Appendix G
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Abbreviations and Acronyms

AF	acre-foot/feet
AIP	Alternative Intake Project
Banks Pumping Plant	Harvey O. Banks Pumping Plant
Bay/Delta Plan	Water Quality Control Plan for San Francisco Bay/Sacramento-San Joaquin Delta Estuary
CALFED	CALFED Bay-Delta Program
CalSim II	California Simulation Model II
CCWD	Contra Costa Water District
CVP	Central Valley Project
DBP	disinfection byproduct
Delta	Sacramento-San Joaquin River Delta
DMC	Delta-Mendota Canal
DOC	dissolved organic carbon
DSM2	Delta Simulation Model 2
EC	electrical conductivity
EPA	U.S. Environmental Protection Agency
Jones Pumping Plant	C.W. “Bill” Jones Pumping Plant
LOD	Level of Development
MCL	maximum contaminant level
µg/L	microgram(s) per liter
µmhos/cm	micromhos per centimeter
mg/L	milligram(s) per liter
MWQI	Municipal Water Quality Investigations Program
Old River	Old River/Los Vaqueros Reservoir
Rock Slough	Contra Costa Canal/Rock Slough
SJR	San Joaquin River
SWP	State Water Project
TDS	total dissolved solids
TOC	total organic carbon

Appendix G
Drinking Water Evaluation

G.1 Introduction and Background

The U.S. Department of the Interior, Bureau of Reclamation is evaluating the feasibility of using recirculation strategies to improve water quality and flows in the lower San Joaquin River (SJR). The Delta-Mendota Canal (DMC) Recirculation Project involves the recirculation of water from the Sacramento-San Joaquin River Delta (Delta) through export pumping and conveyance facilities to the SJR upstream of Vernalis. The purpose of this investigation is to identify and evaluate the feasibility of the alternative plans for the DMC Recirculation Project and to determine whether the project will provide greater flexibility in meeting existing water quality and flow standards while reducing water demands from New Melones Reservoir.

This appendix provides an evaluation of potential effects to drinking water resources due to the alternative plans. These potential effects were evaluated based upon results of hydrologic and water quality modeling presented in **Appendices A and B**.

G.1.1 Delta Intakes

The Delta is a source of drinking water for more than two-thirds of California residents (over 23 million people) and irrigation water for more than 3 million acres of farmland. Large-scale diverters in the Delta include the State Water Project (SWP), the federal Central Valley Project (CVP), and Contra Costa Water District (CCWD), which withdraw about 3.7 million, 2.5 million, and 126 thousand acre-feet (AF) in an average year, respectively (DWR 2005a).

The principal water intakes in the Delta include C.W. “Bill” Jones Pumping Plant (Jones Pumping Plant), Harvey O. Banks Pumping Plant (Banks Pumping Plant), the Old River/Los Vaqueros Reservoir intake (Old River), the Contra Costa Canal/Rock Slough intake (Rock Slough), and the Barker Slough intake. Formerly known as Tracy Pumping Plant, Jones Pumping Plant is a federally owned facility used to move water from the Delta for transfer into the DMC. CVP water is largely used for irrigation but is also used for drinking water supply for nearly 2 million people, including the city of Tracy. Banks Pumping Plant lifts water into the California Aqueduct for delivery to SWP contractors in the Central Valley and Southern California. The South Bay Aqueduct branches from the California Aqueduct and provides water for Alameda and Santa Clara counties. CCWD diverts water primarily through the Old River and Rock Slough intakes and less frequently through its Mallard Slough intake and provides raw and treated water to a large portion of Contra Costa County. CCWD is also constructing an alternative intake at Victoria Canal. Barker Slough intake provides water for the North Bay Aqueduct, which conveys water to communities in Napa and Solano counties. In addition to the principal drinking water intakes in the Delta, the city of Antioch has an intake on the SJR.

South Delta Exports

Banks and Jones pumping plants are components of the SWP and CVP water conveyance facilities. The SWP has over 600 miles of conveyance channels and pipelines and 20 storage facilities and delivers 3 million AF per year of water from the Delta to 29 different agencies. The CVP delivers 7 million AF per year, partially through the Delta, to 2 million consumers and 3 million acres of farmland (Brown and Caldwell 2005a). The two water projects meet at the San Luis Joint-Use Complex, where both conveyance systems merge into the San Luis Reservoir and then separate again into the DMC and the California Aqueduct (see **Section 2.2.1**.)

The SWP and CVP coordinate project operations to maintain standards established by Water Rights Decision 1641 by releasing water from upstream reservoirs and by curtailing export pumping at Banks and Jones pumping plants during specified time periods (DWR 2005a). The pumping rates at Banks and Jones pumping plants follow a similar trend and intake rate, with the lowest pumping in the spring months and higher pumping rates for other months (Brown and Caldwell 2005b).

Contra Costa Water District

CCWD diverts Delta water for direct use when chloride concentrations are approximately 65 to 100 milligrams per liter (mg/L) or less. Diversions occur primarily through the Old River and Rock Slough intakes. CCWD also diverts water at Mallard Slough, near Chipps Island in Suisun Bay, but diversions occur infrequently and only after periods of very high Delta outflow (CCWD 2005).

Los Vaqueros Reservoir is used to store water diverted from the Delta during periods of higher water quality and is then used for blending when Delta water quality is poor. Los Vaqueros Reservoir is filled when the monthly chloride average is at or below 50 mg/L (CCWD 2005).

Consumptive Use

Delta islands divert water for irrigation and leaching. Soil is leached when irrigation water is used to flush salts from the root zone. Irrigation diversions from about 1,800 sites in the Delta total about 1 million AF annually. During peak summer months, surface-water diversions in the Delta that are used to irrigate crops may exceed 4,000 cubic feet per second, which is similar in magnitude to CVP exports from the Delta in summer (DWR 2005a).

Return flows pumped back into Delta channels are a composite of agricultural return flow, subsurface drainage, seepage, and rainfall runoff. The quality of the water in the drainage reflects the combination of water diverted onto the island for irrigation, the peat soils of the island, and the agricultural chemicals used. Water discharged from the islands is usually higher in salinity than the adjacent channels due to evaporation, transpiration, and additional solutes (CALFED 2007a). Delta island return flows pumped back into the channels can contribute to higher levels of bromide, salinity, and organic carbon.

G.1.2 Drinking Water Constituents of Concern

Drinking water disinfection targets water-borne pathogens to reduce health risks associated with infectious disease. Disinfection can be chemical (free chlorine, chloramines, chlorine dioxide, or ozone) or physical (ultraviolet light). Disinfection byproducts (DBPs) are formed when certain natural precursors, such as organic matter, salts, or nutrients, are exposed to oxidants used to inactivate microbes. DBP formation is increased when source water contains both dissolved organic compounds and bromide (CALFED 2007a, 2007b).

Numeric water quality criteria for raw water are summarized in **Tables G-1**. Regulatory requirements for raw water are included in the *Water Quality Control Plan for San Francisco Bay/Sacramento-San Joaquin Delta Estuary* (Bay/Delta Plan). The U.S. Environmental Protection Agency (EPA) has determined primary and secondary maximum contaminant levels (MCLs) for treated water. Because dissolved constituents are difficult to remove during treatment, MCLs are included here as water quality criteria for municipal supply.

In contrast to regulatory requirements, numeric water quality goals for raw water are summarized in **Tables G-2**.

Raw water quality goals for the Delta have been developed by the CALFED Bay-Delta Program (CALFED). CALFED was established, in part, to develop a long-term solution that will address four categories of problems: ecosystem quality, water quality, water supply reliability, and levee system vulnerability. For water quality, primary concerns have focused on the effects of elevated salts, organic carbon, and bromide on drinking water and agricultural supplies coming from the Delta (CALFED 2000).

Table G-1. Numeric Water Quality Criteria for Delta Municipal Intakes or Supply

Analyte	Concentration	Extent of Criteria	Source
Electrical Conductivity (EC)	1,000 µmhos/cm	Monthly average of the mean daily EC at Clifton Court and Jones Pumping Plant for agricultural beneficial uses.	Bay/Delta Plan
Chloride	250 mg/L and 150 mg/L	250 mg/L maximum mean daily chloride concentration at Rock Slough, Clifton Court, Jones Pumping Plant, North Bay Aqueduct, Barker Slough, and the City of Vallejo intakes; 150 mg/L maximum mean daily chloride concentration for a specified number of days dependent on hydrologic water year type (between 155 and 240 days per year) at Rock Slough or at the City of Antioch's intake for the protection of municipal and industrial beneficial uses	Bay/Delta Plan
	250 mg/L	Secondary MCL based on aesthetic (taste) considerations	EPA
Total Dissolved Solids	500 mg/L	Secondary MCL to address taste, staining, and mineral deposits	EPA
Nutrients (Nitrate)	10 mg/L	Nitrate as N, primary MCL	EPA

Sources: EPA 2003; SWRCB 2006.

Key:

Bay/Delta Plan = Water Quality Control Plan for San Francisco Bay/Sacramento-San Joaquin Delta Estuary
Delta = Sacramento-San Joaquin River Delta
EPA = U.S. Environmental Protection Agency
MCL = maximum contaminant level
µmhos/cm = micromhos per centimeter
mg/L = milligram(s) per liter

Table G-2. Numeric Water Quality Goals for Delta Municipal Intakes or Supply

Analyte	Concentration	Extent of Goals	Source
Chloride	250 mg/L and 150 mg/L	250 mg/L maximum mean daily; 150 mg/L for a specified number of days depending on hydrologic water year type at Rock Slough or Antioch intakes, CALFED goal for municipal supply	CALFED WQP ROD
	65 mg/L[1]	CCWD long-term goal for delivered water based on meeting the needs of domestic and industrial customers	CCWD
	50 mg/L	Maximum monthly average, CCWD source-water quality goal for filling Los Vaqueros Reservoir	CCWD
Bromide	50 µg/L[2]	Running annual average or equivalent level of health protection, CALFED goal for municipal supply at southern and central Delta drinking water intakes	CALFED WQP ROD
		CCWD source-water quality goal	CCWD
Total Dissolved Solids	440 mg/L	Monthly average (and 220 mg/L 10-year average), CALFED goal for municipal supply	CALFED WQP ROD
Total Organic Carbon (TOC)	3 mg/L[2]	Running annual average or equivalent level of health protection, CALFED goal for municipal supply at southern and central Delta drinking water intakes	CALFED WQP ROD
Nutrients (Nitrate)	10 mg/L	Nitrate as N; no increase in nitrate levels (for reservoir management where nutrients are a governing factor in the growth of taste and odor-producing algae), CALFED goal for municipal supply	CALFED WQP ROD
Turbidity	50 NTU	For raw water, CALFED goal for municipal supply	CALFED WQP ROD
Microbiological	1 oocyst/100L	For *Giardia* and *Cryptosporidium* and no net increase in pathogens, CALFED goal for municipal supply	CALFED WQP ROD
	0.75 oocyst/100L	For *Cryptosporidium,* based on a 24 month average, CCWD source-water quality goal	CCWD

Sources: CALFED 2007a; CCWD 2005.

[1] This goal is equivalent to 250 µg/L bromide.

[2] CALFED goals for bromide and TOC: The 3 mg/L TOC and 50 µg/L bromide running annual averages are to allow for either enhanced coagulation or ozone disinfection under the more stringent long-term scenario. More advanced technologies, such as granular activated carbon or membranes, could allow relaxation of these targets but the feasibility for large-scale application has not been established. For the less stringent near-term regulatory scenario, TOC from 4 to 7 mg/L and bromide from 100 to 300 µg/L was determined to be acceptable (CALFED 2007a).

Key:

CALFED = CALFED Bay-Delta Program
CCWD = Contra Costa Water District
Delta = Sacramento-San Joaquin River Delta
µg/L = micromgram(s) per liter
mg/L = milligram(s) per liter
NTU = nephelometric turbidity unit(s)
TOC = total organic carbon
WQP ROD = Water Quality Program Record of Decision

CCWD has also developed raw water goals for their intakes; however, these goals are not required to be met. CCWD currently evaluates and blends its raw water according to chloride levels. CCWD has a long-established goal of 65 mg/L chloride (approximately 250 micrograms per liter [µg/L] bromide) based on meeting the needs of domestic and industrial customers. CCWD's primary water quality issue is high bromide concentrations at its Delta intakes (CCWD 2005).

Chloride, Bromide, and Total Dissolved Solids

Salinity is associated with electrical conductivity (EC), total dissolved solids (TDS), bromide, and chloride. TDS is a measurement of the salinity in water. EC is often measured and used as a surrogate for TDS. Chloride and bromide are both constituents that contribute to salinity.

Most drinking water treatment processes do not remove salinity because processes that can remove salinity are energy intensive. Thus, drinking water supply is often managed for municipal use by source control and blending. Delta salinity is highly variable both geographically and over time, when viewed from a drinking water perspective, and highly managed (CALFED 2007a).

The amount of water flowing into the Delta is an important determinant of salinity at the export pumps. The highest salinities occur during the fall and early winter when Delta inflow is the lowest. When EC, TDS, chloride, and bromide are highest at Delta diversions, seawater is often a significant contributing source. Seawater has approximately 965,500 mg/L TDS, 19,000 mg/L chloride, and 65 mg/L bromide (Brown and Caldwell 2005b) and, thus, a trace amount of seawater can influence the quality of the municipal supply.

During periods of low natural inflow, the combination of reservoir releases and Delta diversions govern salinity. The combined influence of the Sacramento inflow and export pumping at Banks and Jones pumping plants is thought to be the cause of a "freshwater corridor" extending across the central Delta from north to south (CALFED 2007b). Conversely, when the SJR inflow exceeds approximately 3,500 cubic feet per second, the dominant source of exported water at south Delta intakes is from the SJR (CCWD 2005).

Chloride Chloride concentration is often used as an indicator of seawater intrusion and of the usability of raw water.

The Bay/Delta Plan specifies water quality objectives for chloride for the protection of municipal and industrial beneficial uses at several drinking water intakes in the Delta. The maximum mean daily chloride concentration at Rock Slough, Clifton Court, Jones Pumping Plant, Barker Slough, and the City of

Vallejo intakes is 250 mg/L. This concentration is consistent with the EPA secondary MCL for chloride (EPA 2003). The Bay/Delta Plan also specifies a maximum mean daily chloride concentration of 150 mg/L required at Rock Slough or the City of Antioch's intake for a specified number of days, between 155 and 240 days per year, dependent on hydrologic water year type (SWRCB 2006). The 250-mg/L chloride objective was established to protect municipal supply and the 150-mg/L chloride objective was based on industrial supply use (CALFED 2007a).

Bromide. Bromide concentrations at Delta diversion points are closely correlated with chloride and high concentrations of bromide are usually associated with seawater intrusion, directly or indirectly (CALFED 2007b).

The average bromide concentration in U.S. drinking water sources is 62 µg/L, while the concentration of bromide in seawater is approximately 1,000 times higher. At Banks and Jones pumping plants, the average bromide concentrations are 230 and 260 µg/L, respectively. The consistently high bromide concentrations at the export pumps rank the Delta among the drinking water sources with the highest bromide concentrations in the U.S. (CALFED 2007a, 2007b)

When water is disinfected for municipal supply, bromide is a precursor to formation of a variety of harmful DBPs. Bromide reacts with organic carbon and chlorine to form brominated trihalomethanes and haloacetic acids. Bromide also reacts directly with ozone to form bromate. Ozone is often used for disinfection or for taste and odor control (CALFED 2007a, 2007b).

The MCLs for trihalomethanes and haloacetic acids are 80 and 60 µg/L, respectively, and the MCL for bromate is 10 µg/L (EPA 2003). These criteria are for treated water, but act as constraints on the water quality of raw water.

Nearly all treatment plants using Delta water as the primary water supply modify the raw-water supply and treatment systems to minimize bromate formation. When bromide is high, utilities may use a combination of disinfectants such as chlorine dioxide, ultraviolet light, chlorine, and chloramines; have constraints on ozonation such as lowering pH or adding ammonia; or may use other treatment techniques such as membranes, to comply with water quality standards (CALFED 2007b; CCWD 2005).

The CALFED goal of 50 µg/L bromide is based upon a study that concluded that, if the bromate MCL was reduced from 10 to 5 µg/L, it would be necessary to keep raw-water bromide concentrations below 50 µg/L for unmodified ozone disinfection used to inactivate *Cryptosporidium*. For the less stringent near-term regulatory scenario, bromide from 100 to 300 µg/L was determined to be acceptable (CALFED 2007a).

Total Dissolved Solids The CALFED goal for municipal supply is 440-mg/L TDS monthly average and 220-mg/L TDS 10-year average. The 440-mg/L TDS monthly average is considered insufficiently protective, particularly in April and September. The 220-mg/L 10-year average is based on the SWP water service contract, and may be changed to a 6-month or 1-year average target (CALFED 2007a). The EPA MCL for TDS is 500 mg/L to address taste, staining, and mineral deposits (EPA 2003).

Organic Carbon

Organic carbon comes from recently produced organic material in the watershed, older plant residues in the soil, and peat deposits in the Delta. Organic carbon in water is a varying mix of thousands of different chemical compounds. Total organic carbon (TOC) is a measure of organic material that is both particulate and dissolved. Dissolved organic carbon (DOC) is a measure of the dissolved fraction. Excess organic carbon in raw water can lead to color formation, taste, and odor problems, interfere with treatment processes, and react with disinfectants.

Some forms of organic carbon react with chlorine and produce potentially carcinogenic DBPs, such as trihalomethanes and haloacetic acids. DOC is generally considered the more important fraction for DBP production because of its greater abundance and reactivity during chlorination (Tetra Tech 2006).

In the presence of high organic carbon concentrations, drinking water treatment may include enhanced coagulation by using higher coagulant dose and lower pH to achieve specified organic carbon removal, may optimize disinfection to minimize DBP formation, or use alternative treatment technologies such as membranes or magnetic ion exchange resin adsorption (CCWD 2005).

Some water utilities that rely on raw water from the Delta use ozone as a primary disinfectant to avoid the formation of trihalomethanes and haloacetic acids. Organic carbon in the source water impacts facilities using ozone treatment because high concentrations of organic carbon require increased ozone dosage and high levels of ozone in the presence of bromide can increase bromate concentrations (Tetra Tech 2006).

The CALFED goal of 3 mg/L TOC is based upon a prediction that assumes that the MCL for total trihalomethanes will be reduced from 80 to 40 µg/L, running annual average; the MCL for haloacetic acids will be reduced from 60 to 30 µg/L, running annual average; enhanced coagulation will be used to achieve the required percent removal of TOC; and free chlorine will be used to inactivate

Giardia. For the less stringent near-term regulatory scenario, TOC from 4 to 7 mg/L was determined to be acceptable (CALFED 2007a).

G.2 Evaluation Approach

Modeling was conducted to indicate the potential changes in Delta raw-water quality to allow for comparison among the recirculation alternative plans. Modeling results obtained from Delta Simulation Model 2 (DSM2) for EC, flow, and volumetric source fraction were used in calculations to predict changes in chloride, bromide, TDS, and DOC concentrations due to the alternative plans.

DSM2 HYDRO and QUAL were used in conjunction with California Simulation Model II (CalSim II) Common Assumptions full system model to predict EC and flow in the Delta (**Appendices A and B**). The DSM2 simulation was for an 82-year hydrologic trace (1922 through 2003) with daily model outputs of flow, EC, and volumetric source fraction for interior Delta locations.

DSM2 output was evaluated at locations near drinking water intakes in the Delta. Changes in EC, chloride, bromide, TDS, and organic carbon were calculated for Clifton Court, Jones Pumping Plant, Rock Slough, Old River, and Antioch. Salt loads were calculated at Clifton Court and Jones Pumping Plant. Output at Barker Slough intake was not evaluated because the alternative plans do not affect north-of-Delta operations. Output at the Mallard Slough intake was not evaluated due to limited use.

Table G-3 lists the output locations used in the calculations and **Figure G-1** shows the location of these Delta intakes and DSM2 source fraction boundary inputs.

Table G-3. DSM2 Data Output Locations

Intake Location	Station Name	DSM2 Channel or Node Number
Clifton Court	CLFCT	Node 72
Jones Pumping Plant	CHDMC006	Channel 216, upstream end
Rock Slough	SLRCK005	Channel 247, upstream end
Old River	ROLD034	Channel 90, 3,021 feet from upstream end
Antioch	RSAN007	Channel 52, 366 feet from upstream end

Key:
DSM2 = Delta Simulation Model 2

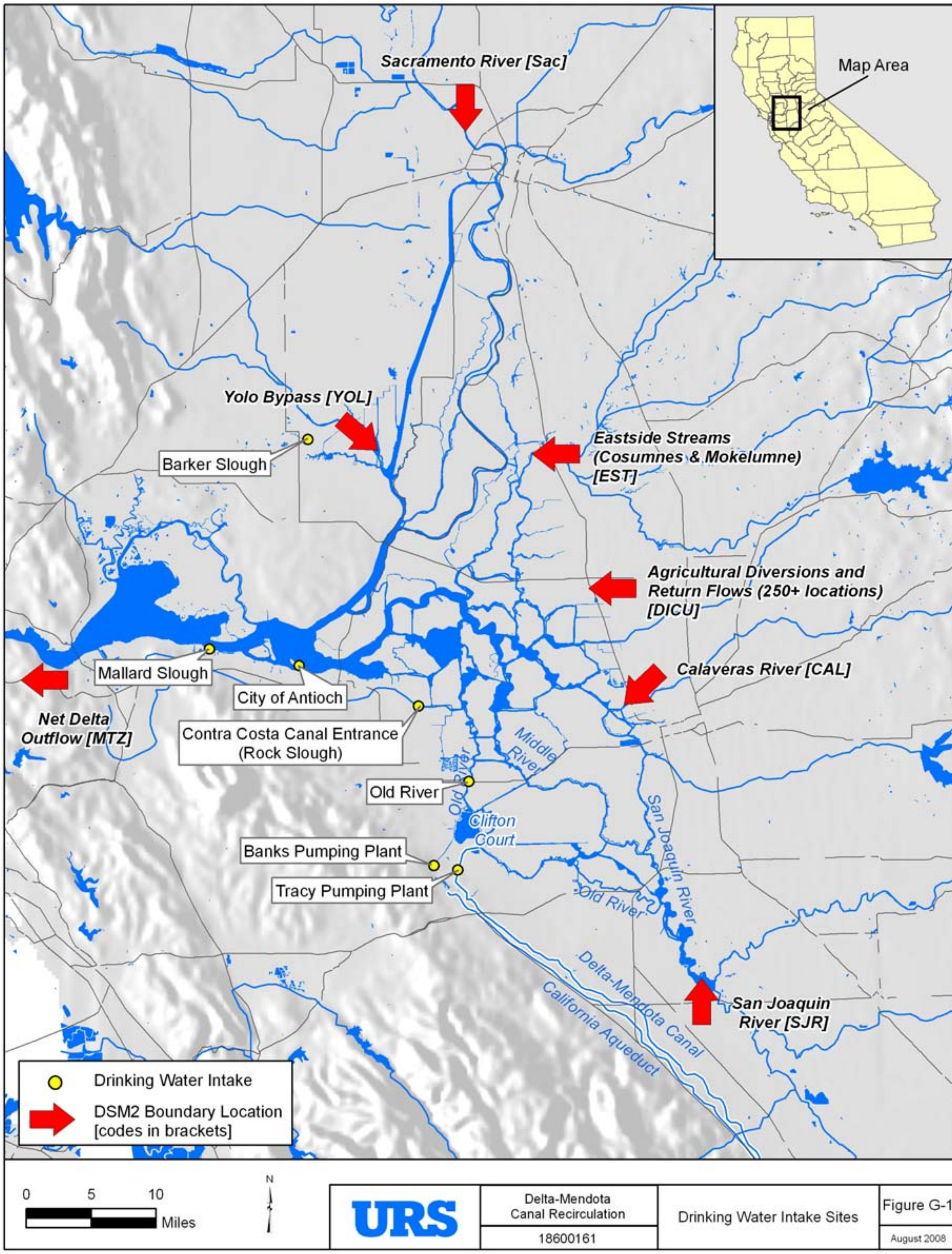


Figure G-1. Delta Intakes and DSM2 Boundary Locations

G.2.1 Modeling Assumptions

Assumptions that are associated with the CalSim II modeling or the DSM2 modeling are propagated into the salinity and organic carbon calculations.

General modeling assumptions for the No-Action Alternative and the alternative plans include the following. (See **Appendices A and B** for a more detailed discussion of modeling assumptions).

- Common Assumptions Future Level of Development (LOD).
- DSM2 boundary inflows, provided by CalSim II, divided into 14 periods per year (10 full months and 4 semi-monthly periods, inclusive of Vernalis Adaptive Management Plan periods).
- CCWD diversions modeled at Rock Slough, Old River, and the Victoria Canal Alternative Intake Project (AIP); however, the AIP intake flows added to the Old River intake.

The future setting is developed by assuming future LOD land use, facilities, and operational objectives and is used for the No-Action Alternative condition and applied to the alternative plans modeled using future LOD. For additional information see **Appendix A**.

The Plan Formulation Report analysis includes the No-Action Alternative and six alternative plans (A1, A2, B1, B2, C, and D) modeled using the future LOD (see **Section 4** for a description of these alternative plans). With each consecutive alternative plan, the quantity of total recirculation flow and the number of recirculation periods increases above the previous alternative plan (**Table G-4**). DSM2 was run for the No-Action Alternative conditions and for Alternatives B1, B2, and D. Although Alternatives A1, A2, and C were not modeled by DSM2, results may be interpolated qualitatively based on trends, when trends are apparent. When trends exist, results for Alternatives A1 and A2 may be assumed to fall between the results for the No-Action Alternative and Alternative B1, and the results for Alternative C would fall between the results for Alternatives B2 and D.

Table G-4. Summary of Recirculation Frequency by Alternative Plan

	A1	A2	B1	B2	C	D
Total Recirculation (thousand AF per year)	7	9	12	16	28	32
Recirculation for Flow (thousand AF per year)	7	7	12	13	26	25
Recirculation for Water Quality (thousand AF per year)	0	2	0	3	3	7
Years with Recirculation (out of the 82 years)	23	30	33	44	54	56
Periods with Recirculation (out of 1,148 periods)	32	45	57	77	124	148

Notes:

Recirculation is evaluated as average annual recirculation during the 82-year simulation period.

Model periods represent the CalSim II-modeled periods (14 periods per year, which include the months of June through March and the April and May pulse and nonpulse periods) with the future Level of Development.

Key:

AF = acre-foot/feet

G.2.2 Input Parameters and Calculations

Chloride and Bromide

The EC-chloride relationship and the bromide-chloride relationship developed by CCWD were used to calculate chloride and bromide concentrations from DSM2 output for EC (Moses, pers. comm., 2008).

The EC-to-chloride conversions used are as follows.

$$Cl = 0.285*EC - 50 \qquad (G\text{-}1)$$

when the DSM2 volumetric source fraction from Martinez is greater than 0.4% (seawater-influenced relationship)

$$Cl = 0.15*EC - 12 \qquad (G\text{-}2)$$

when the DSM2 volumetric source fraction from Martinez is less than 0.4% (nonseawater-influenced relationship)

where chloride is in mg/L and EC is measured in micromhos per centimeter (µmhos/cm).

The chloride equation above with the greater slope was developed in a regression of Municipal Water Quality Investigations Program (MWQI) grab samples collected near the confluence of Sacramento River and SJR and analyzed in the laboratory for EC and chloride, and reflects the EC-chlorine relationship typically found in seawater-influenced Delta waters. The equation with the lesser slope was developed from a similar regression on data from samples collected near Vernalis, and reflects the EC-chlorine relationship typically found in Delta water that is not seawater-influenced (Moses, pers. comm., 2008).

MWQI grab samples collected around the Delta exhibit a fairly constant relationship between chloride and bromide concentration (Moses, pers. comm., 2008). The chloride-bromide relationship provided by CCWD and used to predict bromide concentrations is as follows.

$$Br = 0.00341*Cl + 0.033 \quad \text{(G-3)}$$

where bromide and chloride are both in mg/L.

The EC-chloride and the chloride-bromide relationships used in the analysis (Equations G-1 through G-3) are similar to published salinity relationships.

MWQI has published findings of its data in biannual summary reports that include relationships between monitored parameters (DWR 2003, 2005b, 2006, 2008a). Chloride and EC were found to be highly correlated at various stations; however, a single linear regression equation could not describe the relationship (DWR 2003). A linear relationship was developed between EC and the sum of chloride and sulfate concentrations (DWR 2003); however, because sulfate was not a modeled parameter, this relationship can not be directly compared to the relationships used in the analysis.

In the 1980s, the California Department of Water Resources developed a table of salinity relationships for various Delta locations (Guivetchi 1986). In the Guivetchi memorandum, the EC coefficient of the EC-chloride relationships for the SJR at Vernalis range from 0.138 to 0.200, depending on year type. This is similar to the EC coefficient of Equation G-2 (the nonseawater-influenced relationship). For the SJR at Antioch, the EC coefficients reported in the Guivetchi memorandum range from 0.298 to 0.322, which are slightly greater than the EC coefficient in Equation G-1 (the seawater-influenced relationship). For the west canal at the mouth of the Clifton Court intake, the EC coefficients range from 0.197 to 0.257, and for the Old River 0.5 km south of the North Tip of Palm Tract (the closest reported station to the Rock Slough intake), the EC coefficients range from 0.158 to 0.266, depending on year type.

The chloride-bromide relationship in Equation G-3 is similar to relationships reported by MWQI and is also similar to the chloride-bromide ratio for seawater (0.0034). Chloride-bromide relationships reported by MWQI for central and western Delta stations range from 0.0032 to 0.0036, depending on the range of years represented by the dataset (DWR 2003, 2005b, 2006, 2008a).

Total Dissolved Solids and Salt Load

An EC-TDS ratio was developed to calculate TDS concentrations and salt loads for the SWP and CVP south Delta exports. The EC-TDS ratio used to calculate TDS concentrations is as follows.

$$TDS = 0.57*EC \qquad \text{(G-4)}$$

at Clifton Court and Jones Pumping Plant
where TDS is in mg/L and EC is in umhos/cm.

This EC-TDS ratio was developed by linear regression of MWQI grab samples reported in the Water Data Library during 2000 through 2008 (DWR 2008b). EC-TDS ratios developed from the 2000–2008 data are representative of raw-water supply for Clifton Court, Banks Pumping Plant, Rock Slough, and Old River intakes and can be seen on **Figure G-2**.

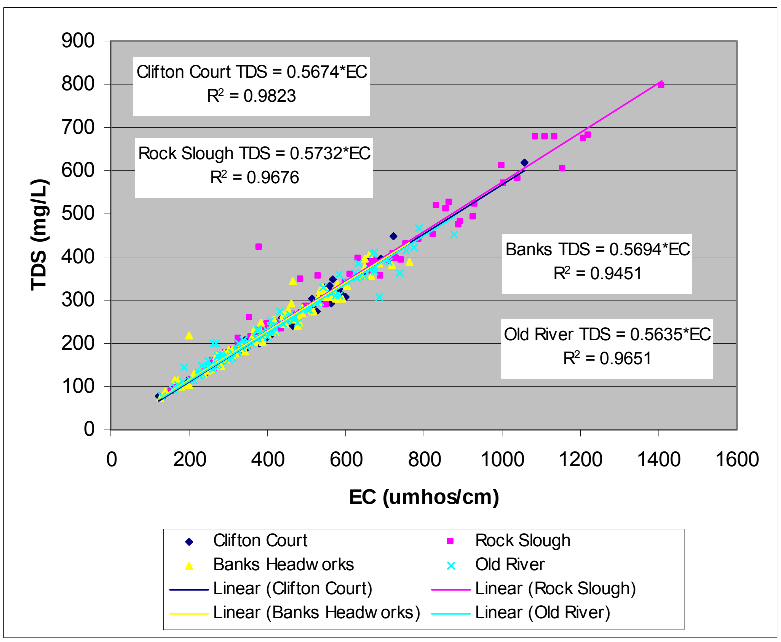


Figure G-2. Electrical Conductivity–Total Dissolved Solid Ratios for Clifton Court, Banks Pumping Plant, Rock Slough, and Old River

This EC-TDS relationship (Equation G-4) is similar to relationships reported by MWQI for 14 Delta stations. The EC-TDS ratios reported by MWQI ranged from 0.58 to 0.60, depending on the range of years represented by the dataset (DWR 2003; DWR 2005b).

TDS concentrations were calculated from DSM2-modeled EC output and salt loads were calculated from EC and flow output. In DSM2, flow output at Jones

Pumping Plant represents flow boundary conditions (i.e., exports); however, Clifton Court is modeled as a reservoir. Flow at Clifton Court represents the average daily flow entering the reservoir; due to changes in stage at Clifton Court, the flow input to the reservoir is not the same, on a daily basis, as export pumping by Banks Pumping Plant. Therefore, the DSM2 boundary conditions at Clifton Court (as modeled by CalSim II) were used to represent exports for salt load calculations.

Organic Carbon

A weighted DOC concentration was calculated on a daily basis from the DSM2-modeled volumetric source fraction and assumed DOC concentrations (**Table G-5**) for each of the sources. This concentration is calculated as follows.

$$DOC = \sum_i (x_i * DOC_i) \qquad \text{(G-5)}$$

where x_i is the fractional contribution from source *i*, DOC_i is the DOC concentration for source *i*, and *DOC* and DOC_i are in the same units (mg/L).

DOC concentrations were estimated for each of the DSM2 boundary conditions accounted for in the volumetric source fraction analysis. Median DOC concentrations were estimated from figures contained in the organic carbon conceptual model developed for the Central Valley Drinking Water Policy workgroup (Tetra Tech 2006). **Table G-5** shows the organic carbon concentrations used in DOC calculations.

Table G-5. Dissolved Organic Carbon Concentrations Assumed for Boundary Inflows

DSM2 Boundary Location	DSM2 Code	Estimated Median DOC Concentration (mg/L)
Calaveras River	CAL	2.5
Delta Island Consumptive Use	DICU	12
Eastside Streams (Mokelumne and Cosumnes Rivers)	EST	1.5
Delta Outflow (Martinez)	MTZ	2.4
Sacramento River	Sac	1.8
San Joaquin River	SJR	3.0
Yolo Bypass	YOL	4.3

Data source: Tetra Tech 2006

Key:

DOC = dissolved organic carbon
DSM2 = Delta Simulation Model 2
mg/L = milligram(s) per liter

G.2.3 Uncertainties

Uncertainties associated with the salinity and organic carbon calculations are discussed below.

Transients are present in the DSM2 model; since the model is time-dependent, responses to inputs are not immediate, but take time to propagate through the system. Transients in incremental concentrations can occur during the beginning of the recirculation periods; however, these transients represent actual differences between the No-Action Alternative and the alternative plans due to changes in flow rates and concentrations.

Bromide and Chloride

Bromide and chloride calculations are based upon the relationships shown in Equations G-1 to G-3. These salinity relationships are not site-specific, but are generalized relationships for Delta water.

The chloride relationship described in Equations G-1 and G-2 is bimodal. As the volumetric source fraction from Martinez approaches 0.4%, a transition between using the seawater-influenced relationship and the nonseawater-influenced relationship can happen. When EC is greater than 325 umhos/cm, the difference between the predicted chloride concentrations from the seawater-influenced relationship and the nonseawater-influenced relationship can be greater than 5 mg/L.

The No-Action Alternative and the alternative plans were calculated using the same basis for comparison; the Martinez source fraction for the No-Action Alternative condition determines the relationship for the No-Action Alternative and Alternatives B1, B2, and D daily values. Therefore, incremental changes from No-Action Alternative conditions reflect differences between the No-Action Alternative conditions and the alternative plans, not artifacts due to the Martinez source fraction transitioning through 0.4%.

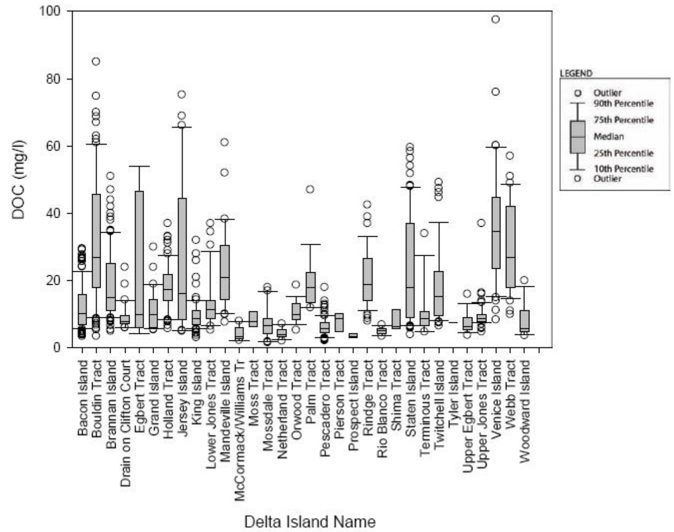
Organic Carbon

The organic carbon calculations are dependent upon the DOC concentrations assumed for each of the boundary inflows. The concentrations used in the calculations represent a median value for each source; however, measured concentrations can vary by season or year type and, for Delta island consumptive use, they can also vary by location. These variations are not accounted for in the DOC calculations.

Seasonal variation has been found in measured DOC data for the SJR at Vernalis and in the Sacramento River at Hood. Variation between wet and dry years has been found in measured DOC data for the Sacramento River at Hood

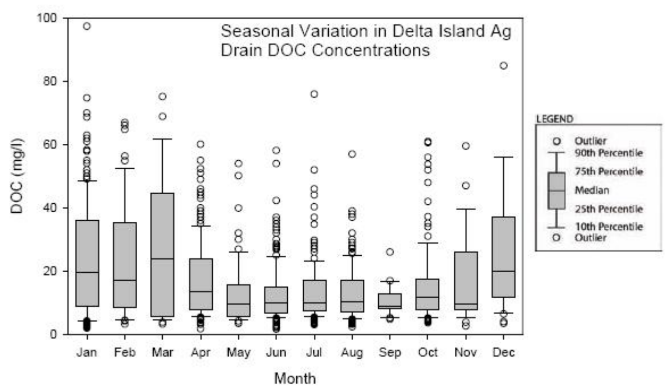
(CALFED 2007a). The wet season typically has higher DOC concentrations than the dry season at these locations.

The variation in DOC concentrations for Delta island consumptive use is not captured by the DOC calculations. **Figure G-3** shows variation by location in DOC concentration from Delta island agricultural drainage and **Figure G-4** shows variation by month and season.



Source: Tetra Tech 2006

Figure G-3. Dissolved Organic Carbon Concentrations from Delta Island Drainage



Source: Tetra Tech 2006

Figure G-4. Seasonal Variation in Dissolved Organic Carbon Concentrations from Delta Island Drainage

In-Delta sources of organic carbon that are not directly accounted for by the source fraction analysis and organic carbon calculations include primary production, exports from tidal marshes, urban runoff, and wastewater discharges. The concentrations and geographic distribution of these sources may contribute to concentrations at different intakes in a non-uniform manner.

Incremental changes in DOC due to recirculation are primarily due to increases in SJR source fraction and, thus, the DOC calculations account for the primary difference between the No-Action Alternative and the alternative plans.

G.3 Results

Large storage facilities can decrease the effects of short-duration variations in concentrations; concentration spikes can be diluted during transport and storage. For CCWD, incremental concentrations on a daily basis are more of a concern, because raw water from the Delta is treated directly.

Alternatives B1, B2, and D are evaluated with the following criteria:

- The number of months EC is predicted above 1,000 μmhos/cm at Clifton Court and Jones Pumping Plant
- The number of days chloride is predicted above 250 mg/L, and the number of years when the 150 mg/L chloride standard is not met at Rock Slough
- The number of days TDS is predicted above 500 mg/L
- The number of days when the incremental chloride concentration is increased by at least 5 mg/L
- The number of days when the incremental chloride concentration is decreased by at least 5 mg/L
- Incremental change from No-Action Alternative conditions averaged over the 82-year period for chloride, bromide, TDS, and DOC concentrations
- Salt load for Banks and Jones pumping plants

Comparisons of these criteria for the alternative plans are presented in **Tables G-6 through G-10**. Chloride, bromide, and DOC increments are presented as a time series in **Figures G-5 through G-9**. Chloride, bromide, and TDS increments are similar, but with different scales on the y-axis.

Predicted EC, chloride, and TDS are compared to Bay/Delta Plan water quality standards for specific intakes or EPA secondary MCLs for drinking water. The comparison to secondary MCLs provides information about the relative suitability of Delta water for municipal supply, as seen on a daily basis.

Incremental changes in chloride, bromide, and DOC are evaluated over the 82-year period to allow for direct comparison of alternative plans evaluated over an extended period of time and a variety of hydrologic year types. Predicted changes of at least 5 mg/L chloride were used to further differentiate among alternative plans and to give an indication of the frequency of potentially larger changes of raw water quality as seen on a daily basis.

The threshold of 5 mg/L chloride was chosen to indicate larger changes in concentrations because modeled changes of 5 mg/L chloride, or 5% or more on a daily basis at the Old River intake may be of interest to CCWD (Orloff, pers. comm., 2008). A 5-mg/L chloride increment is equivalent to a 17-µg/L bromide increment, when chloride concentrations are approximately 100 mg/L.

G.3.1 Jones Pumping Plant

Jones Pumping Plant draws CVP exports into the DMC. Water in the DMC has the potential for limited storage as well as more extensive storage prior to use as municipal supply. Short-duration concentration increments may be diluted prior to treatment.

Chloride concentrations predicted at Jones Pumping Plant are always less than 250 mg/L for the alternative plans (**Table G-6**). Monthly average EC is predicted below 1,000 µmhos/cm, with the exception of February 1991 for Alternative B1 and March 1924 for Alternatives B1, B2, and D. TDS concentrations are below the EPA secondary MCL of 500 mg/L, with the exception of less than 1.5% of the modeled days for each alternative plan.

The total number of days when the chloride concentration is either increased or decreased by 5 mg/L is less than 1.3% of the modeled days for Alternative D. For Alternatives B1 and B2, net salinity concentrations are reduced during the 82-year hydrologic trace; for Alternative D, the net concentrations are increased. Salt load is increased with consecutive alternative plans (**Table G-6**).

Recirculation during periods of low flow may increase the portion of SJR source at intakes, but decrease the amount of seawater intrusion. The SJR tends to have higher salinity than Sacramento River flow, but significantly less salinity than seawater. Alternative D has more frequent recirculation than other alternative plans, particularly for the purpose of meeting the flow objective at Vernalis (**Table G-6**). Recirculation may increase the SJR source fraction when net Delta inflow would otherwise be low; however, it may increase or decrease salinity concentrations at the export pumps.

The maximum increase in incremental daily chloride is 19 mg/L, which was modeled to occur in March 1990 (a Critical year) for Alternative D. The maximum decrease in incremental daily chloride is 21 mg/L, which was modeled to occur in April 1932 (an Above Normal year) for all alternative plans. These amounts correspond to a maximum increase of 66 µg/L bromide and a maximum decrease of 72 µg/L bromide (**Figure G-5**).

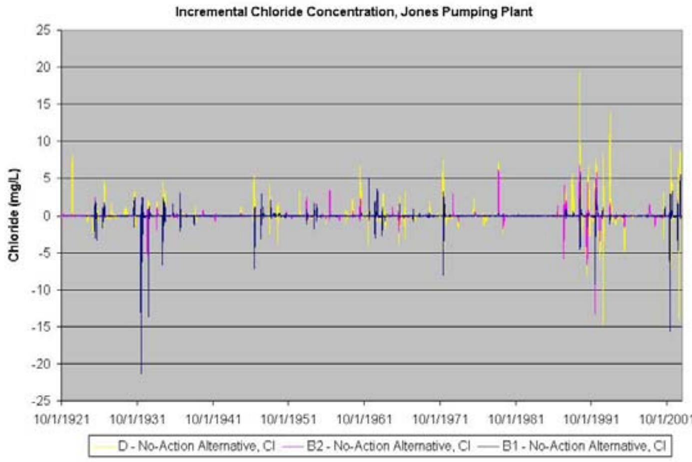
The maximum increase in incremental daily DOC is 0.21 mg/L and the maximum decrease is 0.27 mg/L DOC (**Figure G-5**). These changes are much smaller than the CALFED organic carbon goal of 3 mg/L or the less stringent near-term goal of 4 to 7 mg/L.

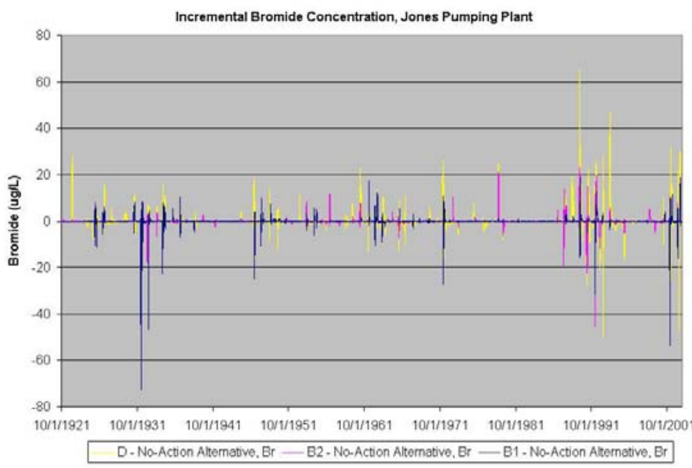
Table G-6. Summary of EC, Chloride, Bromide, TDS, and Salt Load at Jones Pumping Plant

Criteria	Unit	Alternative B1	Alternative B2	Alternative D
Number of months EC is predicted above 1,000 µmhos/cm	months	2	1	1
Number of days chloride is predicted above 250 mg/L	days	0	0	0
Number of days TDS is predicted above 500 mg/L	days	422	417	415
Number of days chloride is increased by at least 5 mg/L	days	6	30	234
Number of days chloride is decreased by at least 5 mg/L	days	93	116	155
Average chloride increment	mg/L	-0.017	-0.009	0.053
Average bromide increment	µg/L	-0.058	-0.030	0.182
Average TDS increment	mg/L	-0.066	-0.026	0.247
Average dissolved organic carbon increment	mg/L	0.00003	0.00015	0.00279
Average salt load increment (per day)	tons	8.4	10.1	11.7

Note:
Criteria evaluated over the 82-year modeling period; total number of days is 29,950; total number of months is 984.

Key:
EC = electrical conductivity
µmhos/cm = micromhos per centimeter
mg/L = milligram(s) per liter
µg/L = microgram(s) per liter
TDS = total dissolved solids





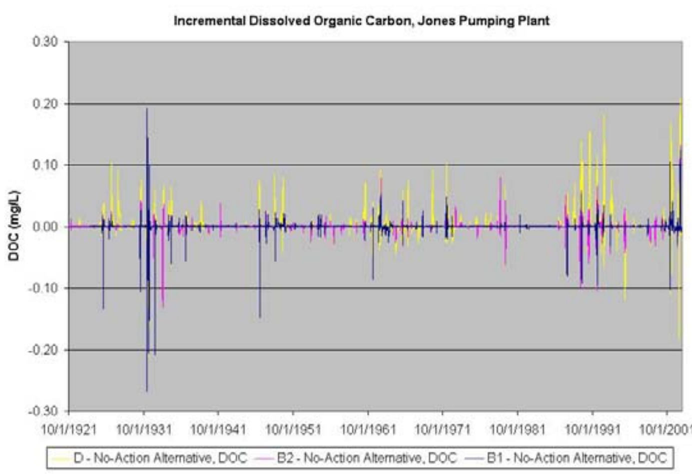


Figure G-5. Incremental Changes Predicted at Jones Pumping Plant

G.3.2 Clifton Court

SWP exports are drawn through Clifton Court, Banks Pumping Plant, and the California Aqueduct. This water has the potential for large-scale transport and storage and, thus, short-duration concentration increments would likely be diluted prior to drinking water treatment.

Chloride concentrations predicted at Clifton Court are less than 250 mg/L for all of the modeled days and modeled alternative plans (**Table G-7**). Monthly average EC is predicted below 1,000 µmhos/cm for all months. TDS concentrations are below the EPA secondary MCL of 500 mg/L, with the exception of less than 0.8% of the modeled days for each alternative plan.

The total number of days when the chloride concentration is either increased or decreased by 5 mg/L chloride is less than 1.0% of the days modeled during the 82-year hydrologic trace (**Table G-7**). No distinct pattern occurs in average concentrations or salt loads with consecutive alternative plans.

The maximum increase in incremental daily chloride is 12 mg/L, which was modeled to occur during April 1990 (a Critical year) for Alternative D. The maximum decrease in incremental daily chloride is 20 mg/L, which was modeled to occur in March 1948 (a Below Normal year) for all alternative plans. These amounts correspond to a maximum increase of 39 µg/L bromide and a maximum decrease of 68 µg/L bromide. The maximum increase in incremental daily DOC is 0.17 mg/L and the maximum decrease is 0.21 mg/L DOC (**Figure G-6**).

Table G-7. Summary of EC, Chloride, Bromide, TDS, and Salt Load at Clifton Court

Parameter	Unit	Alternative B1	Alternative B2	Alternative D
Number of months EC is predicted above 1,000 µmhos/cm	months	0	0	0
Number of days chloride is predicted above 250 mg/L	days	0	0	0
Number of days TDS is predicted above 500 mg/L	days	241	233	231
Number of days chloride is increased by at least 5 mg/L	days	0	0	182
Number of days chloride is decreased by at least 5 mg/L	days	53	79	129
Average chloride increment	mg/L	0.002	-0.004	0.090
Average bromide increment	µg/L	0.006	-0.013	0.306
Average TDS increment	mg/L	0.039	0.019	0.399
Average dissolved organic carbon increment	mg/L	-0.00007	-0.00043	0.00284
Average salt load increment (per day)	tons	0.91	0.54	3.08

Note:

Criteria evaluated over the 82-year modeling period; total number of days is 29,950; total number of months is 984.

Key:

µg/L = microgram(s) per liter
EC = electrical conductivity
mg/L = milligram(s) per liter
TDS = total dissolved solids
µmhos/cm = micromhos per centimeter

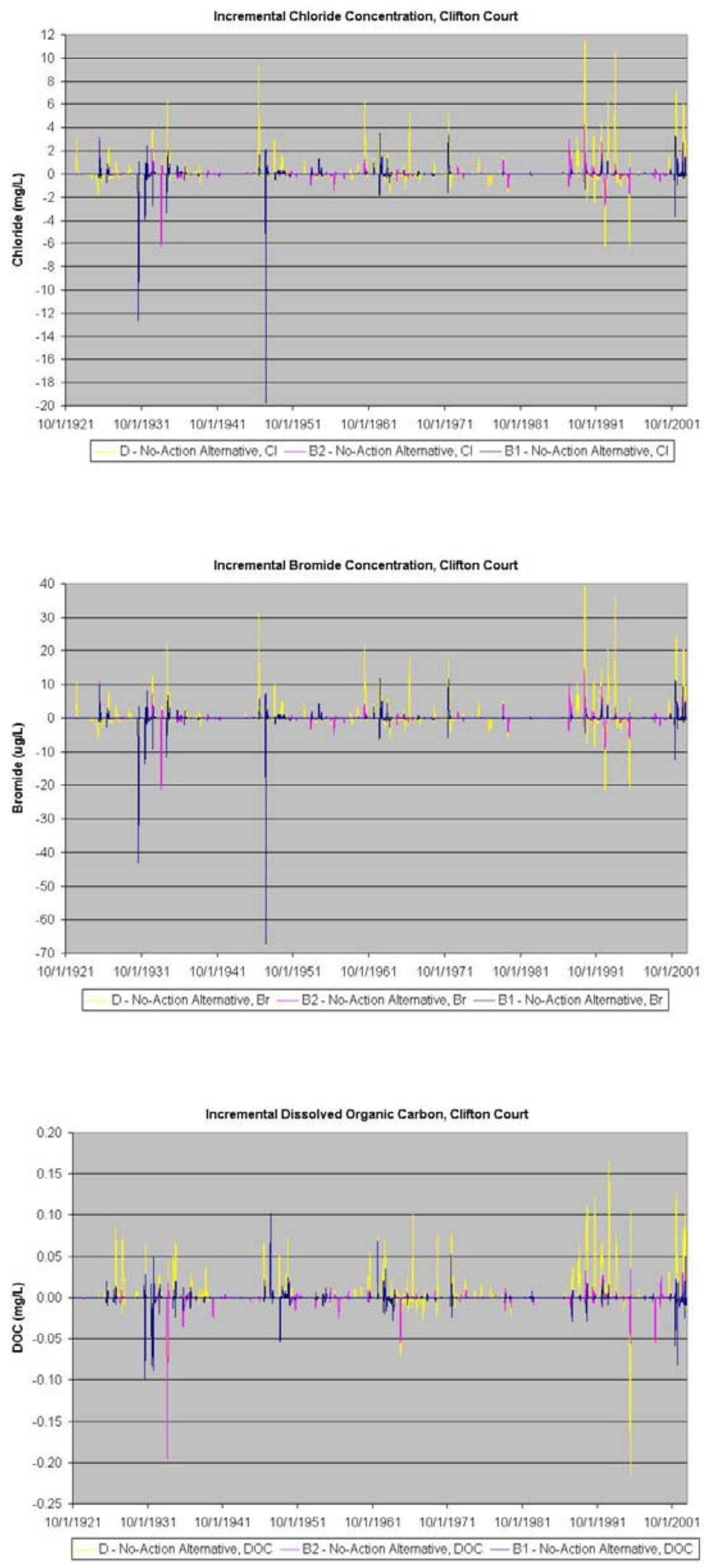


Figure G-6. Incremental Changes Predicted at Clifton Court

G.3.3 Old River

The Old River intake is used for filling Los Vaqueros Reservoir and for direct use as municipal supply.

Chloride concentrations predicted at the Old River intake are less than the EPA secondary MCL of 250 mg/L, with the exception of approximately 0.4% of the modeled days for each alternative plan (**Table G-8**). TDS concentrations are also predicted below 500 mg/L, with the exception of approximately 3.5% of the modeled days.

The total number of days when the chloride concentration is either increased or decreased by 5 mg/L chloride is less than 0.45% of the days modeled during the 82-year hydrologic trace (**Table G-8**). Average incremental changes in chloride, bromide, and TDS for modeled alternative plans tend to be slightly positive.

The maximum increase in incremental daily chloride is 10 mg/L, which was modeled to occur during February 1996 (a Wet year) for Alternative D. The maximum decrease in incremental daily chloride is 10 mg/L, which was modeled to occur in November 1992 (a Wet year following a Critical year) for Alternative D. These amounts correspond to a maximum increase of 35 µg/L bromide and a maximum decrease of 33 µg/L bromide. The maximum increase in incremental daily DOC is 0.54 mg/L and the maximum decrease is 0.36 mg/L DOC (**Figure G-7**).

Table G-8. Summary of Chloride, Bromide, and TDS at Old River

Parameter	Unit	Alternative B1	Alternative B2	Alternative D
Number of days chloride is predicted above 250 mg/L	days	122	122	121
Number of days TDS is predicted above 500 mg/L	days	1,084	1,072	1,049
Number of days chloride is increased by at least 5 mg/L	days	0	0	68
Number of days chloride is decreased by at least 5 mg/L	days	9	9	66
Average chloride increment	mg/L	0.016	0.013	0.034
Average bromide increment	µg/L	0.053	0.044	0.114
Average TDS increment	mg/L	0.061	0.061	0.236
Average dissolved organic carbon increment	mg/L	-0.00080	–0.00088	0.00232

Note: Criteria evaluated over the 82-year modeling period; total number of days is 29,950.

Key:

mg/L = milligram(s) per liter
µg/L = microgram(s) per liter
TDS = total dissolved solids

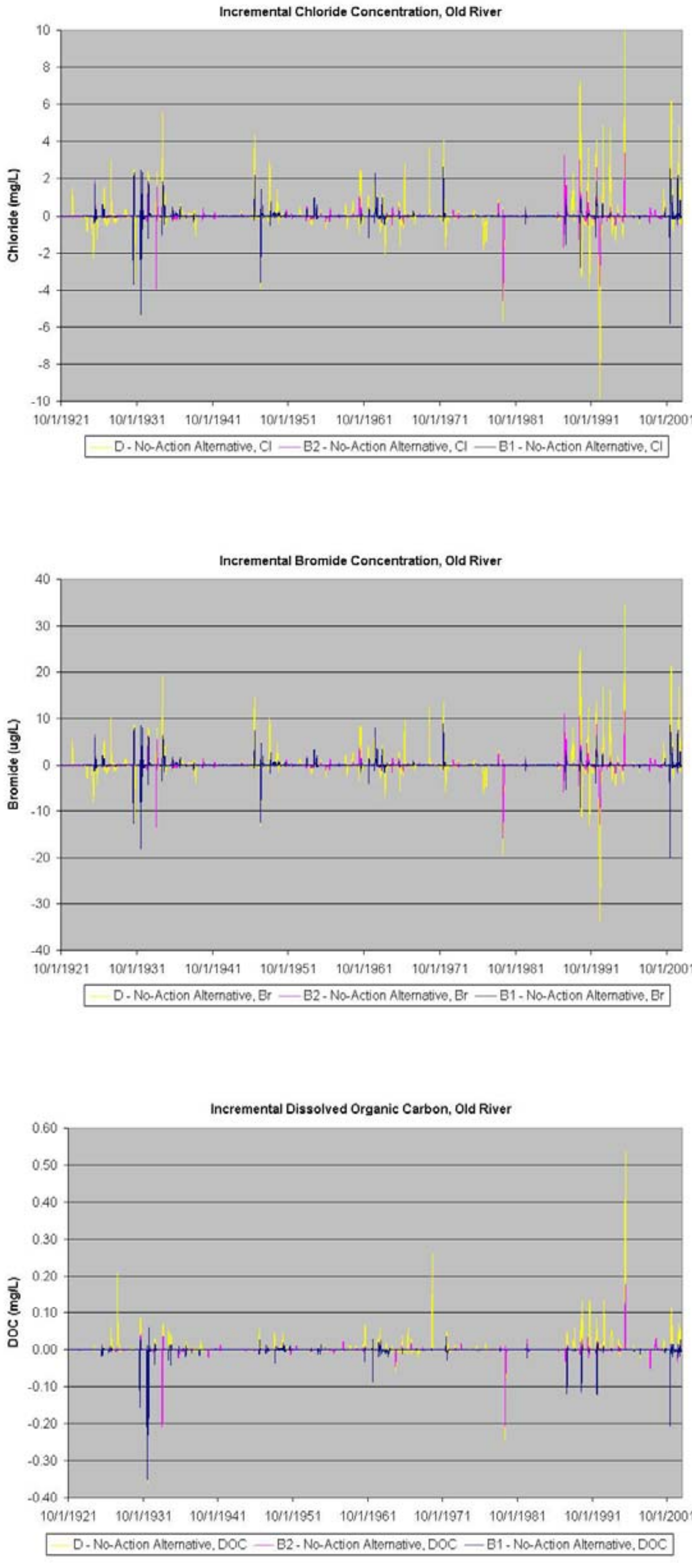


Figure G-7. Incremental Changes Predicted at Old River

G.3.4 Rock Slough

CCWD uses the Rock Slough intake when raw water from the Delta is of acceptable quality (65-100 mg/L chloride or less). Water quality at Rock Slough may not be suitable for municipal supply year-round.

Chloride concentrations predicted at the Rock Slough intake are predicted to be less than 250 mg/L, with the exception of approximately 3.3 to 3.5% of the modeled days (**Table G-9**). However, chloride concentrations are not predicted to be below 150 mg/L during the number of days specified by the Bay/Delta Plan for approximately 10% of the modeled years. TDS concentrations are predicted to be above the EPA secondary MCL of 500 mg/L during approximately 15% of the modeled days.

The total number of days when the chloride concentration is either increased or decreased by 5 mg/L chloride is less than 0.41% of the days modeled during the 82-year hydrologic trace (**Table G-9**). Average incremental changes in chloride, bromide, and TDS for modeled alternative plans tend to be slightly negative.

The maximum increase in incremental daily chloride is 23 mg/L, which was modeled to occur during March 1996 (a Wet year) for Alternative D. The maximum decrease in incremental daily chloride is 13 mg/L, which was modeled to occur in December 1992 (a Wet year following a Critical year) for Alternative D. These amounts correspond to a maximum increase of 77 µg/L bromide and a maximum decrease of 45 µg/L bromide. The maximum increase in incremental daily DOC is 0.89 mg/L and the maximum decrease is 0.30 mg/L DOC (**Figure G-8**).

Table G-9. Summary of Chloride, Bromide, and TDS at Rock Slough

Parameter	Unit	Alternative B1	Alternative B2	Alternative D
Number of days chloride is predicted above 250 mg/L	days	1,044	1,029	987
Number of days TDS is predicted above 500 mg/L	days	4,554	4,555	4,555
Number of years the 150 mg/L chloride standard is not met	years	8	8	8
Number of days chloride is increased by at least 5 mg/L	days	0	5	31
Number of days chloride is decreased by at least 5 mg/L	days	8	8	93
Average chloride increment	mg/L	–0.002	–0.006	–0.073
Average bromide increment	µg/L	–0.006	–0.022	–0.248
Average TDS increment	mg/L	–0.003	–0.003	–0.085
Average dissolved organic carbon increment	mg/L	-–0.00039	–0.00029	0.00189

Note: Criteria evaluated over the 82-year modeling period; total number of days is 29,950.

Key:

µg/L = microgram(s) per liter
mg/L = milligram(s) per liter
TDS = total dissolved solids

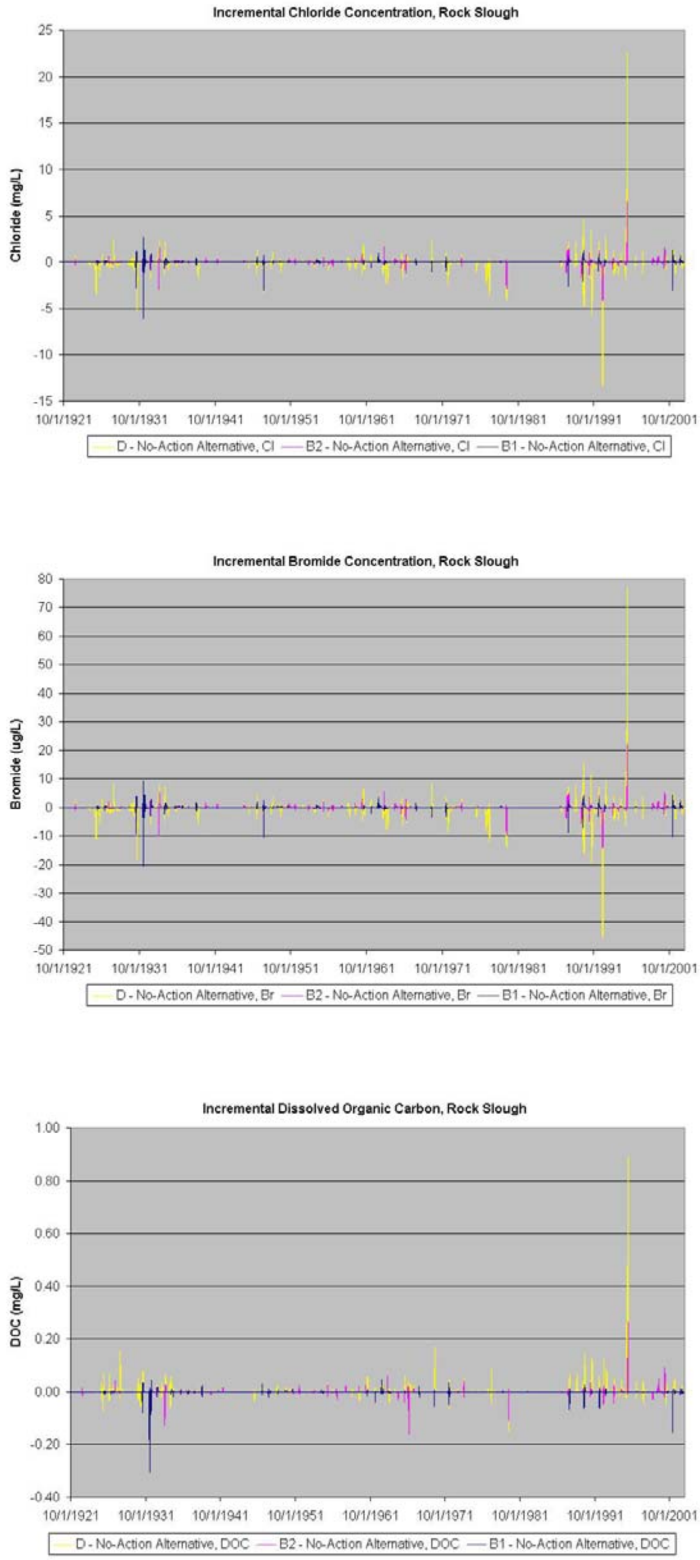


Figure G-8. Incremental Changes Predicted at Rock Slough

G.3.5 Antioch

Raw water at Antioch is not suitable for drinking water purposes during most of the year. During 57% of the modeled days for No-Action Alternative conditions, the chloride concentration at Antioch was greater than the EPA secondary MCL of 250 mg/L chloride (**Table G-10**). This percentage is unchanged with the action alternative plans. TDS concentrations are also predicted above the EPA secondary MCL of 500 mg/L during approximately 60% of the modeled days.

The total number of days when the chloride concentration is either increased or decreased by 5 mg/L chloride is 6.1% of the days modeled during the 82-year hydrologic trace for Alternative D (**Table G-10**). Although the average salinity increments are negative, these changes are small compared to overall concentrations.

The maximum increase in incremental daily chloride is 26 mg/L, which was modeled to occur during July 1999 (an Above Normal year) for Alternatives B2 and D. The maximum decrease in incremental daily chloride is 78 mg/L, which was modeled to occur in May 1990 (a Critical year) for Alternative D. These amounts correspond to a maximum increase of 87 µg/L bromide and a maximum decrease of 268 µg/L bromide. The maximum increase in incremental daily DOC is 0.04 mg/L and the maximum decrease is 0.01 mg/L DOC (**Figure G-9**).

Table G-10. Summary of Chloride, Bromide, and TDS at Antioch

Parameter	Unit	Alternative B1	Alternative B2	Alternative D
Number of days chloride is predicted above 250 mg/L	days	17,062	17,066	17,037
Number of days TDS is predicted above 500 mg/L	days	17,920	17,925	17,898
Number of days chloride is increased by at least 5 mg/L	days	4	160	132
Number of days chloride is decreased by at least 5 mg/L	days	13	93	1696
Average chloride increment	mg/L	–0.011	–0.005	–1.118
Average bromide increment	µg/L	–0.036	–0.018	–3.814
Average TDS increment	mg/L	–0.021	–0.010	–2.236
Average dissolved organic carbon increment	mg/L	0.00006	0.00015	0.00069

Note: Criteria evaluated over the 82-year modeling period; total number of days is 29,950.

Key:

µg/L = microgram(s) per liter
mg/L = milligram(s) per liter
TDS = total dissolved solids

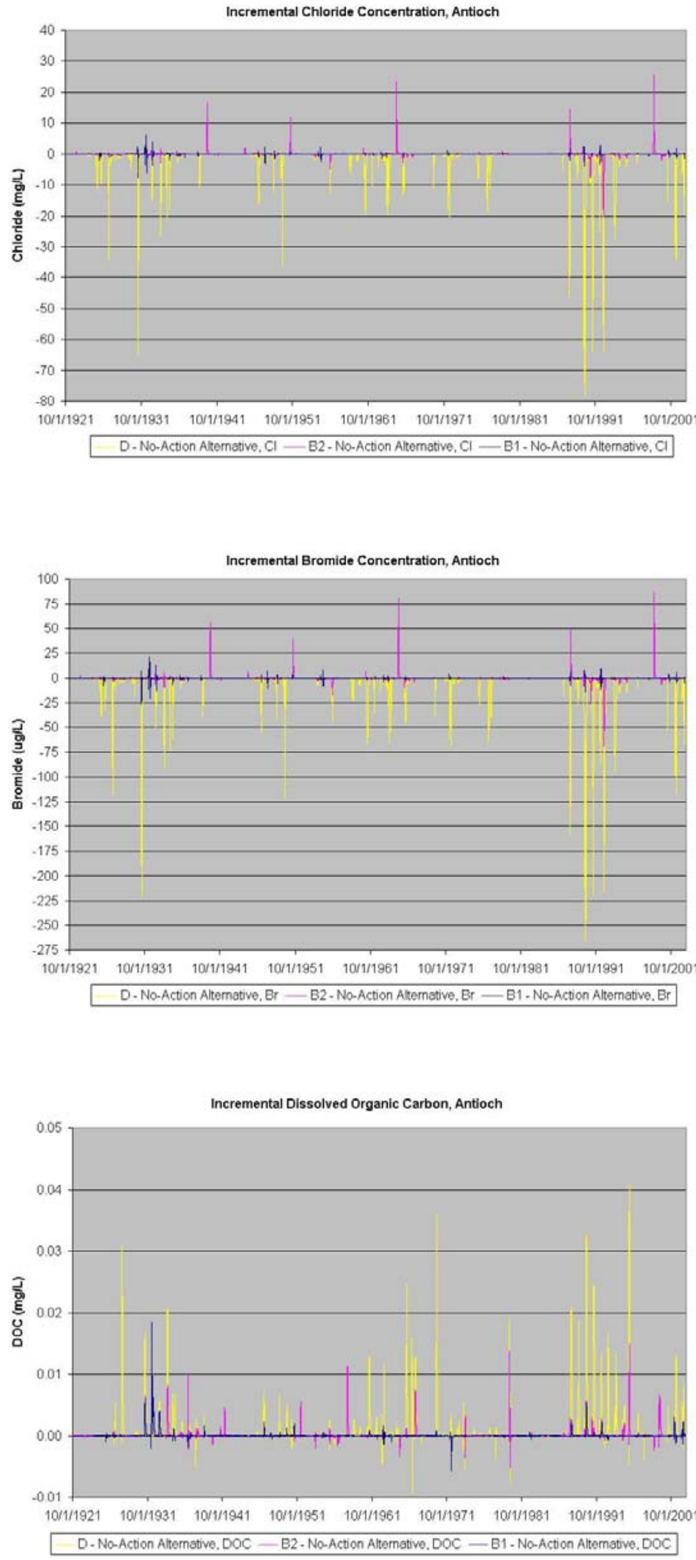


Figure G-9. Incremental Changes Predicted at Antioch

G.4 Conclusions

Drinking water treatment costs are dependent on the operations of the treatment plant and the treatment goals of the water utility. Costs due to changes in water quality may occur due to additional operations and maintenance costs such as modified treatment techniques or additional pretreatment, capital improvements, or costs associated with storage and source-water blending.

Large storage facilities can decrease costs or benefits due to short-duration variations in concentrations. Concentration spikes can be diluted during transport and storage. For water conveyed to San Luis Reservoir by the SWP or CVP, the volume of water associated with concentration increments would be small compared to the total volume of the storage facility. For CCWD, incremental concentrations are more of a concern, because raw water from the Delta is treated directly.

Of the modeled alternative plans, Alternative D has the greatest quantity of total recirculation flow and the greatest number of recirculation periods. For this alternative plan, predicted chloride concentrations both increase and decrease by 5 mg/L, or more, for at least one of the modeled days at all of the drinking water intakes evaluated. Incremental chloride changes of 5 mg/L occurred approximately 1% of the time at the southern Delta intakes. The maximum chloride increase predicted at the CCWD Old River intake was 10 mg/L (Alternative D); however, increases above 5 mg/L were predicted to occur less than 0.3% of the modeled days. No increases above 5 mg/L chloride at Old River were predicted for Alternatives B1 or B2.

Modeled changes in organic carbon were small compared to the organic carbon goal for municipal supply and overall organic carbon concentrations.

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