Need for
CWEMF Delta Water Quality Modeling Workshop
Delta Water Quality Modeling: Pollutant Transport, Transformation, & Impacts

Purpose: Review the current understanding of the modeling of Delta water quality:

- sources, transport & transformations of pollutants that cause violations of water quality objectives and impairment of water quality-related beneficial uses of the Delta
- deficiencies in modeling approaches for Delta water quality and in data for reliable water quality modeling.

Organizers: Dr. G. Fred Lee, PE, BCEE and Dr. Anne Jones-Lee
G. Fred Lee & Associates
El Macero, CA
530 753-9630
gfredlee@aol.com www.gfredlee.com

Date: Tentatively scheduled for the spring 2010 ??

Tentative Program Agenda

Topic

Introduction to CWEMF

Overview of Workshop

Modeling Approaches
Relationships among pollutant sources/loads, transport, transformations to/of toxic/available forms, and impacts in Delta waters, as affected by flow patterns of the Sacramento and San Joaquin Rivers in the Delta

Overview of General Pollutant Models

AQUATOX Release 3 http://www.warrenpinnacle.com/prof/AQUATOX/howcani1.html	US EPA
MINTEQA2 Exposure Assessment Model http://www.epa.gov/ceampubl/contact.html	US EPA Exposure Assessment Modeling
BASS (bioaccumulation model) http://www.epa.gov/athens/research/modeling/bass.html	US EPA
DRERIP Conceptual Models http://www.science.calwater.ca.gov/drerip/drerip_index.html http://www.cwemf.org/drerip.htm	

Delta Pollutant Water Quality Modeling Issues
Delta Channel Transport & Residence times under altered flow

Domestic Water Supply Tastes and Odors

Ammonia and other N species

Planktonic Algae

Salinity

Organophosphate Pesticides

Pyrethroid Pesticides
Water Column & Sediments

Organochlorine "Legacy" Pesticides
Sediments Bio-uptake

PCBs Sediments and bio-uptake

Total and Methyl Mercury

Nutrients and Aquatic Plants (Egeria and Hyacinth)

Suspended Sediment Transport and Deposition

Total and Dissolved Organic Carbon

Algal BOD/low DO SJR DWSC and South Delta Channels

Domestic Wastewater PPCP & Other Unregulated Chemicals

Heavy Metals (Cu, Zn, Se)

Unknown Toxicity

Pathogen Indicators Fecal Coliforms, Giardia

Background to Delta Water Quality Modeling

The occurrence of numerous violations of water quality objectives (WQO) have caused the CVRWQCB to list various Delta channels as Clean Water Act Section 303(d) "impaired." These listings have triggered the Regional Board's development of TMDLs (Total Maximum Daily Loads) for the input of those chemicals that are present in excess of their WQOs. The locations and magnitudes of the WQO violations are influenced by the pattern of export pumping of Delta water to the San Francisco Bay area, the Central Valley, and Southern California. The current 303(d) listing is based on a Delta flow pattern in which about 10,000 to as much as 13,000 cfs of Sacramento River water is drawn through the Delta to the Central Valley Project (CVP) and

State Water Project (SWP) export pumps in the southwestern area of the Delta. As part of developing an alternative for exporting Sacramento River to the Bay area and Central and Southern California, consideration is being given to channeling Sacramento River water flow through the Central Delta in an isolated channel, and/or around the Delta in a peripheral canal, to the export pumps. Such alterations in Sacramento River flow will impact the location and magnitude of WQO violations that are now occurring in Delta channels.

The Bay Delta Conservation Plan (BDCP) is calling for reductions in the loads of selected pollutants that are causing violations of WQOs in the Delta channels. There is need, therefore, to reliably estimate and compare the effects of potential scenarios for altering the loads of pollutants to the Delta and within the Delta on water quality in the Delta, and for meeting WQOs. In order to do this, water quality models are needed that can reliably, demonstrably, and causally relate the changes in the loads of the various pollutants to and conditions of the Delta to resultant impacts on the location and magnitude of the WQO violations in the Delta channels and on beneficial uses of the Delta. The output of such models is also needed to implement the TMDLs and evaluate their efficacy for controlling WQO violations in the Delta.

Existing models and the state of understanding of Delta water quality issues are inadequate for developing water quality models of the type needed for these purposes. In view of those deficiencies, the California Water and Environmental Modeling Forum (CWEMF) is organizing a “Delta Water Quality Modeling Workshop” to review and discuss the current state of understanding of, and information needed to describe and model, how changes in the loads of pollutants and the flow of the Sacramento River in, through, and around the Delta impact violations of WQOs in Delta channels. The workshop will provide information on studies and monitoring needed to develop reliable models.

As will be discussed at the workshop, for each major source/load of the potential pollutants being considered, a model will need to consider the range of potential flow characteristics that are known to occur as well as those that could result with each of the various alternative strategies for extracting Sacramento River water for export, and the impact of those flow characteristics on concentrations and water quality/beneficial-use effects of the pollutant and its transformation products. In addition to considering the routing of Sacramento River water to the export pumps, the modeling also needs to account for other factors that influence how water from the Sacramento and San Joaquin Rivers moves through the Delta including the Vernalis Adaptive Management Program (VAMP), operation of the Head of Old River (HOR) and Delta Cross Channel barriers, and tides. Further, the alteration of the flow of the Sacramento River to the export pumps will change the flow of the SJR through the Delta. Presently, any SJR flow that gets past the HOR is drawn into Turner Cut to Middle River and the exports pumps. If Sacramento River flows are channeled through or around the Delta to the export pumps, the SJR and its associated pollutant loads will be transported into the Central Delta along its original channel. This can greatly change the pollutant loads to that area of the Delta and result in WQO violations and/or impacts that have not existed under the export pumping scenarios of recent years.

A program of proposed source controls for selected toxic “contaminants” is presented in the “Toxic Contaminants” section – Other Stressors – Conservation Measures of the October 31, 2008 draft report to the Bay Delta Conservation Plan (BDCP) Steering Committee. That Plan includes:

Conservation Measure TOCO2: Reduce the Load of Endocrine Disrupting Compounds in Effluent Discharged from Wastewater Treatment Plants into Delta 7 Waterways to Less than __ if Warranted Based on Research.

Conservation Measure TOCO3: Reduce the Load of Methylmercury Entering Delta Waterways by __ Percent from 200_ Levels.

Conservation Measure TOCO4/5: Reduce the Load of Pesticides and Herbicides Entering Delta Waterways from In-Delta Sources that are Believed to be Toxic to Covered Fish Species by __ Percent from 200_ Levels.

Conservation Measure TOCO7: Reduce the Loads of Toxic Contaminants in Stormwater Pollution and Urban Runoff by Working with Existing Efforts in the Delta.

Conservation Measure TOCO12: Provide for Rapid Detection of and Response to Toxic Contaminant Events that could Affect Covered Fish Species.

Conservation Measure OTWQ1: Maintain Dissolved Oxygen Levels of at Least __ ppm in the Stockton Deep Water Ship Channel during Periods Covered Fish Species are Present.

Conservation Measure OTWQ2: Improve the Quality of Water Discharged from Managed Seasonal Wetlands into Suisun Bay and Delta Waterways to Prevent Dissolved Oxygen Sags.

Many of those proposed toxic contaminant (pollutant) recommendations prescribe an unspecified amount of control. In order for contaminant/pollutant control to be cost-effective, it needs to incorporate an understanding of how the control of a source of a pollutant to a given degree impacts Delta water quality. The development of water quality models of the type that will be discussed at the workshop herein can lead to gaining this understanding.

Summary
Water Quality Modeling Associated with
Altered Sacramento River Flows in & around the Delta
G. Fred Lee PhD, PE, BCEE and Anne Jones-Lee PhD

- As part of implementing the Delta Vision Strategy for addressing resource management issues in the Delta, the flow of the Sacramento River in & around the Delta, and the USBR and DWR export projects' pumping of Delta water, will be changed.
  - These changes will impact Delta water quality.
- Delta water quality is impaired by discharges of chemicals from various sources to Delta tributaries and directly to the Delta.
  - Discharges cause violations of numeric water quality objectives (WQO)
  - Violations lead to Clean Water Act 303(d) listings & TMDLs to control pollutant sources
    - Salinity, mercury, organophosphate pesticides (DDT, toxaphene), aquatic life toxicity, dioxin/furans, copper, zinc, boron, low DO
- There are water quality impairments in Delta channels without violation of numeric WQOs
  - TOC, nutrients, pyrethroid pesticides, excessive siltation, sediment toxicity, PPCPs, PBCPs, pharmaceuticals and hormones, unregulated chemicals
- Magnitude, location, & duration of water quality impairments depend on the flow of water through Delta channels.
  - Flow in many Delta channels depends on flow of the Sacramento River through the Delta and the pumping of water by the export projects
- Flow of Sacramento River in the Delta and projects' export pumping impact the location, duration, and magnitude of water quality impairment in water in Delta channels.
- To properly evaluate the impact of alterations in Sacramento River flow through/around the Delta and the export pumping of Delta water, models of transport, fate, and transformation of pollutants in Delta channels need to be developed
  - For each source of chemical pollutant, develop a model that can be used to predict the location, duration, and magnitude of water quality impairment in each of the Delta channels as impacted by altered flow of the Sacramento River and projects' export pumping of Delta water
- CWEMF could/should be a leader in formulating Delta water quality modeling to address alterations in Sacramento River flow and export pumping of Delta water
  - Modeling information needed for TMDLs to evaluate the impact of reducing loads of pollutants from various sources on Delta channel water quality
- Recommended approach
  - Develop a "white paper" on the need for this modeling and to provide guidance on how this modeling should be developed
  - Develop a workshop on this modeling

Background information on this issue is available in:

Lee, G. F., and Jones-Lee, A. "Review of Need for Modeling of the Impact of Altered Flow through and around the Delta on Delta Water Quality Issues" Report to CWEMF Steering Committee, March (2009). http://www.gfredlee.com/SJR-Delta/Model-Impact-Flow-Delta.pdf

Background
Review of Need for Modeling of the Impact of Altered Flow through and around the Delta on Delta Water Quality Issues

G. Fred Lee, PhD, PE, BCEE Anne Jones-Lee, PhD
G. Fred Lee & Associates
El Macero, California
gfredlee@aol.com, www.gfredlee.com
March 2009

The Sacramento San Joaquin Delta is formed from the confluence of the Sacramento and San Joaquin Rivers with lesser contributions from other tributaries such as the Mokelumne River. Figure 1 presents a map of the Delta showing the numerous interconnected channels before discharge to upper San Francisco Bay. Major exports of Delta water occur at the south western area of the Delta at the federal (USBR) and state DWR pumping stations. Except near the upper San Francisco Bay the Delta is a freshwater tidal system with appreciable tidal currents in each of the channels. The tributary and tidal flows in the Delta are major factors in affecting Delta water quality.

Delta Water Quality Issues

Delta's water quality is impaired due to excessive concentrations of several potential pollutants. Violations of water quality objectives (WQO)/standards leads to violations of Clean Water Act (CWA) Section 303(d) which requires that the Central Valley Regional Water Quality Control Board (CVRWQCB) develop a Total Maximum Daily Load (TMDL) to control the sources of the pollutants that cause the violation of the WQO. This listing of WQO violations is prepared by the CVRWQCB, State Water Resources Control Board (SWRCB) and the US EPA. Lee (2008) has summarized the current WQO violations and other impairments of water quality in Delta tributaries and channels.

This 303(d) listing includes in addition to listing the WQO violations includes a location in the Delta channels where these violations have been found to occur. Lee and Jones-Lee (2004) have discussed the Delta water quality standards violations as known in 2002 and other water quality impairments of the beneficial uses of the Delta waters that while do not at that time and today causes WQO violations since there are no WQOs for the parameters causing the water quality impairment. This type of situation occurs for nutrients (N and P compounds), TOC. pyrethroid pesticides, etc.

Lee and Jones-Lee (2007a) presented updated information based on the 2006 303(d) CWA listing at the California/Nevada American Water Works fall meeting. The updated 303(d) listing is available at
http://www.swrcb.ca.gov/water_issues/programs/tmdl/303d_lists2006_epa.shtml. Figures 2 and 3 present a chart of existing and potential CWA Section 303(d) impaired waterbodies and the constituents responsible for the listing.

Basically, the 2007 discussion of the WQO violations data is the same as the 2004 results. At this time the CVRWQCB/SWRCB/USEPA is developing an updated listing of WQO violations that should be available in a year or so. With increased attention being given to Delta water quality issues it is possible that there will be changes in the 303(d) listings for the Delta channels.

Figure 1 Map of the Delta

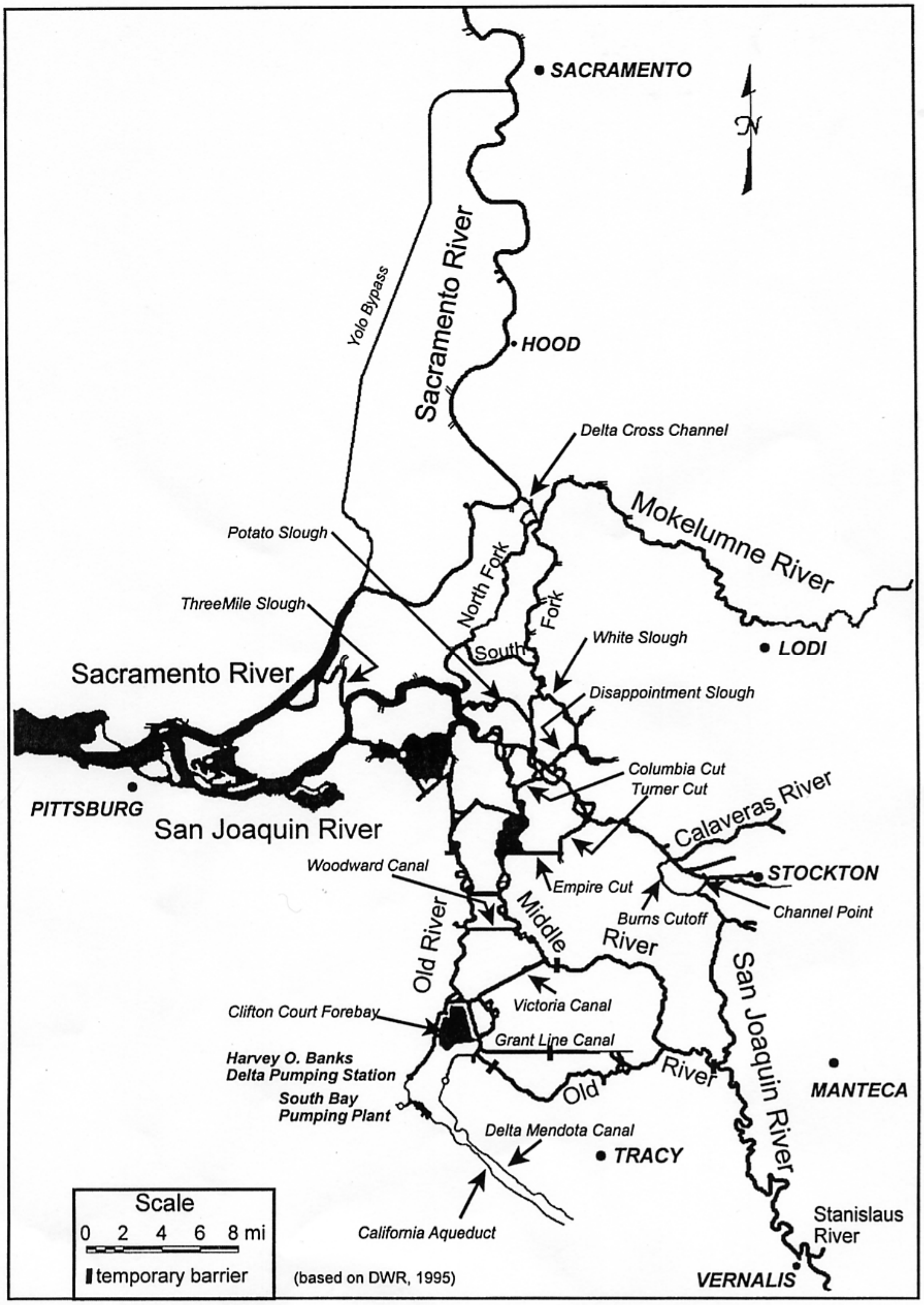


Figure 2

2006 CWA 303(d) List of "Impaired" Delta Waterbodies (SWRCB, June 2007)

Pollutant*/Stressor	Location (see key below)													Potential Sources (see key below)				
	CD	ED	SE	ND	NW	SD	SC	WD	SJ	MS	OR	MR	MDR	Ag	R/S	SU	AM	Other
Chlorpyrifos	X	X	X	X	X	X	X	X						X	X			
Diazinon	X	X	X	X	X	X	X	X						X	X			
DDT	X	X	X	X	X	X	X	X	X					X				
Group A Pesticides (legacy)	X	X	X	X	X	X	X	X	X					X				Formerly-used pesticides
EC/TDS			X		X	X		X	X					X				
Exotic Species	X	X	X	X	X	X	X	X								X		
Mercury	X	X	X	X	X	X	X	X	X								X	
Unknown Toxicity	X	X	X	X	X	X	X	X	X					X		X		
Dioxin/Furan							X											Point source; McCormick/Baxter; Contaminated sediment
Pathogens							X			X					X			Non-boating recreation; tourism
PCBs				X			X									X		Point source
Low DO											X		X			X		Hydromodification
							X								X			WWTP ammonia
										X					X			
Copper												X					X	
Zinc												X					X	
Boron									X					X				
Toxaphene									X							X	X	

Location Designations
CD - Central Delta
ED - Eastern Delta
SE - South Delta export area
ND - North Delta
NW - Northwestern Delta
SD - Southern Delta
SC - Stockton Ship Channel
WD - Western Delta
SJ - Lower San Joaquin River
MS - Mormon Slough
OR - Old River - South Delta
MR - Lower Mokelume River
MDR - Middle River

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

Pyrethroids
bifenthrin
lambda cyhalothrin
efenvalerate/fedvalerate
permethrin

Source Designations
Ag - Agriculture
R/S - Urban runoff/Storm sewers
SU - Source unknown
AM - Abandon mine
WWTP - Domestic wastewaters

CWA - Clean Water Act
* Violates water quality objective

Figure 3

Delta Impaired Waters Not Listed on CWA 303(d)

Should Be Listed	Known Impairments
Nutrients - N & P	Excessive growth of algae & macrophytes
TOC/DOC	Trihalomethanes formed in water treatment
Pyrethroid pesticides used in agriculture & urban areas	Watercolumn & sediment toxicity
Could Be Listed - Need Investigation for Potential Impacts	**Sources**
PBDE - polybrominated diphenylethers	Domestic wastewater discharges
PPCP - pharmaceutical & personal care products	Domestic wastewater discharges
Pharmaceuticals & hormones	Dairy & animal husbandry operations
Other unregulated chemicals	Various

Water quality characteristics of the Delta is determined by exceedance of WQOs, impairment of the designated beneficial uses of the Delta independent of whether a WQO violation is found/designated by the regulatory agencies. According to the Delta Protection Commission, http://www.delta.ca.gov/plan/water.asp, the Central Valley Regional Water Quality Control Board has designated the following beneficial uses in the Delta:

- Municipal and Domestic Supply
- Agricultural Supply: Irrigation and Stock Watering
- Industrial Process and Service Supply
- Groundwater Recharge
- Freshwater Replenishment
- Navigation
- Hydroelectric Power Generation
- Water-Contact and Nonwater-Contact Recreation
- Freshwater Habitat
- Preservation of Rare and Endangered Species
- Fish Migration/Fish Spawning

This listing is derived from the CVRWQCB Basin Plan at http://www.waterboards.ca.gov/centralvalley/water_issues/basin_plans/. The key beneficial uses for the Delta are municipal and domestic water supply, agricultural water supply, water contact and non water contact recreation, freshwater habitat, preservation of rare and endangered species and fish migration/fish spawning.

Impact of Delta Channel Flow and Export Pumping on Delta WQO

Beginning in 1999 with support by the William Jennings (DeltaKeeper) Drs. G. Fred Lee and Anne Jones-Lee became involved in SJR Deep Water Ship Channel (DWSC) low DO issues as advisors to the SJR DO TMDL Steering Committee. The focus of this activity was on the first seven miles of the DWSC near the Port of Stockton. The Lee and Jones-Lee activity evolved into their becoming the principal investigators for a $ 2 million several year study on the causes of the low DO and the sources of oxygen demand that causes this problem. Lee and Jones developed a series of reports on this activity including a synthesis report (Lee and Jones-Lee 2003) and a supplement Lee and Jones-Lee (2004a). These and the other papers and reports on these issues are available on the Lee and Jones-Lee website, www.gfredlee.com, www.gfredlee.com at http://www.gfredlee.com/psjriv2.htm.

As discussed by Lee and Jones-Lee (2003a,b, 2004a,b, and Lee et al. 2004) and as summarized in Lee and Jones-Lee (2004b) the flow (direction and magnitude) of water in the Delta channels is highly influenced/controlled by diversion of Delta water by the Delta US Bureau and Reclamation (USBR) and Department of Water Resources (DWR) federal and state export projects at Tracy and Banks to Central Valley, San Francisco Bay area and southern California. At times until recently from about 8,000 to 13,500 cfs of Delta water is exported by these pumps. As documented by the studies of Lee and Jones-Lee with DeltaKeeper support, most of the water diverted by the export projects is Sacramento River water that is drawn through the Delta to the export pumps. These export caused altered flows through the Delta channels have impacted the location/magnitude/duration of WQO objective violations in the Delta channels. Subsequently, Monsen et al. (2007) have develop a paper that present the same information on the impact of the state and federal south Delta export projects on altering the flow in the Delta as Lee and Jones-Lee discussed in their earlier studies.

The distribution of pollutants added to the Delta from the tributaries such as the San Joaquin River, Sacramento Rivers and the other tributaries as well as within Delta sources including irrigated agriculture discharges which are the sources of the pollutants that cause the WQO violations in Delta channels are distributed in the Delta based on the location and magnitude of export pumping by the export projects. At this time there is essentially little or no understanding of how the export projects altered flow through the channel impact the WQO violations in the Delta. While as discussed by Lee and Jones-Lee (2005a,b) the SWRCB water right Decision 1641 required that all water diversions permits include that the permittee determine the impact of the diversion on water quality, this requirement has not been enforced by the SWRCB.

The 2007 Judge Wranger court rulings designed to better protect certain fish in the Delta from the adverse impacts of the pumps have significantly influenced the water diversions by these export projects that can take place. These issues are discussed in,
http://www.sfgate.com/cgi-bin/article.cgi?file=/c/a/2007/09/01/MNPCRT83Q.DTL.
The restriction on export projects pumping of Delta water has stimulated renewed interest in developing an alternative approach to taking water from the of Sacramento River/Delta including the development of a “peripheral cannel” to take Sacramento River water just below Sacramento and thereby eliminate the drawing of Sacramento River through the Delta to the export pumps. Another approach that is being discussed is a “through Delta” armored channel that would

largely eliminate the interaction of Sacramento River water with the waters in many of the Delta channels that are being impacted by the past and current export of water from the Delta. The adoption of the currently being discussed alternative approaches for exporting Sacramento River water around and/or through the Delta will also impact the occurrence, location, and magnitude WQO violations and water quality/beneficial uses that occur in Delta channels.

One of major conclusions of the Lee and Jones-Lee studies of the low DO problem in the DWSC was that the export pumping of south western Delta waters at Tracy and Banks at times greatly decreased the amount of SJR water that enters the Delta at Vernalis. At discussed in Lee and Jones-Lee (2003a, 2004a) the magnitude of the DO depression in the DWSC was directly related to the amount of SJR flow through the DWSC. At low SJR flow through the DWSC the DO depression in the DWSC was increased due to the longer hydraulic residence time in the DWSC that enabled a greater exertion of the oxygen demand load that enters the DWSC from the City of Stockton wastewater discharges just upstream of the DWSC. This situation occurs when the Head of Old River Barrier was not in and the export project pumps are drawing most of the SJR Vernalis water into the south Delta via the Head of Old River. Altering the SJR flow through the DWSC as a result of altering the Sacramento River flow into/or around the Delta and export pumping location will impact the low DO problem in the DWSC. It will also impact the path that the SJR associated pollutants that enter the Delta at Vernalis take in the Delta.

As discussed by Lee and Jones-Lee (2006a,b, 2007a,b,c) for many of the pollutants that cause WQO violations in the Delta that are derived from San Joaquin River and in Delta sources, the export projects drawing of generally high quality Sacramento River water through the Delta tends to dilute the concentration of some pollutants in Delta channel waters. The diversion of Sacramento River around the Delta or in an isolated facility through the Delta has the potential to greatly adversely impact Delta water quality due to reduced dilution of the pollutants from some sources by the export projects drawing Sacramento River through the Delta. At this time the potential adverse impacts of altered approach for exporting Sacramento River water on Delta water quality is poorly understood. As part of developing the altered approach for exporting Sacramento River water around/through the Delta, a high priority should be given to developing the an understanding of how the water quality designated beneficial uses in the Delta channels is impacted. This understanding should be focused on developing models that can be used to related altered flow in the Delta channels as influenced by water diversions on WQO violations in those Delta channels where WQO violations have been found or could be found under altered flow in the channels.

Need For Delta Water Quality Modeling

The Delta water quality models would be used to guide the types of studies needed to develop the information needed to support the decisions to predict the impact of altered Delta channel flow as a result of altered Sacramento River diversion on Delta channel water quality and on the impact of water diversions from the Delta on Delta water quality. The California Water and Environmental Modeling Forum (CWEMF) can/should play a major role in formulating this modeling approach.

As an example of this type of modeling is the work that Dr. Chris Foe of the CVRWQCB has been doing on the methyl mercury (MeHg) concentration and fate in the Delta. Methyl mercury is the form of mercury that bioaccumulate in fish to a sufficient extent to cause the fish to represent a threat to the health of those who use the fish as food. Through comprehensive field studies he has been able to formulate information on the fate and transport of MeHg to the Delta and most important it transport/fate in the Delta including the role of Delta wetlands as a source of MeHg that results in increased bioaccumulation in Delta fish. His model will be available for review in 2009. Information on these issues is available at Stephenson et al. (2008).

The Delta water quality models can be used to guide the potential impact of altering Sacramento River flow through/around the Delta on excessive bioaccumulation of mercury in Delta fish. This modeling approach will also provide guidance on implementing wetland restoration projects in the Delta on developing areas that impact the conversion of total mercury to methyl mercury.

Similar models need to be developed for the organochlorine legacy pesticides such as DDT and its transformation products and PCBs. These chemicals are bioaccumulating in some Delta fish to be a human heath threat to those who use these fish as food. These chemicals are present in waters added to the Delta and are released from Delta sediments to bioaccumulate to excessive levels in Delta fish. As discussed by Lee and Jones-Lee (2002) at this time there is essentially no understanding of the sources of the organochlorine chemicals that are bioaccumulating to excessive levels in Delta fish as well as how altering the flow of the Sacramento and San Joaquin Rivers into the Delta will impact the excessive bioaccumulation of these chemicals in edible fish. A modeling effort directed to developing the information on these issues is needed to evaluate how altering flow to and around the Delta will impact the water quality issues associated with organochlorine legacy chemicals such as DDT and PCBs. This modeling must include consideration of water column and sediments.

A particularity important group of chemicals that impact Delta water quality/beneficial uses are the aquatic plant nutrients, N & P compounds. As demonstrated in the presentations on nutrient related water quality issues in the CWEMF Delta nutrient modeling workshop, and as summarized Lee and Jones-Lee (2008) in the workshop synopsis at,
http://www.gfredlee.com/SJR-Delta/CWEMF_WS_synopsis.pdf, there is need to understand the source or nutrients that lead to excessive aquatic plant growth that impairs Delta water quality related beneficial uses as well as the importance of nutrient loads to development of desirable fish populations in the Delta. There is no doubt that altering the flow of the Sacramento River and San Joaquin River into and through the Delta will impact excessive aquatic plant growth that is detrimental to the beneficial uses of the Delta and promote the development of desirable fish populations. As discussed by Lee and Jones-Lee (2008) in developing nutrient control programs there is need to balance nutrient control programs in the Delta watershed and within the Delta to minimize water quality impairments due to excessive aquatic plant growth in the Delta and in downstream water supply reservoirs versus desirable fish production in the Delta.

It is understood that the current understanding of water modeling in the Delta is limited. The proposed CWEMF modeling effort devoted to Delta water quality modeling could be the stimulus to define the information gaps and approaches that are needed to develop the models to guide the management of flow in the Delta as it impacts Delta water quality.

Characteristics of Delta Water Quality Models

Jones-Lee and Lee (2008, 2009) have reviewed the approach that should be used to evaluate/model the water quality impact of a chemical that is introduced into a waterbody. An excerpt from these publications is appended to this report. For each potential source of a potential pollutant there is need to evaluate the concentration in the source, the rate of dilution and transport in the receiving waters and the kinetics and thermodynamics of the potential transformations of the pollutant that impact the concentration of toxic/available forms of the pollutant. These transformations are shown in Figure 4-1. The importance of the initial rate and amount of dilution determine the potential impact of acute (short term toxicity) which as shown in Figure 4-2 the WQO that should be used to evaluate the violation of the WQO.

Apply this modeling approach to the Delta channels requires that a comprehensive monitoring program be conducted for each channel water column and sediments that has a WQO violation. An Evaluation Monitoring approach as described by Jones-Lee and Lee (1998) that examines whether a WQO violation represents a real significant impairment of the beneficial uses of the waterbody or represents an administrative exceedance of the worst case water criteria/standard/objective. This approach focuses on examining the impact of chemicals rather than their concentrations. This monitoring should try to be conducted under the range of export/flow conditions that are occurring in the Delta channels.

Through developing an understanding of the sources, transport and transformation of chemicals that potentially impact water quality it will be possible to better define how water exports within and upstream of the Delta impact the beneficial uses of the Delta. These models will define the studies that need to be conducted to define the potential impacts of altering the flow into/around and export of water from the Delta on Delta water quality. The monitoring and continued modeling development should continue after an altered flow is implemented.

Impact of Exports on Chinook Salmon Home Steam Water Chemical Signal

One of the major issues of concern in managing Delta resources is the impact of altering Delta flow patterns as influenced by Delta flow exports on fishery resources. As part of the investigation of the impact of flow diversions on SJR DWSC low DO problem Lee and Jones-Lee (2003b) conducted studies to determine the fate of the SJR water that enters the Delta during periods of normal federal and state export pumping of south Delta water. As they found the export pumping caused the SJR water that enters the DWSC to be mixed with Sacramento River water and drawn into Turner Cut to Middle River and to the export pumps. This export pumping induced flow pattern carried all SJR pollutants that made it past the Head of Old River diversion to be transported into the Central Delta where the impacts due to WQO violations and impacts would occur. Without the export pumping the SJR pollutants would have been transported to the northern area of the Delta. Further, as discussed by Lee and Jones-Lee (2003b) this prevented all of the upper San Joaquin River Chinook Salmon homing signal from reaching the north western Delta and thereby help to guide the fall run Chinook Salmon to their SJR home stream waters upstream of the Delta. This could lead to increased straying and thereby impairing the reproduction of fall run Chinook Salmon in the SJR watershed. A summary of these issues is appended to this report. It will be important that any diversions of Delta waters consider the impact on fall run Chinook Salmon home stream signal to the SJR watershed.

References

Jones-Lee, A. and Lee, G. F., "Evaluation Monitoring as an Alternative to Conventional Water Quality Monitoring for Water Quality Characterization/Management," Proc. NWQMC National Conference Monitoring: Critical Foundations to Protect Our Waters, US Environmental Protection Agency, Washington, D.C., pp. 499-512 (1998).
http://www.gfredlee.com/Runoff/wqchar_man.html

Jones-Lee, A. and Lee, G. F., "Modeling Water Quality Impacts of Stormwater Runoff – Why Hydrologic Models Aren't Sufficient," CENews.com Feature Article, January 29 (2008).
http://www.cenews.com/article.asp?id=2631
http://www.gfredlee.com/Runoff/CENewsStmWaterModeling.pdf

Jones-Lee, A., and Lee, G. F., "Modelling Water Quality Impacts of Stormwater Runoff: Why Hydrologic Models Are Insufficient," Chapter 4 IN: **Modelling of Pollutants in Complex Environmental Systems**, Volume I, ILM Publications, St. Albans, Hertfordshire, UK, pp.83-95 (2009). http://www.gfredlee.com/Runoff/HydrologicModelsInadeq.pdf

Lee, G. Fred, "Water Resource and Quality Crisis Issues in Sacramento San Joaquin Delta, CA." Stormwater Runoff Water Quality Newsletter, Volume 10 Numbers 10 & 11, Topic: October 18, (2007). http://www.gfredlee.com/newsindex.htm

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/SurfaceWQ/OClTMDLRpt12-11-02.pdf

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/Technical Advisory Committee and CALFED Bay-Delta Program, G. Fred Lee & Associates, El Macero, CA, March (2003a). http://www.gfredlee.com/SJR-Delta/SynthesisRpt3-21-03.pdf

Lee, G. F., and Jones-Lee, A., "SJR Deep Water Ship Channel Water Not SJR Watershed Water below Columbia Cut," Report of G. Fred Lee & Associates, El Macero, CA (2003b).
http://www.gfredlee.com/SJR-Delta/IEP-SJR-Delta7-24-03Final.pdf

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 (2004a).
http://www.gfredlee.com/SJR-Delta/SynthRptSupp.pdf

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 (2004b).
http://www.gfredlee.com/SJR-Delta/Delta-WQ-IssuesRpt.pdf

Lee, G. F., and Jones-Lee, A., "Impact of State and Federal Delta Water Export Projects on Delta Water Quality and Aquatic Resources: Issues That Need to Be Addressed," Report of G. Fred Lee & Associates, El Macero, CA, October (2004c).
http://www.gfredlee.com/SJR-Delta/ImpactDelExpProj.pdf

Lee, G., F., and Jones-Lee, A., "Need for Reliable Water Quality Monitoring/Evaluation of the Impact of SWRCB Water Rights Decisions on Water Quality in the Delta and Its Tributaries," Submitted to CA Water Resources Control Board Workshop on D-1641 Water Rights, Sacramento, CA, March 22 (2005a).
http://www.gfredlee.com/SJR-Delta/DeltaWaterExportImpactsPaper.pdf

Lee, G. F., and Jones-Lee, A., "Impact of SJR & South Delta Flow Diversions on Water Quality," PowerPoint Slides, Presentation to CA Water Resources Control Board, D1641 Water Rights Review, January 24 (2005b).
http://www.gfredlee.com/SJR-Delta/D1641SlidesSWRCBJan2005.pdf

Lee, G. F., Jones-Lee, A., "San Joaquin River Water Quality Issues," Report of G. Fred Lee & Associates, El Macero, CA, June (2006a).
http://www.gfredlee.com/SJR-Delta/sjr-WQIssues.pdf

Lee, G. F. and Jones-Lee, A., "Agriculture-Related Water Quality Problems in the San Joaquin River," PowerPoint slides presented at 2006 International Conference on "The Future of Agriculture: Science, Stewardship, and Sustainability," Sacramento, CA, August 7 (2006b).
http://www.gfredlee.com/SJR-Delta/SJRAgAug06Sli.pdf

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 (2007a).
http://www.gfredlee.com/SJR-Delta/DeltaWQCANVAWWAOct07.pdf

Lee, G. F., and Jones-Lee, A., "Water Quality Issues of Irrigated Agricultural Runoff/Discharges—San Joaquin River, Central Valley, California," Presented at Agriculture and the Environment - 2007 Conference, Central Coast Agricultural Water Quality Coalition, Monterey, CA, November (2007b).
http://www.gfredlee.com/SJR-Delta/SJR-WQ-Ag-Monterey.pdf

Lee, G. F., and Jones-Lee, A., "Synopsis of CWEMF Delta Nutrient Water Quality Modeling Workshop – March 25, 2008, Sacramento, CA," Report of G. Fred Lee & Associates, El Macero, CA, May 15 (2008). http://www.gfredlee.com/SJR-Delta/CWEMF_WS_synopsis.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.gfredlee.com/SJR-Delta/Central-Delta-Tours.pdf

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

Stephenson, M., Foe, C., Gill, G., and Coale, K., “Transport, Cycling, and Fate of mercury and Monomethyl Mercury in the San Francisco Delta and Tributaries: An Integrated Mass Balance Assessment Approach,” CALFED Mercury Project Final Report” submitted to CA Department of Fish and Game, CA Bay Delta Authority September 15, (2008).
http://mercury.mlml.calstate.edu/

4.3 AQUATIC CHEMISTRY*

There is a general lack of understanding and consideration of the importance of aquatic chemistry in water quality evaluation and management. Aquatic chemistry can be complex and not easily modelled, and requires a more in-depth understanding than many in the field possess. It can also be more challenging to explain why the removal of particular "chemicals" in a situation is not warranted for water quality protection than it is to cause the development of a treatment works. That notwithstanding, it has been well known since the late 1960s that the total concentrations of potentially toxic constituents in the water column and/or sediment are an unreliable basis for estimating the water quality impacts on the beneficial uses of a waterbody as designated by the Clean Water Act.

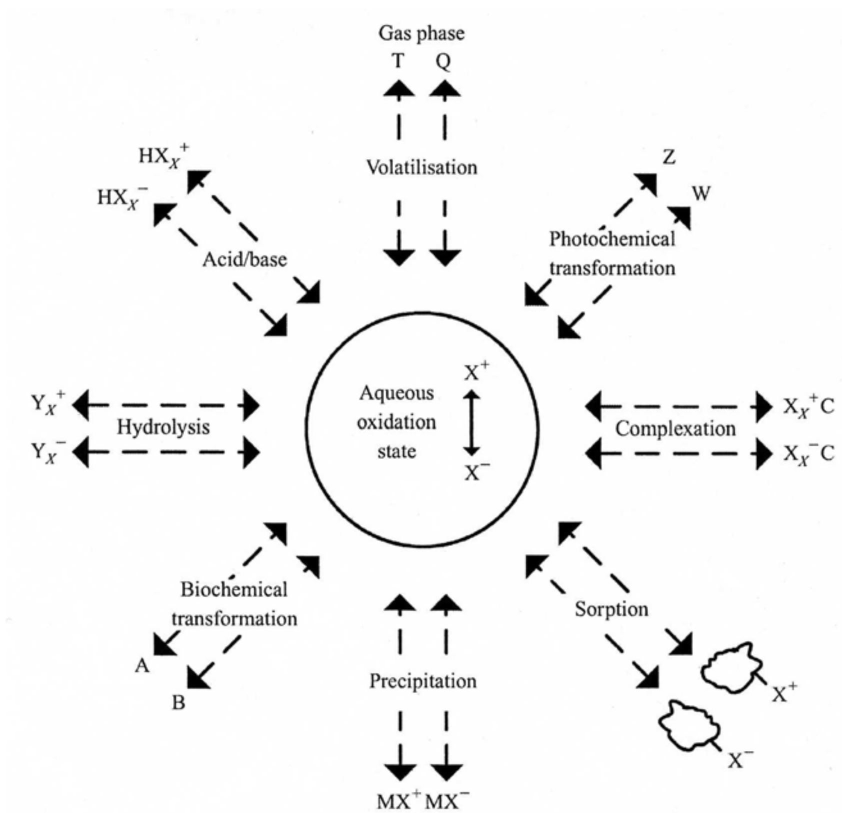
The reason why total concentrations of a selected chemical(s) are unreliable in assessing water quality or use-impairment is that many chemical constituents in aquatic systems exist in a variety of chemical forms, only some of which are toxic or otherwise available to adversely affect water quality. This is shown conceptually in the aquatic chemistry "wheel" presented in Figure 4.1. Different forms of a chemical can have vastly different degrees of impact on the beneficial uses of a waterbody (such as aquatic life propagation, or the wholesomeness of aquatic life used as food). The forms in which a chemical exists in a particular aquatic system depend on the nature and levels of detoxification materials in the water and sediments. These materials, such as organic carbon, sulfides, carbonates, hydrous oxides and clay minerals, react with potentially toxic forms of chemicals, yielding chemical forms that are non-toxic, less toxic, or otherwise less available to aquatic life. The reactions that actually take place, and the toxicity/availability of the various forms of chemicals that are created through those reactions, depend both on the nature of the particular contaminant and on the characteristics of the aqueous environment being considered.

Represented at the "hub" of the wheel in Figure 4.1 is a chemical in its readily available state. The spokes about the hub represent reactions into which a chemical can enter in aqueous environmental settings (volatilisation, photochemical transformation, complexation, adsorption and absorption, precipitation, biochemical transformation, hydrolysis, and acid/base transformation), and the resulting products formed. The bioavailability of those transformation products can be more or less than that of the available form at the hub. The extent to which a particular chemical participates in each of these reactions to generate the transformation products depends on the nature of the chemical and the characteristics of the aqueous environmental setting, and is controlled by the kinetics (rates) and thermodynamics (positions of equilibrium) of the reactions. The total concentration of a chemical includes the most available form at the hub as well as the less-available/unavailable transformation products at the spokes of the diagram. Using the total concentration of a chemical contaminant as a measure of impact presumes that all of the forms are equally and totally available The Stumm and Morgan (1996) graduate-level text, *Aquatic Chemistry,* provides information on the chemical issues that need to be considered in evaluating the "chemistry" of a potential pollutant in aquatic systems.

While shown simplistically in Figure 4.1, these reactions are often not readily modelled mathematically in a manner that accurately represents a real aquatic system. Rarely is information developed on the amounts of the active forms of detoxification components of water and/or sediments, or on the characteristics of the reactions that occur with the potentially toxic or available forms. Therefore it is not possible to predict, based on typical chemical analyses, the toxic or available forms of potential pollutants such as heavy metals, selected organics or nutrients, that impact on the beneficial uses of a waterbody of concern to the public.

In order to try to better represent aquatic chemistry in water quality assessment, the US EPA developed the MINTEQA2 exposure assessment model. Information on that model and its use is available at: http://www.epa.gov/ceampubl/mmedia/minteq/index.htm.

Figure 4.1: Aquatic chemistry of chemical constituents



According to the US EPA website for the MINTEQ model:

"MINTEQA2 is an equilibrium speciation model that can be used to calculate the equilibrium composition of dilute aqueous solutions in the laboratory or in natural aqueous systems. The model is useful for calculating the equilibrium mass distribution among dissolved species, adsorbed species, and multiple solid phases under a variety of conditions including a gas phase with constant partial pressures. A comprehensive data base is included that is adequate for solving a broad range of problems without need for additional user-

supplied equilibrium constants. The model employs a pre-defined set of components that includes free ions such as Na^+ *and neutral and charged complexes (e.g.,*H_4SiO_4*,* $Cr(OH)^{2+}$*). The data base of reactions is written in terms of these components as reactants . An ancillary program, PRODEFA2, serves as an interactive pre-processor to help produce the required MINTEQA2 input files."*

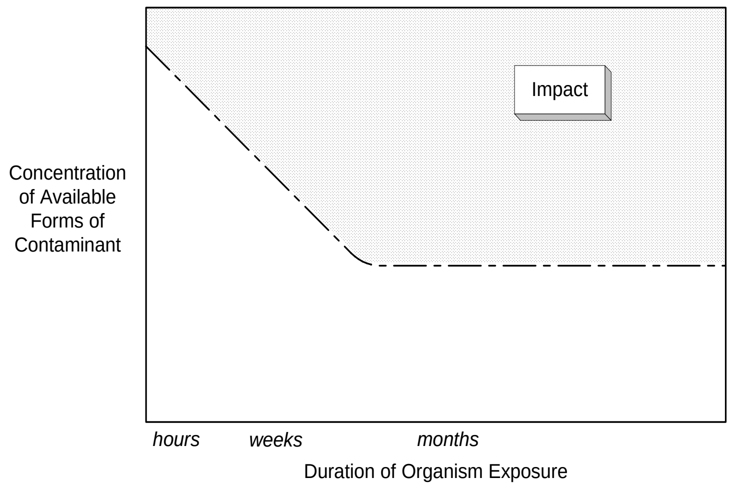
MINTEQA2 can be used to some extent to describe the position of equilibrium for the potential reactions that a chemical may undergo in an aqueous environmental system. However, it does not account for the kinetics of those reactions – that is, the rates at which equilibrium is attained – and hence the actual concentrations of the various forms expected in a particular system. The rates of some of the reactions that govern the distribution of the components of potential pollutants are sufficiently slow that equilibrium may not be achieved in runoff waters as they mix with receiving waters. Site-specific studies are needed to determine whether this situation exists for a particular chemical and runoff. Nor do the MINTEQ models include information on the concentration of each of the chemical species that may impact on aquatic-life-related beneficial uses, or on how the concentrations of specific chemical species change with time. Thus, although the MINTEQA2 model is useful in describing the aquatic chemistry of a constituent, it must be used in conjunction with site-specific investigations of the site to which it is being applied.

DURATION OF EXPOSURE

In addition to considering the bioavailability of the chemical species present in a given aquatic system, it is necessary to consider the duration of exposure that aquatic life of concern can receive as the runoff waters mix into the receiving waters. Figure 4.2 illustrates the general relationship among the concentration of available chemical forms, duration of organism exposure, and laboratory toxicity measurement ("impact"). As shown, comparatively high concentrations of the available forms of a toxic chemical can be tolerated by some forms of aquatic life without impact as long as the duration of exposure is sufficiently short. As the duration of exposure is increased, the concentration of available forms that can be tolerated without impact lessens, until, for many chemicals, a concentration is reached to which an organism can be exposed for a lifetime or over critical life stages without adverse impact.

How this relationship is manifested in an aquatic environment can be influenced by the characteristics of the organisms of concern, the nature of the discharge being considered, as well as the hydrodynamics of the receiving water. Some discharges, such as stormwater runoff, are short-term and episodic in nature; organisms would be unlikely to be exposed to the discharge for a substantial duration. Mobile organisms such as fish may move in and out of an effluent/receiving water mixing area, altering the exposure they receive to contaminants in the discharge. There can be characteristics of a discharge, such as its temperature, that attract fish to it; other characteristics may repel fish. These discharge characteristics thus affect the exposure that a mobile organism may receive. There may also be zones of passage in a receiving water such that a mobile organism may avoid exposure altogether. To model the potential water quality impacts of stormwater runoff reliably it is necessary to conduct site-specific studies of the mixing of the runoff waters with the receiving waters. Since the concentrations of potential pollutants in runoff are typically the greatest at the point at which the runoff enters the receiving water, there is concern about whether there can be toxicity to aquatic life at or near the point of runoff entry. There is also concern about toxicity in areas outside the mixing zone of runoff with the receiving water. The concentrations of runoff-associated contaminants in those areas are typically substantially lower than those in the runoff water itself. Potential impacts both within the mixing zone and outside it need to be addressed. One of the difficulties with the application of some states' regulations to stormwater runoff is that they do not allow a mixing zone for runoff-associated constituents in the receiving waters. Such a regulatory approach presumes that the concentrations in the discharge persist in the receiving water, which is rarely the case.

Figure 4.2: Critical concentration/duration of exposure relationship.



In summary, it is not possible to develop a simple mathematical model for the water quality impacts of potential pollutants in urban stormwater runoff. The nature and availability of the actual chemical species present in the particular runoff and receiving water, as well as the site-specific, complex, and variable exposure an organism may receive in the receiving water, require that a different approach be used to evaluate the water quality impacts of urban stormwater and agricultural runoff.

* Derived from Jones-Lee, A., and Lee, G. F., "Modelling Water Quality Impacts of Stormwater Runoff: Why Hydrologic Models Are Insufficient," Chapter 4 IN: **Modelling of Pollutants in Complex Environmental Systems**, Volume I, ILM Publications, St. Albans, Hertfordshire, UK, pp.83-95 (2009). http://www.gfredlee.com/Runoff/HydrologicModelsInadeq.pdf

Originally published as an invited presentation as, Jones-Lee, A. and Lee, G. F., "Modeling Water Quality Impacts of Stormwater Runoff – Why Hydrologic Models Aren't Sufficient," CENews.com Feature Article, January 29 (2008).
http://www.cenews.com/article.asp?id=2631
http://www.gfredlee.com/Runoff/CENewsStmWaterModeling.pdf

References in quote.

Stumm, W. and Morgan, J. (1996). Aquatic Chemistry, 3rd edn. Wiley, New York.

Impact of Export Projects on Chinook Salmon Home Stream Water Signal

G. Fred Lee, PhD, PE, BCEE and Anne Jones-Lee PhD
G. Fred Lee & Associates
El Macero, California
gfredlee@aol.com www.gfrfedlee.com
July 2003

Summary
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.

Background
At a California Bay Delta Authority (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 (2003) 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. Additional information on flow patterns in the Central and southern Dealt is available in reports on www.gfredlee.com http://www.gfredlee.com/psjriv2.htm.

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.

Lee, G. F. and Jones-Lee, A., "SJR Deep Water Ship Channel Water Not SJR Watershed Water below Columbia Cut," Submitted to *IEP Newsletter* for publication, Report of G. Fred Lee & Associates, El Macero, CA,(2003). http://www.gfredlee.com/IEP-SJR-Delta7-24-03Final.pdf