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CALFED BAY-DELTA PROGRAM

ORGANIC CARBON DRINKING WATER QUALITY WORKSHOP PROCEEDINGS

AUGUST 26 & 27, 1999
9:00 a.m. to 5:00 p.m.

The overall objective of this workshop was to explore the state of knowledge and current research efforts concerning organic carbon in Delta water supplies and implications for drinking water quality, and to discuss related monitoring and research needs. The first day of the workshop was devoted to technical presentations, followed on the second day by a facilitated working group session to formulate recommendations to the CALFED Water Quality Program regarding organic carbon monitoring and research.

LOCATIONS

Thursday, August 26, 1999
9:00 a.m. to 5:00 p.m.
State Personnel Board Auditorium
801 Capitol Mall
Sacramento, CA 95814

Friday, August 27, 1999
9:00 a.m. to 12:00 p.m.
Office Building 8 Auditorium
714 P Street
Sacramento, CA 95814

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WORKSHOP AGENDA

Thursday, Aug. 26, 1999

9:00-9:30	Steve Ritchie, CALFED: Drinking Water Quality Improvement Strategy (including discussion on Delta Drinking Water Council), PEIR/S Actions Related to Organic Carbon
9:30-10:00	Alan Jassby, UC Davis: Organic Carbon in the Delta: an Ecological Perspective
10:00-10:30	Stuart Krasner, MWD: Treatment of Delta Waters - What are the impacts of using different treatment methods on Delta water? What are the current and future regulations? Can future regulations be met?
10:30-10:45	Break
10:45-11:15	George Aiken, USGS: The effects of NOM Source and Environmental Factors on the Variability of DOC Composition
11:15-11:45	Rich Breuer, DWR MWQI: Monitoring of Carbon in the Delta
11:45-1:00	Lunch
1:00-1:30	Roger Fujii, USGS: Effects of Land Use on the Release of DOC and THM Precursors, Sacramento – San Joaquin Delta, California
1:30-2:00	Marvin Jung, DWR MWQI. Modeling Delta Alternatives To Improve Drinking Water Quality Work Plan: Part 1— Examining Drainage Control Options, Costs, and Benefits
2:00-2:30	Miranda Fram, USGS: Specific UV Absorbance, Aromaticity, and THM Formation Potential Relationships for DOC in Waters from the Delta and Throughout the USA
2:30-3:00	Brian Bergamaschi, USGS: THM Precursors in the Delta
3:00-3:15	Break
3:15-4:15	Marvin Jung, DWR MWQI. Modeling Delta Alternatives To Improve Drinking Water Quality Work Plan Part 2: Experiments on Designing Wetlands With Minimal Impacts on Drinking Water Quality
4:15-5:00	Panel Discussion

Friday, August 27, 1999

9:00 - Noon	The second day of the workshop was a facilitated working group session to consider all information presented the first day and formulate recommendations to the CALFED Water Quality Program.

INTRODUCTION

The Sacramento-San Joaquin Delta provides drinking water for more than 22 million people in California as well as being a major water supply for irrigated agriculture. The Delta provides source water to the Santa Clara Valley, the Central Coast, and southern California through the California Aqueduct and San Luis Reservoir; the east and south Bay Area through the South Bay Aqueduct; and north bay cities through the North Bay Aqueduct. In addition Delta water is diverted into the Contra Costa Canal and Los Vaqueros Reservoir for portions of Contra Costa County.

Treating Delta water to meet drinking water standards requires, among other things, simultaneous disinfection for pathogens and minimization of disinfection byproducts (DBPs), many of which are suspected carcinogens. Disinfection byproducts result when chlorine or ozone react with organic carbon and bromide, both of which are present in significant concentrations in Delta waters. Although present treatment plants are able to meet or exceed EPA standards for DBPs using Delta source water, EPA's regulatory process is likely to lead to more stringent standards for DBPs that are currently regulated, standards for DBPs that are not currently regulated, and more stringent pathogen removal and inactivation requirements . Unless levels of pathogens, organic carbon, and bromide can be reduced in Delta withdrawals, meeting anticipated future drinking water standards will require substantial investments in treatment facilities, new treatment technologies, or high quality water sources to blend with Delta supplies.

Reducing the quantity of sea water mixed into Delta withdrawals is the mechanism for lowering bromide concentrations because sea water is the dominant source of bromide. This process involves balancing the simultaneous effects on mixing in the Delta of tides, freshwater inflows, withdrawals, in-Delta consumption, and weather (Note to Larry – routine project operations cannot achieve the 50 µg/L bromide that is needed.) Mechanisms are less clear, however, for controlling organic carbon in withdrawals, particularly for controlling those fractions that form DBPs. Organic carbon comes from several sources, is a complex mixture of chemicals with different potentials to form DBPs, and, although organic carbon is considered a "contaminant" for drinking water supplies, it is a vital nutrient for the Bay-Delta ecosystem.

The workshop was organized primarily to explore what is known about organic carbon sources, chemical qualities of the sources, and in-Delta transformations, and to identify research needs. A previous effort has already addressed potential water treatment options (Owen *et al*, 1998). In addition, CALFED has already convened an expert panel to review bromide in Delta drinking water (Amy *et al*, 1998).

The first day of the workshop was devoted primarily to a series of technical presentations. These presentations are documented in the next section by abstracts followed by summaries of discussions that followed each presentation. Authors were given the opportunity after the workshop to append responses to points raised in the discussions.

The last hour of the first day and the second day were devoted to panel discussions with the speakers and the audience. These discussions have been summarized in the third section below.

WORKSHOP ABSTRACTS & NOTES

Drinking Water Quality Improvement Strategy (including discussion on Delta Drinking Water Council), PEIR/S Actions Related to Organic Carbon

Steve Ritchie, Chief Deputy Director
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I. Abstract
<An abstract was not submitted>

II. Notes from talk
The San Francisco Bay-Delta is an unprotected source of drinking water. Bromide and organic carbon react with ozone and chlorine to form disinfection by-products.

Organic carbon is good for the ecosystem, but is bad for drinking water quality.

Bromide in drinking water has
uncertain health effects,
faces regulatory uncertainty
has uncertain treatment issues

A drinking water improvement strategy (see Figure 1 - diagram) has been developed to
- set goals to improve source water quality in the Delta
- recommend studies and actions

Actions + monitoring & research
- Storage & operations – ISI, EWA
- Source Control – within Delta & upstream, along aqueducts(vehicles), & local
- Conveyance – South Delta, North Delta, Through Delta Alternative

Studies + monitoring & research
- Drinking Water Treatment
- Health Effects – DHS, USEPA, OEHHA
- Alternative Source Water – Southern California, Bay area
- Additional Conveyance Measures – isolated facility
- Storage & Operations – ISI

CALFED plans to form a Drinking Water Council which will be a subcommitte to BDAC and will oversee the Delta Drinking Water Quality Improvement Strategy. The Delta Drinking Water Council will also convene Expert Panels to review studies and make recommendations in 2003 and 2007. CALFED must make progress on all fronts. Handouts on CALFED Stage 1a and Stage 1 actions for Drinking Water Program and Ecosystem Restoration Program were handed out (see appendix)

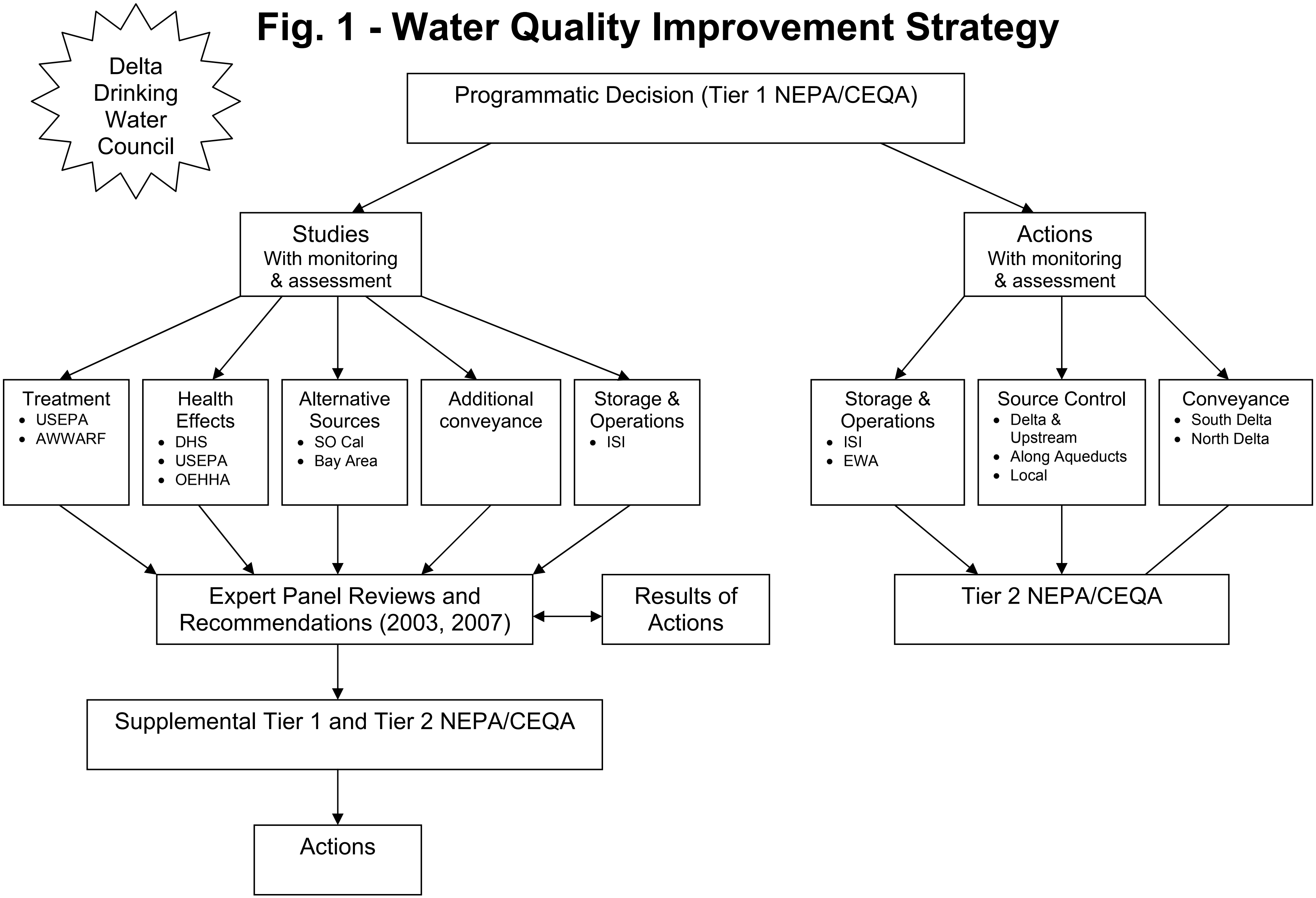
CALFED formed a Bromide Expert Panel to provide the CALFED policy makers with information to help them understand the significance of bromide to drinking water quality, define the co-occurrence of bromide and organic carbon, develop models of DBP formation to assess treatment options, define short and long-term strategies for regulatory compliance, and support health research.

III. Points from Discussion Following Presentation

1) UV technology won't be sufficient for everything needed for disinfection is not ready for large scale application.
2) More research has been conducted to support earlier studies that show that brominated by-products cause health problems
3) CALFED actions are not hard-wired. Some actions have more support than others
4) In the tradeoff between treating organic carbon and bromide, treating bromide appears more critical
5) The Delta Drinking Water Council will be a sub-committee of the Bay-Delta Advisory Council and members will be selected by the BDAC chair. A potential candidate list has already been compiled.
6) Organic carbon in drinking water is a nation-wide issue
7) Overall bromide concentrations in the San Francisco Bay-Delta exceed national averages.

IV. Author's Response to Discussion

Fig. 1 - Water Quality Improvement Strategy



Organic Carbon in the Delta: an Ecological Perspective

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[PRELIMINARY - These are preliminary results from a study that will not be in final form until the end of the year. The numbers could slide about somewhat and therefore should not be quoted, although the qualitative conclusions will remain unchanged.]

I. Abstract

Organic carbon supply to the Delta was estimated for a variety of different sources. Autochthonous (internal) sources evaluated include phytoplankton, aquatic vascular plant, and benthic microalgal productivity. Allochthonous (external) sources evaluated include river-borne loading, agricultural drainage, tidal marsh export, sewage treatment plant discharge, and urban runoff. Other sources could not be evaluated quantitatively but are negligible. On an average annual Delta-wide basis, river-borne loading, phytoplankton productivity, and agricultural drainage account for about 90% of the total. Dissolved organic matter (DOM) from river-borne loading and drainage, however, is not comparable to phytoplankton productivity. DOM must first be biodegraded and then assimilated into microbial cell biomass before it can be compared as a food source. The conversion process results in significant losses of the initial dissolved organic carbon (DOC), depending on the hydraulic residence time, biodegradation rates, and assimilation efficiencies; typically, 90% may be lost in the Delta. Taking into account DOC availability, phytoplankton productivity is probably the main organic matter source in spring and summer. Refractory DOC most likely to form DBPs is least likely to participate in the food web. These results are preliminary and are undergoing further refinement by water year type, season, and Delta sub-region.

II. Notes from talk

Organic Carbon Sources for the Delta	TOC (10^9 g/yr)	SE	N
Primary Producers (Autochthonous)			
- Phytoplankton	17	12	9
- Higher aquatic plants	<45		
- Benthic Microalgae	0.14		
Allochthonous			
- River-borne load	100	20	16
- Delta agricultural drainage	13		
- Tidal marsh export	5		
- Delta sewage treatment plant discharge	4.5		
- Delta urban runoff	0.82		

Phytoplankton Production

Photosynthesis is affected by solar radiation, biomass, water clarity, and water chemistry. Based on these factors one can estimate photosynthesis at individual water quality stations. DWR water quality stations were clustered into 8 regions, the amount of water area of each region was determined, and the Delta-wide productivity was estimated.

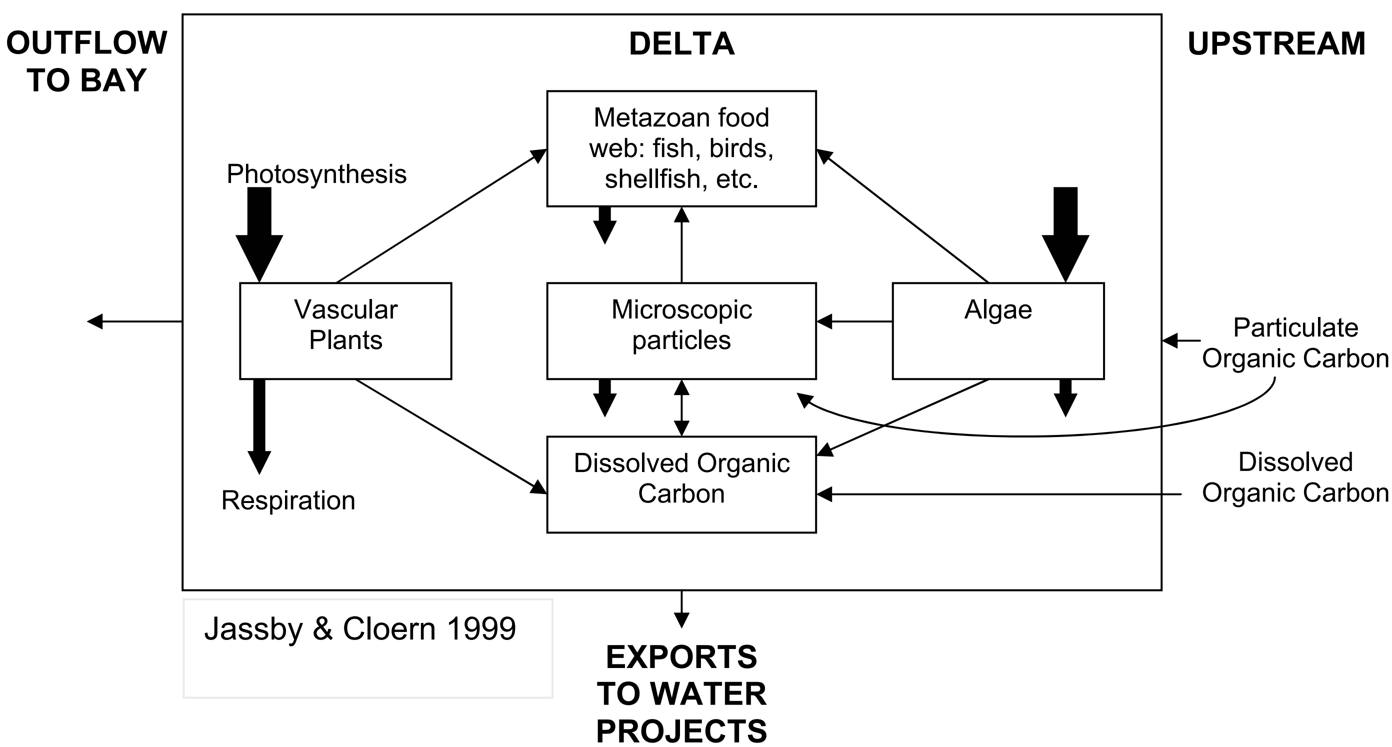
Results: Delta-wide productivity was found to be quite stable from one year to the next. Spatial anomalies moved around a lot from year to year depending on flow but remained in the Delta, so a single station showed much more variability than the Delta-wide estimate.

Historic organic nitrogen and chlorophyll a concentrations for the Delta are available. They are not fine enough to catch pulse flows in winter and spring but still give a lot of information and can be converted to organic carbon estimates.

Organic Carbon Sources

Autochthonous:	mostly particulate organic matter
Allochthonous:	mostly dissolved organic matter

<u>Conceptual model</u>



Jassby & Cloern 1999

Dissolved organic carbon (DOC) must be transformed into particulate organic carbon (POC) form, mainly by bacteria and protozoans, in order to be a source of organic carbon. This transformation must occur more quickly than the rate at which DOC is flushed from the system.

Dissolved organic carbon:Total organic carbon ratio (DOC:TOC) ranges mostly from 0.6 to 0.95 in the upstream Delta, depending on the technique. Measured bulk DOC decay rates over a 3-wk time period range from 0.005-0.02 per day in the Delta. A 25% assimilation efficiency into the food chain for DOC is approximately the median value for lakes and rivers. Just as an example, consider what happens when we choose some values from these ranges:

River TOC load corrected for availability and compared with net phytoplankton productivity (T C/d)

Season	River TOC Load	Metabolized DOC	Biomass Produced	Net TOC Load	Net PP
Winter	660±140	51	13	79	12±4
Spring	260±40	37	9.3	35	70±9
Summer	180±20	36	9	27	50±3
Autumn	240±50	37	9.1	33	15±2

Assumptions:
DOC = 0.9 TOC
DOC decay rate = 0.015/d
Assimilation efficiency = 25%

Given these example assumptions, river sources of TOC appear to dominate in the winter. Phytoplankton productivity (PP) appears to dominate in the spring & summer. These results are meant as an example, only, of what can happen when we take into account the utilizability of the DOC.

This is one reason why the paradigm that developed several decades ago–that detrital pathways are highly important–is being rebalanced in favor of phytoplankton and aquatic vascular plants. Indeed, fisheries yield is generally correlated with primary production across ecosystems (but not necessarily within).

DOC is therefore less important biologically than apparent from its concentration. Removal of especially refractory DOC is unlikely to affect food supply to the food web on a regional basis. However, on a sub-regional basis, more detailed information is needed.

Refractory DOC is the most important form of organic carbon for drinking water quality problems, but the least important for the food web.

III. Points from Discussion Following Presentation

1) The decay constant mentioned will be related to different sources of organic carbon in another report.
2) It was noted that DOC remains in water all the way down the aqueduct to Los Angeles. This decay rate was calculated only in the Delta and based upon 10-day decay rate study.
3) There may be a cascade of decay from one carbon type to another.
4) The contribution of boat waste to organic carbon loads seems small.
5) The MWQI has found that most of the TOC is DOC in rivers, whereas Jassby's results found that DOC:TOC ratio ranges from 0.6-0.95.

IV. Author's Response to Discussion

1) The bulk decay constant depends not only on the mix of compounds but also on the time period over which the measurement is made. Shorter time periods give higher values, as the most labile material gets used up first. Values for a 3-wk time period thus underestimate the biodegradability when residence time is shorter and overestimate it when residence time is longer. Three weeks is close to the median residence time for the Delta, and is therefore a good choice if one has to be made. Ideally, to model this process more accurately, one should divide the DOC into classes of compounds that have similar biodegradation rates. Good luck!

2) This is simply a corollary of what was said in (1), namely, that the 3-wk rate (0.005-0.02 per day) is an overestimate for longer time periods. Another example: in a multi-reservoir water distribution system I am working on in the Rockies, the water may be held in certain reservoirs for up to three years. During this time, the TOC–high molecular weight leachate from forest soils–drops from about 10 to 3 mg/L, which implies a decay rate of about 0.001 per day! Not surprisingly, this is the value for refractory DOC that some people stick in their models.

3) I think this refers to the obvious fact that the most labile stuff gets used up first.

4) If you take the number of recreational user-days per year in the Delta, and assume ALL the excrement goes into Delta waterways–unlikely, I hope–it amounts to about 10% of the TOC effluent from sewage treatment plants.

A further point of interest is the availability of the different kinds of POC. These are not all alike. We don't know, for example, how or even if mineral suspensoids with tightly bound OC participates in the food web. Zooplankton feeding experiments done by our postdoc Anke Mueller-Solger at UCD are showing a strong effect of different kinds of Delta POC on growth rates.

ONE FINAL CAVEAT: Please remember that these are preliminary results from a study that will not be in final form until the end of the year. The numbers could slide about somewhat and therefore should not be quoted, although the qualitative conclusions will remain unchanged.

Treatment of Delta Waters

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I. Abstract

Current Treatment/Disinfection Practices

A typical conventional water treatment plant is designed to remove particulate matter (turbidity) and to disinfect the water. Drinking water systems use predisinfection/ preoxidation to control a variety of water quality problems (e.g., iron and manganese, sulfides, zebra mussels, Asiatic clams, taste and odor). Disinfectants used in drinking water include the following:

- Chlorine: Proven effectiveness, low capital and operating costs, extensive experience.
- Chloramines: Compared to chlorine, (1) produces less disinfection by-products (DBPs), (2) has a longer lasting residual, but (3) is less effective at microbial inactivation.
- Chlorine dioxide: Effective disinfectant and oxidant, does not form trihalomethanes (THMs), but principal by-product is chlorite ion.
- Ozone: Highly reactive, very effective disinfectant and oxidant, however produces oxidation by-products.

Chemistry of DBP Formation

DBP formation can be summarized by the following equation:

$$\text{Disinfectant} + \text{Precursor} \rightarrow \text{DBPs}$$

All disinfectants (chlorine, chloramines, ozone, chlorine dioxide) are known to form various types of DBPs. DBP precursors include natural organic matter (NOM) and bromide. DBP formation is affected by various water quality parameters (e.g., pH, temperature, time, disinfectant dose and residual. Some DBPs are halogen (chlorine, bromine)-substitution by-products (e.g., bromodichloromethane [BDCM]: $CHCl_2Br$). Other DBPs are oxidation by-products (e.g., formaldehyde: HCHO).

Sources of NOM include decaying vegetation, peat soil, algae, etc. Total organic carbon (TOC)—a surrogate parameter—is a measure of the amount of NOM in water. Sources of bromide include saltwater intrusion, geologically trapped ancient seawater, and oil-field brines. Sources of contaminants in the Delta include saltwater intrusion (bromide) and peat-soil (NOM).

Reckhow and Singer (1985) developed a generalized conceptual model for the formation of the major organic halide products from fulvic acids (a portion of the NOM). In this model, there is the formation of a ß-diketone moiety, of which the activated carbon will quickly become fully substituted with chlorine. Hydrolysis then occurs rapidly, yielding a monoketone group. If the remaining "R" group (alkyl or carbon group attached to molecule) is a hydroxyl group, the reaction will stop, yielding dichloroacetic

acid (known as DCAA [$CHCl_2COOH$]). Otherwise, the structure will be further chlorinated to a trichloromethyl species. This intermediate species is base-hydrolyzable to chloroform. At neutral pH, if the R group is an oxidizable functional group that is capable of readily donating an electron pair to the rest of the molecule, trichloroacetic acid (known as TCAA [CCl_3COOH]) is expected to form. In the absence of such an oxidative cleavage, hydrolysis will prevail, yielding chloroform.

Reckhow and colleagues (1990) isolated 10 aquatic humic and fulvic acids and studied their reactions with chlorine. These researchers observed a significant positive correlation between the TCAA/THM ratio and the specific ultraviolet absorbance (SUVA). UV absorbance is also a measure of the degree of conjugation of a compound. This is consistent with the proposed haloform reaction of Reckhow and Singer (1985) in which a conjugated system (R group) capable of donating electrons to the carbonyl group in the intermediate (trichloromethyl) species will preferentially lead to TCAA formation over chloroform formation.

On a weight basis, THMs are typically the largest class of DBPs detected in chlorinated drinking water; the second largest fraction is typically the haloacetic acids (HAAs) (e.g., DCAA, TCAA). Typically, the measured halogenated compounds, cumulatively, account for between 30 to 60 percent of the total organic halogen (TOX) found in these samples. Thus, a significant portion of the TOX produced during chlorination is unknown. Ozone can convert NOM in water to aldehydes, aldoketoacids, carboxylic acids, and other assimilable organic carbon (AOC). Carboxylic acids typically represent the largest fraction (e.g., ~30 percent) of the AOC. However, a large fraction (e.g., ~60 percent) of the AOC has not been identified.

Regulatory Background

The Stage 1 DBP Rule was promulgated December 1998. It lowered the maximum contaminant level (MCL) for THMs to 80 µg/L. It established an MCL for the sum of 5 HAAs at 60 µg/L. It established MCLs for bromate at 10 µg/L and for chlorite at 1 mg/L. It also requires removal of DBP precursors (i.e., TOC).

The Stage 2 DBP Rule will be promulgated by May 2002. It is currently being negotiated. “Placeholder” MCLs in the 1994 proposed Stage 2 DBP Rule include 40 µg/L for THMs, 30 µg/L for HAAs, and 5 µg/L for bromate. The Stage 2 DBP Rule is to be promulgated with an Enhanced Surface Water Treatment Rule (ESWTR). The ESWTR may include an inactivation requirement for *Cryptosporidium*. Other Stage 2 DBP rule options include (1) setting MCLs for individual DBPs of health concern (2) eliminating the running daily average compliance formula, and 3) rules governing effects of TOC on bromide. Certain brominated DBPs (e.g., bromodichloromethane) (1) have higher cancer potencies and (2) have been associated with adverse reproductive/developmental health effects (e.g., spontaneous abortion).

Effect of TOC (NOM) and Bromide on DBP Formation

An increase in either TOC or bromide will result in an increase in the formation of THMs, including the formation of BDCM. An increase in TOC will result in an increase in the formation of ozone by-products (e.g., aldoketoacids) during ozonation. Moreover, an increase in either TOC or bromide will result in an increase in the formation of bromate during ozonation.

Effect of Using Different Treatment Methods on Delta Water

Effect on TOC (NOM). Coagulation removes humic and large-molecular-weight NOM. Coagulation does not remove much of the non-humic or low-molecular-weight NOM. The reduction in the value of SUVA correlates with the removal of humic NOM. Ozonation can convert some of the humic and high-molecular-weight NOM to non-humic and low-molecular-weight NOM, respectively, which results in water somewhat less amenable to TOC removal by coagulation.

Effect on DBPs. Coagulation removes TOC, but not bromide. This results in a shift to the formation of more brominated DBPs upon chlorination. Humic NOM—which can be removed by coagulation—can form THMs and HAAs during chlorination. In addition, certain portions of the non-humic NOM—which are typically not removed by coagulation—can also form significant amounts of THMs and especially HAAs. Biofiltration can remove a portion of the AOC produced during the ozonation of NOM. However, during certain water quality or operational conditions, the ability to remove AOC can be compromised or lost.

Can Future Regulations Be Met?

The California Urban Water Agencies (CUWA) expert panel indicated that we need a TOC of 3 mg/L and a bromide of 50 µg/L in source waters to meet a future anticipated DBP Rule and ESWTR. Moreover, we may need to meet these goals at all times of the year if compliance with the DBP MCLs no longer allows for running annual averages. In fact, the California Department of Health Services even considered eliminating certain aspects of the running annual average during the State's implementation of the Stage 1 DBP Rule.

<u>II. Notes from talk</u>

< See copies of overheads handed out>

The major point of this presentation was that we can't just focus on THMs and bromate. There are numerous identified DBPs and many potentially unidentified DBPs. If a particular treatment technology seems to be the solution to eliminating or reducing the formation of one class of DBPs, it will most likely not be the answer for all DBPs or it may actually form DBPs that are currently unknown.

<u>III. Points from Discussion Following Presentation</u>

1) Currently time series are being generated for bromide and TOC and quarterly measurements on DBP
2) The economics of treating at the plant vs. the tap might be evaluated, since only a small portion of the water is being used as drinking water. However, our laws require treatment at the plant.
3) Europe invented many of these treatment techniques. They have little information on DBPP, but in general they are seeing the same problems we are.

4) Europe doesn't treat their water with chlorine as much as we do—however Europeans also do not drink their tap water as much as Americans do. Their problems of treating the drinking water are the same.

IV. Author's Response to Discussion

Effects of NOM Source and Environmental Factors on Variability of DOC Composition

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I. Abstract
The importance of source materials, soil chemistry and hydrology on the amount and composition of natural organic matter (NOM), measured as dissolved organic carbon (DOC), in aquatic systems will be presented. Each of these factors influences not only the amount of organic matter in a given system, but its reactivity as well. Organic matter derived from different source materials has distinctive chemical characteristics associated with those materials. Interactions between organic matter and the minerals and inorganic constituents in soil can result in the removal and fractionation of the organic matter altering the composition and reactivity of the DOC. Oxidative processes, such as photooxidation, can result in the decrease of DOC concentration and the selective removal of high molecular weight, more aromatic constituents in the carbon pool. The resulting DOC can be more hydrophilic, lower molecular weight and more biodegradable. Finally, the transport of organic carbon is largely dependent on hydrologic conditions, which define the flow path and control the rate of transport of DOC within the system. The nature, distribution and reactivity of organic matter in a given system is determined to a large extent, by the strength and nature of interactions between the various components of the environment. Understanding these factors will help in identifying effective solutions to problems posed by its presence.

II. Notes from talk

Organic Carbon

- controls pH and light absorption
- assists in transport
- redox reaction
- affects bioavailability of nutrients and metals
- controls biochemical reactions
- causes water treatment problems

Organic Carbon is a complicated picture

DOC ——→ Colloidal ——→ Particulates
1 nm 450 nm

DOC is defined analytically as that fraction that passes through a 0.45u filter, however true DOC is < 1 nm. There are many colloids and viruses that will pass through the filter.

Organic Carbon is actually a complex heterogeneous mixture.

- ranges from low to high molecular weight
- differing solubilities and polarities
- differing reactivities
- ranges from labile to refractory.

There are no universal methods of isolation or analysis.
Characterization tools provide only "average" information, not the whole picture.
Quality of the organic carbon is more important than the quantity when one is trying to understand processes – the amount of reactive carbon is what is important.

In the Everglades, the organic carbon consisted of about half hydrophobic organic acids (SUVA=0.045) with the remaining consisting of hydrophobic organic neutrals (SUVA=0.036), hydrophillic organic acids (SUVA=0.023), and hydrophillic organic neutrals (SUVA=0.017) and low molecular weight compounds.

Note: SUVA stands for specific ultraviolet absorbance at 254 nm.
SUVA=UV absorbance at 254nm / DOC

In the Everglades, mercury methylation depended on the quality of the DOC rather than just the TOC or the SUVA.

Key factors controlling the nature of organic carbon

- Source materials
- lignin
- algae/bacteria
- crude oil
- Geochemical interactions
- sorption
- charge suppression
- S addition (HS^-)
- Subsequent degradation
- microbial
- photolytic oxidation
- Hydrologic factors
- is water moving up through peat (high SUVA) or down through peat (low SUVA)

In a study on the Colorado River, it was found that the downstream quality of DOM was more complicated than a simple mixing of the DOM found in the tributaries.

A different quality of organic carbon results under flushing (higher SUVA) than under low flow conditions.

DOC photodegradation – over a 5 day period

- lost DOC
- SUVA decreased
- Molecular weight decreased
- Biodegradability increased

<u>III. Points from Discussion Following Presentation</u>

<No discussion points recorded>

<u>IV. Author's Response to Discussion</u>

Monitoring of Carbon in the Delta

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I. Abstract

Since the early 1980s, tTrihalomethane formation potential and organic carbon have been monitored in the Delta. Early findings by the Interagency Delta Health Aspects Monitoring Program (the forerunner of the Municipal Water Quality Investigations Program) found that Delta peat soils enriched water moving through the Delta with organic compounds. These compounds are disinfection by-product precursors that react with disinfectants to form compounds that are harmful to humans, including known and suspected carcinogens. Since 1990, the Municipal Water Quality Investigations Program has continued to monitor organic carbon and other parameters of concern for drinking water in both Delta channels and agricultural drains. This has resulted in the largest collection of historical drinking water quality data for the Delta. In addition, the Program has conducted research on sources of carbon, and possible solutions to reduce impacts to drinking water. Current research is focusing on further quantifying loading of carbon and the reactive fractions. Additional analyses of CALFED actions and alternatives, including restoration, in terms of changes to carbon and other parameters, will provide input into the long-term goal of improving and protecting Delta drinking water quality.

II. Notes from Talk

1982 (?) – Concluded soils in Delta increase organic carbon

- concluded bromides increase DBP

1987-88 – conclude that agricultural drains increase organic carbon and precursors

1990 – MWQI formed to determine and evaluate sources of organic carbon in drinking water in the Delta.

Organic carbon – involves TOC, DOC, POC, and varies seasonally. We may need to find solutions on a seasonal basis.

TOC and DOC usually track closely.

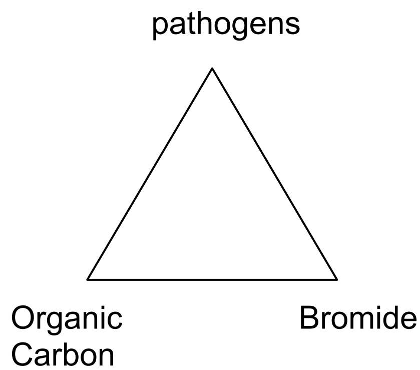
The concentration of organic carbon increases when the agricultural drainage increases.

Concentration of DOC in the wet season is higher than in the dry season.

Sacramento River DOC (Greens) < San Joaquin River (Vernalis) < Pumps (Banks)

Most water at the Banks Pumping Plant is Sacramento River water, however, there is a greater proportion of San Joaquin River water at the Tracy Pumping Plant.
Island drains have high organic carbon concentrations (10x that in the channels)

Current issues:
- Increasing urbanization
- Carbon is beneficial for food web
- Treatment Triangle



THMFP & bromoform formation potential is greatest in the dry season of dry years

Wet season SUVA is greater than dry season SUVA

SUVA Banks > Vernalis ≈ Greene

Conclusion – Delta contributes organic carbon.

Increasing urban discharges is a concern regarding organic carbon. They can increase organic carbon loads or even seasonality of loads.
- Natomas East Main Drain – upstream of Hood
- Sacramento Regional Wastewater Treatment Plan – upstream of Hood
- Growth at Tracy
- Proposed “Gold Rush City” (very close to the pumps)

CALFED Proposed Actions could also impact organic carbon loads
- Wetland restoration actions
- Through Delta Conveyance
- In-Delta Storage (Delta Wetlands Proposal)
- Flooding Delta islands

Possible solutions:

- New Technology
- Protect source water from contamination
- Continue monitoring
- Focus restoration efforts in areas where water will flow to Suisun Marsh rather than to the pumps .
- Determine sources and loadings of key drinking water contaminants
- Develop modeling tools to evaluate possible actions

Studies currently occurring

- Real time TOC monitoring
- Data assessment of existing data
- SMARTS and agricultural drainage
- Natomas East Main Drainage Canal loading study
- Sanitary Survey – Barker Slough, Coordinated Pathogen Study

Messages

- there is lots of reactive organic carbon in the Delta
- additional analyses are needed
- monitoring at more locations and sources should be combined with hydrological data
- modeling efforts needed

III. Points from Discussion Following Presentation

1) There seems to be a contradiction between this talk which says the islands are the problem and a previous talk (Alan Jassby) which said the rivers are the primary source of organic carbon. It depends on the time of the year as to which is more important.
2) What about biosolid application?
3) Have attempts been made to normalize the carbon?

IV. Author's Response to Discussion

Effects of Land Use on the Release of DOC and THM Precursors, Sacramento-San Joaquin Delta, California

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[*PRELIMINARY, SUBJECT TO REVISION*]

I. Abstract

CALFED is considering restoring 100,000 acres, or more, of land in the Delta to wetlands and it is unknown how this significant change in land use will affect the quantity and quality of dissolved organic carbon (DOC) released to Delta channel waters that are used for drinking water supply. Increasing amounts of certain types of DOC (disinfection byproduct precursors, DBPs) will exacerbate the future difficulties for drinking-water suppliers to meet USEPA regulations (discussed in detail in other abstracts). Therefore, it is necessary to determine both the quantity and quality of carbon exported from different types of wetlands and the effects on the quality of water (DBP precursors) diverted for drinking water. It is also important to assess release of carbon from wetlands in terms of its potential positive effects as a food source to the delta and estuarine foodwebs (this topic addressed in other abstracts).

There are three major questions pertinent to the initial evaluation of the effects of land use change on the quality of drinking water in the Delta:

- What concentration and quality (DBP precursors) are released by different land uses in the Delta?
- What are the spatial and temporal (seasonal) variability of DOC and DBP precursor concentrations released by different land uses?
- How do these concentrations relate to loads (concentration x discharge) of DOC and DBP precursors that end up in channel waters and eventually exported for drinking water?

The data presented will begin to address the first two questions, whereas a substantial amount of focused, applied future research will be necessary to address the third question.

Data from several collaborative studies supported by the USGS Drinking Water Initiative, California Department of Water Resources, and CALFED are presented for several types of land uses. The majority of the data focus on spatial and temporal trends over a year or longer for an agricultural field operation (cornfield on Twitchell Island) and several non-tidal, experimental wetlands (for subsidence mitigation) on Twitchell Island. Limited data are presented for near-bottom surface waters collected from several tidal wetlands throughout the Delta for one sampling date.

DOC and THMFP measurements were taken in the soil water extracted from approximately 0.5 to 1.5 ft below land surface for the following treatments: Reverse Flooding Habitat (brood habitat, intentionally irrigated to 1-ft deep from spring to mid

summer), Open-Water Habitat Pond (water bird habitat, > 3ft deep), Permanently Flooded Wetland (continuously flooded to about 1.5ft, 7.5 acre area, cattail and tule vegetation, monitored from initial flooding for 2.5 years), Permanently Flooded Wetland Pond (continuously flooded to about 1ft, 30ft x 30ft enclosure, mainly cattail vegetation, monitored during the fourth year of flooding), and Agricultural Field. In general, median concentrations of DOC and trihalomethane formation potential (THMFP) in soil water were greatest for the Reverse-Flooding Habitat Pond (165 mg/L DOC and 19,000 μg/L THMFP) and lowest for the Open-Water Habitat Pond ((8.4 mg/L DOC, 1400 μg/L THMFP). Soil-water concentrations of DOC and THMFP for the intermediate three treatments were in the order: Permanently Flooded Wetland > Permanently Flooded Wetland Pond > agricultural field. DOC and THMFP measurements were also taken in surface waters and outflow waters for the Permanently Flooded Wetland and from near-bottom surface waters collected from 8 tidally influenced wetlands in the Delta. The median DOC and THMFP of Permanently Flooded Wetland surface water (6.9 mg/L and 825 μg/L, respectively) and outflow water (6.9 mg/L and 740 μg/L, respectively) were higher than the medians for the tidally influenced Delta wetlands' near-bottom surface waters (2.5 mg/l DOC and 215 μg/L THMFP).

A more direct indicator of DOC quality in relation to THM precursors is specific THMFP (STHMFP), which is THMFP/DOC (mmol/mol). This carbon normalized parameter provides a measure of the reactivity of the average DOC in a sample: the higher the number, the greater the propensity of the DOC to form THMs. The median soil-water STHMFP decreased in the order: Open-Water Habitat Pond (14.0 mmol/mol)> Reverse Flooding Wetland Pond (12.5 mmol/mol)> Permanently Flooded Wetland Pond (10.6) = Permanently Flooded Wetland (10.6) > agricultural field (9.6). The median STHMFP of the surface water and outflow from the Permanently Flooded Wetland were similar to the Permanently Flooded Wetland soil water; whereas, the near-bottom surface waters from tidal wetlands had much lower median STHMFP (6.7 mmol/mol).

These preliminary results clearly indicate the need to assess both the quality of the DOC (STHMFP) and the loads, not just concentrations, of DBP precursors in order to evaluate the relative importance DBP precursor sources in the Delta. For example, the Open-Water Habitat Pond had the lowest median DOC concentration but the most reactive DOC quality with respect to THMFP (highest STHMFP). Thus even though the DOC concentrations are much lower than those from the agricultural field, the total contribution of THM precursors may be greater from an Open-Water system compared to an agricultural system if the loads (concentration x discharge) of THM forming DOC from the Open-Water system are greater than that from the agricultural system. The paucity of DOC quality data and THMFP loads for carbon sources throughout the Delta underscores the need for future research and monitoring in these areas.

II. Notes from talk

A summary of the preliminary results is put into the table on the following page.

III. Points from Discussion Following Presentation

1) Actual loading rates were not measured because that section of the proposal was not funded. Measuring loading rates is needed, but difficult to do.

2) A question was asked about the contribution of the decaying corn residue vs. peat soil in the organic carbon from the agricultural field. They are apparently different in quality.

IV. Author's Response to Discussion

Table 1. Summary of results from Roger Fujii's presentation. Data are median concentrations. Please note that these results are preliminary only and combine results from several experiments.

		Reverse Flooding Habitat Pond (brood habitat, intentially irrigated to 1-ft deep from spring to mid-summer)	**Permanently Flooded Wetland** (continuous flood to about 1.5ft, 7.5 acre area, cattail & tule vegetation, monitored from initial flooding for 2.5 years)	**Permanently Flooded Wetland Pond** (continuously flooded to about 1 ft, 30ft x 30 ft enclosure, mainly cattail vegetation, monitored during 4th year of flooding)	**Agricultural Field**	**Open Water Habitat Pond** (water bird habitat, > 3ft deep)	**8 tidally influenced Delta wetlands** (near-bottom surface water used)
Soil Water	DOC THMFP STHMFP	164 mg/L 19,380 ug/L 12.5 mmol/mol	91 mg/L 9085 ug/L 10.6 mmol/mol	67 mg/L 7430 ug/L 10.6 mmol/mol	63 mg/L 5686 ug/L 9.6 mmol/mol	8.4 mg/L 1384 ug/L 14.0 mmol/mol	
Surface Water	DOC THMFP STHMFP		6.9 mg/L 825 ug/L 11.4 mmol/mol				2.5 mg/L 215 ug/L 6.7 mmol/mol
Outflow water	DOC THMFP STHMFP		6.9 mg/L 739 ug/L 10.6 mmol/mol				

Modeling Delta Alternatives To Improve Drinking Water Quality Work Plan: Part 1-- Examining Drainage Control Options, Costs, and Benefits

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I. Abstract

An analytical framework for ranking research and monitoring actions pertaining to the selection of a Delta alternative and its components is described. The work plan conducted by the DWR Municipal Water Quality Investigations Program consists of field, experimental, and computer modeling studies of: (1) drainage control options, (2) wetlands and shallow water storage options, and (3) the relocation of water supply intakes or points of diversion as methods to reduce organic carbon concentrations and loads at municipal water intakes.

The results of the drainage control studies are described. The results included:

1. estimated regional drainage volume and organic carbon mass loads
2. on-island treatment methods and costs for reducing organic carbon loads prior to discharge
3. candidate regions for on-island treatment
4. computer model predictions on DOC reduction at Delta water supply intakes as a result of reducing DOC at the candidate regions

II. Notes from talk

CALFED options to reduce organic carbon in drinking water include
- decreasing drainage discharges
- decreasing TOC in drainages
- relocating water intakes
- blending with water of higher quality
- decreasing water residence time in the delta

The approach involved compiling data, conducting new studies, and creating simulated model runs of hypothetical scenarios in the Delta for comparison.

The Modeling Delta Alternatives Work Plan focuses on studies to examine:
- drainage control options
- wetlands and shallow water storage options
- relocating agricultural drainages and municipal water supply intakes

This first talk described the results of the drainage control option studies and reports. The first report was titled, “Delta Island Drainage Volume Estimates, 1954-55 versus 1995-1996”, published in January 1998.

In this report, the following 1954-55 and 1995-1996 data were compared:

1. Total annual and monthly drainage volumes
2. Rainfall
3. Land use changes
4. Regional and seasonal drainage volumes
5. Completeness of the pumping data set used to compute drainage volumes

More measured (pump efficiency and power use records) data was available from the DWR1954-55 data set than in the USGS 1995-96 data set provided by P.G. & E.

1954 data	1995-96 data
82% real data	20% real data
18% assumed data	80% assumed data

Some differences between the two data sets were also attributed to the difference in the number of data points (i.e., pump stations) on record.

The results of a second report titled,“Candidate Delta Regions for Treatment to Reduce Organic Carbon Loads”, (January 1999) were presented. A hypothetical scenario was developed for a series of computer modeling runs conducted by DWR to compare the relative benefits of reducing drainage organic carbon loads in the Delta at selected sites. The approach consisted of a series of steps to identify areas of high organic carbon loads, ranking of areas for on-island treatment, and making estimates on treatment costs.

The tasks included:

Computing regional organic carbon loads based on the DWR DICU (Delta Island Consumptive Use Model) at a Year 2020 level of development and 16-year average hydrology (1976-1991)

Developing ranking criteria for selecting candidate regions for treatment

Defining treatment model cost assumptions

Scoring the Delta regions for modeling treatment

Composing a set of simulated conditions for DWRDSM2 model runs

The analysis showed:

- The DICU model predicted results had higher highs and lower lows than the 1954-55 data but they tracked each other fairly well, especially in seasonal trends.
- The central Delta contributes the most drainage and up to 75% of the May – September organic carbon load to the Delta. The discharge volume from some aggregated areas approach that of the Sacramento Regional Wastewater Treatment plant (over 100 MGD).

- The areas with the highest loads had the lowest land surface elevations.
- A study on treating island drainage showed that a reduction of up to 60 percent of the organic carbon could be achieved with ferric chloride coagulation.
- The estimated costs of 12-27 agricultural drainage treatment plants was $200-$400 million

Computer runs using the DWRDSM2 model were performed to compare predicted DOC concentrations in the Delta under the CALFED Preferred Alternative 1 and On-Island Treatment at Candidate Delta Regions. The model runs showed:

- Under Preferred Alternative 1, the estimated average DOC concentration at Clifton Court Forebay would not meet the target DOC average of 3 mg/l. However, under the treatment scenario, the target DOC objective was met six times per year.
- Similar reductions in DOC concentrations were predicted for other locations within the interior Delta.

A third report describing these results will be completed this year. The results will be used to guide future work (e.g., pilot plant study) and needs for evaluating drainage control options and water quality benefits.

III. Points from Discussion Following Presentation

1) What are the volumes of organic carbon in exports, and as a % of the total DOC in Delta(?)
2) What is the treatment cost per year of treating in Clifton Court Forebay

IV. Author's Response to Discussion

The volume of organic carbon in exported water and with respect to the total input to the Delta have not been computed. However, we do know it varies with hydrology and season. Loads during the dry months can be easily computed as there is less variability in DOC concentrations entering the Delta from rivers than during wet months. DWR is working on a fingerprinting module for the DWRDSM2 model. This will provide estimates on the age (residence time) and source of organic carbon at different sites. When this module is completed, we can address these questions.

We did not perform any treatment cost estimates for water entering Clifton Court Forebay. We did however have a Water Treatment Costs Model for THM Control developed by Malcolm-Pirnie. This model predicts rough costs for meeting future trihalomethane (THM) standards given a set of raw water quality data. However, the model lacks the very important ability to predict costs for bromate control. Until this bromate control module is completed, the current model would grossly underestimate costs at water treatment plants to meet all USEPA drinking water standards. Much more research is needed on bromate formation and treatment costs to develop the module.

Specific UV Absorbance, Aromaticity, and THM Formation Potential Relationships for DOC in Waters from the Delta and throughout the USA

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I. Abstract
Dissolved organic carbon (DOC) in natural water reacts to form trihalomethanes (THM) and other disinfection byproducts when this water is chlorinated for use as drinking water. In order to better understand the compositional nature of THM precursor material, we examined the trihalomethane formation potential, ultraviolet (UV) absorbance at 254 nm, and aromatic carbon content of dissolved organic carbon in waters from grab sampling in watersheds across the USA, and from detailed sampling in one watershed, the Sacramento-San Joaquin Rivers and Delta, California (Delta).

Linear regressions of DOC with UV absorbance, and UV absorbence with THM formation potential for Delta waters have different slopes and smaller errors than regressions for the national watershed samples. This suggests that different watersheds contain DOC with different compositional characteristics (quality). Further information about DOC quality was gained by removing the effect of carbon concentration by examining carbon-normalized parameters, specific UV absorbance at 254 nm (SUVA) and specific THM formation potential (STHMFP). In Delta waters, specific UV absorbance and specific THM formation potential vary from 0.01-0.09 L/mg/cm and 4-16 mmol/mol, respectively, indicating large variability in carbon quality in the Delta. Furthermore, waters from different environments, such as the Sacramento and San Joaquin rivers upstream of the Delta, main channels within the Delta, ponds and soils from constructed wetlands, and ditches and soils from an agricultural field, contain DOC with different relations between specific UV absorbance and specific THM formation potential. Contrary to expectations, DOC derived from Delta peat soil waters had lower specific THM formation potential than DOC derived from Delta channel waters, indicating that the effect of agricultural drainage water on Delta water quality is not just a function of the quantity of DOC added. These results indicate that Delta environments and processes do affect DOC quality in ways that are significant to drinking water source quality.

DOC was also isolated from Delta waters using XAD resins and was analyzed for specific UV absorbance, specific THM formation potential, and aromatic carbon content (by ^{13}C-NMR). The data revealed considerable variability in the relation between aromatic carbon content and specific UV absorbance, suggesting that the NMR and UV absorbance analyses are measuring features in the DOC in addition to aromatic carbon content. Specific THM formation potential was not well correlated with either aromatic

carbon content or specific UV absorbance at 254 nm, indicating that THM precursor material cannot be simply characterized as aromatic carbon or as UV absorbent carbon.

In conclusion, DOC quality must be considered, along with DOC quantity, when evaluating the potential of Delta waters to form THM when they are treated for use as drinking water.

<u>II. Notes from talk</u>
An understanding is needed of the relationship between Delta processes and Drinking Water Quality

The current regulatory strategy for reducing disinfection by-products in treated drinking water is to decrease TOC and assumes that UV absorbance and DOC can be used as a surrogate measure for THMFP. This is based upon the assumption that

- THMs are aromatic compounds
- Aromatic compounds are concentrated in the humic fraction
- Aromatic compounds are measurable by UV absorbance

However, there is considerable variability in the relationship between aromatic compounds and UV absorbance. This variability does matter.

The variability was examined in data collected from the Sacramento & San Joaquin rivers, Twitchell Island, and NAWQA nation-wide. The slope of the relationship between UV absorbance and DOC was found to be significantly higher for the Delta waters than the nationwide average slope. This implies that the compositional nature of DOC varies from watershed to watershed. DOC composition or "quality" does matter.

SUVA = (UV absorbance at 254 nm) / (DOC Concentration)
STHMFP = (THMFP) / (DOC Concentration)
(molar)

STHMFP increases with SUVA, but there is lots of variability, indicating lots of varaibility in the compositional DOC quality.

STHMFP vs. SUVA relationship varies considerably with the source of organic carbon. The Delta DOC quality varies a lot and depends on source, such as

- rivers
- channels
- wetlands
- agricultural soils
- agricultural ditches

Aromaticity is another measure of DOC quality. Aromatic compounds are hydrophobic and stable. Aromaticity did not show a strong correlation with STHMFP. In addition agricultural soil water did not have a high STHMFP compared with water from agricultural ditches and Delta channels.

Information about organic carbon loads is very much needed.

SUVA-254 does correlate with aromatic carbon content, but there is lots of variation.

Conclusions

- beware of assumptions
- aromaticity alone does not determine THMFP
- UV-254 measures more than just aromaticity
- The effects of DOC quality and quantity on UV and THMFP need to be separated out
- Delta peat island runoff contains an aromatic unreactive carbon fraction
- Delta environments and processes do affect DOC composition for drinking water concerns.

III. Points from Discussion Following Presentation

1) The agricultural drain on Twitchell island is not the agricultural drain with the highest DOC load. Plus the channel outside the drain contains water from other agricultural drains. This may have impacted the results. Agricultural drains themselves vary in UV and DOC. This is a point to look at in the future
2) The word "unreactive" can be misleading. Most unreactive compounds are at least a little bit reactive, and at high concentrations can produce significant concentrations of products.
3) DOC is much more variable in chemistry than we realize. We should look at other things than just aromaticity.
4) It might be useful to evaluate some dairy operations and see if that accounts for some of the variability.

IV. Author's Response to Discussion

THM Precursors in the Delta

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I. Abstract

Dissolved hydrophobic and hydrophilic acids were isolated from samples collected at five channel sites within the Sacramento-San Joaquin Rivers and Delta, California, USA, and from a peat island agricultural drain to examine the relationship between the chemical composition of dissolved organic carbon and the formation of trihalomethane, and to test whether peat island-derived dissolved organic carbon contributed substantially to reactivity in Delta channel waters. The chemical composition of the isolates was quite variable, as indicated by significant differences in carbon-13 nuclear magnetic resonance spectra and carbon to nitrogen concentrations ratios, though the variability was not consistent with simple mixing of river- and peat-derived dissolved organic carbon. The lowest propensity to form trihalomethane observed among this small set of samples was in the peat island agricultural drain sample, suggesting the addition of peat island waters into Delta channels did not increase the amount of trihalomethane formed from channel water dissolved organic carbon, provided these grab-samples represent the general trend. Changes in the chemical and isotopic composition of the isolates and in trihalomethane formed from the isolates suggest the source of the trihalomethane precursors was different among samples and between isolates.

II. Notes from talk

Conclusions

- quality of DOC is as important as the amount of DOC
- non-point source processes are a major factor in determining the amount and quality of DOC

Sacramento River DOC vs. various sampling sites were compared. There was a temporal coherence between the variation in the Sacramento River DOC and the DOC at Banks (Pumps). There was no obvious coherence between the DOC in any of the ag drains evaluated and the DOC at Banks (Pumps).

Processes within the Delta are strongly affecting DOC concentration at Banks. The loadings of DOC from agricultural drains needs to be investigated.

Comparisons of DOC concentration were made at Sacramento River, Twitchell Island, Old River, Middle River and Banks (Pumps-exports)

SUVA

Twitchell > Middle River ≈ Exports > Sacramento River > Old River

Fraction aromatic

Twitchell > Sacramento River, Old River, Middle River > Exports

STHM

Old River, Middle River > Sacramento River > Twitchell, Exports

) *^{13}C was used to trace the source of carbon materials.

- the quality of DOC in the Delta varies
- Channel water DOC is not a simple mixture of peat derived carbon and river born carbon
- Processes within the delta channel waters are affecting the quality of DOC

Possible factors that could change quantity and quality of DOC in delta channels include

- wetlands
- algae
- upland runoff
- microbial degradation
- photolysis
- flocculation

The reactivity STHMFP varies by a factor of four. The THMFP after 5 minutes is an order of magnitude greater than after 24 hours and again after 7 days. There are distinct pools of DOC that occur initially, after 10 hours, 60 hours and 200 hours.

The quality of the DOC is very important to THMFP

There is a need to take a broader look at DOC relationships in the Delta. Currently the focus has been driven by regulations, costs, and ecosystem concerns.

For example important areas of focus include

- DBP formation
- Ozone interaction
- Kinetics
- Surface activity
    - membrane fouling (algae leaks organic goo that fouls membranes)
    - flocculation
- microbial degradation
- DOC composition

The speaker was concerned that productivity of the Bay-Delta estuary bulrush is very high – 5 times as productive as agricultural lands. He is concerned that wetlands may export more carbon as DOC and that putting lots of wetlands in the Delta will increase DOC in drinking water.

Message: Quality of DOC is as important as the quantity. Understanding the processes that alter DOC quality is important to understanding how the quantity of DOC in the Delta will affect generation of disinfection by-products.

III. Points from Discussion Following Presentation

1) The data is just a single snapshot in time. One must be careful about extrapolating beyond the data. Getting a more complete picture throughout the year would be useful.
2) There is a need to understand
- loading of organic carbon in the system
- loading variability and reactivity from various sources
- processes that affect organic carbon in the delta
3) There is a need to better understand ozonation and the generation of disinfection by-products.
4) THMFP is not a perfect surrogate for disinfection by-products because THM is not the only disinfection by-product formed. Measurement of other halo acids would be useful in addition to THMFP

If channel processes are affecting DOC quality – what should be recommended to CALFED? There is a need to understand DOC loads. What is coming from peat soils versus the crop? What will be the loads from current and future wetlands? There is a need to better understand particle tracking in the Delta – what particles reach Banks versus flow out of the estuary?

IV. Author's Response to Discussion

Modeling Delta Alternatives To Improve Drinking Water Quality Work Plan: Part 2-- Experiments on Designing Wetlands With Minimal Impacts on Drinking Water Quality

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I. Abstract
The results of experiments that study water quality changes related to flooded peat soil environments are presented. The series of experiments examine the relationship among peat soil depth, water depth, and water exchange rate as controlling factors of water quality. The experiments are conducted at the new DWR SMARTS (Special Multipurpose Applied Research Technology Station) facility at Bryte. A factorial designed experiment was used. The first trial experiment ran for three months in the summer of 1998. Experiment #2 began in January 1999 and will run for at least one year. The results will be used to help design, construct, and operate wetlands with minimal impact on drinking water quality and yet hopefully meet the ecological needs desired for the Delta. A computer simulation of hypothetical wetlands in the candidate regions for treatment will be made to compare DOC loads in the Delta.

II. Notes from Talk

The results of a new report titled, "Trial Experiment On Studying Short-Term Water Quality Changes In Flooded Peat Soil Environments", were presented.

A facility with 8 large tanks (1.8 m^2 surface area) was created at the DWR West Sacramento Facility called SMARTS to model proposed wetland and storage projects. The facility is designed so that samples can be taken of both surface and peat soil water.

Experiment 1:
A 2^3 (two-cubed) full factorial designed experiment was conducted in the 8 tanks. Three factors each with two treatments were tested.

FACTOR	TREATMENTS
Peat Soil Depth	2 soil depths (1.5' and 4')
Water Depth	2 water depths (2' and 7')
Water Exchange rate	No exchange vs. 1-1.5 surface water volume exchanges per week

The experiment lasted from mid-July to mid-Oct. for 12 weeks. The tanks were sampled weekly. The treatment with 4 ft of peat soil, 2 feet water and no water exchange showed strongly increasing TOC levels as the experiment progressed through time. The tanks without water exchange had higher TOC than tanks with water exchange. Algae did not seem to be a major contributing factor to TOC at that time based on a standard conversion formula of chlorophyll concentration to organic carbon concentration.
Conclusions from the experiment were

- all 3 factors had major effects,
- effects were additive
- eutrophic water conditions were created
- that results agree with reported studies
- experiment is a good simulation of waterlogged peat soil conditions
- experiment is a good simulation of different flood conditions
- algae is not a big factor
- hypothesis: over time the top 1 foot of peat soil affects biogeochemistry seen in the water
- a long-term experiment is needed

It was commented that the tank conditions that exhibited the most TOC buildup (Tank 3 with 4' peat, 2' water, and no water exchange) resembled those conditions desired to create managed wetlands (shallow depth of less than 2 feet with no water exchange). The tank with the next highest TOC was tank 1, which had 1.5 feet of peat soil under 2 feet of water with no water exchange.

Experiment 2

This experiment began in January 1999. This time the tanks were covered to prevent water gain from rainfall, water loss from evaporation, and to prevent algal blooms. Two separate dump truck loads of peat soil had to be collected. The first 4 tanks (1 –4) were filled first with a dry peat. The last 4 tanks (5-8) were filled a month later and the soil was water saturated from a rainstorm. Soil samples were taken for comparison of the two batches. The early peat soil water data showed distinct differences between tanks 1 – 4 and 5 –8, probably due to the two different peat soil batches used. However, the surface water quality responses were similar to those in experiment #1 which used on single batch of peat soil. The tanks showing high TOC concentration in experiment 1 were also showing high concentrations in experiment 2.

<u>III. Points from Discussion Following Presentation</u>

1) Each treatment combination in this experimental design is unreplicated. It is possible the extreme results seen in tanks 1 and 3 are due to initial random minor differences in the soils and biology that accumulated over time. The experiment should be repeated to ensure that this is not the case or additional supporting experiments should be performed.

2) This experiment does not include plants. How would the addition of plants affect the results?

IV. Author's Response to Discussion

A second SMARTS facility would be needed to replicate each experiment. However, the statistical approach plotted the normal order score (rankits) against the computed effects. In this procedure, if the effects are random, the results may be expected to be normally distributed as with any other random variable. The statistical significance of the estimated effects can be evaluated by ranking a normal plot. If the effects represent only random variation, the values will plot as a straight line. If a factor has caused an effect to be greater than expected due to random error alone, then the effect will not fall on a straight line and are considered significant. This was the case in making our conclusions about each factor we tested in experiment #1

Factorial experiments are iterative experiments, where with each succeeding experiment, we change the upper and lower limits of our treatments of each factor. This allows us to pinpoint the best or worst conditions for a specific result. Future runs may include changing the water depths or water exchange rates to help design the wetland with the best water quality condition.

Experiment 2 will continue for an additional year into Year 2000. So far the first six months of data support the experiment #1 observations. A progress report is being written at this time and will be available by November 1999. A new experiment (#3) will take and flood large soil cores from four Delta sites with replicates. The four soils will have different organic carbon content. This experiment will address the question about water quality differences related to soil organic carbon differences. This experiment begins as early as November 1999.

The study did not include plants but will in a future study. To design such an experiment, we need to know which types of plants and the plant densities to simulate. We will use data from ongoing USGS wetland studies to decide on the simulated plant conditions to test.

If plants and algae were allowed to grow in the tanks, we would expect nutrient uptake and lower nitrogen and phosphorus in the surface water. Water logged soils release ammonia and phosphates due to the anaerobic soil conditions. Studies by others have found the aerobic layer to be a few millimeters to only a few centimeters thick. The redox potential measurements in our tanks at the 1,2,3, and 4-foot soil depths confirm this. Our study conditions do inform us of the potential eutrophic conditions and organic carbon releases from new flooded areas not established with wetland plants.

<u>PANEL DISCUSSION SUMMARY– THURSDAY, AUGUST 26</u>

<u>Discussion Objective</u>
Larry Smith asked --what are the major unanswered questions about
1) sources and fate of organic carbon as a whole
2) qualities of organic carbon from various sources, particularly those that relate to DBP formation or to food value for the estuary
3) human activities that might alter 1 or 2

<u>Points Made During Discussion</u>

- DOC should be the focus rather than TOC, with regards to drinking water quality concerns.
- Residence time – important influencing factor
- Flushing flows – important influencing factor
- Seasonality -- annual averages don't show the whole picture
- Often exports are increasing when DOC loads are increasing and flows are increasing
- DOC at the exports is greater than the DOC in the Sacramento River. Where does the rest of the DOC come from?
- DIDI report by DWR gives a 1-2 year mass balance study.
- The quantity and quality of DOC need to be measured throughout 1-2 years
- All three factors are important factors affecting DOC in exports
    - River discharge
    - Island discharge
    - Production/degradation in Delta channels -- simple mixing of carbon from island drains and river water is not occurring
- These factors are not independent. As DOC travels, its quality changes.
- An understanding of carbon loadings is needed, coupled with information on hydrology.
- Good modeling of the system is needed
- SUVA at high levels does not correlate well with THMs. This may be due to simple chemistry
- Better THM measures are needed, otherwise one only gets a narrow understanding of the DOC-THM relationship
    - Supplemental Halo acid measures, total halogen compounds (?)
- A larger, regional approach is needed.
- Better surrogates for DOC reactivity are needed. SUVA and DOC measures are of limited usefulness
- A better understanding of the quality of organic carbon coming from delta islands is needed
- What types of carbon are better biologically is not known. Usually river water is recalcitrant and less useful biologically. Autochthonous material is more useful biologically.

- Maybe we have three axies of measurement?
  - SUVA
  - Labile to recalcitrant
  - DOC to POC
- Wetlands generate DOC because wetlands are oxygen deprived. Degradation of the DOC continues after it leaves the wetland.
- The reactivity of organic matter with chlorine is well-defined. But the bioavailability of various forms of organic matter is not well-defined and are very different reactions.

PANEL DISCUSSION SUMMARY– FRIDAY, AUGUST 27

Discussion Objective:
What are the major unanswered questions on the following issues regarding organic carbon relative to actions within the next decade that may be taken by CALFED or others?

1) Sources and fates
2) Qualities
3) Actions affecting 1) and 2), e.g.,
   a) Agriculture on Delta islands
   b) Wetland restoration
   c) Upland source reductions
      i.) agricultural,
      ii.) municipal
      iii.) non-point source
      iv.) Sacramento and San Joaquin rivers
   d) Other CALFED actions (e.g., water mgt., EWA)

Points Made During Discussion

I. SOURCES AND FATES

ISSUE: Other effects on water quality variation need to be identified: 1) Need to validate whether agricultural drainage in the San Joaquin River is a source of bromide or if the high bromide levels are due to concentrating of the bromide that was applied in the surface water taken from the Delta, e.g. does data from Empire tract represents geologically trapped seawater 2) Need to research islands with different agricultural practices and their effect on DOC loading, e.g., animal grazing (dairy, cattle) vs. grain crops 3) Need to research the extent of decomposing vegetative matter vs. peat soils as source DOC loading. Tom Zuckerman clarified that agricultural soil flooding is done for multiple reasons, but not usually for salt leaching in the Delta (i.e., weed control, residue decomposition, waterfowl, etc). Salt management is an issue at the periphery of the Delta. Farmers on western islands flood and remove salt by dilution rather than leaching

Roger Fujii pointed out that his group is starting a CALFED project on grazed land to assess organic carbon movement and sources

ISSUE: Delta utilities are concerned about ozonation problems as well as chlorination problems. Chlorination and ozonation affect different types of organic carbon differently. There is a long-term need to focus more on ozonation issues

INFORMATIONAL ITEM: Some other funded CALFED projects relate to this issue:
1) Effect of different wetlands on POC and DOC.

2) Organic carbon in the Delta as a source for food chain since there has been a lack of plankton blooms since the introduction of Asian clams.
3) Learning laboratory: subsided islands returned to productive islands/wetlands. Project is not underway yet (Twitchell island funded by Category III. Water quality from Sherman island)
4) MWQI data assessment to establish existing conditions in Delta and to assess future needs. Should involve CMARP.

ISSUE: The question was asked: Is there consensus that river-borne carbon entering the Delta during high flow periods enabling passage to Bay can be eliminated as a significant source?
Answer from participants: NO. River loads are an important factor.

- The river load is the base load. Timing is an important factor
- We need to investigate the amounts and timing of the river loads.
- We need to further investigate rivers at different plants

RESOLVED: Participants decided to retain the working hypothesis that organic matter in diversions contains contributions from all 3 sources (rivers, island discharges and in-Delta production). Which is most important varies with flow, seasonality, and water year. This is a multi-dimensional problem so we need to retain and examine all factors

- Export pumping occurs in every season so we need to look at DOC in all seasons
- Organic matter in agricultural drains is highest from mid-January through mid-February
- We need to examine loadings from major rivers and representative agricultural drains (i.e., not just Twitchell Island)
- We need to examine effects of water year, operations, facilities, etc. as sources of variability
- We need to know the true hydrology of the system and exports. The hydrology models need to be validated! Is San Joaquin River water at Vernalis just recycled Delta water? What effect does San Joaquin River water play at the export facilities? How does timing of export pumping and hydrology (flushing, residence time) affect DOC at the export facilities? Is 70% of the water at the export facilities Sacramento River water at all times of the year?
- We need to know mass loading and balance seasonally, not just on an annual basis

RECOMMENDATION 1: Form a Multi-agency technical group effort to analyze 15 years of data from all sources to outline the big picture, characterize sources, develop baseline data, resolve issues, and develop a process for evaluating CALFED progress. (The group could be formed either as a CALFED action item or as a part of the Drinking Water Council). Interested individuals from the workshop identified themselves on a sign-up sheet. (see below)

Discussion items:

- Changes to operations may not be represented by historical conditions

- Will need to have consensus of what baseline conditions are in order to determine effectiveness of CALFED actions
- Should be possible to get some water quality improvements by improving operations and models as a result of this effort
- Demonstrable drinking water quality improvements may help in getting flexibility from existing regulations
- Operational flexibility may be limited. However, only Contra Costa Water District and several smaller cities rely exclusively on Delta water; others usually blend and exchange. There may be ways to improve drinking water source without necessarily improving the entire Delta water quality as only a small percentage ends up as drinking water
- Some of the source of conflicts in the viewpoints discussed reflects the scale of focus (big picture regional monitoring efforts which monitor a few variables or focused small-scale studies which produce a lot of information in a specific area). Both viewpoints are needed. The combination of the big regional picture with the results from the more focused studies would be very powerful and would produce a better understanding of the processes involved and better predictions in the future. The combination will also allow better determination of where money should be spent.

ISSUE: Water operators need to know the worst case conditions in order to design treatment facilities, e.g. periods of drought couples the worst DOC and Bromide problems with the least flexibility in water supply & operations.

RECOMMENDATION 2: Have multi-agency technical group define worst-case conditions given the existing system

RECOMMENDATION 3: Recommend for early implementation of MWQI DOC study on rivers

OPERATIONS ISSUE: Conducting water operations in California is very complex and involves balancing multiple problems. Operators cannot simply manage only for TOC. The problem is too complex to simply target one water quality constituent such as TDS, Br, TOC, Salinity etc. Also it is too simplistic to identify just one source. Trends in water quality from the State Project indicate these constituents vary by different rates and are important at different times. Operational flexibility is needed.

RESOLVED: CALFED decision-makers and scientists should consider all alternatives to improve drinking water quality and adopt an approach considering a broad range of actions, including:

- consideration of all 3 alternatives identified by CALFED
- cost analysis of treatment at the source vs. treating at the treatment plant
- seasonality of pumping
- holding water on islands.
- Identification of what we can and can't do to decrease organic carbon in exports.

A real- time data network would be needed.

INFORMATIONAL ITEM: Paul Hutton--Drinking Water Quality Ops. Working Group is looking at operation rules to improve drinking water quality as part of CALFED's Integrated Storage Investigation. They are only looking at salinity/bromide for now. They will look at other things as well for other objectives, e.g., water supply reliability, ERP, etc.

INFORMATIONAL ITEM: MWD manages storage and conveyance comprehensively. A suite of options is applied to allow operational flexibility in a cost-effect manner.

II. QUALITY OF ORGANIC CARBON

ISSUE: Historical data should be used to "paint the big picture" and address questions, e.g., what types of carbon dynamics are associated with islands based on organic soils? A tiered approach from the big picture to the small picture should be used, guided by the conceptual model. We should think broadly in terms of DOC effects on other issues and processes, e.g., Hg, food web, etc. Identify key areas of uncertainty to focus studies. Sophisticated analysis should compliment the tiered approach.

RECOMMENDATION 4: Task Technical Group to also A) develop additional monitoring and analysis to resolve questions that cannot be answered by the historical data analysis, B) identify where more detailed technical studies are needed to bound uncertainty and where levels of uncertainty are acceptable, C) predict consequences of Delta wetland restoration on organic carbon quality and quantity (data won't be available for at least 3-5 years). May need to examine related efforts from other areas (e.g., Newport, VA, Everglades, etc.) as well as sensitivity analyses to incorporate quality concerns.

RECOMMENDATION 5: Task Technical Group to also develop and execute laboratory experiments with Delta water mixtures to assess DBPs formed

ISSUE: What large scale experiments could be conducted? We should think big as well as small. As an example-- Could all the agricultural drains be shut down for a sufficient period of time to assess the affects of agricultural drains on DOC at the export pumps? Response—There is a possibility during April or May. The issue would have to be discussed with the farmers. The limitation of such a large experiment is that there is no control. The DOC levels will either change or they won't. But sorting the effects of shutting down the drains from other factors in producing this change is difficult.

Discussion Items:

- MWD/DWR fingerprinting water models may be of use for these experiments
- Group should look at processes and flowchart 1) river carbon from source to treatment plants 2) agricultural lands and 3) ecosystem

RECOMMENDATION 1 Revisited: The technical group should flowchart the carbon sources, processes and flow in the system, i.e. rivers -> delta-> plants

ISSUE: Can wetlands be designed to improve water quality as defined by reduced DBPs?

RECOMMENDATION 6: Identify and consult with experts in the wetlands field to scope out issues relative to design of wetlands for water quality.
Suggested: Kimberly Gray at Northwestern, Joy Zedler at Wisconsin, Mike Hotelling at Newport News, VA

INDIVIDUALS INTERESTED IN PARTICIPATING IN A ORGANIC CARBON DRINKING WATER QUALITY TECHNICAL GROUP

The following individuals placed their names on a sign-up sheet for expressing interest in participating in the technical group recommended during the panel discussion.

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SUMMARY POINTS FROM
ORGANIC CARBON DRINKING WATER WORKSHOP,
AUGUST 26 & 27, 1999

General Points of Agreement

Following is perhaps an overly-simplified list of points from the workshop about organic carbon that seemed to have general agreement.

- Rivers, island discharge, and in-channel processes all contribute to DOC in the Delta withdrawals and at the export facilities. The relative importance of each at any given time depends on
  - water year
  - season
  - timing of exports and sources
  - river flows
  - tides

  River sources of organic carbon appear to dominate in the winter. Biological processes (phytoplankton) in the Delta appear to dominate in the spring and summer.
- DOC varies considerably in quality. It is a complex heterogenous mixture of different molecular weights, solubilities, polarities, reactivities, labile to refractory compounds.
- DOC quality varies considerably among sources.
- DOC in Delta channels is not a simple mixture of DOC from the rivers and DOC in the agricultural drains
- The quality of the DOC is as important as the quantity in affecting THMFP in exports.
- TOC and SUVA are used as surrogates for THMFP because they correlate with each other. Because the quality of DOC varies considerably, the relationship between these surrogates and THMFP has considerable variability and involves several assumptions. In addition there are other haloacetic acids formed that could be of concern that are not measured by THMFP. This may affect accurate estimation of THMFP & other DBP formation to some degree and obscure some of the details of what is occurring.

Recommendation for a Technical Group

The workshop participants recommended that a Technical Group of agency and stakeholders be formed who are tasked with:

A. Analysis of existing historical data to establish baseline conditions, characterize organic carbon sources, resolve issues and outline the “big picture”.
B. Define worst-case conditions for which treatment facilities will have to prepare
C. Develop additional monitoring and analysis to resolve questions that cannot be answered by the historical analysis
D. Identify technical studies needed to bound uncertainty as well as identifying where levels of uncertainty are acceptable (i.e., prioritizing information needs)
E. Increase predictive capabilities relative to consequences of wetland restoration activities on organic carbon

F. Develop and execute experiments with Delta water mixtures to assess DBP formation
G. Identify and consult with experts in the wetlands field to scope out issues relative to designing wetlands to improve water quality

The technical group should integrate and coordinate with other components of CALFED such as the Integrated Storage Investigation, coordinate with existing agency efforts, and maintain awareness of the recent advances in drinking water treatment methodologies.

Draft summary of research needs .

Following is a summary of various research needs and uncertainties expressed by workshop speakers and participants. The list is not prioritized. Not all the items mentioned have agreement that they are *priority* research need.

<u>Quantity & Quality of organic carbon</u>

- A better understanding is needed of organic carbon loading amount, quality, reactivity & variability from all sources throughout the year and the processes that affect them, including
    - rivers
    - sewage treatment plants discharge
    - wetlands
    - channel processes, non-point sources such as algae and macrophytes,
    - agricultural drains
      * peat soil vs. crop residue contributions
      * effects of different agricultural practices: grazing, crops, dairy operations
    - urban runoff & increasing urbanization
    - boat waste
- A good conceptual model and simulation modeling of organic carbon source loadings, sinks, and processes in the system is needed. A regional viewpoint as well as a local view point is needed.
- An improved understanding of water year effects, water operations and facilities on variability of DOC in the system is needed. What amount of organic carbon as a percentage of the whole amount in the Delta is exported?
- A number of studies have measured organic carbon in various source waters. An understanding is needed of how organic concentrations in these various sources relate to loads.
- An understanding of spatial and temporal variability of organic carbon loading is needed.
- Organic carbon issues must be coupled with Delta hydrology modeling to better understand their importance in affecting drinking water. If DOC is released at different points in the system, what is the probability that it will affect reactive DOC concentrations at the export facilities? A good validated hydrology model is needed.
- A 1-2 year mass balance study is needed that measures quantity and quality of DOC throughout that period, similar to DWR's DIDI report

- Agricultural drainage should be investigated as a source of bromide, e.g. data from Empire tract represents geologically trapped seawater
- DOC quality should be further investigated as it degrades/is converted from one type to the next in Delta channels and outside Delta channels (as it travels through the aqueducts).

Organic Carbon for Drinking Water vs. Food Web

- The types of organic carbon that are more useful biologically versus the types that affect drinking water quality are unclear. Are they the same or different? POC appears more important biologically and DOC more important for drinking water quality, but this needs research on a sub-regional as well as regional basis. In general, river water is recalcitrant and less useful biologically whereas autochthonous material is more useful. Would removal of DOC to benefit drinking water affect the food web?
- What effect will increasing wetland acreage in Delta have on DOC at export facilities? Can wetlands be placed in locations where the impact on DOC at export facilities will be less?
- All wetlands are not the same. Wetlands can even be designed to improve water quality by acting as sediment traps and heavy metal traps. Can wetlands be designed to improve water quality as defined by reducing DBPs?
- How do marsh plants affect DOC concentrations and loadings?
- What concentration and quality of DBP precursors are exported from different types of wetlands, how do they affect drinking water quality at the export facilities and how do they affect delta and estuarine food webs?

Drinking Water Quality Issues

- Laboratory experiments with various Delta water mixtures should be developed and executed to assess DBPs formed
- The effects of DOC quality and quantity on SUVA and THMFP need to be separated
- Simple surrogates such as SUVA and TOC that moderately correlate with THMFP should be replaced by surrogates that better reflect the most reactive organic matter forms that affect drinking water and more tightly correlate with THMFP and DBPs.
- What are the DOC precursors of DBP other than THM?
- More comprehensive total organic halogen measures are needed that measure not only THMFP but also haloacetic acid measures, total organic halogen compounds, etc. Haloacetic acid analyses are needed to better understand the reactivity of natural organic matter to form DBPs of health and regulatory concern. Otherwise only a narrow understanding of the DOC-DBP relationship is achieved.
- What is the usefulness of UV disinfection as an alternative to chlorination? (a speaker pointed out that it won't meet all needs)
- What is the worst case scenario that the export facilities must be prepared for?
- The economics of treating at the plant vs. the tap might be evaluated since only a small portion of the water is being used as drinking water. However, our laws require treatment at the plant.

- What would be the treatment cost per year of treating water in Clifton Court Forebay (in contrast to treating agricultural drainage water)
- Retain consideration of all CALFED alternatives when looking for ways to improve drinking water quality
    - consideration of all 3 alternatives identified by CALFED
    - cost analysis of treatment at exports vs. treatment plant
    - seasonality of pumping
    - holding water on islands
    - identification of what can and cannot be done to decrease organic carbon in exports

<u>Monitoring Methods</u>

- An evaluation of the monitoring being conducted is needed, i.e. long-term monitoring of lots of sites for a few parameters vs. very detailed studies of a few sites

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HANDOUTS

CALFED Bay-Delta Program: Ecosystem Restoration Program Stage 1A Actions

CALFED Bay-Delta Program: Organic Carbon Drinking Water Quality Workshop – Draft Agenda

CALFED Bay-Delta Program: Organic Carbon Drinking Water Quality Workshop – Participants list

CALFED Bay-Delta Program: Water Quality Program Stage 1A Drinking Water Actions

CALFED Bay-Delta Program: Water Quality Program Stage 1A and Stage 1 Actions

Draft Summary of Research Needs identified on Thursday, Aug. 26 of workshop

Treatment of Delta Waters, Copies of overheads, by Stuart W. Krasner, MWD

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Trial Experiment On Studying Short-Term Watrer Quality Changes In Flooded Peat Soil Environments

ACRONYMS

AOC	Assimilable Organic Carbon
BDCM	Bromodichloromethane
BDAC	Bay-Delta Advisory Committee
CMARP	Comprehensive Monitoring, Assessment and Research Program
CUWA	California Urban Water Agencies
DBP	Disinfection Byproduct Precursor
DCCA	Dichloroacetic Acid
DOC	Dissolved Organic Carbon
DOM	Dissolved Organic Matter
DHS	California Department of Health Services
DIDI	Delta Island Drainage Investigation
DPLA	DWR- Division of Planning and Local Assistance
DWR	California Department of Water Resources
EWA	CALFED Environmental Water Account
ESWTR	Enhanced Surface Water Treatment Rule
HAA	Haloacetic Acid
ISI	CALFED Integrated Storage Investigations
MCL	Maximum Contaminant Level
MWD	Metropolitan Water District of Southern California
MWQI	Municipal Water Quality Investigations Program (DWR)
NAWQA	National Water Quality Assessment Program
NMR	Nuclear Magnetic Resonance
NOM	Natural Organic Matter
PEIR/S	Programmatic Environmental Impact Report / Programmatic Environmental Impact Statement
POC	Particulate Organic Carbon
PP	Primary Productivity
SMARTS	Special Multipurpose Applied Research Technology Station
STHMFP	Specific Trihalomethane formation potential (THMFP) / (DOC Concentration)
SUVA	Specific Ultraviolet Absorbance at 254 nm (UV absorbance at 254 nm) / (DOC Concentration)
TCCA	Trichloroacetic Acid
TDS	Total Dissolved Solids
THM	Trihalomethanes
THMFP	Trihalomethane Formation Potential
TOC	Total Organic Carbon
TOX	Total Organic Halogen
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
UV	Ultraviolet