CHAPTER 6.0
MAJOR FINDINGS AND RECOMMENDATIONS FOR FUTURE WORK

The development of the conceptual model in this report involved the synthesis of a large amount of data and information from published reports. The model provides a succinct summary of a tremendous amount of work that has been conducted in the Central Valley-Delta region in the last 25 years. The conceptual model can be used to direct future investigations to improve understanding of organic carbon-related sources, transformations, impacts, and management. This chapter summarizes key findings and highlights future concerns.

6.1 MAJOR FINDINGS

Organic carbon in the dissolved form (DOC) is the form considered to be more likely to react during chlorination and form disinfectant byproduct compounds. DOC is generally less bioavailable to the base of the web compared with particulate organic carbon and/or organic carbon freshly derived from primary production. Thus, efforts in the Central Valley and Delta to control or manage DOC levels for drinking water quality may not have direct adverse effects on the food web, although this is a subject that needs to be studied further. There is general agreement in the literature that THM formation is correlated to TOC concentrations, although the relationship is more complex when a specific structural characteristics of DOC is compared with THM formation potential. A commonly used measure of DOC aromaticity, SUVA at 254 nm, was found to be poorly correlated to THM formation in Delta waters. Characterization of organic matter through sophisticated analytical tools such as stable isotope signatures is an active area of research; published information that was available at this time, however, is limited to a small number of locations near the Delta, and with limited temporal resolution. The data are indicative of a contribution

due to in-Delta primary production, although the variability of this contribution as a function of time is not known. There is limited knowledge on the relative propensity of different sources to form THMs, although it appears that Delta island drainage, is somewhat less reactive than tributary sources.

Flows in the Central Valley, albeit modulated by the existence of a large number of reservoirs, are nonetheless highly variable, especially in the winter months. In a pattern that is widely seen, at most stream sampling locations concentration data were obtained for a small number of dates, whereas the flow data were obtained daily. In such a situation, loads are estimated using a relationship between flow and concentration to interpolate for the dates on which no concentration data are available. Flows and organic carbon concentrations are weakly correlated, if at all. Best fit regression lines between log of concentration and log of flow were used to estimate flows. When the data are poorly correlated and these lines effectively have zero slope, they essentially reflect the mean of concentration observations. At a station where daily flow and concentration data were available, the load calculation approach presented here was found to estimate loads reasonably well.

Loads of organic carbon delivered by the tributaries are substantially greater in the winter months. Tributary loads were found to vary significantly between wet and dry years, with loads from the Sacramento River Basin exceeding the San Joaquin River loads by a factor of two. There are few sources of data for in-Delta contribution of organic carbon, and these sources are more approximate than the tributary loads. Current estimates show that annual loads of organic carbon from the tributaries are substantially greater than the best estimates of in-Delta production. However, in dry years these may be a significant fraction of the total loads. The organic carbon export in aqueducts is relatively uniform from year to year, particularly when compared with the tributary loads. In dry years, the export of organic carbon in aqueduct is nearly as large as the average internal Delta production.

The loads transported in streams were compared to the organic carbon export rates from different land uses. A small number of stations in the existing database could be used for the purpose of characterizing export from a particular land use; however, very few of the stations were sited specifically for this purpose, the export rates may be confounded by more than one land use. Export rates of organic carbon (mass of carbon exported per unit area per year) were computed key land uses: urban land, agricultural land, wetlands, and natural areas (including forests, shrubland, and rangeland). The calculated total watershed exports matched well with the stream loads at key locations (such as Sacramento River at Freeport and San Joaquin River at Vernalis) although not at all locations considered. Export rates, as currently approximated, could be improved through focused flow and concentration data collection in small, relatively homogenous watersheds.

The contribution of various sources to organic carbon concentrations at the intakes is best estimated through modeling. California Department of Water Resources' DSM2 model was found to be the best tool for this task. This model is well calibrated and

widely used for water flow and water quality applications throughout the Delta. The model is routinely used by DWR staff to evaluate the effect of specific scenarios on concentrations at various intakes. A similar mechanistic model of the tributaries may need to be developed if impacts at stations outside the Delta need to be studied.

6.2 UNCERTAINTIES IN EXISTING DATA AND RECOMMENDATIONS FOR FUTURE WORK

This section focuses on the uncertainties associated with the quantitative information presented in preceding chapters, and identifies key data gaps that should be addressed in future work, primarily through targeted monitoring and detailed mechanistic modeling. A summary of the uncertainty associated with quantitative information presented in Chapters 2, 4, and 5 is shown in Table 6-1. The uncertainty associated with the sources and the importance of obtaining more data to decrease uncertainty are discussed in this section. Recommendations are made for additional data collection, analysis of existing data, and modeling studies.

6.2.1 ORGANIC CARBON CHEMISTRY AND DISINFECTION BYPRODUCT FORMATION

Uncertainty and Importance

The chemistry of organic carbon, and particularly the propensity of organic carbon from different sources to form THMs and other disinfection byproducts, continues to be investigated actively. However, because of the dynamics in the system (in the flows and production of organic carbon), available data are insufficient to draw conclusions about the quality or the THMFP of organic carbon from different sources. The data are especially lacking in much of the watershed upstream of the Delta. There is significant uncertainty associated with this information even though it is important for assessing drinking water impacts. A better understanding of the potential for disinfection byproduct formation of different sources of organic carbon could lead to more informed decisions on how to best manage organic carbon in the system. For the immediate future, total organic carbon will be the primary focus of the Central Valley Drinking Water Policy Workgroup because drinking water suppliers are regulated on the concentrations of total organic carbon in the source water, and the research to characterize the quality of carbon from the various sources in the Central Valley will be costly and time consuming.

Table 6-1.
Relative levels of uncertainty and importance of organic carbon sources identified in the Conceptual Model.

Source	Level of Uncertainty	Importance
Tributary Loads		
Sacramento Basin		
Sacramento R. at Bend Bridge	High	Medium
Butte Cr.	High	Low
Sacramento R. at Colusa	High	Medium
Yuba R.	High	Medium
Bear R.	Medium	Low
Feather R.	High	Medium
American R.	Medium	Medium
Sacramento R. at Hood/Greene's Landing	Low	High
Cache Cr.	High	Low
Putah Cr.	High	Low
San Joaquin Basin		
San Joaquin R. at Sack Dam	High	Low
Chowchilla R.	High	Low
Bear Cr.	High	Low
Merced R.	High	Medium
San Joaquin R. at Newman	Medium	Medium
Tuolumne R.	Medium	Medium
Stanislaus R.	Medium	Medium
San Joaquin R. at Vernalis	Low	High
Delta		
Cosumnes R.	Medium	Low
Mokelumne R.	Medium	Low
Delta North	High	Medium
Delta South	High	Medium
In-Delta Sources		
Delta Island Agricultural Drainage	High	High
Export Rates		
Agricultural Land	High	High
Urban Runoff	Low	High
Background Areas	High	High
Wetlands	High	High
Other		
Point Source Discharges	Medium	High
Reservoirs	High	Medium

Recommendations

The Workgroup should stay apprised of research that is being conducted by USGS and MWQI on carbon quality.

6.2.2 TRIBUTARY LOADS

Uncertainty and Importance

The number of water quality samples and the length of the flow data record were used to assign the rankings of low, medium, and high uncertainty associated with each of the subwatersheds listed in Table 6-1. The loads in the Sacramento River at Hood/Greenes Landing and the San Joaquin River at Vernalis are well characterized due to many years of data collection and more recent real time monitoring. In general, the loads of organic carbon in the other subwatersheds that discharge to the Sacramento and San Joaquin rivers are not adequately characterized. Currently, the DWR modelers treat the Sacramento River at Hood/Greenes Landing and the San Joaquin River at Vernalis as boundary conditions to the Delta model. Although the models are able to predict how much of the load at a Delta pumping plant is due to each of the rivers, the models do not predict the sources of organic carbon within the Sacramento and San Joaquin watersheds. Additional data collection in the upper watersheds will allow the models to be extended upstream of the current boundary conditions.

Recommendations

The real time data collected in the Sacramento River at Hood, the San Joaquin River at Vernalis, and the Banks Pumping Plant should be reviewed to better define the relationships between concentration and watershed processes such as precipitation and reservoir releases. A more detailed review of these data can provide guidance on the importance of monitoring during certain times of the year, during specific events (such as storms), and on the frequency of monitoring needed to fully characterize organic carbon at an individual site. In addition, there are substantial data that were not used in this study because the concentration data were collected at locations for which there are no flow data or because the database did not contain latitude and longitude information. The Workgroup should review all of the data that have been collected for each of the subwatersheds and determine the key locations that require additional monitoring. The information gained from the review of the real time data should be used to determine the timing and frequency of monitoring.

6.2.3 IN-DELTA SOURCES

Delta Agricultural Drainage

Uncertainty and Importance

There are extensive data on organic carbon concentrations in Delta island agricultural drainage; however drainage volumes are currently estimated with the DICU model. Fingerprinting studies have shown that Delta agricultural drainage contributes a substantial amount of organic carbon to the Banks Pumping Plant under some

conditions. It is important to have an accurate estimate of the drainage volumes before management options can be considered.

Recommendations

USGS is currently monitoring drainage volumes on Twitchell Island and MWQI is conducting a study of drainage volumes on Staten Island. These measured drainage volumes should be compared to estimates from the DICU model to assess how accurately the model predicts drainage volumes. Then decisions can be made on the importance of obtaining additional drainage volume data.

Delta Primary Production

Uncertainty and Importance

In-Delta primary productivity estimates are based on one study whose results were extrapolated both spatially and temporally to calculate organic carbon loads from this source.

Recommendations

The Workgroup should track the investigations being conducted on the Pelagic Organism Decline (POD) and request that additional work be conducted on Delta primary productivity, if it is not included in the POD work plan.

Tidal Marshes

Uncertainty and Importance

Tidal marshes, although a small area compared to the watershed of the Sacramento and San Joaquin rivers, have the largest export rate of any land use evaluated in Chapters 4 and 5 (150 tons of carbon/km^2/year). This export rate was based on a literature review because studies on Delta tidal marshes have not been completed. Because of the potential magnitude of this source, its proximity to Delta intakes, and the likelihood that these areas will grow in future years because of planned restoration efforts, the importance of this source should be evaluated.

Recommendations

The USGS study results on Twitchell Island should be reviewed when the study is completed to determine if Delta research confirms the findings in the literature. In addition, fingerprinting analyses should be conducted to determine the sensitivity of organic carbon concentrations at the major Delta pumping plants to varying estimates of tidal marsh export rates and acreage. This information can then be used to determine if additional research is needed on Delta tidal marshes.

6.2.4 EXPORT RATES

There is an extensive amount of organic carbon concentration data collected in the major streams in the Central Valley. These data can be used to compute export rates from mixed land uses. However, for distinguishing sources, it is important to estimate the contribution of specific land uses. To meet this objective, focus should be placed on studying small indicator watersheds or specific sources.

Reservoirs

Uncertainty and Importance

There are reservoirs on most of the rivers in the Central Valley watershed but there are currently limited data on the concentrations of organic carbon released from the reservoirs. Based on the data that are available in the Sacramento Basin, the watersheds upstream of the reservoirs contribute substantial volumes of water that contains low concentrations of organic carbon (1-2 mg/L).

Recommendations

The Workgroup should gather any additional data that are available on reservoir releases, particularly in the San Joaquin watershed. If sufficient data are not available to confirm that organic carbon concentrations are low in reservoir releases, additional data should be collected on the major rivers immediately downstream from reservoirs in the San Joaquin Basin.

Agricultural Land

Uncertainty and Importance

Over 5,460,000 acres (20%) of the Central Valley watershed is used for agricultural production. There are currently limited data on the loads of organic carbon discharged from agricultural land in the tributary watersheds. The data from the Colusa Basin Drain in the Sacramento Basin is representative of loads from rice fields. Information is needed on other types of agricultural in the Sacramento Basin, such as orchards and row crops. Due to different sources of water and different methods for management of drainage in the San Joaquin Basin, the loads of organic carbon from agricultural operations on the west side of the San Joaquin Basin may differ from those on the east side of the Basin.

Recommendations

The Workgroup should obtain data collected by the agricultural waiver monitoring programs and from the Regional Board agricultural monitoring to determine if organic carbon loads from agricultural lands can be adequately estimated or if more focused monitoring is needed. In addition, USGS recently started a project to estimate

contaminant loads from a small agricultural watershed, Willow Slough. This study should be tracked, and, when the results are available, they should be used to refine the estimate of agricultural loads.

Wetlands

Uncertainty and Importance

Data from Mud and Salt Sloughs were used for estimating the wetland export rate for both the Sacramento and San Joaquin watersheds because no other wetland data were available. Wetlands only represent 234,000 acres (less than one percent) of the Central Valley watershed.

Recommendations

Due to the limited extent of wetlands in the watershed no additional data collection is recommended at this time.

6.2.5 WASTEWATER TREATMENT PLANTS

Uncertainty and Importance

Organic carbon and flow data were available for three wastewater treatment plants (Sacramento Regional Wastewater Treatment Plant, Davis and Vacaville for this study. There was considerable variability in the concentrations of organic carbon in wastewater effluent from these three plants. Due to the volume of wastewater discharged in the Central Valley and the fact that population growth will lead to even greater volumes in the future, this source needs to be better characterized.

Recommendations

Organic carbon data should be collected from a number of wastewater treatment plants representing different treatment processes. These data can be analyzed to determine if organic carbon loads are related to treatment processes and to improve the estimates of organic carbon loads from wastewater treatment plants. Regional Board staff is reviewing permit files to determine if additional data are available on organic carbon concentrations from wastewater treatment plants. The Workgroup should review the additional data and determine if any additional monitoring is needed.

6.2.6 FISH HATCHERIES

Uncertainty and Importance

Fish hatcheries are permitted to discharge up to 352 MGD (average dry weather flow of 256 MGD) into Central Valley waters and there are currently no data on organic carbon concentrations in fish hatchery waste. The importance of this source is currently unknown and should be investigated.

Recommendations

The Workgroup should collect organic carbon data from several fish hatcheries during the next year or two. These data will be useful in determining if fish hatcheries are a source of organic carbon that should be included in refined conceptual models.

6.2.7 URBAN RUNOFF

Uncertainty and Importance

The export rate for urban runoff was estimated from a three year study of a single developed watershed, Arcade Creek. Additional data on urban runoff loads are needed to refine the load estimates presented in this report.

Recommendations

MWQI is completing a seven year study on organic carbon loads from a rapidly urbanizing watershed in Sacramento and Placer counties. The Workgroup should review the MWQI study results and compare the export rate with the one calculated from Arcade Creek. In addition, the Workgroup should work with the City and County of Sacramento and the City of Stockton to determine if loads can be calculated from the data collected as part of their NPDES storm water permit programs.

6.3 FUTURE CONCERNS

From a review of the temporal variability of the loads, where available, it is clear that the year-to-year variations are so large that, on average, gradual changes in typical sources, such as increasing population or gradual increase in area of urban land, are unlikely to be discernible. In other words, over a two-decade time frame, given similar hydrology, the variability of loads is unlikely to be much different than what it is has been in the recent past. There are four areas of additional concern, however. The first pertains to dry and critically dry years. In these years, the relative contribution of organic carbon from anthropogenic sources is much larger, and the volumes of water withdrawals are a large fraction of total tributary inflows. Under these conditions, there is a stronger likelihood in future years of excessive DOC

concentrations in source waters, and a stronger possibility of adverse ecological impacts to the Delta due to large withdrawals. The second concern pertains to the occurrence of catastrophic events such as levee failure. As the data have shown, organic carbon concentrations in the Delta agricultural drains are far in excess of any other concentrations measured in the system. Levee failure has the potential to effectively raise Delta-wide organic carbon concentrations substantially, with significant impacts on water suppliers. The third concern relates to the increase in area of tidal wetlands as part of Delta-wide restoration. Based on current knowledge, the contribution of organic carbon from this source, on a unit area basis, far exceeds any other non-point source. Because of the proximity of these wetlands to drinking water intakes, the potential significance of an increase in their area on drinking water quality must be closely investigated. The final concerns relate to the changing regulatory landscape. If the allowable THM and HAA5 limits in drinking water supply are lowered, or if additional compounds are added to the list of regulated chemicals, water suppliers may well face significant challenges in meeting such standards.