe taste and odor problems for domestic water supplies. Janik’s and Losee’s PowerPoint slides, available on the CWEMF website, summarize those issues.

The frequency and magnitude of taste and odor problems in Delta-based domestic water supplies have been increasing over the past 10 to 15 years. While the reasons for this increase are not well-understood, tastes and odors in the Delta water supplies are caused by chemicals (primarily geosmin and methylisoborneo [MIB]) apparently released by benthic bluegreen algae. Domestic water utilities have to spend substantial amounts of money to treat the water supplies with activated carbon and/or ozone to remove the chemicals that cause the tastes and odors. The domestic water supply tastes and odors are of concern in that those conditions cause the public to perceive, albeit incorrectly, that the water is not safe to drink. This promotes increased use of purchased bottled water at great cost to the public.

In addition to taste and odor problems, water utilities experience shortened filter runs when planktonic algae plug the filters; the water treatment plants have to use more of the treated water to backwash the filters. This also increases the costs of domestic water treatment.

The Metropolitan Water District of Southern California staff has been practicing selective copper sulfate treatment of reservoirs that have benthic algal mats in order to control the algae that are contributing to taste and odors.

In addition to large benthic mats of bluegreen and other types of algae, the large blooms of planktonic algae, particularly planktonic bluegreen algae, are also of concern for water quality problems. Such blooms are more typical of eutrophic (excessively fertile) lakes. The blooms of bluegreen algae can greatly impair recreational use of waterbodies. Also, the bluegreen algae are known to be of less nutritive value to zooplankton. This is of concern in the current pelagic organism decline (POD) which is affecting several types of small fish including the endangered Delta Smelt. Information on the POD is available at,
http://www.science.calwater.ca.gov/pod/pod_index.html.

Some of the bluegreen algae produce toxic chemicals that, in water supplies, can be of concern for human health. However, DWR monitoring has shown that the concentrations of algae-produced toxic chemicals are below those that are considered to be toxic to humans. While not discussed by Dr. Janik, there is also concern about the potential toxicity of bluegreen algal toxins to aquatic life including fish and wildlife. That issue has been reviewed by Lehman in:

> P. W. Lehman, G. Boyer, S. Teh, E. Bass and C. Hogel, "*Microcystis* Biomass and Toxicity," Prepared for the Interagency Ecological Program Pelagic Organism Decline work group, September 30, (2005),
> http://www.science.calwater.ca.gov/pod/pod_csp.html

They concluded that there is need for more study to evaluate whether bluegreen algae blooms that occur in the Delta are causing toxicity to the foodweb.

Dr. Paul Hutton, Senior Engineer of the Metropolitan Water District of Southern California Water Resources Management Group, Sacramento, CA (phutton@mwdh2o.com) discussed current issues and the status of modeling of nutrient loads/concentrations and domestic water supply water quality problems in the Delta. He indicated that at this time there is limited ability to relate nutrient loads or in-channel concentrations to domestic water supply water quality. While there is some ability to model the relationship between the nutrient load to a waterbody and the planktonic algal biomass that develops in the waterbody, it is not possible to adequately model the relationship between nutrient load to a waterbody and the development of benthic and attached algae in that waterbody.

An extremely complex issue is the relationship between nutrient loads and taste and odor problems in water supplies related to benthic algal mats. Overall, it not possible to predict how reducing the nutrient loads to the Delta and from in-Delta sources will impact the location, magnitude, or frequency of taste and odors problems. Optimistically, it may be anticipated that reducing the nutrient loads to the Delta is in the direction of tending to reduce the magnitude of taste and odors that occur in Delta waters. An adaptive management approach could be followed to control nutrients from various sources to some degree and then determine the degree to which taste and odor problems in Delta domestic water supplies have been reduced. An alternative is to conclude that because of the characteristics of taste and odor sources, the control of nutrients should not be based on an attempt to control algae-caused taste and odors.

Aquatic Weed Problems in the Delta

Dr. Lars Anderson, Lead Scientist/Plant Physiologist with the USDA, Agricultural Research Service Exotic and Invasive Weed Research, Davis, CA (lwanderson@ucdavis.edu) presented a comprehensive review of the presence of aquatic weeds, including water hyacinth, egeria, and other native and invasive aquatic plants, in the Delta. He was assisted in his presentation by **Marcia Carlock**, Aquatic Weed Control Program Manager, California Department of Boating and Waterways, Sacramento, CA (MCARLOCK@dbw.ca.gov). The Delta is highly impacted by invasive floating, emergent, and submerged aquatic plants that are significantly adverse to the beneficial uses of the Delta, specifically aquatic life habitat, recreation, and other uses. Dr. Anderson pointed out that the Delta is still being invaded by aquatic plants new to the area.

Dr. Anderson reviewed the current approach for controlling excessive growths of aquatic weeds in the Delta. He indicated that herbicides are effective for controlling water hyacinths and egeria, but they are costly. The California Department of Boating and Waterways is currently spending about $6-million per year for aquatic pest (weed) control in the Delta (http://www.dbw.ca.gov/aquatic.asp). By California Legislative requirements, the use of herbicides in the Delta is restricted to water hyacinth and egeria. Funds made available are not available to control excessive growths of other water weeds.

Dr. Anderson reviewed the issues relating the nutrient loads to the Delta and excessive growths of water weeds. He indicated that the current models available for relating nutrient loads to the growths of water hyacinth are not necessarily applicable to the conditions in the Delta. Because of the tidal characteristics of the Delta, modeling of nutrients loads/concentrations and water hyacinth biomass is markedly are more complex than the systems typically addressed in the current models. He is not optimistic that reduction of nutrient loads to the Delta will significantly reduce the growth of invasive water weeds in the Delta.

Low Dissolved Oxygen in SJR Deep Water Ship Channel

This summary is based on the presentation of **M. Gowdy** of the California State Water Resources Board, Sacramento, CA (mgowdy@waterboards.ca.gov) (formerly with the Central Valley Regional Water Quality Control Board, Rancho Cordova, CA). Additional information on the low-DO problem in the San Joaquin River Deep Water Ship Channel is provided in the Lee and Jones-Lee 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
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> Lee, G. F. and Jones-Lee, A., "Supplement to Synthesis Report on the Low-DO Problem in the SJR DWSC," Report of G. Fred Lee & Associates, El Macero, CA, June (2004). http://www.members.aol.com/duklee2307/SynthRptSupp.pdf

From 1999 through 2003, CALFED funded studies on the SJR DWSC low-dissolved oxygen (DO) problem. The results of many of those studies are available on the San Joaquin River DOTMDL -- Technical Working Group website at http://www.sjrdotmdl.org/background.html

Gowdy briefly summarized some of the issues associated with the low dissolved oxygen conditions that occur in the San Joaquin River Deep Water Ship Channel near the Port of

Stockton. The DO concentrations in the first 7 miles of the SJR DWSC continue to be below the water quality objective (WQO) for the channel. The DO depletion there is controlled in part by the discharge of nutrients from the SJR watershed upstream of the Delta. Those nutrients support the development of algae that are carried into the SJR DWSC where they die; the bacterial decomposition of those algae depletes the DO in the first 7 miles of the SJR DWSC. Another cause of DO depletion in the DWSC is the oxidation of ammonia and organic N that is discharged by the City of Stockton wastewater treatment plant to the SJR just up stream of where the SJR enters the DWSC. The amounts of ammonia discharged to the SJR by the City of Stockton have recently been decreased in conformance with the Central Valley Regional Water Quality Control Board (CVRWQCB) revised permit limitation for ammonia in the wastewater discharge. That discharge limitation of a monthly average of 2 mgN/L ammonia was based on toxicity to fish, not on the impact of ammonia as source of oxygen demand. The ammonia and organic N in the city’s permitted wastewater discharge will continue to contribute to the oxygen demand in the SJR DWSC and thus contribute to the potential for low-DO conditions in the SJR DWSC. The significance of that source of oxygen demand, relative to upstream algal sources of oxygen demand, depends on the flow of the SJR through the DWSC. Under low-flow conditions, the city’s domestic wastewater discharge is a dominant source of oxygen demand for the DWSC.

The flow of the SJR water through the DWSC also influences the amount of DO depletion in the DWSC. When the SJR flow through the DWSC is low (typically associated with the export projects’ drawing large amounts of SJR water through the Head of Old River upstream of the DWSC) the residence time of the oxygen demand from algae and ammonia in the critical reach of the DWSC increases from a few days (under high SJR DWSC flow) to as much as a month (under low flow). The longer residence times leads to greater DO depletion in the critical reach (first seven miles) of the DWSC, i.e., upstream of Turner Cut. When the state and federal export projects are operating at or above normal pumping capacity of about 8,000 to 10,000 cfs, the export projects draw Sacramento River water to Turner Cut where it dilutes the residual SJR DWSC oxygen demand that reaches Turner Cut to the extent needed to eliminate DO depletions below WQOs in the DWSC and in Turner Cut.

Another major factor contributing to the low DO conditions in the SJR DWSC is the channel geometry of the DWSC. The Corps of Engineers was commissioned by Stockton interests to dredge the DWSC to a depth of 35 feet to enable the Port of Stockton to accommodate deeper-draft ships (35 ft).

M. Gowdy mentioned that one of the approaches being considered to try to address the DO depletion below the DO WQO in the DWSC is to improve operation of the Port of Stockton aeration facilities and the DWR’s newly constructed aeration facility near the Port. It remains to be determined whether the aeration facilities that exist would be adequate to eliminate the DO depletion below the WQOs in the SJR DWSC. Further, there is concern that the DWR facility, which injects pure oxygen into the water, could cause supersaturation of the water with oxygen. Such supersaturation would violate the US EPA water quality criterion that protects fish from toxicity due to dissolved gas supersaturation.

M. Gowdy briefly mentioned that the results of a several-year SJR watershed monitoring program are scheduled to be made available in a few months. Those studies were intended to provide a more detailed understanding of nutrient and algal sources that contribute to the low-DO water quality problems in the SJR DWSC. One of the issues that is still not being addressed is the ability to control upstream nutrients sufficiently to control the growth of algae that contribute to the low-DO problems in the SJR DWSC. The current upstream study program did not include studies that would specifically address the ability to control nutrients from sources such as Mud and Salt Sloughs that have been found to be a major source of algal seed and nutrients that ultimately lead to the low DO in the SJR DWSC. This is one of the major deficiencies of the planning for the current upstream studies.

The CVRWQCB SJR DWSC low-DO problems are being addressed through a TMDL to control the occurrence of DO concentration below the DO WQO. The current TMDL requirements are set forth at CVRWQCB SJR DWSC DO TMDL, http://www.swrcb.ca.gov/centralvalley/water_issues/tmdl/central_valley_projects/san_joaquin_oxygen/index.shtml.

Dr. Carl Chen, President (carl@systechengineering.com) and **Joel Herr,** Vice President and Chief Engineer of Systech Engineering, San Ramon, CA (joel@systechengineering.com) summarized their numeric modeling efforts to relate nutrient sources in the SJR watershed to the development of algae that contribute to the low-DO conditions in the DWSC. The watershed modeling is being conducted through the use of the WARMF model. Information on WARMF is available at http://www.epa.gov/athens/wwqtsc/html/warmf.html. Their DO depletion modeling is being developed through the "link node" model, "Modeling Oxygen Demand in the SJR DWSC" – C. Chen (http://sjrdotmdl.org/library_folder/final_modeling_report1.pdf). Herr mentioned that there is need to recalibrate the link node and the WARMF models using the new information that has been developed in more recent studies, to better tune the model to simulate existing conditions.

Impact of Altering the Phosphorus Loads to the Delta on Delta Algal Concentrations

Dr. Erwin Van Nieuwenhuyse, Fishery Biologist with the US Bureau of Reclamation Division of Environmental Affairs, Sacramento, CA (evannieuwenhuyse@mp.usbr.gov) discussed his review of the impact of the decrease in the Sacramento Regional Wastewater Treatment Facility's P discharges to the Sacramento River on the concentrations of phosphorus and planktonic algal chlorophyll at three northern Central Delta IEP monitoring stations. He reported that in 1993-4 the concentrations of phosphorus and phytoplankton chlorophyll decreased apparently as a result of the decreased load of phosphorus from the Sacramento Regional Wastewater Treatment Facility. The results of those studies are presented in his paper,

> van Nieuwenhuyse, E., "Response of Summer Chlorophyll Concentration to Reduced Total Phosphorus Concentration in the Rhine River (Netherlands) and the Sacramento–San Joaquin Delta (California, USA)," Can. J. Fish. Aquat. Sci. <u>64</u>:1529-1542 (2007). (evannieuwenhuyse@mp.usbr.gov)

Van Nieuwenhuyse also presented data describing the impact of reducing the phosphorus concentrations in the Rhine River in Europe on phytoplankton chlorophyll. He reported that there was a significant decrease in planktonic algal chlorophyll there associated with decreased phosphorus concentrations. He also pointed out that those data suggest that phosphorus concentrations of about 400 ng/L appear to be an upper limit of the concentration range in which decreasing the P concentration effects a reduction in planktonic algal biomass.

Van Nieuwenhuyse listed the following sources of additional information on this issue and indicated that he can make the data sets available to anyone interested.

> Van Nieuwenhuyse, EE and JR Jones.(1996). "Phosphorus*chlorophyll relationship in temperate streams and its variation with stream catchment area." Can. J. Fish. Aquat. Sci. 53: 99-105 91996).
>
> Jassby, A.D., and J.E. Cloern. "Organic matter sources and rehabilitation of the Sacramento-San Joaquin Delta (California, USA). Aquatic Conserv. Mar. Freshw. Ecosyst. 10: 323-352. "2000."
>
> Reynolds, C.S., and J.-P. Descy. "The production, biomass and structure of phytoplankton in large rivers. Arch. Hydrobiol. Suppl. 113: 161-187. "1996."
>
> Meeuwig, J.J., J.B. Rasmussen, and R.H. Peters. "Turbid waters and clarifying mussels: their moderation of empirical chl:nutrient relations in estuaries in Prince Edward Island, Canada. Mar. Ecol. Prog. Ser. 171: 139-150. (1998).
>
> Nicholls, K. H., G. J. Hopkins, and S. J. Standke. Reduced chlorophyll to phosphorus ratios in nearshore Great Lakes waters coincide with the establishment of dreissenid mussels. Can. J. Fish. Aquat. Sci. 56: 153-161 (1999).

Dr. Lee mentioned that Rast et al. conducted a review of the literature to assess and quantify the impacts of altering the phosphorus loads to waterbodies (and hence, in-waterbody concentrations) on phytoplankton concentrations. The results of their investigations are presented in:

> Rast, W., Jones, R. A. and Lee, G. F., "Predictive Capability of US OECD Phosphorus Loading-Eutrophication Response Models," *Journ. Water Pollut. Control Fed.* **55**:990-1003 (1983). http://www.members.aol.com/annelhome/PredictiveCapabilityOECD.pdf

Rast et al.'s findings also support the position that for waterbodies with apparently surplus phosphorus compared to the typically reported phosphorus half-saturation-constant of a few nanograms per liter, phosphorus reduction can be expected to result in reduction of planktonic algal chlorophyll levels, up to a limit of a few hundred nanograms P per liter

Conceptual Model of Delta Nutrient Sources

Dr. Sujoy Roy, Principal Engineer Tetra Tech Inc. Lafayette, CA (Sujoy.Roy@tetratech.com) presented a review of a conceptual model of nutrient sources for the Delta that was developed by Tetra Tech for the USEPA Region 9 in support of the CVRWQCB's Drinking Water Policy. His PowerPoint slides are available on the CWEMF website.

His presentation was based on the report,

> Katherine Heidel, Sujoy Roy, Clayton Creager, Chih-fang Chung, Tom Grieb, "Conceptual Model for Nutrients in the Central Valley and Sacramento-San Joaquin Delta" *Prepared for* US Environmental Protection Agency, Region IX and the Central

Valley Drinking Water Policy Workgroup Tetra Tech, Inc. Lafayette, CA September, (2006) http://www.waterboards.ca.gov/centralvalley/water_issues/drinking_water_policy/

The Tetra Tech conceptual model is based on existing data, which is limited for some sources. This can cause some of the estimates of Delta nutrient sources to be of limited reliability.
Dr. Roy presented information on the amounts of N and P derived from various sources in the Delta watershed including, for some sources, nutrient export coefficients, the amount of N and P derived from a unit area of land per unit time, such as g $P/m^2/yr$. Dr. G. F. Lee indicated that the nutrient export coefficients developed in that study are similar to those developed for various types of land use such as agriculture, by

Rast, W. and Lee, G. F., "Nutrient Loading Estimates for Lakes," *J. Environ. Engr. Div. ISCHIA* **109**:502-517 (1983). See also closure discussion, "Nutrient Estimates for Lakes," *Journ. Environ. Engrg*. **110**:722-724 (1984). http://www.members.aol.com/annejlee/NutrientLoadEstimRast.pdf

Nutrient export coefficients are useful for estimating the amounts of N and P that are derived from a type of land use and to estimate how changes in land use, such as urbanization, impact the amounts of nutrients discharged from a watershed.

Dr. Roy indicated that there is need for detailed studies to better define the role of various sources of nutrients and their control relative to managing the excessive fertilization of the Delta.

Regulatory Issues

Steve Camacho, Environmental Scientist with the Planning, Standards, and Implementation Unit, State Water Resources Control Board, Sacramento, CA (scamacho@waterboards.ca.gov) discussed the development of nutrient criteria for use in regulating excessive nutrient discharges to manage excessive fertilization of California waters. He indicated that the nutrient criteria being developed by the State Water Board consider site-specific characteristics of waterbodies. He suggested that a key source of information on this work is http://rd.tetratech.com/epa/.

The US EPA has developed a series of webcasts called "Nutrient Scientific Technical Exchange and Support" ("N-STEPS") devoted to providing information on the investigation and regulation of nutrient-related water quality impacts. Information on N STEPS is available at
http://n-steps.tetratech-ffx.com/ The May 7, 2008 webcast was devoted to a review of the development of nutrient criteria in the state of Michigan. The webcasts are archived on the N-STEPS website.

Key aspects of the development of technically reliable waterbody-specific water quality criteria for nutrients have been discussed by Drs. G. F. Lee and Anne Jones-Lee.

Lee, G. F. and Jones-Lee, A., "Developing Nutrient Criteria/TMDLs to Manage Excessive Fertilization of Waterbodies," Proc. WEF TMDL 2002 Conf., Phoenix, AZ (2002a). http://www.gfredlee.com/WEFN.Criteria.pdf

Their PowerPoint slides for that presentation are available at,

Lee, G. F. and Jones-Lee, A., "Developing Nutrient Criteria/TMDLs to Manage Excessive Fertilization of Waterbodies," Proceedings Water Environment Federation TMDL 2002 Conference, Phoenix, AZ, November (2002).
http://www.gfredlee.com/WEFN.Criteria.pdf

Lee and Jones-Lee stated in that paper,

> **"***In developing the appropriate nutrient criteria, it is suggested that the TMDL development approach is an appropriate approach to follow. This approach involves the following steps:*
>
> - *Developing a problem statement of the excessive fertilization situation of concern.*
> - *Establishing the goal of nutrient control (i.e., the desired eutrophication-related water quality).*
> - *Determining nutrient sources, focusing on available forms.*
> - *Establishing linkage between nutrient loads and eutrophication response (modeling).*
> - *Initiating a Phase I nutrient control implementation plan to control the nutrients to the level needed to achieve the desired water quality.*
> - *Monitoring the waterbody for three to five years after nutrient control is implemented to determine whether the desired water quality is being achieved.*
> - *If not, initiating a Phase II where, through the monitoring results, the load-response model is improved and thereby able to more reliably predict the nutrient loads that are appropriate for the desired water quality.*
>
> *This approach is an iterative approach, where, over a period of at least five to possibly 15 years, through two or more consecutive phases, it will be possible to achieve the desired water quality and thereby establish the nutrient loads which can be translated to in-waterbody concentrations and, therefore, the nutrient criteria for the waterbody."*

Their recommended approach requires detailed study of a waterbody's characteristics focusing on the relationship between available nutrient loads and the nutrient-related water quality response of the waterbody. It also requires a waterbody-specific evaluation of the desired nutrient-related water quality characteristics for the waterbody.

In their writings on developing nutrient control programs over the past three decades, Lee and Jones-Lee have discussed the importance of focusing on available forms of phosphorus rather than on total phosphorus. Available P is typically equivalent to the soluble orthophosphate concentration plus about 20% of the concentration of particulate P associated with runoff from urban and agricultural sources. This focus is especially important in the evaluation of the potential benefits of controlling P in stormwater runoff from urban and agricultural sources such as occurs in the Delta watershed. These issues have been reviewed by

Lee, G. F., "Assessing Algal Available Phosphorus," Proceedings of US EPA Science Symposium: Sources, Transport, and Fate of Nutrients in the Mississippi River and Atchafalaya River Basins, Minneapolis, MN, November 7-9 (2006). http://www.members.aol.com/annejlee/AvailPEPASymp06.pdf

Lee, G. F., Jones, R. A., and Rast, W., "Availability of Phosphorus to Phytoplankton and its Implications for Phosphorus Management Strategies," Published in: Phosphorus Management Strategies for Lakes, Ann Arbor Science Publishers, Inc. pp. 259-307 (1980). http://www.members.aol.com/duklee2307/Avail-P.pdf

Lee, G. F., "A Proposal for Assessing Algal-Available Phosphorus Loads in Runoff from Irrigated Agriculture in the Central Valley of California," Report of G. Fred Lee & Associates, El Macero, CA, November (2006). http://www.members.aol.com/annejlee/AlgalAssayAvailP.pdf

The US EPA inappropriately focuses its nutrient criteria development on control of total P rather than on available P. For some P sources, such as urban and agricultural runoff, that approach can cause the expenditure of large amounts of money to control particulate, largely unavailable, P in high flow events while achieving limited improvement of excessive fertilization of receiving waters.

Karen Larsen, Senior Environmental Scientist, Central Valley Regional Water Quality Control Board, Rancho Cordova, CA (klarsen@waterboards.ca.gov) reviewed the Drinking Water Policy that is under development at the CVRWQCB. The URL for the current development of this policy is available at, CVRWQCB Drinking Water Policy,
http://www.swrcb.ca.gov/centralvalley/water_issues/drinking_water_policy/.
This policy includes addressing the impact of nutrients on Delta domestic drinking water quality. Larsen pointed out that considerable work remains to be done to formulate the final version of the CVRWQCB Drinking Water Policy.

Margie Read, REAII, Chief, Monitoring and Assessment Unit, Irrigated Lands Conditional Waiver Program, CVRWQCB, Rancho Cordova, CA (mread@waterboards.ca.gov) discussed the current CVRWQCB irrigated lands agricultural conditional waiver water quality nutrient monitoring program. She indicated that additional information related to her workshop presentation may be found on the website for the CVRWQCB Monitoring Data Report 2003-2006
(http://www.waterboards.ca.gov/centralvalley/water_issues/irrigated_lands/monitoring/index.shtml)
and the website for the Coalition Group Monitoring and Reporting Program
(http://www.waterboards.ca.gov/centralvalley/board_decisions/adopted_orders/waivers/r5-2008-0005_mrp.pdf).
Additional information (such as flow) that may not be on the website may be obtained by contacting the Irrigated Lands Program or Ms Read.

Information on the CVRWQCB Irrigated Lands Conditional Waiver Program is available at, http://www.swrcb.ca.gov/centralvalley/water_issues/irrigated_lands/. That program requires that agricultural interests in the Central Valley monitor waterbodies that are dominated by irrigated agriculture discharges/runoff for a variety of potential pollutants including nitrogen and phosphorus compounds. At this time nutrients are potentially regulated by the CVRWQCB Basin Plan's narrative water quality objective for controlling "biostimulatory substances," which states,

> "*Water shall not contain biostimulatory substances which promote aquatic growths in concentrations that cause nuisance or adversely affect beneficial uses.*

The CVRWQCB Basin Plan is available at,
http://www.swrcb.ca.gov/centralvalley/water_issues/basin_plans/index.shtml.

At this time the CVRWQCB has not developed guidance on the interpretation/implementation of this WQO. Lee and Jones-Lee have discussed key issues that need to be considered in evaluating the allowed nutrient discharges to waters tributary to the Delta and within the Delta. in their presentations:

> Lee, G. F. and Jones-Lee, A., "Assessing the Water Quality Significance of N & P Compound Concentrations in Agricultural Runoff," Invited presentation to the Agrochemical Division, American Chemical Society national meeting, San Francisco, CA, September (2006). http://www.members.aol.com/annejlee/N-PRunoffACS.pdf
>
> Lee, G. F., and Jones-Lee, A., "Assessing Water Quality Significance of N & P Compound Concentrations in Agricultural Runoff," PowerPoint Slides for Invited Paper Presented at Agrochemical Division, American Chemical Society National Meeting, San Francisco, CA, September (2006).
> http://www.members.aol.com/GFLEnviroQual/N-PSlidesACS.pdf

Future Delta Nutrient Workshops
Dr. Lee's PowerPoint slides included a list of topic areas that could be the focus of future Delta nutrient water quality workshops. This list included,

- Nutrient Sources & Their Control
- Impact of Nutrient Input Reductions on Primary Production (Algae) & Fish Production in the Delta
- How Future Delta Channel Flow Manipulations May Impact Delta Nutrient-Related Water Quality Characteristics
- Modeling Delta Nutrient-Related Water Quality Impacts
- Balancing Nutrient Control with Fish Production
- Development of Site-Specific Nutrient Criteria

Those who responded to the workshop evaluation form indicated that there was interest in future Delta nutrient workshops. Greatest interest was expressed in nutrient sources and their control, impact of nutrient input reductions on primary production (algae) & fish production in the Delta, how future Delta channel flow manipulations may impact Delta nutrient-related water quality characteristics, and modeling Delta nutrient-related water quality impacts. Interest in these, as well as other topics for potential future Delta nutrient workshops should be sent to gfredlee@aol.com.

This discussion of Workshop issues has included references to several papers written by Dr. G. F. Lee and his associates on related work in which he has been involved over the past 40 years. Additional papers and reports on related issues are available on his website: www.gfredlee.com in the "Excessive Fertilization" section at, http://www.gfredlee.com/pexfert2.htm.

Comments on this summary of issues that were discussed at the Delta Nutrient Water Quality Modeling workshop are welcome. Please send comments to gfredlee@aol.com.