<u>*Preliminary Report - Subject to Revision*</u>

Preliminary Assessment of Reducing Organic Carbon Loads from Delta Island Drainages to Improve Drinking Water Quality

by

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Prepared for Municipal Water Quality Investigations Program
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California State Department of Water Resources

1. Introduction

On January 30, 1998, representatives from CALFED, the State Water Contractors, and the California Urban Water Agencies, requested a preliminary gross assessment of the impact of reducing organic carbon concentrations in delta island drainage through wastewater treatment. At their request, the level of detail and analysis were limited to meet a February 15, 1998 deadline. A more extensive analysis is planned for completion by April 1998.

The Municipal Water Quality Investigation Program is proceeding to assess the potential benefits of reducing organic carbon loads in drainage discharged into the Sacramento-San Joaquin Delta from Delta Lowland islands and tracts. In 1997 Brown and Caldwell Engineers conducted a study for MWQI to examine current treatment technologies for reducing TOC from agricultural drainage. This study included an extensive literature review, jar testing of drain water samples, and treatment cost estimates. The study findings showed that up to a 60 percent reduction in TOC concentrations could occur with conventional coagulation-flocculation.

In January 1998 a comparison of historical and recent drainage volume estimates was completed. The results were published in a consultant's report to the MWQI Program, titled "Delta Island Drainage Volume Estimates, 1954-55 versus 1995-96". Discussions with the Department's Delta Modeling Unit will be held to ascertain what are reasonable drainage volume estimates for modeling and water quality assessment purposes.

The results of the Brown and Caldwell report and drainage volume estimates will be used to develop a set of agricultural drainage TOC reduction options. Organic carbon mass loads will be computed from drainage volume estimates and DOC concentration data collected by the MWQI Program since 1982. Delta areas with the highest organic carbon loads discharged into the delta channels will be identified. A report titled, "Candidate Regions in the Delta for Reduction of Organic Carbon Loads", is scheduled for completion by April 1998.

Subsequent work will include computer model runs by the Department's Delta Modeling Group to run predictive water quality impacts in the Delta from various treatment scenarios. The Delta Water Treatment and Costs Model for THM

Control, developed by Malcolm-Pirnie for MWQI, will then be used to assess the cost of treating the resulting modeled water quality.

The preceding described work is one part of a much larger two-year effort titled "Modeling Delta Alternatives to Improve Drinking Water Quality." Other studies on wetlands and shallow water storage facilities and water supply intake options will be studied concurrently. The cumulative results of these studies will be used to develop an assessment report of delta alternatives.

2. Approach

The following sources of data and assumptions were used in this preliminary gross assessment. Our more extensive analysis for the April 1998 report may yield different results due to the simple approach used in this analysis. However, the general trend or outcome may be similar.

Drainage Quantity

This analysis assumes that the monthly drainage volume estimates for the delta lowlands measured in 1954-55 by DWR are still representative of current conditions (DWR, 1956). The delta lowlands is geographically defined as those lands approximately at the five foot contour and below elevation (Figure 1; DWR, 1993). Monthly drainage volumes were rounded to the nearest thousand acre-feet. Estimates for the same calendar month were averaged and then rounded off.

Water year 1954 (October 1, 1953 - September 30, 1954) was classified as an above average condition. The following water year 1955 was a dry year.

Organic Carbon Concentrations

In this analysis, we assume that:

- the total organic carbon (TOC) concentrations are equal to the dissolved organic carbon (DOC) concentrations. We use TOC and DOC interchangeably when referring to organic carbon discussions.

- the delta lowland islands and tracts can be grouped into two regions based on high or medium-low DOC concentrations and adjacent unmonitored or similar soil type areas follow the same DOC concentration pattern. The observed DOC at all MWQI monitored pump stations were lumped together into these two DOC concentration subgroups to compute nonparametric values (e.g., median, range, quartiles).

- the selected monthly DOC point statistics are not skewed by sampling bias (e.g., unequal number of observations or sampling period) and median concentration values correspond to when median river flows occur.

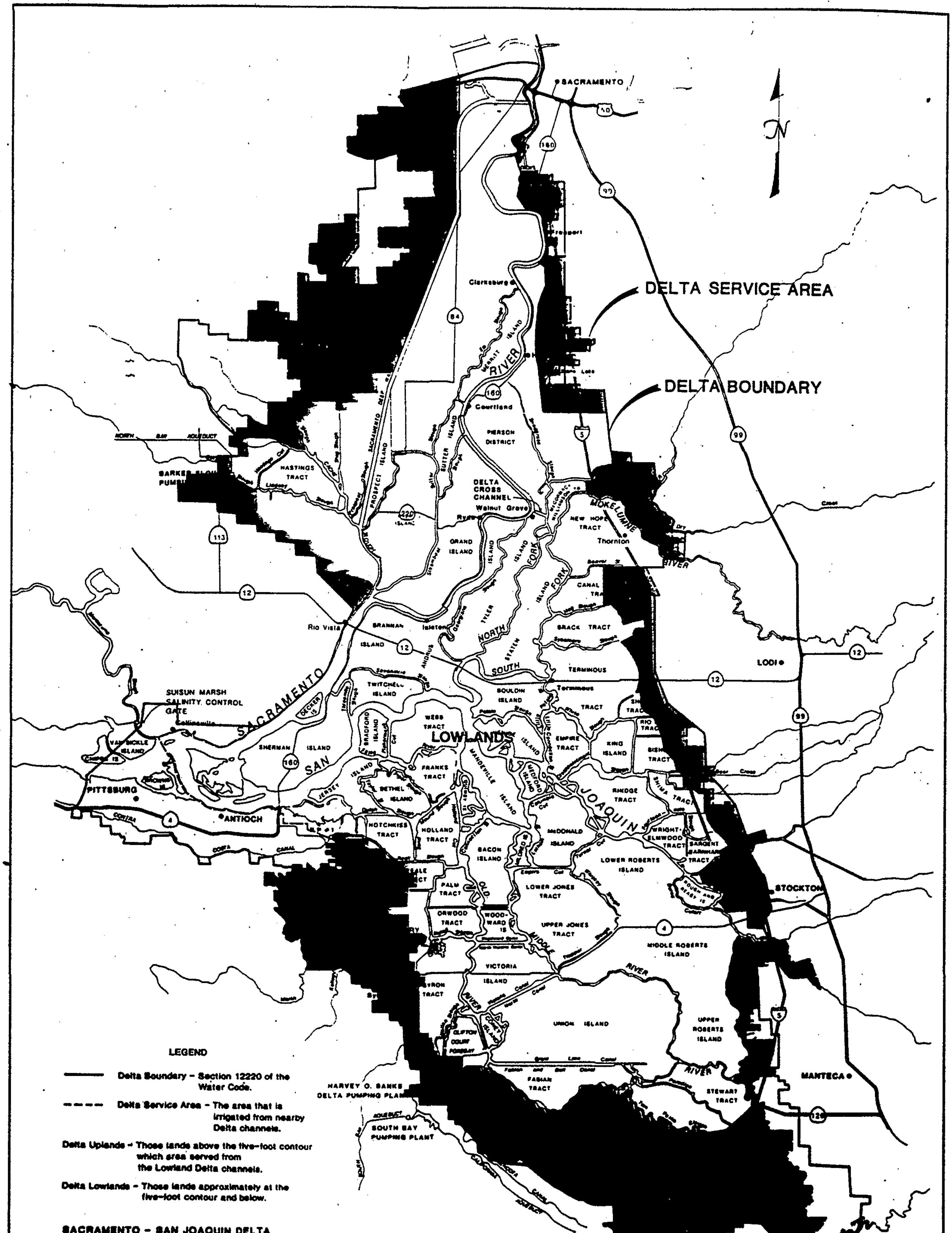

Figure 1.
The Legal Delta

River Flows

This analysis assumes that only the Sacramento and San Joaquin rivers contribute significant flow and DOC to the delta. The contributions of flow and constituents from eastside streams are negligible. The monthly median flows (cfs) at USGS stations at the Sacramento River at Freeport and at the San Joaquin River near Vernalis were used. These median daily average cfs values were taken from tables for Figures 6.1.1-3 and 6.1.1-4 of the CALFED Draft Programmatic EIS/EIR Administrative Draft of January 12, 1998. According to this document, the data was based on a 73-year hydrologic record (CALFED, 1998).

The combinations of inflow and pumping conditions (high inflow, low inflow/high pumping volume, and low inflow/low pumping volume) were not tested.

Sacramento and San Joaquin flows were not adjusted to account for net delta outflow and return of San Joaquin water to the CVP Delta Mendota Canal pumping plant. This non-adjustment assumes all Sacramento and San Joaquin flows are used for mixing interior delta channel waters. This may result in underestimating predicted southern delta DOC concentrations due to the higher dilution factors from the unadjusted river flows. An adjusted Sacramento flow would subtract the delta outflow, computed from DWR's DAYFLOW model, from the Freeport flow values. An adjusted San Joaquin flow would subtract pumping rates at the DMC pumping plant at Tracy from Vernalis measurements.

River and Delta DOC

DOC data at MWQI monitoring stations located on the Sacramento River at Greenes Landing and San Joaquin River near Vernalis were used to compute monthly median river input of DOC loads. Monthly median DOC values were multiplied by the monthly median river flow values to yield loads.

Computed monthly DOC concentrations for the southern Delta channels are based on the monthly median DOC values of data from the following five MWQI stations: (1) Rock Slough at Old River, (2) H.O. Banks Headworks, (3) Clifton Court Forebay intake gates, (4) Middle River at Borden Highway, and (5) DMC intake.

Selection of Candidate Delta Regions

It was assumed for this analysis that the islands or tracts with the largest contribution of total annual drainage volume in the delta lowlands also contributed the largest mass load of TOC/DOC. These regions were selected as candidate areas with treated drainages. Other criteria such as proximity to existing and proposed water supply intakes and delta circulation patterns were not considered.

Treatment of Drainage

Two levels of TOC reduction at the drainage treatment plants are assumed cost effective and achievable. For comparison, both 30 and 60 percent reductions of TOC concentrations were made. The costs of treatment per acre-feet of drainage water treated was assumed to be correct and constant for treatment of any drainage in the delta. Information from the Brown and Caldwell study to examine the feasibility of treating agricultural drainage to reduce TOC in the delta was used (DWR, 1998).

Computations

DOC concentration data from the MWQI Program were separately tabulated and sorted by month for delta drains and selected channel stations. Multiple box and whiskers plots were made for the drainage DOC data to identify possible grouping. The plots showed that the delta island/tracts could be grouped into a high DOC concentration subgroup and a low-medium DOC concentration subgroup. Median values for each subgroup by month were computed.

The monthly median drainage DOC values for each subgroup were then multiplied by their monthly drainage volume estimates for 1954-55 to compute DOC mass loads. This yielded flow-weighted mass loads for the high DOC concentration subgroup and the low-medium DOC concentration subgroup. DOC mass loads for selected delta regions undergoing 30 and 60 percent reductions in DOC concentrations were computed for comparison.

The historic median daily cfs values for Freeport and Vernalis were multiplied by 30 and 1.98 to yield monthly total AF values. The monthly median river flow values for Freeport were multiplied by monthly median DOC concentrations for Greenes Landing to compute monthly median river mass loads of organic carbon from the Sacramento River to the delta. Calculations for San Joaquin River TOC contributions were made using Vernalis flow and DOC data.

The equations used for computing the estimates are described in Table 1 and are based on a similar approach that was used to make estimates in 1990 and 1994 by MWQI (DWR, 1990; DWR 1994). However, the assumptions used in this preliminary assessment are less rigorous and less refined than what will be conducted later for the April 1998 consultant's report.

Table 1. Equations for Computing Estimates

Term	Equation	Comment
Dc	Dc=[(Sv)(Sc) + (SJRv)(SJRc)]/(Sv+SJRv)	Used to compute theoretical DOC concentration in southern delta channels
Sv	Sacramento River at Freeport volume in AF	
Sc	Sacramento River at Greenes Landing DOC concentration	
SJRv	San Joaquin River Vernalis volume in AF	
SJRc	San Joaquin River Vernalis DOC concentrations	
Crd	Crd =[(Fd)(Cw)+(Fr)(Cr)]/(Fd+Fr)	Used to combine river and drainage DOC concentrations
Fd	Total drainage volume in AF	
Fr	Total river volume in AF	
Cw	Flow weighted DOC concentration in all drains or less selected treated drains	
Cr	Flow weighted DOC concentration in Sacramento and SJ rivers	

Conversion factors:
1 cfs * 1.98 = # Acre-feet per day
 # cfs * 1.98 * 30 days/month = total AF for a 30 day month

3. Results

Delta subunits 18, 20, and 22 were identified as regions that discharged the most drainage (DWR, 1956, DWR 1990; Figure 2). Unit 18 included Staten, Bouldin, and Venice islands. Unit 20 includes Empire, King, and Terminous tracts. Unit 22 included Bacon, Mandeville, MacDonald, Mildred, and Medford islands. The three units adjoin each other and are centrally located in the delta lowlands. The soil type at these areas are peaty organic.

The 1954-55 data showed that these areas represented 14 percent of the delta lowlands. From June through August, these three subunits contributed 46 percent of the total delta drainage. From September to May, these areas contributed about 37 percent of the total drainage. In this analysis, these three subunits were selected as the candidate regions for treatment to reduce TOC concentrations in their drainage discharges. Reductions of TOC concentrations by 0, 30, and 60 percent at these subunits were compared. Drainage discharge volumes were not reduced in the calculations for drainage from the three treated subunits.

Results for the computed predicted monthly median DOC concentrations in the southern delta are shown in Table 2 for: (1) an existing condition, (2) TOC concentration reduction by 30 percent at the three delta subunits, and a 60 percent TOC reduction. The first column shows the median of monthly DOC concentrations observed in the five southern delta MWQI stations from 1982 - 97. The second column is the predicted existing condition monthly median DOC for the southern delta. The results are slightly lower than the median value of the observed values in column one. This is, in part, attributed to the unadjusted Sacramento and San Joaquin flows that were used, which yielded a higher dilution ratios and lower DOC concentrations. Columns three and four show the predicted southern delta median DOC when TOC concentrations at the three delta subunits are reduced by 30 and 60 percent, respectively.

The predicted results showed that southern delta DOC could be lowered by reductions in DOC from the three delta subunits. The results also show that the simple approach used in this preliminary analysis underestimates observed DOC levels in the southern delta during the wet season.

The Brown and Caldwell agricultural treatment study for MWQI showed that:

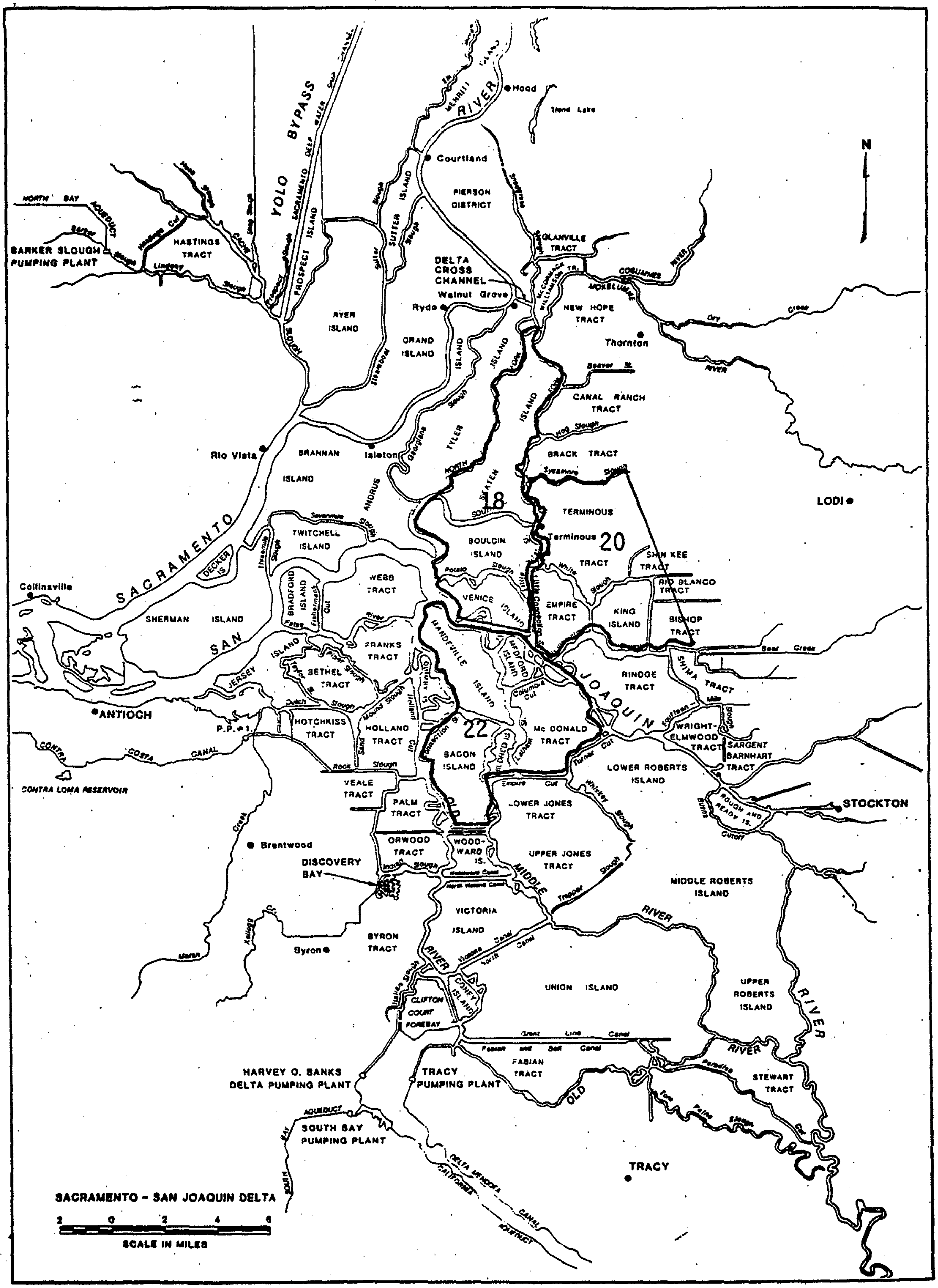

Figure 2. High Drainage Area, 1954-55

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1. Bench tests showed that optimized ferric chloride coagulation removed 55 to 78 percent of the DOC from Twitchell Island and Bacon Island drainage water. Alum coagulation removed 44 to 77 percent of the DOC. Membrane processes removed from 38 to 97 percent of the DOC with tighter membranes producing the highest removals. THMFP and HAAFP were reduced by approximately the same percentage as was DOC by all treatment methods. The drain water samples ranged from 12 to 42 mg/l TOC.

2. Based on drainage quality and quantity at Twitchell Island, optimized ferric chloride coagulation is more cost effective than optimized alum coagulation for TOC removal. A cost analysis showed that ferric chloride coagulation (which includes chemical addition, rapid mixing, flocculation, and sedimentation) could remove 60 percent of the TOC for about $ 1.73 per pound of TOC removed. However, these costs are sensitive to raw water composition and flow rates, which vary seasonally and with location.

3. Treatment by coagulation can increase water chloride, sulfate, sodium, calcium, and iron or aluminum concentrations, depending on the treatment chemicals applied.

4. A follow-up pilot plant is needed to confirm the technical and economic viability of ferric chloride coagulation.

Table 2.
Observed and Predicted Median DOC Concentrations
in the Southern Delta

Month	Drainage TOC Concentration Reduced by: Observed S. Delta MWQI DOC (mg/l)	0 % Computed S. Delta DOC (mg/l)	30 % Computed S. Delta DOC (mg/l)	60 % Computed S. Delta DOC (mg/l)
Jan	**5.5**	3.37	3.14	2.91
Feb	**6.2**	3.56	3.49	3.42
Mar	**5.9**	2.65	2.60	2.55
Apr	**5**	2.48	2.41	2.35
May	**4.35**	2.67	2.58	2.49
Jun	**3.6**	2.46	2.37	2.27
Jul	**3.2**	2.54	2.43	2.31
Aug	**3.1**	2.69	2.53	2.36
Sep	**3**	2.68	2.61	2.54
Oct	**3**	2.46	2.39	2.32
Nov	**2.95**	2.76	2.69	2.63
Dec	**3.4**	3.73	3.51	3.30

4. Conclusions

A preliminary gross assessment of the impact of reducing organic carbon concentrations in delta island drainage by treatment was made for CALFED, the State Water Contractors, and the California Urban Water Agencies. At their request, the level of detail and analysis were limited to meet a February 15, 1998 deadline. A more extensive analysis is planned for completion by April 1998.

The approach used historic river flow, drainage volume, and DOC concentration data. Simple assumptions were made about the amount of river inflow available for mixing with delta island drainage in the delta. Mass load calculations for organic carbon yielded predicted DOC concentrations that would be found in the southern delta. Calculations for the simple existing condition were compared to the observed monthly median DOC concentrations in the southern delta. The calculated predictions were consistently less than the observed median values. In part, this underprediction can be attributed to river flow input values that were not adjusted for water not entering the delta. Other factors that will be examined in the near future will include skewness of the data and input values (point estimates) of river flows and DOC concentrations.

The simple model tested the reduction of TOC/DOC concentrations in drain water by 30 and 60 percent at three delta subregions. These areas comprise about 14 percent of the delta lowlands acreage but contribute 37 to 46 percent of the total seasonal drainage. These regions are in peaty organic soil areas. The calculations showed that southern delta waters would have lower DOC concentrations if drain water at the three delta subregions were treated prior to discharge.

The Brown and Caldwell study on treating agricultural drain water to reduce TOC showed that optimized ferric chloride coagulation is more cost effective than optimized alum coagulation for TOC removal. A cost analysis showed that ferric chloride coagulation (which includes chemical addition, rapid mixing, flocculation, and sedimentation) could remove 60 percent of the TOC for about $ 1.73 per pound of TOC removed. However, these costs are sensitive to raw water composition and flow rates, which vary seasonally and with location.

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5. References

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Department of Water Resources, 1998. Draft 1997 Annual Report of the Municipal Water Quality Investigations Program.

Appendix

Calculated DOC Mass Loads and Concentrations

Sheet 1: Existing Conditions
Sheet 2: 30% TOC reduction
Sheet 3: 60% TOC reduction
Sheet 4: Summary of Results

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Existing conditions							
Calendar Month	Total Agflow AF	High Vol. Area DOC (mg/l)	Pct. of Total Drainage	Low Vol. Area DOC (mg/l)	Pct. of Total Drainage	High Vol. Mass DOC	Low Vol. Mass DOC
1	95000	35.25	37	8.9	63	1239038	532665
2	42000	34.7	37	9.5	63	539238	251370
3	32000	27.9	37	10	63	330336	201600
4	38000	20.8	37	8.1	63	292448	193914
5	53000	16.6	37	9	63	325526	300510
6	71000	12	46	7.6	54	391920	291384
7	81000	13	46	8.05	54	484380	352107
8	71500	15	46	7.3	54	493350	281853
9	44000	11.1	37	8.1	63	180708	224532
10	39500	12.8	37	8	63	187072	199080
11	47000	12.6	37	12	63	219114	355320
12	86000	26.6	37	14	63	846412	758520

Sacramento R. DOC (mg/l)	San Joaquin R. DOC (mg/l)	Sac. R. median cfs	Sacto. flows median AF/mo	SJR median cfs	SJR flows median AF/mo	Total Rivers median AF/mo
2.3	3.75	23452	1393049	2016	119750	1512799
3.1	4.7	33329	1979743	3997	237422	2217164
2.3	3.5	29827	1771724	3415	202851	1974575
1.9	3.4	17664	1049242	3982	236531	1285772
2	3	14100	837540	3821	226967	1064507
1.9	3.2	18150	1078110	2134	126760	1204870
1.9	3.2	18296	1086782	1675	99495	1186277
1.8	3.4	12344	733234	1675	99495	832729
2.1	3.3	10083	598930	1697	100802	699732
1.9	3.3	11807	701336	2000	118800	820136
2.2	3.1	14385	854469	1630	96822	951291
2.4	4	16572	984377	1691	100445	1084822

Sacto. R. Mass DOC	SJR Mass DOC	Total Rivers Mass DOC	Computed Total Rivers DOC(mg/l)	Computed Drains + Rivers DOC (mg/l)	MWQI S. Delta DOC (mg/l)
3204012	449064	3653076	2.41	3.37	5.5
6137202	1115882	7253085	3.27	3.56	6.2
4074965	709979	4784943	2.42	2.65	5.9
1993559	804205	2797764	2.18	2.48	5
1675080	680902	2355982	2.21	2.67	4.35
2048409	405631	2454040	2.04	2.46	3.6
2064887	318384	2383271	2.01	2.54	3.2
1319820	338283	1658103	1.99	2.69	3.1
1257753	332646	1590399	2.27	2.68	3
1332538	392040	1724578	2.10	2.46	3
1879832	300148	2179980	2.29	2.76	2.95
2362504	401782	2764286	2.55	3.73	3.4

Reduce TOC by 30% at High Vol. Areas							
Calendar Month	Total Agflow AF	High Vol. Area DOC (mg/l)	Treated High Vol. DOC (mg/l)	Pct. of Total Drainage	Low Vol. Area DOC (mg/l)	Pct. of Total Drainage	High Vol. Mass DOC
1	**95000**	35.25	24.675	37	8.9	63	867326
2	**42000**	34.7	24.29	37	9.5	63	377467
3	**32000**	27.9	19.53	37	10	63	231235
4	**38000**	20.8	14.56	37	8.1	63	204714
5	**53000**	16.6	11.62	37	9	63	227868
6	**71000**	12	8.4	46	7.6	54	274344
7	**81000**	13	9.1	46	8.05	54	339066
8	**71500**	15	10.5	46	7.3	54	345345
9	**44000**	11.1	7.77	37	8.1	63	126496
10	**39500**	12.8	8.96	37	8	63	130950
11	**47000**	12.6	8.82	37	12	63	153380
12	**86000**	26.6	18.62	37	14	63	592488

Low Vol. Mass DOC	Sacramento R. DOC (mg/l)	San Joaquin R. DOC (mg/l)	Sac. R. median cfs	Sacto. flows median AF/m	SJR median cfs	SJR flows median AF/mo	Total Rivers median AF
532665	**2.3**	**3.75**	23452	1393049	2016	119750	1512799
251370	**3.1**	**4.7**	33329	1979743	3997	237422	2217164
201600	**2.3**	**3.5**	29827	1771724	3415	202851	1974575
193914	**1.9**	**3.4**	17664	1049242	3982	236531	1285772
300510	**2**	**3**	14100	837540	3821	226967	1064507
291384	**1.9**	**3.2**	18150	1078110	2134	126760	1204870
352107	**1.9**	**3.2**	18296	1086782	1675	99495	1186277
281853	**1.8**	**3.4**	12344	733234	1675	99495	832729
224532	**2.1**	**3.3**	10083	598930	1697	100802	699732
199080	**1.9**	**3.3**	11807	701336	2000	118800	820136
355320	**2.2**	**3.1**	14385	854469	1630	96822	951291
758520	**2.4**	**4**	16572	984377	1691	100445	1084822

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Sacto. R. Mass DOC	SJR Mass DOC	Total Rivers Mass DOC	Computed Total Rivers DOC(mg/l)	Computed Drains + Rivers DOC (mg/l)	MWQI S. Delta DOC (mg/l)
3204012	449064	3653076	**2.41**	**3.14**	**5.5**
6137202	1115882	7253085	**3.27**	**3.49**	**6.2**
4074965	709979	4784943	**2.42**	**2.60**	**5.9**
1993559	804205	2797764	**2.18**	**2.41**	**5**
1675080	680902	2355982	**2.21**	**2.58**	**4.35**
2048409	405631	2454040	**2.04**	**2.37**	**3.6**
2064887	318384	2383271	**2.01**	**2.43**	**3.2**
1319820	338283	1658103	**1.99**	**2.53**	**3.1**
1257753	332646	1590399	**2.27**	**2.61**	**3**
1332538	392040	1724578	**2.10**	**2.39**	**3**
1879832	300148	2179980	**2.29**	**2.69**	**2.95**
2362504	401782	2764286	**2.55**	**3.51**	**3.4**

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Reduce TOC by 60% at High Vol. Areas							
Calendar Month	Total Agflow AF	High Vol. Area DOC (mg/l)	Treated High Vol. DOC (mg/l)	Pct. of Total Drainage	Low Vol. Area DOC (mg/l)	Pct. of Total Drainage	High Vol. Mass DOC
1	**95000**	35.25	14.1	37	8.9	63	495615
2	**42000**	34.7	13.88	37	9.5	63	215695
3	**32000**	27.9	11.16	37	10	63	132134
4	**38000**	20.8	8.32	37	8.1	63	116979
5	**53000**	16.6	6.64	37	9	63	130210
6	**71000**	12	4.8	46	7.6	54	156768
7	**81000**	13	5.2	46	8.05	54	193752
8	**71500**	15	6	46	7.3	54	197340
9	**44000**	11.1	4.44	37	8.1	63	72283
10	**39500**	12.8	5.12	37	8	63	74829
11	**47000**	12.6	5.04	37	12	63	87646
12	**86000**	26.6	10.64	37	14	63	338565

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Low Vol. Mass DOC	Sacramento R. DOC (mg/l)	San Joaquin R. DOC (mg/l)	Sac. R. median cfs	Sacto. flows median AF/mo	SJR median cfs	SJR flows median AF/mo	Total Rivers median AF
532665	2.3	3.75	23452	1393049	2016	119750	1512799
251370	3.1	4.7	33329	1979743	3997	237422	2217164
201600	2.3	3.5	29827	1771724	3415	202851	1974575
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300510	2	3	14100	837540	3821	226967	1064507
291384	1.9	3.2	18150	1078110	2134	126760	1204870
352107	1.9	3.2	18296	1086782	1675	99495	1186277
281853	1.8	3.4	12344	733234	1675	99495	832729
224532	2.1	3.3	10083	598930	1697	100802	699732
199080	1.9	3.3	11807	701336	2000	118800	820136
355320	2.2	3.1	14385	854469	1630	96822	951291
758520	2.4	4	16572	984377	1691	100445	1084822

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			Computed	Computed	MWQI
Sacto. R.	SJR	Total Rivers	Total Rivers	Drains + Rivers	S. Delta
Mass DOC	Mass DOC	Mass DOC	DOC(mg/l)	DOC (mg/l)	DOC (mg/l)
3204012	449064	3653076	2.41	2.91	5.5
6137202	1115882	7253085	3.27	3.42	6.2
4074965	709979	4784943	2.42	2.55	5.9
1993559	804205	2797764	2.18	2.35	5
1675080	680902	2355982	2.21	2.49	4.35
2048409	405631	2454040	2.04	2.27	3.6
2064887	318384	2383271	2.01	2.31	3.2
1319820	338283	1658103	1.99	2.36	3.1
1257753	332646	1590399	2.27	2.54	3
1332538	392040	1724578	2.10	2.32	3
1879832	300148	2179980	2.29	2.63	2.95
2362504	401782	2764286	2.55	3.30	3.4

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	TOC Reduction by:	0 %	30 %	60 %	
	MWQI	Computed	Computed	Computed	
	S. Delta	Drains + Rivers	Drains + Rivers	Drains + Rivers	
Month	DOC (mg/l)	DOC (mg/l)	DOC (mg/l)	DOC (mg/l)	
Jan	5.5	3.37	3.14	2.91	
Feb	6.2	3.56	3.49	3.42	
Mar	5.9	2.65	2.60	2.55	
Apr	5	2.48	2.41	2.35	
May	4.35	2.67	2.58	2.49	
Jun	3.6	2.46	2.37	2.27	
Jul	3.2	2.54	2.43	2.31	
Aug	3.1	2.69	2.53	2.36	
Sep	3	2.68	2.61	2.54	
Oct	3	2.46	2.39	2.32	
Nov	2.95	2.76	2.69	2.63	
Dec	3.4	3.73	3.51	3.30	