Appendix F
Water Resources Evaluation

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Acronyms and Abbreviations

ºF	degree(s) Fahrenheit
AWQC	ambient water quality criteria
Basin Plan	*Water Quality Control Plan for the Sacramento River and San Joaquin River Basins*
$CaCO_3$	calcium carbonate
CalSim II	California Simulation Model II
CDFG	California Department of Fish and Game
CDPH	California Department of Public Health
cfs	cubic feet per second
COLD	cold freshwater habitat
CVRWQCB	Central Valley Regional Water Quality Control Board
DBP	disinfection byproduct
DCPA	dimethyl-tetrachloroterephthalate, aka Dacthal
DDE	dichlorodiphenyldichloroethylene
DDT	dichlorodiphenyltrichloroethane
Delta	Sacramento-San Joaquin River Delta
DMC	Delta-Mendota Canal
DO	dissolved oxygen
DOC	dissolved organic carbon
DPR	California Department of Pesticide Regulation
DSM2	Delta Simulation Model 2
DWR	California Department of Water Resources
DWSC	Deep Water Ship Channel
EC	electrical conductivity
EPA	U.S. Environmental Protection Agency
EPTC	Ethyl Dipropylthiocarbamate; aka Eptam
IRIS	Integrated Risk Information System
LC50	lethal concentration that kills 50% of the test population
LOD	Level of Development
LOEC	lowest observed effects concentration
MCL	maximum contaminant level
µg/L	microgram(s) per liter
µmhos/cm	micromhos per centimeter
mg/L	milligram(s) per liter
NTU	nephelometric turbidity unit(s)
SJR	San Joaquin River
SSC	suspended sediment concentration

TDS	total dissolved solids
TMDL	total maximum daily load
TOC	total organic carbon
TSS	total suspended solids
USGS	U.S. Geological Survey
WARM	warm freshwater habitat
WQO	water quality objective
WQP ROD	Water Quality Program Record of Decision

Appendix F
Water Resources Evaluation

F.1 Introduction

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 alternative plans for the DMC Recirculation Project and to determine whether the Project will provide greater flexibility in meeting existing water quality standards and flow objectives while reducing water demands from New Melones Reservoir.

This report describes the water resources evaluation for water quality, flow, and stage based on modeling results from **Appendices A through E** and upon existing water quality data.

The appendix is divided into four primary sections: **Section F1** provides an overview of the project and its objectives. **Section F2** contains the water quality evaluation. **Section F*3*** contains the flow and stage evaluation. **Section F4** presents a concise summary of these evaluations. **Attachment F1** provides additional summary information for water quality, flow, and stage presented by location. **Attachment F2** provides summary statistics by region. **Attachment F3** provides a time series of modeled stage for the Delta.

F.2 Water Quality Evaluation

The water quality parameters identified in **Table F2-1** were selected for evaluation because of their potential impacts from these parameters on aquatic life, drinking water, or agricultural supply. Electrical conductivity (EC), temperature, total suspended solids (TSS), turbidity, selenium, and boron are modeled quantitatively. Modeling results are evaluated with respect to the water quality criteria in **Section F2.1**. The modeling conducted for dissolved oxygen (DO) in the Port of Stockton Deep Water Ship Channel (DWSC) was semiquantitative, and the evaluation is also presented in **Section F2.1**. Existing data for pesticides, trace metals, nutrients, organic carbon and bromide, and selected physical parameters are compared qualitatively in **Section F2.2**.

Table F2-1. Water Quality Criteria for Surface Water

Parameter	Surface Water Criteria	Relevant Extent of Criteria	Basis of Criteria
Ammonia, total	0.179 mg/L as N, 30-day average	Not to be exceeded more than once every 3 years on average. Criteria are expressed as a function of pH, temperature, and the presence or absence of fish in early life stages.[1] The value given here corresponds to pH 9, 30°C, and fish with early life stages.	EPA Ambient Water Quality Criteria for Freshwater Aquatic Life
	0.885 mg/L as N, 1-hour average	Not to be exceeded more than once every 3 years on average. Criteria are expressed as a function of pH and the presence/absence of salmonids.[2] The value given here corresponds to pH 9 with salmonids present.	
Arsenic	10 µg/L, dissolved	Sacramento-San Joaquin Delta	Basin Plan
	0.018 µg/L, inorganic fraction	For inland surface water, consumption of water and organisms[3]	EPA Ambient Water Quality Criteria for Human Health
Boron, total	0.8 mg/L monthly average; 2 mg/L maximum	For Mar 15-Sep 15; for the SJR mouth of Merced River to Vernalis	Basin Plan
	1.0 mg/L monthly average; 2.6 mg/L maximum	For Sep 16-Mar 14; for the SJR mouth of Merced River to Vernalis	
	1.3 mg/L monthly average	In Critical water year types; for the SJR mouth of Merced River to Vernalis	
Bromide	50 µg/L	Goal for municipal supply in the Delta	CALFED WQP ROD
Cadmium, dissolved	0.094 µg/L 4-day average; 0.52 µg/L 1-day average	Criteria are expressed as a function of hardness.[4] The values given correspond to a hardness of 25 mg/L.	EPA Ambient Water Quality Criteria for Freshwater Aquatic Life
Chlorpyrifos	0.015 µg/L 4-day average; 0.025 µg/L 1-hour average	For the SJR from Mendota Dam to Vernalis and for select Delta Waterways; not to be exceeded more than once in a 3-year period	Basin Plan
Chromium, dissolved	24 µg/L 4-day average; 180 µg/L 1-hour average	Criteria are expressed as a function of hardness.[4] The values given here correspond to a hardness of 25 mg/L.	EPA Ambient Water Quality Criteria for Freshwater Aquatic Life
Copper, dissolved	10 µg/L	Sacramento-San Joaquin Delta	Basin Plan
	2.7 µg/L 4-day average; 3.6 µg/L 1-hour average	Criteria are expressed as a function of hardness.[4] The values given correspond to a hardness of 25 mg/L.	California Toxics Rule Criteria to Protect Freshwater Aquatic Life
Diazinon	0.10 µg/L 4-day average; 0.16 µg/L 1-hour average	For the SJR from Mendota Dam to Vernalis and select Delta waterways; not to be exceeded more than once in a 3-year period	Basin Plan
Dissolved Oxygen	8.0 mg/L	For the Merced River from Cressey to New Exchequer Dam all year and for the Tuolumne River from Waterford to La Grange, Oct 15-Jun 15	Basin Plan
	7.0 mg/L	For the Delta waters west of Antioch Bridge; and for surface water bodies outside of the legal Delta designated for use as COLD or Spawning, Reproduction, and/or Early Development	
	6.0 mg/L	For the SJR from Turner Cut to Stockton Sep 1-Nov 30	
	5.0 mg/L	In all other Delta waters with fish; or for surface water bodies outside of the legal Delta designated for use as WARM	
	85% of saturation	In the main water mass (and the 95 percentile concentration not below 75% of saturation), monthly median of the mean daily concentration for surface water bodies outside of the legal Delta	

Table F2-1. Water Quality Criteria for Surface Water

Parameter	Surface Water Criteria	Relevant Extent of Criteria	Basis of Criteria
Electrical conductivity (EC)	450 μmhos/cm	From April 1 (to a variable date depending on water year type) for the following western and interior Delta locations: Sacramento River at Emmaton, SJR at Jersey Point, South Fork Mokelumne River at Terminous, and SJR at San Andreas Landing	Basin Plan
	700 μmhos/cm	Apr 1-Aug 31, maximum 30-day running average of mean daily EC in the SJR at Vernalis, SJR at Brandt Bridge, Old River near Middle River, Old River at Tracy Road Bridge	
	1,000 μmhos/cm	Sep 1-Mar 31, maximum 30-day running average of mean daily EC in the SJR at Vernalis, SJR at Brandt Bridge, Old River near Middle River, Old River at Tracy Road Bridge; and the Oct-Sep, maximum 30-day running average of mean daily EC in the DMC at C.W. “Bill” Jones Pumping Plant	
Lead	15 μg/L	For water designated for use as domestic or municipal supply	Basin Plan
	0.54 μg/L 4-day average; 14 μg/L 1-hour average	Dissolved fraction. Criteria are expressed as a function of hardness.[4] The values given here correspond to a hardness of 25 mg/L.	EPA Ambient Water Quality Criteria for Freshwater Aquatic Life
Mercury	0.05 μg/L 30-day average	For inland surface water, consumption of water and aquatic organisms	California Toxics Rule Criterion for Human Health
Molybdenum, total	10 μg/L monthly mean; 15 μg/L maximum	For the SJR mouth of the Merced River to Vernalis	Basin Plan
	19 μg/L monthly mean; 50 μg/L maximum	For Salt Slough, Mud Slough (north), and the SJR from Sack Dam to the mouth of Merced River	
Nickel, dissolved	16 μg/L 4-day average; 140 μg/L 1-hour average	Criteria are expressed as a function of hardness.[4] The values given here correspond to a hardness of 25 mg/L.	EPA Ambient Water Quality Criteria for Freshwater Aquatic Life
Nitrate	10 mg/L as N	Or no increase in nitrate levels; goal for municipal supply in the Delta	CALFED WQP ROD
Pesticides	Drinking Water Maximum Containment Level (MCL)	(As specified in CCR 22:4:15) the for waters designated as domestic or municipal water supply	Basin Plan
	Below detectable levels	For total identifiable persistent chlorinated hydrocarbon pesticides for surface waters in the Sacramento and San Joaquin River Basins	
pH	6.5–8.5 standard units	Sacramento and San Joaquin River Basins	Basin Plan
Phosphate as P	25 μg/L	For lakes and reservoirs; recommendation for the control of nuisance aquatic growth	EPA Water Quality Criteria (1986, Gold Book)
	50 μg/L	For a stream at the point it enters any lake or reservoir; recommendation for the control of nuisance aquatic growth	
	100 μg/L	For streams not discharging into lakes and impoundments; recommendation for the control of nuisance aquatic growth	
Selenium, total	5 μg/L 4-day average; 12 μg/L maximum	For the SJR mouth of Merced River to Vernalis	Basin Plan
	5 μg/L 4-day average; 20 μg/L maximum	For Mud Slough (north) and the SJR from Sack Dam to the Merced River	
	2 μg/L 4-day average; 20 μg/L maximum	For Salt Slough and water supply channels in the Grassland watershed	

Table F2-1. Water Quality Criteria for Surface Water

Parameter	Surface Water Criteria	Relevant Extent of Criteria	Basis of Criteria
Total Dissolved Solids (TDS)	440 mg/L monthly average; 220 mg/L 10-year average	Goal for municipal supply in the Delta	CALFED WQP ROD
Temperature	Narrative objectives	Daily average water temperature is not to be elevated by controllable factors above 68°F in the SJR at Vernalis, Apr 1-Jun 30 and Sep 1-Nov 3.	Basin Plan
		COLD or WARM waters are not to be increased more than 5°F above natural receiving water temperature.	
Total Organic Carbon (TOC)	3 mg/L	Goal for municipal supply in the Delta	CALFED WQP ROD
Total Suspended Solids (TSS)	Narrative objective	Suspended solids should not reduce the depth of the compensation point for photosynthetic activity by more than 10% from the seasonably established norm for aquatic life.	EPA Water Quality Criteria (1986, Gold Book)
Turbidity	50 NTU	For the Central Delta, except for periods of storm runoff[5]	Basin Plan
	150 NTU	In other Delta waters, except for periods of storm runoff[5]	
	Narrative objective	For increases in turbidity attributable to controllable water quality factors, where natural turbidity is between 0 and 5 NTU, increases are not to exceed 1 NTU; where natural turbidity is between 5 and 50 NTU, increases are not to exceed 20%; where natural turbidity is between 50 and 100 NTU, increases are not to exceed 10 NTU; where natural turbidity is greater than 100 NTU, increases are not to exceed 10%.	
Zinc, dissolved	100 µg/L	Sacramento-San Joaquin Delta	Basin Plan
	36 µg/L 4-day average; 36 µg/L 1-hour average	Criteria are expressed as a function of hardness.[4] The values given here correspond to a hardness of 25 mg/L.	EPA Ambient Water Quality Criteria for Freshwater Aquatic Life

Sources: CVRWQCB 2007; CALFED 2007; EPA 1986, 2000, 2008a.

Notes:

[1] CCC (criterion continuous concentration or chronic criterion): When fish early life stages are present, $CCC = ((0.0577/(1 + 10^{7.688-pH})) + (2.487/(1 + 10^{pH-7.688}))) \times MIN(2.85, 1.45 \cdot 10^{0.028 \cdot (25-T)})$, When fish early life stages are absent, $CCC = ((0.0577/(1 + 10^{7.688-pH})) + (2.487/(1 + 10^{pH-7.688}))) \times 1.45 \cdot 10^{0.028 \cdot (25-MAX(T,7))}$

[2] CMC (criterion maximum concentration or acute criterion): Where salmonid fish are present, $CMC = (0.275/(1 + 10^{7.204-pH})) + (39.0/(1 + 10^{pH-7.204}))$; Or where salmonid fish are not present: $CMC = (0.411/(1 + 10^{7.204-pH})) + (58.4/(1 + 10^{pH-7.204}))$

[3] This criterion is based on carcinogenicity of 10^{-6} risk.

[4] CMC (dissolved) = $\exp\{m_A [\ln(hardness)] + b_A\}$ (CF), and CCC (dissolved) = $\exp\{m_C [\ln(hardness)] + b_C\}$ (CF). For Cadmium, m_A= 1.0166, b_A= -3.924, m_C= 0.7409, b_C= -4.719, CF for the CMC= 1.136672-[(ln(hardness))(0.041838)], and CF for the CCC= 1.101672-[(ln(hardness))(0.041838)]. For Chromium III, m_A= 0.8190, b_A= 3.7256, m_C= 0.8190, b_C= 0.6848, CF for the CMC= 0.316, and CF for the CCC= 0.860. For Copper, m_A= 0.9422, b_A= -1.700, m_C= 0.8545, b_C= -1.702, CF for the CMC= 0.960, and CF for the CCC= 0.960. For Lead, m_A= 1.273, b_A= -1.460, m_C= 1.273, b_C= -4.705, CF for the CMC= 1.46203-[(ln(hardness))(0.145712)], and CF for the CCC= 1.46203-[(ln(hardness))(0.145712)]. For Nickel, m_A= 0.8460, b_A= 2.255, m_C= 0.8460, b_C= 0.0584, CF for the CMC= 0.998, and CF for the CCC= 0.997. For Zinc, m_A= 0.8473, b_A= 0.884, m_C= 0.8473, b_C= 0.844, CF for the CMC= 0.978, and CF for the CCC= 0.986.

[5] Exceptions are considered for dredging operations.

Key:

Basin Plan = *Water Quality Control Plan for the Sacramento River and San Joaquin River Basins* (CVRWQCB 2007)
°C = degree(s) Celsius
CCR = California Code of Regulations
COLD = cold freshwater habitat
Delta = Sacramento-San Joaquin River Delta
DMC = Delta-Mendota Canal
EPA = U.S. Environmental Protection Agency
µg/L = microgram(s) per liter
µmhos/cm = micromhos per centimeter
mg/L = milligrams(s) per liter
NTU = nephelometric turbidity unit(s)
SJR = San Joaquin River
WARM = warm freshwater habitat
WQP ROD = Water Quality Program Record of Decision

Quantitative evaluations are based on modeling results. Alternative plans are compared to water quality criteria, to conditions under the No-Action Alternative, and to each other. Qualitative evaluations are based on comparison of existing water quality data for distinct regions of the project area: the south Delta/export intakes, the Stanislaus River, the mainstem of the SJR between the Merced River and the Stanislaus River, the SJR at Vernalis, and the wasteways.

For box plots that display existing data, the measured data were obtained from the following sources:

- Central Valley Regional Water Quality Control Board (CVRWQCB) Surface Water Ambient Monitoring Program (SWAMP) (CVRWQCB 2008)
- California Department of Water Resources (DWR) Water Data Library (DWR 2008)
- US Geological Survey (USGS) National Water Information System (USGS 2007)
- Westside San Joaquin Water Coalition (Westside San Joaquin Water Coalition 2007)

Water quality data for pesticides were also obtained from the following sources:

- CVRWQCB Pesticide Total Maximum Daily Load (TMDL) Monitoring Program (Aquatic Ecosystems Analysis Laboratory 2006a, 2006b, 2007a, 2007b; Calincini and Johnson 2005a, 2005b, 2005c, 2005d, 2005e, 2005f; CVRWQCB 2004a)
- California Department of Pesticide Regulation (DPR) Surface Water Database (Domagalski and Munday 2003; DPR 2006; Zamora et al. 2003)

Water quality stations are grouped by region. South Delta locations include Clifton Court, Harvey O. Banks Pumping Plant, Middle River at Tracy Road, Middle River at Union Point, Old River at Tracy Road, Old River at Bacon Island, SJR at Mossdale, and SJR at Highway 4.

Stanislaus River stations include Caswell State Park, Knights Ferry, Jacob Meyers Park, and Orange Blossom. Upper mainstem locations are located along the SJR between the confluence with the Merced River and the confluence with the Tuolumne River. The upper mainstem stations include Patterson and Crows Landing.

The lower mainstem location is located on the SJR between the confluence with the Tuolumne and Stanislaus rivers. The lower mainstem location is at Maze. The wasteway locations are Newman Wasteway at Highway 33, Newman

Wasteway near Hills Ferry Road, Westley Wasteway at Refuge Ponds, and Westley Wasteway near Cox Road. The locations used in the data analysis can be seen on **Figure F2-1**.

For the purpose of data evaluation, the concentration of the nondetect data was assumed to equal half of the reporting limit. Duplicate sample data were averaged for each source. The dataset was restricted to Water Years 2000 to 2007 (October 1999 to September 2007). **Attachment F2** provides summary statistics by region.

Newman Wasteway and Westley Wasteway are designed to contain operational spills from the DMC and allow dewatering during routine or emergency maintenance. Typically, discharge from each of these wasteways ranges from 20 to 75 cubic feet per second (cfs) and is composed primarily of agricultural subsurface drainage. Occasional pulse flow is sent down the wasteways to clear accumulated sediment away from the headgates. The wasteway data that were used for the regional analyses were collected by the USGS and Westside San Joaquin Water Coalition and represent the quality of the agricultural drainage within the wasteways, not the quality of recirculation water.

Recirculation pilot studies were conducted in 2004, 2007, and 2008 at Newman Wasteway. The results of the studies are presented by parameter after the discussion of the regional data in **Sections F2.1 and F2.2**. Sample size was limited in the pilot studies, and the samples were collected for approximately 1 month in late summer when large volumes of water had not flowed through the wasteway for some time.

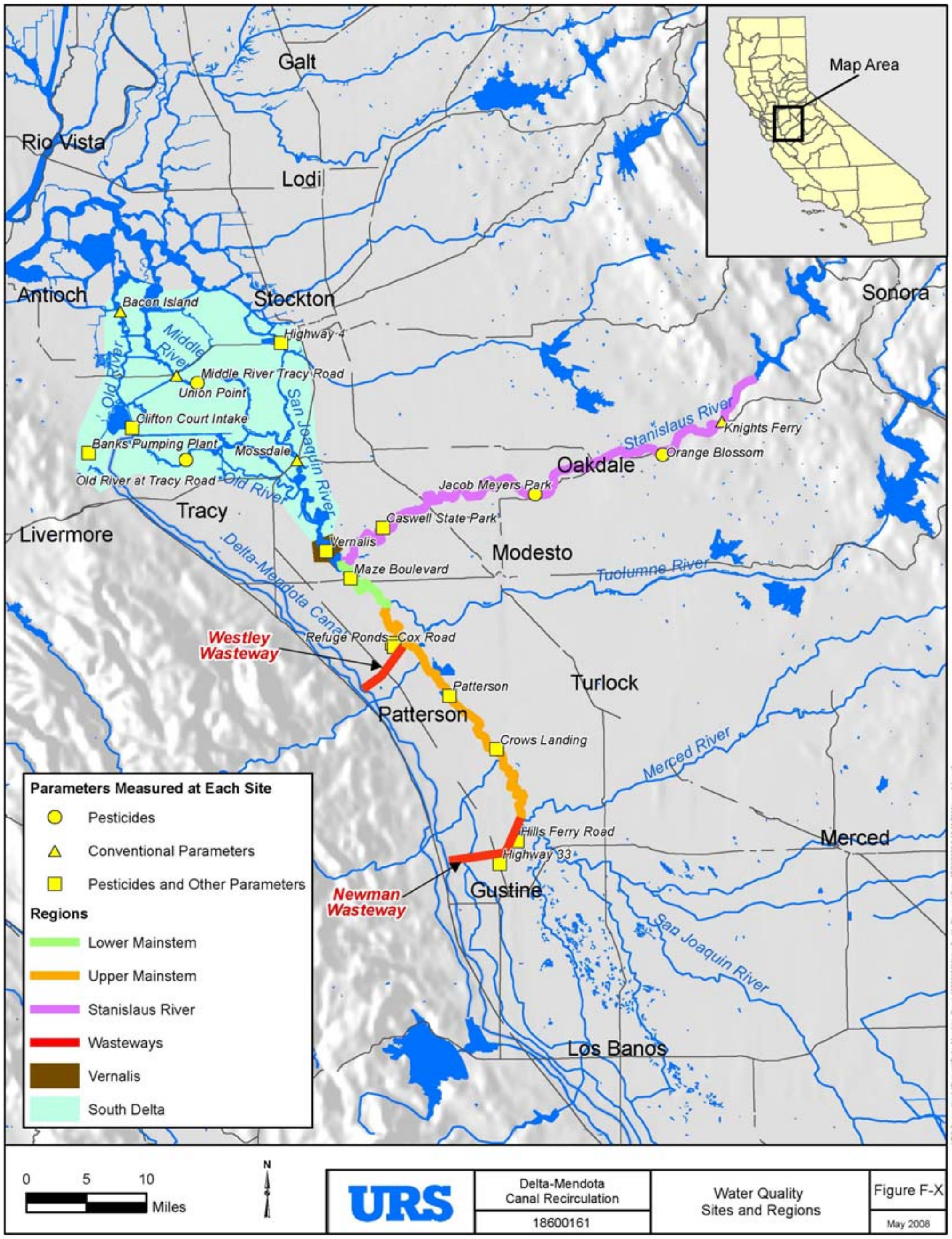


Figure F2-1. Water Quality Sites and Regions

F.2.1 Quantitative Evaluation of Modeled Parameters

This section is a summary of water quality modeled in **Appendices A through E** with respect to water quality criteria. Existing conditions are modeled using the existing Level of Development (LOD); the No-Action Alternative conditions, and alternative plans evaluated in this appendix are modeled using the 2030 future LOD. The No-Action Alternative conditions are those in the project area through the planning time frame if recirculation is not provided to the SJR. The No-Action Alternative includes only regional management and facilities that existed in 2007 or authorized, funded future projects.

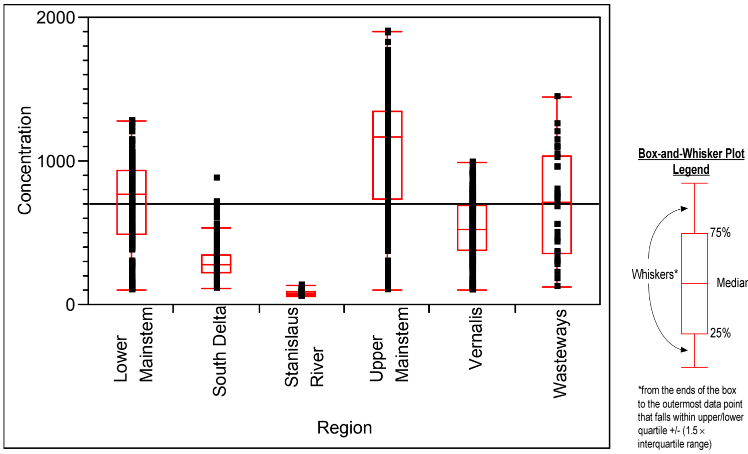
Electrical Conductivity

The *Water Quality Control Plan for Sacramento and San Joaquin River Basins* (Basin Plan) (CVRWQCB 2007) water quality objective (WQO) for EC is 700 µmhos/cm during April through August and 1,000 µmhos/cm during September through March. This objective is calculated as a maximum 30-day running average of the mean daily EC, for the SJR at Vernalis, Old River near Middle River, Old River at Tracy Road Bridge, and the SJR at Brandt Bridge.

In agricultural settings, irrigation with saline water can cause accumulation of salts in the soil profile. Crop yields are reduced when salts accumulate in the root zone and cause an unfavorable osmotic gradient between roots and soil. If water uptake is appreciably reduced, water stress slows the growth rate of the plant and results in crop yield reduction. Symptoms of salt toxicity are similar to drought conditions, which can include wilting, or a darker bluish-green leaf color, and occasionally thicker, waxier leaves (CVRWQCB 2004b).

Measured Regional Data. The box plots on **Figures F2-2 and F2-3** show the range of existing data for EC measured for each region where measured data are available. The box extends from the 25^{th} to the 75^{th} percentile of EC values. Datapoints that are beyond the extent of the whiskers are considered outliers.

Analyte=Electrical Conductivity (EC) (4/1 - 8/31), Unit=µmhos/cm



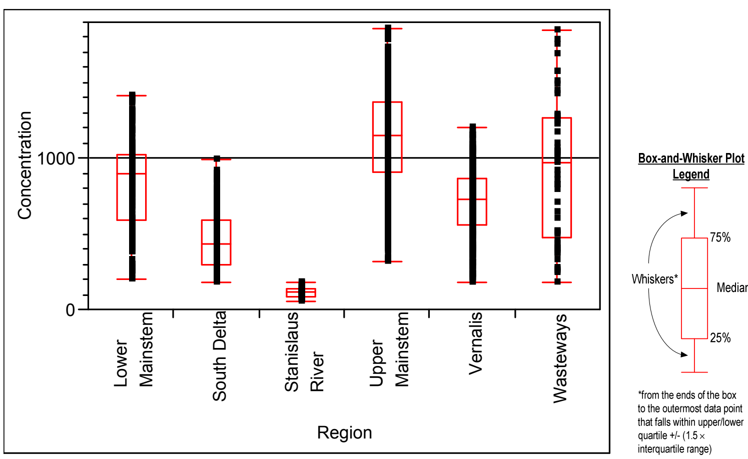
Notes:

Criteria (1)=700 µmhos/cm, Basis for Criteria (1)=Basin Plan WQO at Vernalis, April to August

Data sources and regional groupings are described at the beginning of **Section F2**.

Figure F2-2. Measured Electrical Conductivity by Region, April through August

Analyte=Electrical Conductivity (EC) (9/1 - 3/31), Unit=µmhos/cm



Notes:

Criteria (1)=1000 µmhos/cm, Basis for Criteria (1)=Basin Plan WQO at Vernalis, Sept to March

Data sources and regional groupings are described at the beginning of **Section F2**.

Figure F2-3. Measured Electrical Conductivity by Region, September through March

Recirculation would introduce a relatively large volume of water to the wasteway agricultural drainage, which could dilute contaminants within the wasteway. Although an initial pulse of contaminants to the SJR may occur, the water quality of the recirculation would otherwise be characterized by the water quality in the south Delta.

Median EC of the resident water in the wasteway is less than the upper SJR mainstem segment and similar to median EC in the lower mainstem segment. Median EC in the south Delta is less than the median EC in the SJR (upper mainstem, lower mainstem, and Vernalis) and greater than the median EC in the Stanislaus River. The Stanislaus River has particularly low EC, with a median value of less than 115 µmhos/cm. Although recirculation may not be as efficient a dilution flow as additional Stanislaus River releases, recirculation is generally expected to have a beneficial effect on EC in the upper and lower mainstem segments as well as for Vernalis.

During the 2004, 2007, and 2008 recirculation pilot studies, EC was decreased in the SJR immediately downstream of Newman Wasteway (Reclamation 2005, 2008, and in press).

Modeling Results. California Simulation Model II (CalSim II) Common Assumptions full system model was used in conjunction with Delta Simulation Model 2 (DSM2) HYDRO and QUAL to predict EC system-wide (**Appendices A and B**). CalSim II output was used to evaluate EC against the Vernalis objective. DSM2 output was used to evaluate EC in the south Delta against the objective for Old River near Middle River, the Old River at Tracy Road Bridge, and the SJR at Brandt Bridge.

CalSim II. CalSim II uses a constant set of reservoir operational rules applied to a historically based hydrology, such that it simulates a projected LOD that is imposed on a long-term sequential hydrologic trace. For this project, model simulation was for an 82-year hydrologic period (1922 through 2003) with model output during 14 periods per year. Reservoir operations are consistent throughout the 82-year modeling period and do not always reflect historical operations.

Each period represents a monthly or semimonthly average. Periods during June through March are monthly averages, and periods during April and May are semimonthly averages to account for Vernalis Adaptive Management Plan pulse flow. The total number of periods during the model simulation was 1,148.

The number of periods when EC is predicted to be above the WQO at Vernalis is shown on **Figure F2-4** and in **Table F2-2**. The periods with recirculation when the WQO is predicted not to be met in the No-Action Alternative, and the periods when the WQO is predicted to be met because of recirculation are shown for the alternative plans. For the No-Action Alternative and the alternative plans, Vernalis EC is modeled to be above the WQO less than 2% of the time.

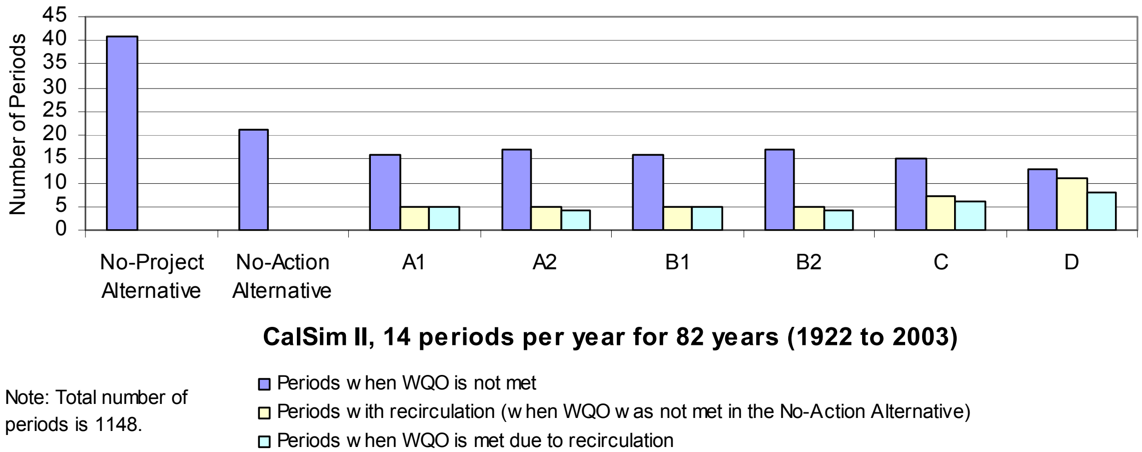


Figure F2-4. Effectiveness of Alternative Plans in Meeting the EC Objective at Vernalis, CalSim II

Table F2-2. Evaluation of the Electrical Conductivity Water Quality Objective at Vernalis, CalSim II

Criteria	No-Project Alternative	No-Action Alternative	A1	A2	B1	B2	C	D
Periods when WQO is predicted not to be met	41	21	16	17	16	17	15	13
Percent of periods WQO is predicted not to be met	3.6	1.8	1.4	1.5	1.4	1.5	1.3	1.1
Periods with recirculation (when WQO was not met in No-Action Alternative)	NA	NA	5	5	5	5	7	11
Periods when WQO is predicted to be met due to recirculation	NA	NA	5	4	5	4	6	8
Median magnitude predicted above WQO, µmhos/cm	5	2	4	5	4	5	6	5
Mean magnitude predicted above WQO, µmhos/cm	32	11	13	10	13	10	11	12
Standard Deviation of the magnitude above WQO, µmhos/cm	71	16	18	12	18	12	12	13

Notes:

Calculations account for rounding error (± 0.05 µmhos/cm)

Periods include monthly and VAMP pulse and nonpulse timesteps; the total number of periods is 1,148.

Alternative plans are modeled using the 2030 future LOD.

Key:

µmhos/cm) = micromhos per centimeter
NA = not applicable
VAMP = Vernalis Adaptive Management Plan
WQO = water quality objective

The frequency, duration, or quantity of recirculation flow increases with each consecutive alternative plan, from Alternative A1 to Alternative D. Recirculation is predicted to have a beneficial effect on EC. Alternative D is predicted to have the greatest effect; however, this effect applies to only 0.7% of the modeling periods.

Alternatives A1, A2, B1, and B2 have a similar number of periods predicted when the EC objective is met because of recirculation (4 or 5 periods out of a total of 1,148). Alternative C has slightly more recirculation predicted to occur and one more period where the WQO is met because of recirculation. Alternative D is predicted to have the greatest number of periods where the WQO is met because of recirculation (8 periods).

Table F2-2 presents the mean, median, and standard deviation for the difference between the predicted EC and the WQO, when the predicted EC is above the WQO. The mean magnitudes above the WQO for the No-Action Alternative and the alternative plans are similar to each other and relatively small. The median magnitude predicted above the WQO is less than the mean; and the median magnitude above the WQO for the No-Action Alternative is slightly less than for the alternative plans. In cases where magnitude above the WQO is relatively small under No-Action Alternative conditions, recirculation for water quality may have been precluded by the operational rules used in the CalSim II model due to availability, modeled EC values for the DMC and Vernalis, or conditional water quality filtering (see **Appendix A**).

DSM2 DSM2 was used to evaluate EC at three south Delta compliance sites. For this project, the DSM2 simulation was for an 82-year hydrologic trace (1922 through 2003) with daily model outputs (**Appendix B**). Total number of days modeled during the 82-year period was 29,950. Output locations include Middle River at Mowery Bridge, Old River at Tracy Road Bridge, and SJR at Brandt Bridge. The water quality in Middle River at Mowery Bridge was assumed to be equivalent to the water quality at Old River near Middle River due to proximity.

The effectiveness of meeting the EC objective was evaluated using the 30-day running average of the modeled daily EC. The number of days when EC was predicted to be above the WQO is shown on **Figure F2-5** and in **Table F2-3** for existing conditions (the No-Project Alternative), future conditions (the No-Action Alternative), and Alternatives B1, B2, and D. The number of days with recirculation when the WQO is predicted not to be met under the No-Action Alternative and the number of days when the WQO is predicted to be met due to recirculation are shown for these alternative plans. The number of occurrences of recirculation (as predicted by CalSim II) and the number of days where the EC objective is predicted to be met due to recirculation increases from Alternative B1 to Alternative B2 to Alternative D.

Alternative D is the most effective alternative plan for meeting the EC objective in the southern Delta. The percentage of days when the EC objective is predicted to not be met in Middle River at Mowery Bridge decreases from 1.9% in the No-Action Alternative to 1.7% in Alternative B1, to 1.6% in Alternative

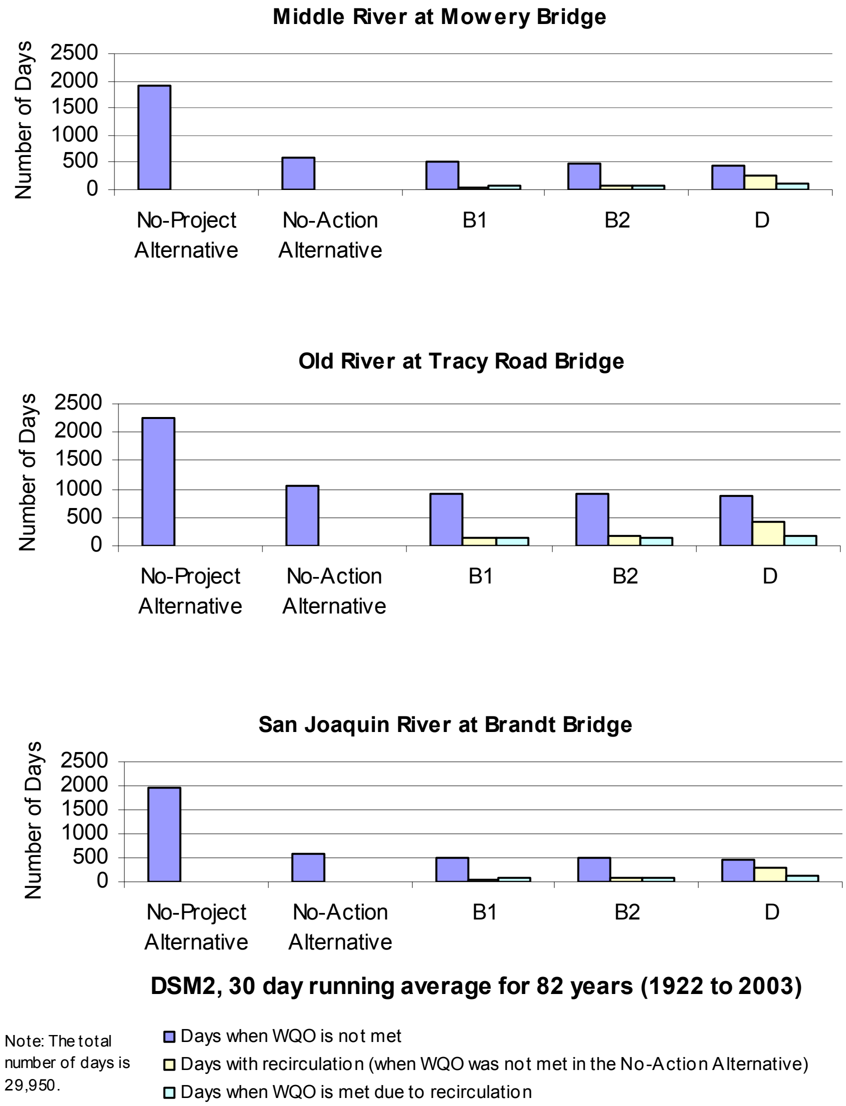


Figure F2-5. Effectiveness of Alternative Plans in Meeting the Electrical Conductivity Objective in the South Delta, DSM2

Table F2-3. Evaluation of the EC Objective in the South Delta, DSM2

Middle River at Mowery Bridge	No-Project Alternative	No-Action Alternative	B1	B2	D
Days when WQO is predicted not to be met	1921	570	498	482	458
Percentage of days WQO is predicted not to be met	6.4	1.9	1.7	1.6	1.5
Days with recirculation (when WQO was not met in the No-Action Alternative)	NA	NA	53	58	258
Days when WQO is predicted to be met due to recirculation	NA	NA	72	88	112
Median magnitude predicted above WQO, µmhos/cm	6.0	4.1	4.1	4.5	4.3
Mean magnitude predicted above WQO, µmhos/cm	17.7	6.2	6.3	5.6	5.4
Standard deviation of the magnitude above WQO, µmhos/cm	37.4	6.8	7.0	4.2	4.1
Old River at Tracy Road Bridge	**No-Project Alternative**	**No-Action Alternative**	**B1**	**B2**	**D**
Days when WQO is predicted not to be met	2258	1061	923	922	895
Percentage of days WQO is predicted not to be met	7.5	3.5	3.1	3.1	3.0
Days with recirculation (when WQO was not met in No-Action Alternative)	NA	NA	158	182	412
Days when WQO is predicted to be met due to recirculation	NA	NA	138	139	166
Median magnitude predicted above WQO, µmhos/cm	12.2	12.1	12.4	12.4	12.0
Mean magnitude predicted above WQO, µmhos/cm	21.0	15.6	16.2	15.9	16.0
Standard deviation of the magnitude above WQO, µmhos/cm	30.8	15.3	15.8	16.0	16.3
San Joaquin River at Brandt Bridge	**No-Project Alternative**	**No-Action Alternative**	**B1**	**B2**	**D**
Days when WQO is predicted not to be met	1940	580	498	486	456
Percentage of days WQO is predicted not to be met	6.5	1.9	1.7	1.6	1.5
Days with recirculation (when WQO was not met in No-Action Alternative)	NA	NA	60	65	273
Days when WQO is predicted to be met due to recirculation	NA	NA	82	94	124
Median magnitude predicted above WQO, µmhos/cm	5.7	4.9	5.1	5.3	4.6
Mean magnitude predicted above WQO, µmhos/cm	17.7	6.9	7.1	6.4	5.7
Standard deviation of the magnitude above WQO, µmhos/cm	36.8	7.3	7.5	5.2	4.2

Notes:

The EC objective is evaluated as a 30-day running average of the mean daily EC.

Total number of days modeled during the 82-year period (1922 through 2003) is 29,950.

Alternative plans are modeled using the 2030 future LOD.

B2, and to 1.5% in Alternative D. The percentage of days when the EC objective is predicted not to be met in Old River at Tracy Road Bridge decreases from 3.5% in the No-Action Alternative to 3.1% in Alternatives B1 and B2 and to 3.0% in Alternative D. The percentage of days when the EC objective is predicted not to be met in the SJR at Brandt Bridge decreases from 1.9% in the No-Action Alternative to 1.7% in Alternative B1, to 1.6% in Alternative B2, and to 1.5% in Alternative D.

Table F2-3 also presents the mean, median, and standard deviation of the difference between the predicted EC and the EC objective, when the predicted EC was above the EC objective. The median magnitude predicted above the

WQO is less than the mean magnitude predicted above the WQO for the three south Delta locations in all alternative plans. This prediction may indicate a few instances when the magnitude above the WQO is relatively large and recirculation is precluded by the operational rules used in the CalSim II.

Temperature

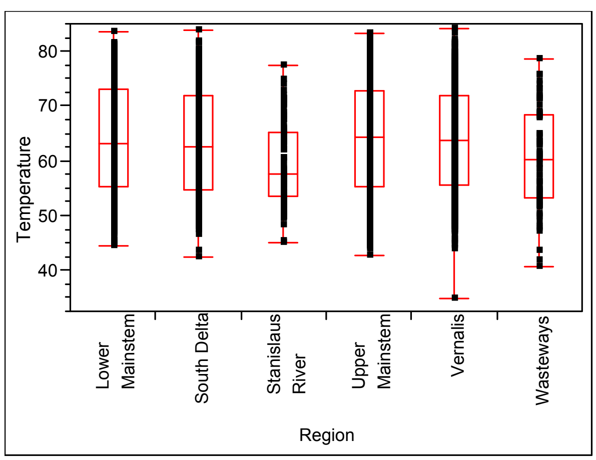
The Basin Plan WQOs for temperature are the following.

- Average daily water temperature is not to be elevated by controllable factors above 68°F in the SJR at Vernalis during April 1 through June 30 and September 1 through November 3 in all water year types;
- Water bodies with the beneficial use of cold freshwater habitat (COLD) or warm freshwater habitat (WARM) are not to be increased more than 5°F above the natural receiving water temperatures.

Measured Regional Data. Figure F2-6 shows measured temperature from grab samples for different regions in the lower San Joaquin basin and Delta. Measured temperatures in the south Delta and the SJR (upper mainstem, lower mainstem, and Vernalis) are similar. The median temperatures measured in the Stanislaus River and in the water resident to the wasteways are less than the median temperatures measured in the SJR and the Delta.

During the 2008 recirculation pilot study, temperature in the SJR immediately downstream of Newman Wasteway tended to decrease in diurnal variability (Reclamation, in press).

Analyte=Temperature, Unit=°F



Notes:

The Basin Plan WQO is evaluated in terms of temperature increases.

Data sources and regional groupings are described at the beginning of **Section F2**.

Figure F2-6. Measured Temperature by Region

Modeling Results. HEC-5Q is used to assess temperature and conservative water quality constituents in basin-scale planning and management decisions. Water temperature is predicted in 6-hour intervals for No-Action Alternative conditions and Alternatives A2, B2, C, and D for the Stanislaus River from Goodwin Dam to the confluence with the SJR and in the SJR from the confluence with the Stanislaus River to Vernalis (**Appendix C**). Alternatives A1 and B1 were not evaluated because releases from the New Melones Reservoir would not change under these alternative plans. Modeled water temperature for No-Action Alternative conditions and Alternatives A2, B2, C, and D at four locations (the Stanislaus River at Orange Blossom Bridge, Riverbank, and Ripon, and the SJR at Vernalis) were evaluated against WQOs. Output from the HEC-5Q model includes modeled temperature for 1980 through 2003 in 6-hour intervals. Additional model information and analyses are found in **Appendix C**.

Average Daily Temperature at Vernalis. Predicted water temperature for alternative plans was compared to the No-Action Alternative condition to determine if increases in modeled temperature would raise temperatures at Vernalis above 68ºF during April 1 through June 30 and September 1 through November 3. The average daily water temperature at Vernalis is predicted to increase temperatures above 68ºF because of changes in water operations during some days under each alternative plan evaluated.

For the purpose of this evaluation, No-Action Alternative conditions are assumed to represent natural receiving water temperatures. Because No-Action Alternative conditions are used to model background temperatures, predicted increases in temperature above background levels do not apply to No-Action Alternative conditions. Furthermore, if Vernalis was predicted to be above 68ºF in the No-Action Alternative condition, the alternative plans do not increase temperatures above this objective.

The number of days when water temperature is predicted above the WQO is shown on **Figure F2-7** and in **Table F2-4**. The frequency, duration, and/or quantity of recirculation flow increase with each consecutive alternative plan. Likewise, the number of days when modeled temperature is predicted above the WQO increases with each consecutive alternative plan. The greatest number of days when modeled temperature is predicted above the WQO (53 out of 3,687 days, or less than 1.5% of the days in the specified date ranges) occurs under Alternative D.

Average daily water temperature is not predicted to decrease below 68ºF as a result of the alternative plans. There are two 6-hour modeling periods when temperatures are predicted to decrease below 68ºF for all alternative plans; however, temperatures do not decrease below 68ºF when calculated as a daily average. These periods are predicted to occur in October 1991 and May 1995.

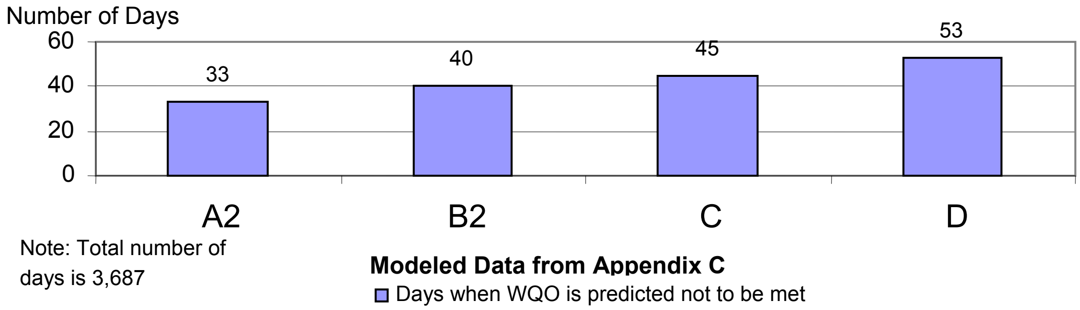


Figure F2-7. Number of Days when the Temperature Water Quality Objective is Predicted to Not be Met at Vernalis

Average daily water temperatures are predicted to be above the WQO most frequently during the Critical water year type. During Critical years, Alternative D is predicted to result in temperatures most frequently above the WQO. Excluding Critical years, distinctions between alternative plans are less. For all water year types, the greatest temperature increase when the temperature objective is predicted to not be met is an average daily period of 2.05 degrees Fahrenheit (ºF).

Table F2-4. Number of Days When Predicted Water Temperature Does Not Meet the Vernalis Objective

Criteria	Alternative Plans			
	A2	B2	C	D
Number of days the WQO is predicted to not be met at Vernalis	33	40	45	53
Percentage of days the WQO is predicted not to be met at Vernalis	0.9	1.1	1.2	1.4
Maximum temperature increase (ºF)	2.04	2.05	2.05	2.05

Notes:

The total number of modeled days from April 1 through June 30 and September 1 through November 3 during the model period 1980 to 2003 is 3,687.

Alternative plans are modeled using the 2030 future LOD.

Key:

ºF = degree(s) Fahrenheit
LOD = Level of Development
WQO = water quality objective

COLD and WARM Beneficial Use. No-Action Alternative conditions include New Melones releases for the purpose of meeting EC and flow objectives in the SJR at Vernalis. Modeled temperature changes in the Stanislaus River for alternative plans are due primarily to the reduction of these additional New Melones releases. Although reduction in releases from New Melones generally results in lower temperatures in stored water, lower flow rates in the Stanislaus result in higher temperatures downstream. For the purpose of this evaluation, No-Action Alternative conditions are assumed to represent temperature conditions for natural receiving waters.

Predicted water temperatures for the alternative plans evaluated (A2, B2, C, and D) were compared to No-Action Alternative conditions to examine if any of the alternative plans are likely to increase the water temperature by more than 5ºF. Two of the locations, the Stanislaus River at Orange Blossom Bridge and Ripon, had water temperatures predicted to increase during some periods by more than 5ºF compared to the No-Action Alternative because of changes in water operations. These waters have COLD and WARM beneficial use.

The number of periods and the percentage of total periods when the temperature is predicted above the WQO in the Stanislaus River at Orange Blossom Bridge are shown in **Table F2-5**. For 83 6-hour periods (out of 34,696) the temperature is predicted to increase by more than 5ºF under one or more alternative plans. At Orange Blossom Bridge, the temperature is predicted to increase by more than 5ºF during 0.23% or less of the 6-hour periods, and by more than 2ºF during 1.9% or less of the 6-hour periods, evaluated in any alternative plan. The largest temperature increase for any alternative plan during a 6-hour period is 6.26ºF.

Table F2-5. Number of 6-hour Periods for Which the Temperature is Predicted to Increase by More than 5ºF at Orange Blossom Bridge

Criteria	Alternative Plans			
	A2	B2	C	D
Number of 6-hour periods for which the temperature is predicted to increase by more than 5ºF	1	80	67	14
Percentage of 6-hour periods for which the temperature is predicted to increase by more than 5ºF	0.003	0.23	0.19	0.04
Maximum Temperature Increase (ºF)	5.01	6.15	6.26	5.19

Notes:

The total number of 6-hour periods modeled is 34,696.

Alternative plans are modeled using the 2030 future LOD.

Key:

ºF = degree(s) Fahrenheit
LOD = Level of Development

The number of periods and the percentage of the total periods for which the temperature is predicted to increase by more than 5ºF in the Stanislaus River at Ripon are shown in **Table F2-6**. For 73 6-hour periods (out of 34,696) one or more alternative plans are predicted to increase the natural receiving waters temperature by more than 5ºF. At Ripon, the WQO is predicted to not be met during 0.20%, or less, of the 6-hour periods and by more than 2ºF during 2.7% or less of these periods for Alternative D. The largest water temperature increase for any alternative plan during a 6-hour period is 5.63ºF.

Table F2-6. Number of 6-hour Periods for Which the Temperature is Predicted to Increase by More than 5ºF at Ripon

Criteria	Alternative Plans			
	A2	B2	C	D
Number of 6-hour periods for which the temperature is predicted to increase by more than 5ºF	9	9	9	70
Percentage of 6-hour periods for which the temperature is predicted to increase by more than 5ºF	0.03	0.03	0.03	0.20
Maximum Temperature Increase (ºF)	5.30	5.31	5.31	5.63

Notes:

The total number of 6-hour periods modeled is 34,696.

Alternative plans are modeled using the 2030 future LOD.

Key:

ºF = degree(s) Fahrenheit

LOD = Level of Development

Temperature in the Stanislaus River would rise as New Melones releases decreased, with the greatest effects at Orange Blossom Bridge under Alternative B2 and at Ripon under Alternative D. However, the largest of the predicted temperature increases are still small and infrequent and not likely to be of major concern to resource management agencies.

Suspended Sediment and Turbidity

The Basin Plan does not have an established numeric objective for suspended sediment but rather this narrative objective: "waters shall not contain suspended material in concentrations that cause nuisance or adversely affect beneficial uses" (CVRWQCB 2007).

The U.S. Environmental Protection Agency (EPA) also has a narrative water quality criterion for TSS; this narrative objective is "suspended solids are not to reduce the depth of the compensation point for photosynthetic activity by more than 10% from the seasonably established norm for aquatic life" (EPA 1986).

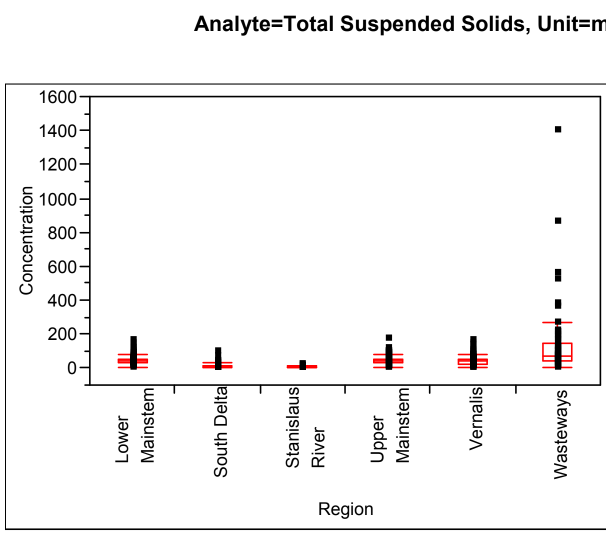
The Basin Plan has numeric WQOs for turbidity that are based on turbidity increments above natural levels when the turbidity increments can be attributable to controllable water quality factors. The turbidity WQOs indicate that when natural turbidity is between 0 and 5 nephelometric turbidity units (NTU), increases are not to be above 1 NTU; when natural turbidity is between 5 and 50 NTU, increases are not to be above 20%; when natural turbidity is between 50 and 100 NTU, increases are not to be above 10 NTU; and when natural turbidity is greater than 100 NTU, increases are not to be above 10%.

The Basin Plan WQOs for turbidity in the Delta are 50 NTU for the central Delta and 150 NTU for all other Delta waters, except for periods of storm runoff. The CALFED Water Quality Program Record of Decision (WQP ROD) has a numeric target of 50 NTU at Clifton Court Forebay and other Delta drinking water intakes.

Excessive amounts of suspended material in water reduce the amount of sunlight that reaches river and streambeds. Submerged aquatic plants can be affected by the lack of sufficient sunlight. Sedimentation can reduce the carrying capacity in streams, reduce the habitat size for fish, and can increase stress in adult fish. Clay and silt particles can harm fish by clogging gills or smothering larvae. Other pollutants like fertilizers, pesticides, and metals are often attached to the soil particles and wash into downstream water bodies.

High turbidity can affect the reproduction, growth, and health of fish and other aquatic life. Turbidity is also associated with higher levels of disease-causing microorganisms such as viruses, parasites, and some bacteria (EPA 1999a).

Measured Regional Data. Figure F2-8 shows measured TSS concentrations for different regions in the lower San Joaquin basin and Delta. The median concentration in the south Delta and the Stanislaus River are less than the median concentrations in the SJR. Median TSS concentrations in the resident water of the wasteways are greater than the median concentrations in the south Delta or the SJR. A plume of suspended solids is expected to enter the SJR during recirculation.



Notes: Data sources and regional groupings are described at the beginning of **Section F2**.

Figure F2-8. Measured Total Suspended Solids by Region

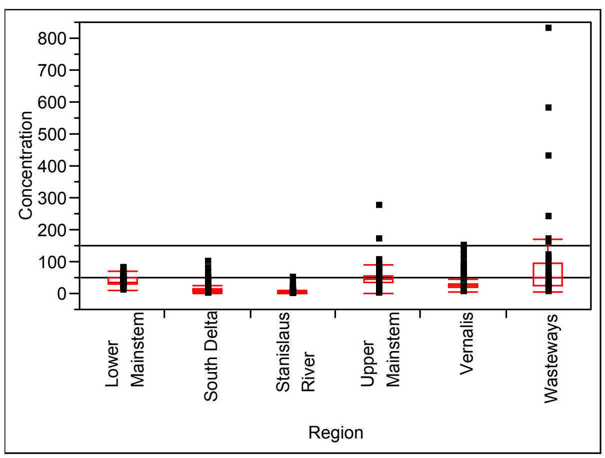
During the 2004, 2007, and 2008 recirculation pilot studies, TSS concentrations in the SJR immediately downstream of Newman Wasteway remained elevated with respect to the upstream location for the duration of the study (Reclamation

2005, 2008, and in press). During the 2004 and 2008 pilot studies, declining trends in concentrations were observed after the first few days of recirculation. During the 2008 pilot study, TSS concentrations were monitored at Crows Landing, and only small changes were observed.

Figure F2-9 shows measured turbidity for different regions in the lower San Joaquin basin and Delta. Similar to TSS distributions, the Stanislaus River and the south Delta had lower median turbidity than the SJR mainstem segments and Vernalis, and the wasteway was the region of highest median turbidity.

Similar to TSS, turbidity measurements from discrete samples collected during the 2004, 2007, and 2008 recirculation pilot studies were elevated at the SJR immediately downstream of Newman Wasteway in comparison with the upstream location (Reclamation 2005, 2008, and in press). During the 2008 pilot study, turbidity was also measured continuously by in-stream meters. During recirculation, turbidity varied considerably in the SJR immediately downstream of Newman Wasteway; however, turbidity values decreased substantially and were similar to background levels at Crows Landing.

Analyte=Turbidity, Unit=NTU



Notes:

Criteria (1)=150 NTU, Basis for Criteria (1)=Basin Plan WQO for the Delta

Criteria (2)=50 NTU, Basis for Criteria (2)=CALFED WQP ROD goal for municipal supply

Data sources and regional groupings are described at the beginning of **Section F2**.

Figure F2-9. Measured Turbidity by Region

Modeling Results. The objective of the modeling analysis is to summarize predicted changes in TSS concentrations in the SJR for the alternative plans.

Flow output for the SJR from the CalSim II model (**Appendix A**) was used as the input flow data for the TSS model (**Appendix D**). Flow was modeled by a monthly or semi-monthly time step, with April and May flow separated into pulse and nonpulse time periods. Recirculation flow was predicted to occur for at least one model period.

Modeled alternative plans include No-Action Alternative conditions and Alternatives A1, A2, B1, B2, C, and D. Representative years were selected for each water year type (1993, 1963, 2003, 2002, and 1992, which correspond to Wet, Above Normal, Below Normal, Dry, and Critical, respectively). Only those time periods for which recirculation was predicted to occur under at least one alternative plan were modeled for TSS. Of the 70 possible periods over the 5 representative years, 24 of these periods were modeled. This evaluation assumes that recirculation flow would be introduced into the SJR at Newman Wasteway.

Change in the Cross-Sectional Average TSS Concentration. The frequency and/or intensity of recirculation flow would increase with each consecutive alternative plan, from A1 to D. Likewise, the difference between the cross-sectional, average TSS concentration predicted in alternative plans and the No-Action Alternative condition is predicted to increase with subsequent alternative plans (**Table F2-7)**. However, a significant reduction in average TSS concentrations would occur after dilution and mixing with the water from the Merced River (as seen by the data for the SJR prior to the Tuolumne River).

Table F2-7. Average Increase in Modeled Total Suspended Solids Concentration (mg/L) for Periods when Recirculation Would Occur Under at Least One Alternative Plan

Location	A1	A2	B1	B2	C	D
SJR below Newman Wasteway (100 feet)	9	11	17	19	38	42
SJR above Merced River (6,500 feet)	5	7	10	12	25	27
SJR below Merced River (7,000 feet)	5	7	10	13	28	29
SJR at the Tuolumne River (165,000 feet)	1	2	3	4	8	9

Notes:

TSS increments reflect increases in the cross-sectional average of the suspended sediment plume.

Only those time periods for which recirculation was predicted to occur under at least one alternative plan are modeled.

Total number of periods modeled is 24.

Alternative plans are modeled using the 2030 future LOD.

Key:

LOD = Level of Development
mg/L = milligram(s) per liter
SJR = San Joaquin River
TSS = total suspended solids

San Joaquin River Total Suspended Solids Concentrations 100 feet below Confluence with Newman Wasteway. The first tabulated model output location after the introduction of recirculation flow is located in the SJR 100 feet below the confluence with Newman Wasteway. This location represents the greatest increase in TSS within the predicted plume in the SJR, as little mixing or settling would occur before this point.

TSS concentrations at this location that are predicted to occur during recirculation range from 90 milligrams per liter (mg/L) (Alternatives B1 and B2 in March of the Wet year) to 127 mg/L (Alternatives C and D of June in the Below Normal year). Alternative D consistently has the largest predicted TSS concentrations due to recirculation. In contrast, recirculation would not occur as often under Alternatives A1 and A2, and therefore the predicted TSS concentrations are the same as those predicted under No-Action Alternative conditions for 19 out of 24 model runs. The largest predicted increase in the predicted concentration (56 mg/L) would occur during March of the Below Normal year. During this period, the predicted concentration is 58 mg/L under Alternatives A1, A2, B1, B2, and the No-Action Alternative, 113 mg/L under Alternative C, and 114 mg/L under Alternative D. Large increases in predicted TSS concentrations (55 mg/L) also occur for Alternatives A1, A2, B1, B2, C, and D in March of the Above Normal year, Alternative C in March of the Below Normal year, and Alternative D in the Dry year. The smallest predicted increase of TSS due to recirculation (21 mg/L) occurs during June of the Critical year. In this period, the predicted concentration is 121 mg/L under the alternative plans as compared to 100 mg/L under the No-Action Alternative (**Appendix D, Table D-6**).

Relationship between Turbidity and Suspended Sediment A linear relationship was developed to relate turbidity and suspended sediments. Model output for TSS was converted to turbidity using this relationship.

Most of the measurements relating to suspended sediment in the study area are collected as turbidity and reported as NTU. It is not uncommon for a relationship to develop between suspended sediment (e.g., suspended sediment concentration [SSC], TSS) and turbidity and use turbidity as a surrogate for suspended sediment (see Schoellhamer 2001; Gray and Glysson 2002). To make the maximum use of the turbidity data available in the study area a general relationship between turbidity and suspended sediment was developed for the SJR and vicinity.

The relationship between turbidity and suspended sediment can be a function of the particle size, shape, color, etc. A site specific relationship is preferred; however, if the sediment properties do not vary significantly between sites a more general relationship may be possible. Two major datasets were used to develop a relationship between turbidity and suspended sediment. The SJR mainstem data collected as part of the CVRWQCB San Joaquin River Watershed Surface Water Ambient Monitoring Program (CVRWQCB 2008) and data collected as part of the 2007 Pilot Study (Reclamation 2008). It should be noted that some of the suspended sediment data were analyzed as TSS and some as SSC. However, for purposes of developing a general relationship between suspended sediment and turbidity the data were combined. The error associated with combining the TSS and SSC data is expected to be within the error of using a general TSS (SSC) – Turbidity relationship.

Figure F2-10 shows the data and relationship developed for the study. The relationship using both the CVRWQCB and the 2007 Pilot Study data is:

$$TSS\ (or\ SSC) = 1.10 * NTU + 6.43$$

Relationships from other sources are also included on the figure for comparison. Ganju et al. (2005) measured turbidity and SSC in wetland channels on Browns Island located near the confluence of the San Joaquin and Sacramento Rivers. The relationship developed for the “main” channel is above the relationship developed for this study but the one developed for the “side” channel follows closely the relationship developed for the SJR. A relationship the USGS developed for its long-term turbidity gage on the Benicia Bridge is also shown on **Figure F2-10** (Buchanan and Ganju 2002). A similar relationship was reported for calibration data collected in 2003 (Buchanan and Ganju 2003).

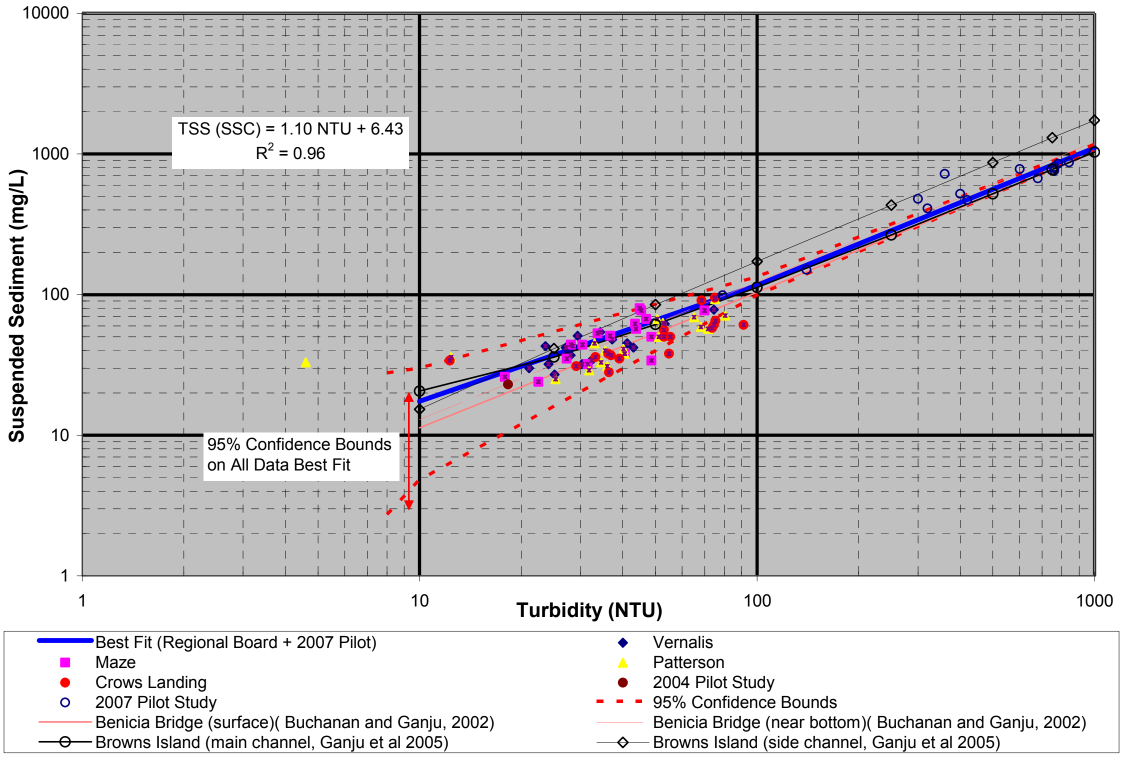


Figure F2.10. Relationship Between Turbidity and Suspended Sediment in the San Joaquin River

Comparison to Turbidity Water Quality Objectives. Model output for TSS was converted to turbidity using this linear relationship. The calculated model turbidity was then used to evaluate alternative plans in relation to the turbidity WQO.

The Basin Plan WQOs for turbidity are the following.

- Where natural turbidity is between 0 and 5 NTU, increases are not to be above 1 NTU; where natural turbidity is between 5 and 50 NTU, increases are not to be above 20%; where natural turbidity is between 50 and 100 NTU, increases are not to be above 10 NTU; and where natural turbidity is greater than 100 NTU, increase are not to be above 10%.
- The turbidity of Delta waters is not to be above 50 NTU in the waters of the central Delta and 150 NTU in all other Delta waters.

Since the geographical extent of the TSS model was the SJR from Newman Wasteway to the Tuolumne River, increases in turbidity are compared to the first objective. The WQOs for Delta water are not relevant for comparison to the modeled data.

For the purpose of this evaluation, No-Action Alternative conditions are assumed to represent natural turbidity; therefore, predicted increases in turbidity do not apply to No-Action Alternative conditions.

Table F2-8 shows the number of model periods with recirculation and the number of model periods with turbidity increases that are predicted to be above the WQO at four locations on the SJR. All recirculation events are predicted to cause increases in turbidity above the WQO in the SJR below Newman Wasteway. The number of periods for which turbidity is predicted to be above the WQO increases with each consecutive alternative plan. After dilution and mixing with the Merced River, the number of periods predicted above the WQO is reduced (as seen by the data for SJR prior to the Tuolumne River).

Table F2-8. Comparison of Modeled Turbidity to the Water Quality Objectives

Criteria	A1	A2	B1	B2	C	D
Number of Periods with Recirculation	5	6	11	12	22	24
Number of Periods predicted to be above the WQO in the SJR below Newman Wasteway (100 feet)	5	6	11	12	22	24
Number of Periods predicted to be above the WQO in the SJR above Merced River (6,500 feet)	4	5	10	11	21	23
Number of Periods predicted to be above the WQO in the SJR below Merced River (7,000 feet)	4	5	10	11	21	23
Number of Periods predicted to be above the WQO in the SJR at the Tuolumne River (165,000 feet)	1	3	2	4	10	11

Notes:

Only those time periods for which recirculation was predicted to occur under at least one alternative plan are modeled.

The total number of periods modeled is 24.

Alternative plans are modeled using the 2030 future LOD.

Key:

SJR = San Joaquin River
LOD = Level of Development
WQO = water quality objective

Selenium and Boron

The Basin Plan WQOs for selenium in the SJR from the Merced River to Vernalis are 5 micrograms per liter (μg/L) 4-day average and 12 μg/L maximum concentrations. Selenium undergoes bioconcentration and biomagnification as trophic levels increase. Aquatic organisms can experience loss of equilibrium and other neurological disorders, liver damage, reproductive failure, reduced growth, reduced movement rate, chromosomal aberrations, reduced hemoglobin and increased white blood cell count, and necrosis of the ovaries (EPA 2008b).

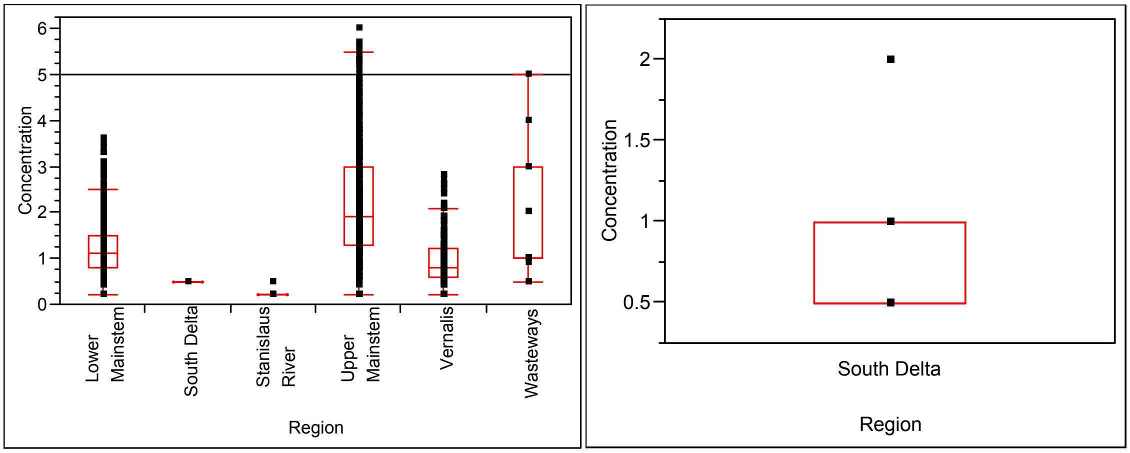
The Basin Plan WQOs for boron stipulate an average monthly concentration of 0.8 mg/L from March 15 to September 15, 1.0 mg/L from September 16 to March 14, and 1.3 mg/L during Critical year types for the SJR from the Merced River to Vernalis. The Basin Plan also stipulates a maximum concentration of 2 mg/L from March 15 to September 15, and 2.6 mg/L from September 16 to March 14, during non-Critical year types for the SJR from the Merced River to Vernalis. These WQOs are established to be sufficiently protective of agriculture. Boron toxicity in plants is characterized by leaf malformation (such as leaf cupping in young grape leaves) and by thickened, curled, wilted, and chlorotic leaves (CVRWQCB 2004b).

Measured Regional Data. Figure F2-11 shows measured selenium concentrations by region in the lower San Joaquin basin and Delta. The box plot on the left shows total selenium concentrations and the box plot on the right shows dissolved selenium concentrations. The detection rates for selenium in the Stanislaus River and south Delta are minimal; total selenium is detected in the Stanislaus River in 2% of the samples and dissolved selenium in the south Delta was detected in less than 50% of the samples. The visual representation of the selenium concentrations for these regions may be influenced by the reporting limits of the data. Data were available for only one sample for total selenium in the south Delta; this sample size is too low to be a reliable indicator of concentration in this region.

The median selenium concentrations in the south Delta and the Stanislaus River are less than the median concentrations in the SJR (lower mainstem, upper mainstem, and Vernalis). Selenium concentrations in the upper mainstem and the resident agricultural drainage in the wasteways are similar. Recirculation may dilute selenium concentrations within the wasteway to concentrations less than the upper mainstem. The majority of the recirculation flow is expected to have concentrations similar to the south Delta. If total and dissolved selenium concentrations are assumed to be similar, recirculation would have a beneficial effect in the lower and upper mainstem as well as for Vernalis.

During the 2004, 2007, and 2008 recirculation pilot studies, total selenium concentrations were decreased in the SJR immediately downstream of Newman Wasteway; however, selenium concentrations were already below WQOs (Reclamation 2005, 2008, and in press).

Analyte=Selenium, Unit=µg/L **Analyte=Selenium, dissolved, Unit=µg/L**



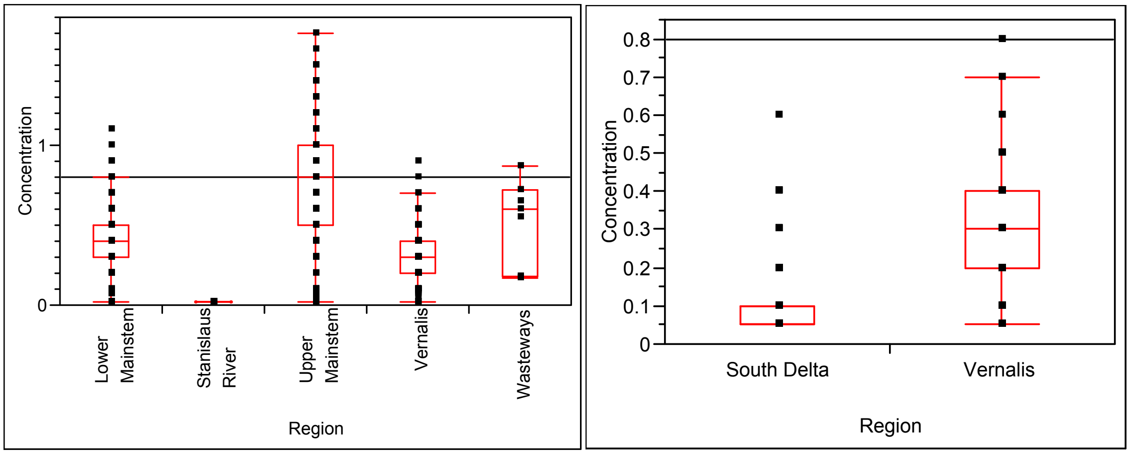
Notes:
Criteria (1)=5 µg/L, Basis for Criteria (1)=Basin Plan WQO for the SJR from the Merced River to Vernalis
Data sources and regional groupings are described at the beginning of **Section F2**.

Figure F2-11. Measured Selenium in the Project Area

Measured boron concentrations are shown by region and by season; the seasons are separated into March 15 to September 15 (**Figure F2-12)** and September 16 to March 14 (**Figure F2-13**) to correspond to the WQOs. The box plots on the left show total boron concentrations and the box plots on the right show dissolved boron concentrations. Boron has a 0% detection rate in the Stanislaus River. Median concentrations in the south Delta are less than the median concentrations at Vernalis for dissolved boron and may be less than the upper and lower mainstem segments. Although the amount of data for total boron for the wasteway agricultural drainage is limited, the median concentrations for this data are between the median concentrations for the upper and lower SJR mainstem. If total and dissolved boron concentrations are assumed to be similar, south Delta concentrations would be lower than concentrations in the SJR. Although recirculation may not be as efficient a dilution flow as additional Stanislaus River releases, recirculation may have a beneficial effect on boron in the upper and lower mainstem segments as well as for Vernalis.

During the 2004, 2007, and 2008 recirculation pilot studies, total boron concentrations were decreased in the SJR immediately downstream of Newman Wasteway, often reducing the concentration in the SJR below 0.8 mg/L boron (Reclamation 2005, 2008, and in press).

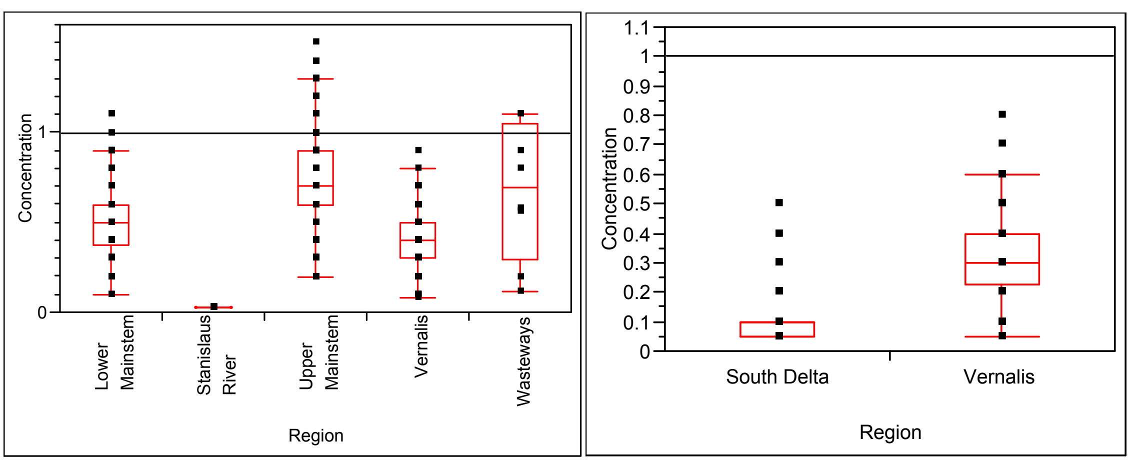
Analyte=Boron (3/15 - 9/15), Unit=mg/L **Analyte=Boron, dissolved (3/15 - 9/15), Unit=mg/L**



Notes:
Criteria (1)=0.8 mg/L, Basis for Criteria (1)=Basin Plan WQO, March 15 to September 15
Data sources and regional groupings are described at the beginning of **Section F2.**

Figure F2-12. Measured Boron by Region, March 15 to September 15

Analyte=Boron (9/16 - 3/14), Unit=mg/L **Analyte=Boron, dissolved (9/16 - 3/14), Unit=mg/L**



Notes:
Criteria (1)=1 mg/L, Basis for Criteria (1)=Basin Plan WQO, September 16 to March 14
Data sources and regional groupings are described at the beginning of **Section F2**.

Figure F2-13. Measured Boron by Region, September 16 to March 14

Modeling Results. The average monthly concentrations modeled for selenium and boron in the SJR at Crows Landing and Vernalis are predicted to be below the WQOs for the No-Action Alternative and the alternative plans (**Appendix**

E). Furthermore, the predicted monthly concentrations for selenium for the No-Action Alternative and the alternative plans are less than the benchmark values that correspond to the 4-day average concentration (3.25 to 4.25 µg/L selenium). Modeled concentrations assume the removal of Grassland bypass inputs, which otherwise would contribute a significant amount of selenium and boron to the SJR. Distinctions between the alternative plans are not relevant because concentrations are predicted to be lower than the WQOs under all alternative plans.

Dissolved Oxygen

Regulatory DO WQOs have been set in the CVRWQCB Basin Plan that pertain to the SJR and the DWSC.

The DO objectives are:

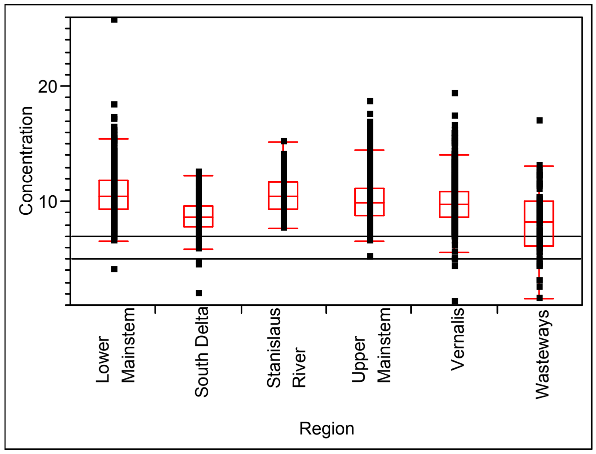
- A minimum DO concentration in the Delta, in the SJR from the Merced River to Vernalis, and in water bodies designated for use as warm freshwater habitat (WARM) of 5.0 mg/L. This standard is applicable throughout the year.
- A minimum DO concentration of 6.0 mg/L in the SJR inside the reach from Turner Cut to Stockton during the period of September 1 through November 30. This higher DO concentration was imposed to enhance aquatic conditions during critical migration periods for salmon.
- A minimum DO concentration of 7.0 mg/L in water bodies outside of the legal Delta designated for use as cold freshwater habitat (COLD) or spawning, reproduction, and/or early development.

These WQOs were established to protect aquatic organisms (including fish), allow for successful fish reproduction and juvenile rearing, and prevent odor problems. Discharges into the SJR and the Delta can be high in nutrients, which can encourage algal growth. Increases in biological activity can reduce DO levels. These discharges, along with reduced flow, channel configuration, and water temperatures, have resulted in some areas in the Delta with DO levels below the current standards. On the SJR, low DO levels may pose a barrier to fall-run salmon migrating upstream to spawn (DWR 2005a).

Measured Regional Data. Figure F2-14 shows measured DO by region in the lower San Joaquin basin and Delta. Median DO concentrations in the south Delta and the wasteway agricultural drainage are lower than median concentrations in the SJR. DO has been detected at concentrations less than 5 mg/L in the south Delta, the wasteways, the lower mainstem, and at Vernalis. The Stanislaus River has the highest median DO concentration of these regions; the minimum measured concentration in the Stanislaus River was greater than 7 mg/L.

During the 2004, 2007, and 2008 recirculation pilot studies, DO concentrations were generally decreased in the SJR immediately downstream of Newman Wasteway, but rarely below 5 mg/L (Reclamation 2005, 2008, and in press).

Analyte=Dissolved Oxygen, Unit=mg/L



Notes:

Criteria (1)=5 mg/L, Basis for Criteria (1)=Basin Plan WQO for WARM,

Criteria (2)=7 mg/L, Basis for Criteria (2)=Basin Plan WQO for COLD

Data sources and regional groupings are described at the beginning of **Section F2**.

Figure F2-14. Measured Dissolved Oxygen by Region

Dissolved Oxygen in the Stockton Deep Water Ship Channel The SJR regularly experiences low DO concentrations within the Stockton DWSC (CVRWQCB 2005). This portion of the SJR has been dredged to a depth of 35 feet to allow for navigation of cargo vessels between the San Francisco Bay and the Port of Stockton. The low DO has been attributed to low flow, excess phytoplankton growth and elevated ammonia concentrations.

Modeling Results. Data collected from the DWSC at Rough and Ready Island from 1995 through 2005 were downloaded from the San Joaquin River Modeling Interface program, which includes data from the San Joaquin River Data Atlas (Jones & Stokes 2005) and the USGS (**Figure F2-15**). Based on monitoring data collected, the DO concentration in the DWSC most frequently violates the 5.0 mg/L WQO during the summer and fall, although concentrations less than the WQO have occurred during all months of the year. WQO violations tend to be more frequent in Dry years and less frequent during Wet years. Furthermore, a diurnal variation of about 1 mg/L occurs between peak DO concentrations during daylight hours and low DO concentrations during nighttime hours during the months of June through September.

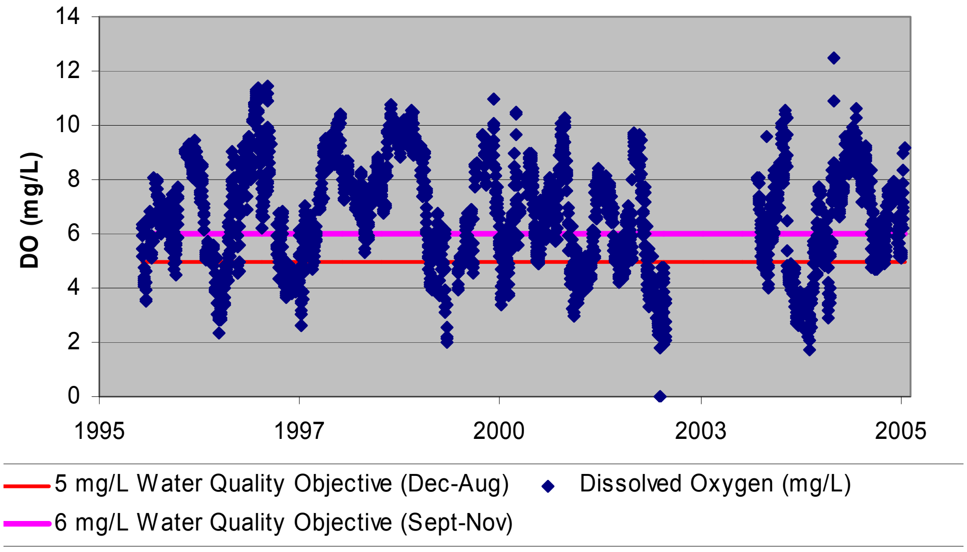


Figure F2-15. Dissolved Oxygen Concentration at Rough and Ready Island (1995–2005)

No-Action Alternative The No-Action Alternative defines conditions in the project area through the planning time frame if recirculation is not provided to the SJR. The No-Action Alternative includes only regional management and facilities that existed in 2007 or authorized, funded future projects.

The following actions unrelated to recirculation may have a future effect on DO concentration in the DWSC but were not taken into account during the No-Action Alternative modeling:

A recent settlement agreement (August 6, 2007) between Port of Stockton and stakeholders (Natural Resources Defense Council, Bay Keeper, Riviera cliffs and various individual stakeholders). As part of this settlement, the Port of Stockton has agreed to take over the current U.S. Army Corps of Engineers aeration commitments. The Corps operates a jet aeration system that injects oxygen into the DWSC, from September through November, during the Chinook salmon run when oxygen concentrations fall below 6 mg/L. This existing jet aeration device has been in operation since 1993. In addition to taking over the current aeration commitments, the Port will extend the operation of the aeration system to include December through August if oxygen concentrations fall below 5.2 mg/L.

New ammonia discharge requirements for the Regional Wastewater Control Facility exist based on RWQCB Order No. R5-2002-0083, NPDES No. CA0079138; Waste Discharge requirements for City of Stockton Regional Wastewater Control Facility. The permit contains new effluent limitations for ammonia and DO, requirements to construct Title 22 tertiary facilities, and requires the continuous operation of the existing tertiary facilities. The ammonia effluent limitations are 5 mg/L daily maximum or a load of 2,294 lbs/day and 2 mg/L monthly average or a load of 917 lbs/day at the permitted flow rate of 55,000,000 gallons per day.

The DWR 2-year aeration demonstration project is currently testing whether injecting oxygen into the DWSC using U-Tube technology will have an appreciable effect on low DO levels. U-Tube technology promises to efficiently inject enough oxygen into DWSC to offset the DO deficit. However, because this is only a demonstration project and not a permanent project, it is not taken into consideration in this analysis. The aeration project and enactment of the regulations are likely to increase DO concentrations in the DWSC as compared to existing conditions.

Potential Effects of Recirculation. The Plan Formulation Report analysis includes the No-Action Alternative and six alternative plans (A1, A2, B1, B2, C, and D). With each consecutive alternative plan, recirculation flow and the number of recirculation periods increase above the previous alternative plans. Five water year types are modeled for existing conditions (the No-Project Alternative) and future levels of development for the alternative plans and for conditions under the No-Project Alternative. Water year types include Wet, Above Normal, Below Normal, Dry, and Critical.

Flow downstream of Vernalis was modeled using DSM2 (**Appendix B**) for only the No-Action Alternative and Alternatives B1, B2, and D and not for Alternatives A1, A2, or C and is, therefore, absent in the DO calculations described below.

DO vs. Flow Relationship. The relationship between reduced flow through the DWSC and DO impairment is discussed in CVRWQCB (2005). As flows slow through the DWSC, the oxygen input rate decreases and, therefore, reduces the amount of oxygen available for biological or chemical processes. If these oxygen-demanding processes are similar to those prior to entering the DWSC, an oxygen deficit will occur in the DWSC as less oxygen is assimilated into the water in this area. If oxygen demand in the DWSC is increased, the oxygen concentrations will drop further still. This relationship between low flows and low oxygen concentration is depicted on **Figures F2-16 and F2-17**. In both plots, when flow is reduced below 2,000 cfs, oxygen concentrations begin to decrease below Basin Plan objectives.

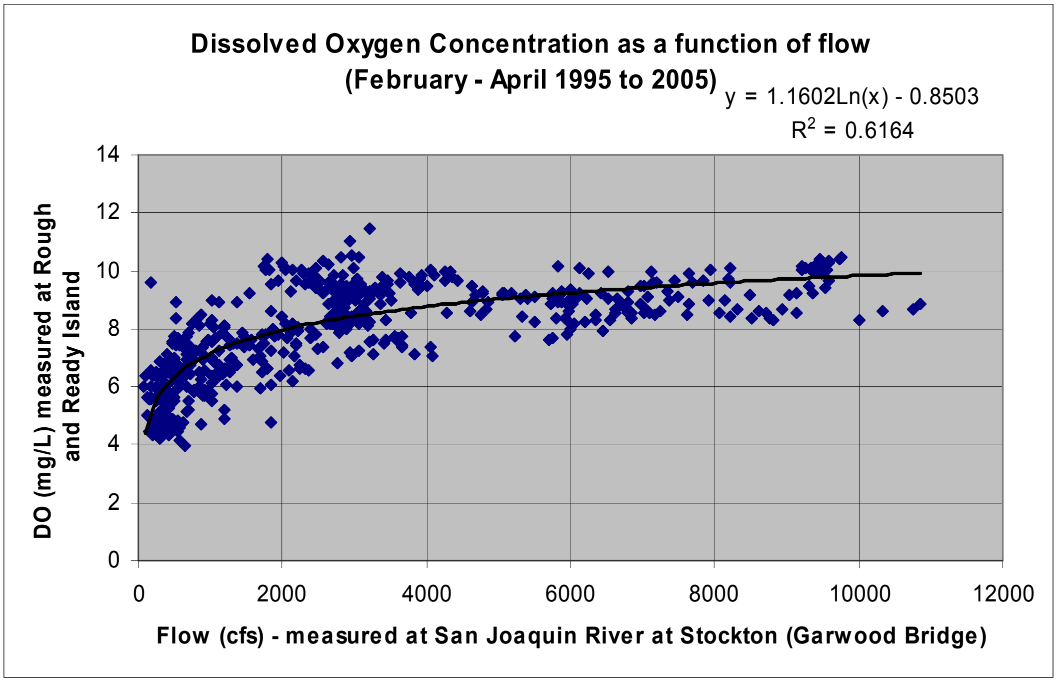


Figure F2-16. Dissolved Oxygen Concentration as a Function of Flow (February–April 1995 to 2005)

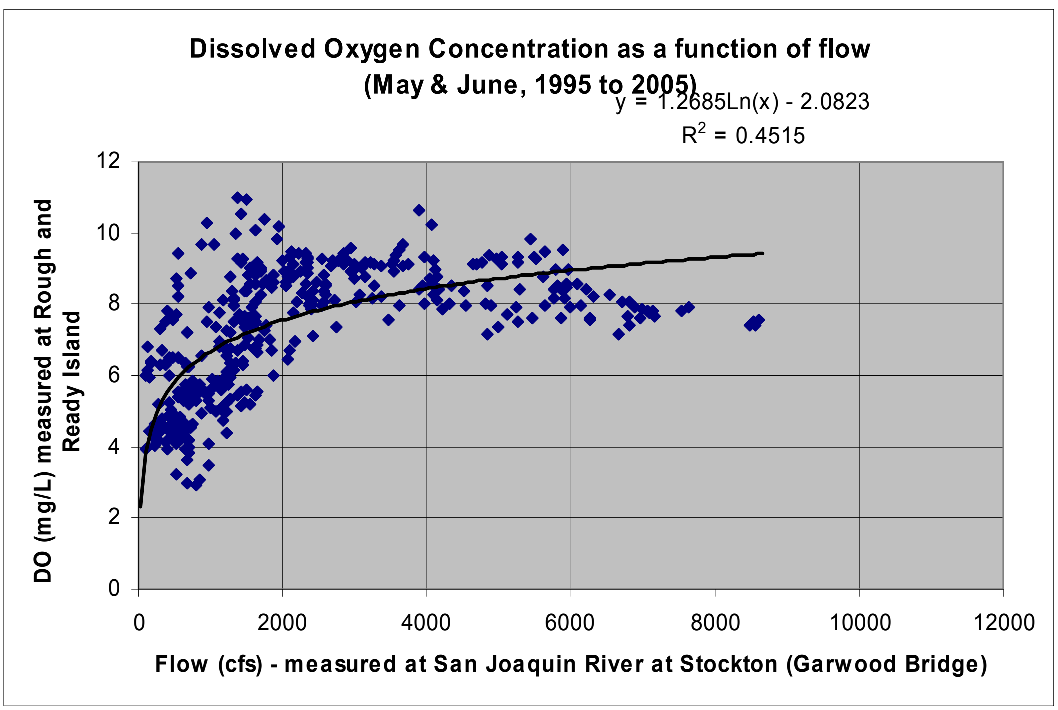


Figure F2-17. Dissolved Oxygen Concentration as a Function of Flow (May and June 1995 to 2005)

The following approach was used to estimate the potential effect of DMC recirculation on DO concentrations in the DWSC:

1. A relationship between DO and flow in the DWSC during both the Wet and Dry seasons was determined using existing data.

2. This relationship was used to predict DO based on DSM2 flow predictions.

Historical data were used to determine the existing relationship between DO and flow in the DWSC using logarithmic regression analysis. To establish a relationship that represented various water year types, data from 1995 through 2005 were downloaded from the San Joaquin River Modeling Interface program, which includes data from the San Joaquin River Data Atlas (Jones & Stokes 2005) and the USGS. A long-term dataset was not available for both flow and DO from one site, so DO data from the Rough and Ready Island station were utilized as well as flow data collected just upstream at the SJR at Stockton (Garwood Bridge) station. The dataset was split into two sets to represent Wet and Dry season months that correspond to the months during which recirculation is predicted to occur; February through April represents the Wet season and May through June represents the Dry season.

DO as a function of flow was fit to a logarithmic regression for each dataset, which determined the relationship of the February through April data to be

$$y = 1.1602 \ln(x) - 0.8503 \qquad \text{(F1)}$$

and the relationship of the May and June data to be

$$y = 1.2685 \ln(x) - 2.0823 \qquad \text{(F2)}$$

where y = DO (mg/L) and x = flow (cfs) in both equations.

The relationships are presented on **Figures F2-16 and F2-17**.

Estimating DO From Predicted Flow. Flow output from the DSM2 model (**Appendix B**) was used as the input flow data for the TSS models. The DSM2 daily flow output was averaged into 14 periods prior to the DO analysis. The 14 periods correspond with monthly and semi-monthly averages that have April and May flow separated into pulse and nonpulse time periods.

To evaluate changes in DO, representative years were selected for each water year type (1993, 1963, 2003, 2002, and 1992, which correspond to Wet, Above Normal, Below Normal, Dry, and Critical, respectively). These years were selected as representative because recirculation flow was modeled by CalSim II

(**Appendix A**) to occur in these years under the future LOD. For each representative year, the time periods from February to June were evaluated because recirculation is predicted to occur primarily during this period.

Flow was modeled for the Brandt Bridge location downstream of Vernalis, using the DSM2 model described in **Appendix B** for the No-Action Alternative and Alternatives B1, B2 and D. Modeled flow at Brandt Bridge was influenced primarily by the boundary flow condition in SJR at Vernalis, which was provided in 14 period time steps to DSM2 from CalSim II.

Utilizing the relationships in Equations F1 and F2, DO concentrations in the DWSC were estimated using predicted flows at the SJR Brandt Bridge station. The Brandt Bridge site is the closest modeled flow site to the Garwood Bridge site and is assumed to be similar to flow rates going into the DWSC (see **Figure F2-18**). However, one input, French Camp Slough, does enter the SJR downstream of Brandt Bridge before the Garwood Bridge site. French Camp Slough flows fluctuate seasonally as shown on **Figure F2-19** (DWR 2005b), which is Water Year 2004, a "Below Normal" year. This additional flow was not taken into consideration in the calculations.

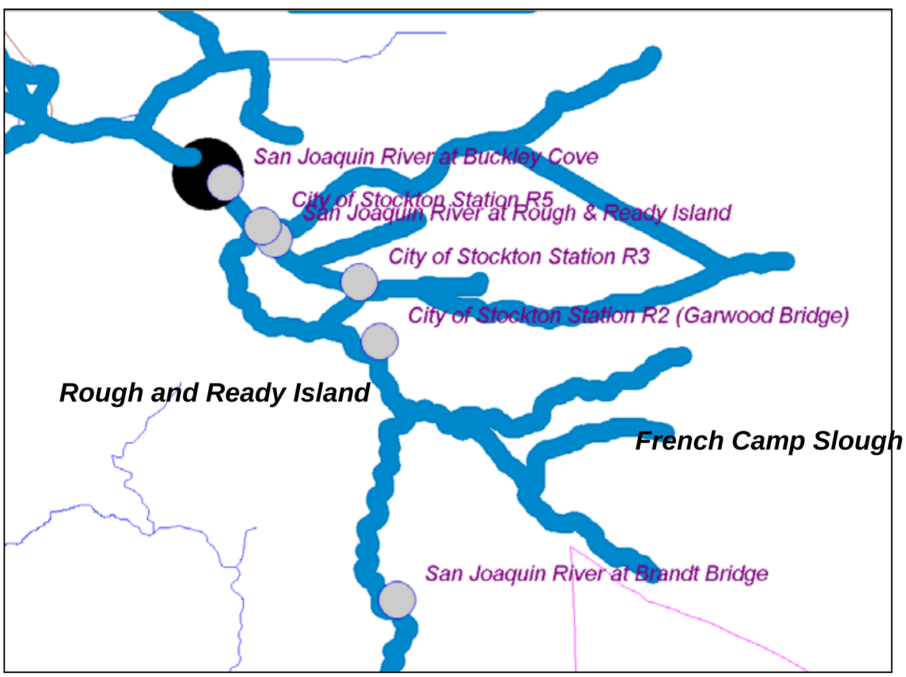


Figure F2-18. Water Quality Stations near Rough and Ready Island on the San Joaquin River

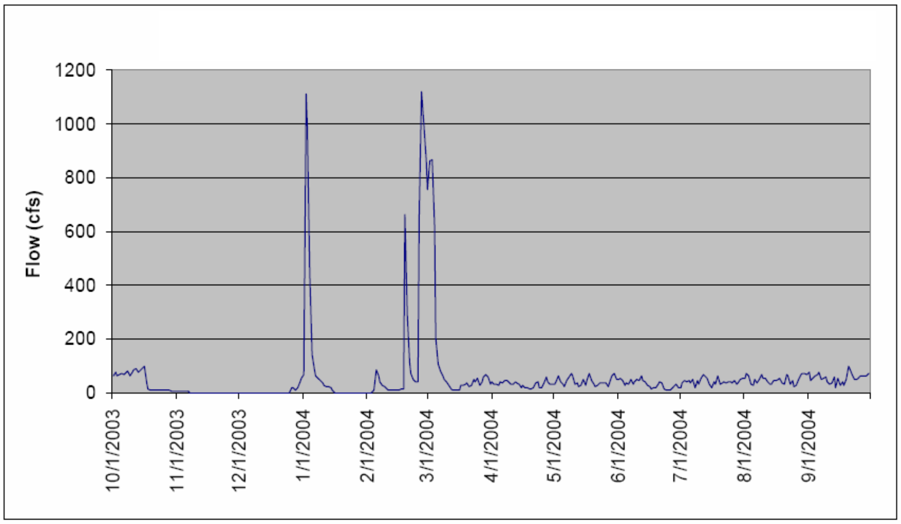


Figure F2-19. French Camp Slough Flow Data, 2004

Estimated DO concentrations in the DWSC for the No-Action Alternative and Alternatives B1, B2, and D and are presented in **Table F2-9**. The results indicate that DO would not fall below the Central Valley Basin Plan WQO of 5 mg/L during the Wet or Above Normal water years. However, for the Below Normal, Dry and Critical water years, DO concentrations are predicted to occur below the WQO under the No-Action Alternative and the recirculation alternative plans evaluated. Under the No-Action Alternative, DO concentrations are predicted to fall below the WQO during 17% of the periods during February through June for all 5 representative years combined. Under Alternatives B1 and B2, DO concentrations are predicted to increase from those predicted under the No-Action Alternative for all representative years combined. Under Alternative B1, DO concentrations are predicted to fall below the WQO in 12% of the periods and under Alternative B2 in 8% of the periods for all 5 representative years combined. Under Alternative D, DO concentrations are predicted to increase even more so that predicted concentrations would fall below the WQO during 3% of the periods for all representative years combined.

Table F2-9. Modeled Dissolved Oxygen Concentrations in the Stockton Deep Water Ship Channel for No-Action Alternative and Alternatives B1, B2, and D

Date	Water Year	Month	Calculated Flow Using DSM2 at Brandt Bridge (cfs)				Calculated Dissolved Oxygen in the DWSC (mg/L)			
			No-Action Alterna-tive	B1	B2	D	No-Action Alterna-tive	B1	B2	D
1993	Wet	February	1361	1361	1362	1364	7.5	7.5	7.5	7.5
		March	1023	1214	1215	1298	7.2	7.4	7.4	7.5
		April	195	209	209	1241	5.3	5.3	5.3	7.4
		April-pulse	3501	3501	3502	3575	8.6	8.6	8.6	8.6
		May-pulse	3696	3696	3695	3694	8.3	8.3	8.3	8.3
		May	538	538	539	710	5.9	5.9	5.9	6.2
		June	2983	2983	2987	3002	8.1	8.1	8.1	8.1
1963	Above Normal	February	914	914	914	1191	7.1	7.1	7.1	7.4
		March	706	1281	1281	1289	6.8	7.5	7.5	7.5
		April	1139	1180	1180	1182	7.3	7.4	7.4	7.4
		April-pulse	3128	3128	3128	3129	8.5	8.5	8.5	8.5
		May-pulse	3258	3258	3259	3258	8.2	8.2	8.2	8.2
		May	1105	1105	1106	1581	6.8	6.8	6.8	7.3
		June	1011	1473	1473	1490	6.7	7.2	7.2	7.2
2003	Below Normal	February	517	778	774	774	6.4	6.9	6.9	6.9
		March	355	365	364	698	6.0	6.0	6.0	6.7
		April	110	110	110	634	**4.6**	**4.6**	**4.6**	6.6
		April-pulse	3528	3528	3528	3564	8.6	8.6	8.6	8.6
		May-pulse	3647	3647	3647	3647	8.3	8.3	8.3	8.3
		May	596	596	596	884	6.0	6.0	6.0	6.5
		June	233	487	487	797	**4.8**	5.8	5.8	6.4
2002	Dry	February	669	907	907	907	6.7	7.1	7.1	7.1
		March	445	690	690	690	6.2	6.7	6.7	6.7
		April	75	91	91	640	**4.2**	**4.4**	**4.4**	6.6
		April-pulse	2387	2387	2387	2430	8.2	8.2	8.2	8.2
		May-pulse	2602	2602	2602	2602	7.9	7.9	7.9	7.9
		May	635	635	635	894	6.1	6.1	6.1	6.5
		June	418	558	558	567	5.6	5.9	5.9	6.0
1992	Critical	February	572	572	573	575	6.5	6.5	6.5	6.5
		March	256	256	256	366	5.6	5.6	5.6	6.0
		April	133	190	242	247	**4.8**	5.2	5.5	5.5
		April-pulse	721	726	736	1210	6.8	6.8	6.8	7.4
		May-pulse	669	1029	1035	1105	6.2	6.7	6.7	6.8
		May	242	261	381	380	**4.9**	5.0	5.5	5.5
		June	108	176	181	181	**3.9**	**4.5**	**4.5**	**4.5**
Number of periods when WQO (5 mg/L) is predicted not to be met							6	3	3	1
Percent of periods when WQO (5 mg/L) is predicted not to be met							17	9	9	3
Number of periods when WQO is predicted to be met due to recirculation							NA	3	3	5

Table F2-9. Modeled Dissolved Oxygen Concentrations in the Stockton Deep Water Ship Channel for No-Action Alternative and Alternatives B1, B2, and D

Note:
Bold concentrations are below the WQO of 5 mg/L.

Key:
cfs = cubic feet per second
DSM2 = Delta Simulation Model 2
DWSC = Deep Water Ship Channel
mg/L = milligram(s) per liter
NA = not applicable
WQO = water quality objective

Flows for Alternatives A1, A2, and C were not modeled; however, the results may be qualitatively interpolated based on the trend of the results. As flow and the number of recirculation periods increase, the percentage of recirculation periods for which model predicts WQO (5 mg/L) is not met decreases as shown in **Table F2-9**. Therefore, it is assumed that the DO results for Alternatives A1 and A2 would fall between the results for the No-Action Alternative and Alternative B1 and that Alternative C would be between the modeled results for Alternatives B2 and D.

The results are based on several assumptions and uncertainties that may effect the estimated DO results. As discussed previously, existing DO and flow data were utilized from two different sites to calculate a DO/flow relationship. These stations were in close proximity to one another in the DWSC so it was assumed the relationship was the same as if the data had been collected from a single site. Also, the modeled flows from Brandt Bridge are several miles upstream from the DWSC and do not take into consideration the flow inputs from French Camp Slough as discussed earlier. However, for the purposes of this analysis, it was assumed that the modeled flows from Brandt Bridge would be similar to those entering the DWSC.

Several uncertainties are also associated with the No-Action Alternative. The only future project accounted for in the modeled No-Action Alternative for the Plan Formulation Report is the Grasslands Bypass project. The No-Action Alternative does not take into account the South Delta Improvements Program, which includes operable barriers within the Delta, the new Waste Discharge Requirements for the Stockton Wastewater Treatment Plant, or the recent Port of Stockton Settlement. All of these projects are likely to impact DO concentrations but are not taken into account in this analysis.

F.2.2 Qualitative Evaluations Based on Existing Data

Existing data for the various regions were used to evaluate qualitatively the potential effects of recirculation for each parameter. Under Alternatives A1 and B1, no change to New Melones Releases would occur; therefore, the changes to water quality in the SJR would occur only as a result of recirculation inputs. Under Alternatives A2, B2, C, and D, New Melones releases would be reduced and flows in the SJR would be supplemented by recirculation; therefore, the changes to water quality in the SJR could occur as a result of both recirculation inputs and reductions in New Melones releases**.**

Pesticides, metals, nutrients, organic carbon, bromide, pH, and total dissolved solids (TDS) are qualitatively evaluated in this section. Measured water quality is compared among the south Delta, the Stanislaus River, the mainstem segments of the SJR, and Vernalis. The water quality of the wasteways is also included for comparison.

Newman Wasteway and Westley Wasteway are designed to contain operational spills from the DMC and allow dewatering during routine or emergency maintenance. Typically, discharge from each of these wasteways ranges from 20 to 75 cfs and is composed mostly of agricultural subsurface drainage. Occasional pulse flow is sent down the wasteways to clear accumulated sediment away from the headgates. The existing wasteway data represent the quality of the wasteway agricultural drainage, not the quality of the recirculation.

In the absence of recirculation, the wasteways contribute contaminant loads to the SJR as a result of low-level flow. The water quality of the wasteway agricultural drainage is often worse than the water quality in the south Delta or in the SJR. Recirculation would introduce a large volume of water to the wasteway, which could dilute contaminants within the wasteway. Without sufficient dilution, recirculation may create a pulse flow of wasteway contaminants to the SJR, which would be short in duration, but may have a greater impact to aquatic life than the low-flow conditions in the wasteways without recirculation. A pulse of wasteway contaminants could occur on a time scale of hours to days, depending on recirculation rates and the relative dilution provided by the DMC. Thereafter, the water quality of the recirculation is expected to be similar to the south Delta.

Recirculation pilot studies were conducted in 2004, 2007, and 2008 at Newman Wasteway to investigate changes in SJR concentrations due to recirculation. The results of the studies are presented by parameter after the discussion of the regional data (see **Sections F2.1 and F2.2**). The sample size was limited for the pilot studies, and samples were collected for approximately 1 month in late summer when large volumes of water had not flowed through the wasteway for some time.

Parameters discussed in **Section F2.2.1** include insecticides and herbicides. The aquatic toxicity of pyrethroid and organophosphrous insecticides is of concern, as seen by specific pesticide objectives for chlorpyrifos and diazinon that have recently been included as Basin Plan amendments.

Parameters discussed in **Sections F2.2.2 through F2.2.5** include metals, nutrients, organic carbon, bromide, pH, and TDS. Many of these parameters were included because of concerns expressed by the California Department of Fish and Game (CDFG 2007).

Pesticides

Pesticides are insecticides, herbicides, and fungicides that prevent, deter, or exterminate pests. Several types of pesticides are widespread in the SJR and Delta, including pyrethroids, organophosphates, and organochlorines. Each pesticide has certain risks for humans and aquatic life because they are meant to disrupt biological processes. Pyrethroids are synthetic versions of a naturally occurring pesticide in chrysanthemums, and can be extremely toxic to the nervous systems of fish and invertebrates. Pyrethroids are becoming more widely used. Organophosphates, such as chlorpyrifos and diazinon, affect the nervous system and are used as insecticides. While usually not as persistent in the environment as organochlorines, organophosphates could impact the distribution and abundance of aquatic species. Organochlorines, such as dichlorodiphenyltrichloroethane (DDT), were used extensively in the past, but are now much less widely used because of their toxicity and persistence. Organochlorines can bioaccumulate in fish tissue and can pose risks to humans and animals (DWR 2005a).

The following methodology was used to choose pesticides for individual evaluation:

- At least one pyrethroid insecticide, organophosphorus insecticide, organochlorine pesticide, carbamate insecticide, and herbicide were selected.
- To allow for regional comparisons, only pesticides detected in at least three regions were included for further evaluation.
- Within each major grouping of pesticides, parameters were selected based on toxicity, sample size, detection frequency, and the geographical extent of the data.

Bifenthrin was included because it was the only detected pyrethroid insecticide; it was also detected in three regions. Multiple organophosphate insecticides were included because of concerns regarding toxicity. Selected organophosphates include azinphos-methyl, chlorpyrifos, diazinon, malathion, and methyl parathion because of documented toxicity issues in the SJR watershed and recent regulatory actions taken on these compounds.

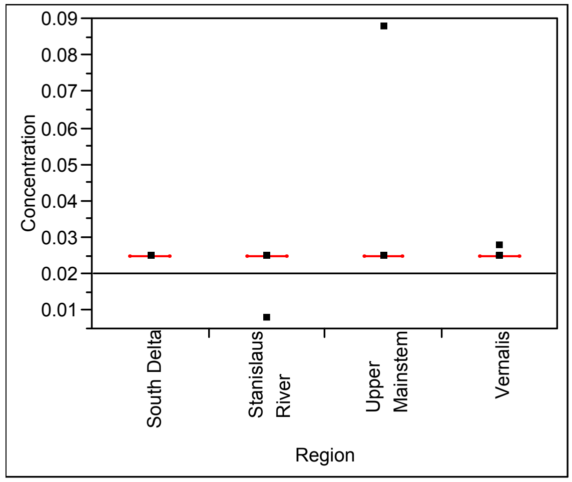
4,4′-dichlorodiphenyldichloroethylene (DDE) was included because it had the most complete dataset among organochlorine pesticides; it had a higher overall count and more regions with data available. Carbaryl was included because it had the most complete dataset among carbamate insecticides; it had more data due to a higher overall count. Multiple herbicides were included because of generally higher detection rates for herbicides over multiple regions. Selected herbicides include ethyl dipropylthiocarbamate (EPTC), atrazine, cyanazine, dimethyl-tetrachloroterephthalate (DCPA; aka Dacthal), diuron, metolachlor, simazine, and trifluralin. DCPA was included because it was detected multiple times during the 2004 Recirculation Pilot Study (Reclamation 2005).

Pyrethroid Insecticides

Bifenthrin. Bifenthrin is a synthetic pyrethroid most commonly used to control fire ants (Fecko 1999). It was the only pyrethroid detected in surface water among all the data sources. It is registered for use on greenhouse ornamentals and cotton (EXTOXNET 2008). No regulatory water quality limits exist for bifenthrin. However, bifenthrin has an EPA Integrated Risk Information System (IRIS) Reference Dose of 110 μg/L, which is greater than all the datapoints collected for this analysis. According to the ECOTOX database, the lowest observed effects concentration (LOEC) of bifenthrin to invertebrates is 0.02 μg/L, and the lethal concentration that kills 50% of the test population (LC50) for fish is 0.207 μg/L (EPA 2008c). Bifenthrin is moderately toxic to mammals when ingested and moderately toxic to many species of birds. This pesticide affects the nervous system of insects and is highly toxic to aquatic organisms (EXTOXNET 2008). Bifenthrin binds tightly to soil and sediment particles, limiting its bioavailability (Fecko 1999).

The box plot on **Figure F2-20** shows the range of datapoints for each region where bifenthrin concentration data are available. This box plot depicts all datapoints, including nondetected data with an assumed value of half of the reporting limit, by region. The detection rate for bifenthrin was low, 0 to 1% in each region, with a count of 36 to 115. No data were available for the wasteways. Comparisons of the data by region are inconclusive, and data are insufficient to evaluate potential effects of recirculation on concentrations of this pesticide in the SJR. Bifenthrin was not analyzed in the recirculation pilot studies.

Pesticide=Bifenthrin, Unit=µg/L



Notes:
Criteria (1)=110 µg/L, Criteria (1) Source=EPA IRIS
Criteria (2)=0.02 µg/L, Criteria (2) Source=ECOTOX LOEL for Invertebrates
Data sources and regional groupings are described at the beginning of **Section F2.**

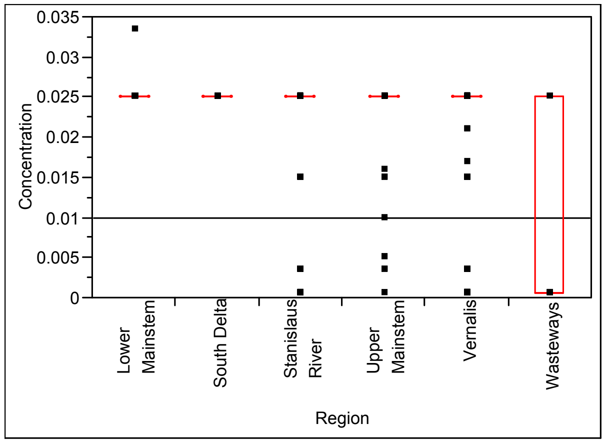
Figure F2-20. Measured Bifenthrin Concentrations by Region

Organophosphorus Insecticides

Azinphos methyl. Azinphos methyl (aka, Guthion) is a highly persistent organophosphorus pesticide that is commonly applied to nuts in California to combat navel orangeworm and codling moth (EPA 2006a). The EPA recommends an ambient water quality criteria (AWQC) of 0.01 µg/L (instantaneous maximum) for freshwater aquatic life protection. Azinphos methyl is one of the most toxic of the organophosphorus insecticides, and it is highly toxic to mammals via inhalation, dermal absorption, ingestion, and eye contact. It is slightly to-moderately toxic to birds, and moderately to very highly toxic to freshwater fish (EXTOXNET 2008).

Figure F2-21 shows the measured azinphos methyl concentrations by region relative to the EPA AWQC for aquatic life. The detection rate was low in each region, ranging from 0 to 3%. The reporting limits for azinphos methyl vary, but the majority of datapoints correspond to reporting limits that are greater than the EPA AWQC. Therefore, the data comparisons by region are inconclusive, and data are insufficient to evaluate potential effects of recirculation on concentrations of this pesticide in the SJR. Azinphos methyl was not analyzed in the recirculation pilot studies.

Pesticide=Azinphos Methyl (Guthion), Unit=µg/L



Notes:

Criteria (1)=0.01 µg/L, Criteria (1) Source=EPA AWQC for Aquatic Life

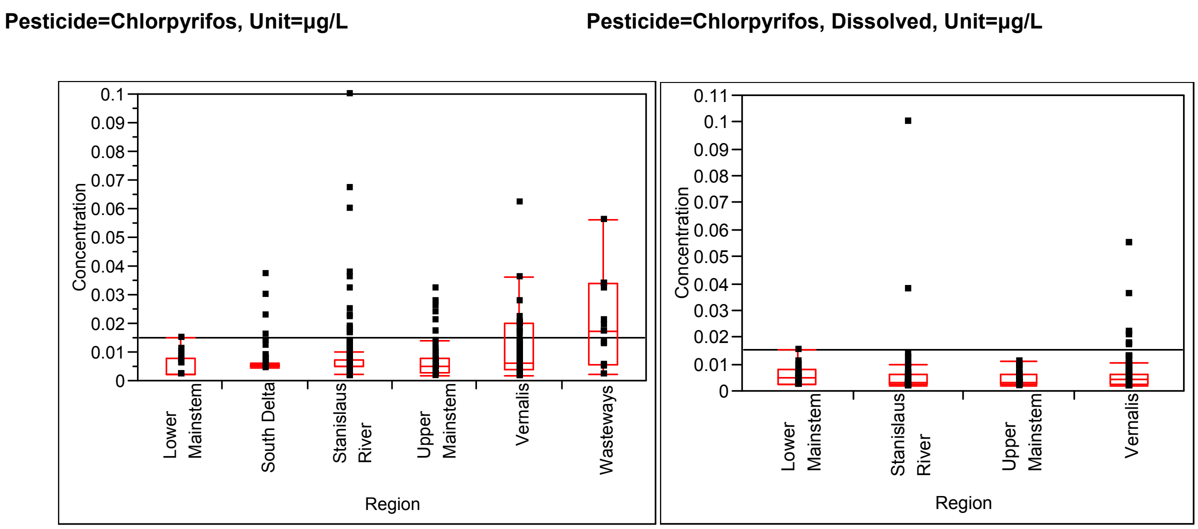
Data sources and regional groupings are described at the beginning of **Section F2.**

Figure F2-21. Measured Azinphos Methyl Concentrations by Region

Chlorpyrifos. Chlorpyrifos is used to control foliage and soil-borne insect pests on a variety of food and feed crops (EPA 2002). Because of its prevalence in the SJR, the CVRWQCB identified numeric WQOs for chlorpyrifos for the Delta and the SJR from Mendota Dam to Vernalis. The Basin Plan 4-day average WQO is 0.015 µg/L and the 1-hour average WQO is 0.025 µg/L (CVRWQCB 2007). Chlorpyrifos also has an EPA IRIS Reference Dose of 21 µg/L, an EPA Drinking Water Health Advisory level of 2 µg/L, and an EPA recommended AWQC of 0.041 µg/L (4-day average) and 0.083 µg/L (1-hour average) for the protection of freshwater aquatic life. Chlorpyrifos is moderately toxic to humans, moderately to very highly toxic to birds, and highly toxic to aquatic life (EXTOXNET 2008).

Figure F2-22 shows the measured total and dissolved chlorpyrifos concentrations by region relative to the Basin Plan WQO (chronic criteria). The box plot on the left shows total chlorpyrifos concentrations and the box plot on the right shows dissolved chlorpyrifos concentrations. The detection rate ranged from 28% (in the south Delta) to 87% (in the wasteways). Although data for chlorpyrifos in the wasteways and the lower mainstem are limited, the median concentration for total chlorpyrifos in the wasteways was higher than median concentrations in the SJR and south Delta. The median concentration in the wasteways was also higher than the WQO.

Recirculation would introduce a relatively large volume of water to the wasteway agricultural drainage, which may dilute contaminants within the wasteway. The wasteways may contribute higher concentrations of chlorpyrifos during the initial stages of recirculation, but, in general, the water quality of recirculation flows would be characterized by the south Delta. Chlorpyrifos concentrations in the upper mainstem may increase while concentrations of chlorpyrifos in the lower mainstem and Vernalis may decrease (as seen by comparison of median concentrations in the SJR and south Delta). The median chlorpyrifos concentration in the south Delta is similar to that in the Stanislaus River; thus, recirculation may provide the same level of dilution at Vernalis as the Stanislaus River.



Notes:
Criteria (1)=0.015 µg/L, Criteria (1) Source=Basin Plan WQO for the SJR and Delta
Data sources and regional groupings are described at the beginning of **Section F2.**

Figure F2-22. Measured Total and Dissolved Chlorpyrifos Concentrations by Region

Chlorpyrifos was analyzed in the 2004 and 2007 recirculation pilot studies but was not detected (Reclamation 2005, 2008). The reporting limits of the chlorpyrifos data (0.1 and 0.05 µg/L) were greater than the Basin Plan WQO; therefore, comparisons of chlorpyrifos concentrations relative to water quality criteria are inconclusive. The pilot study data do not provide additional insights into relative changes in chlorpyrifos concentrations during recirculation.

Diazinon. Diazinon is commonly used to control insects and pests of many fruit, nut, vegetable, forage, and field crops (EPA 2008d). Similar to chlorpyrifos, diazinon has been detected frequently in the SJR. The CVRWQCB has identified numeric WQOs for diazinon for the Delta and the SJR from Mendota Dam to Vernalis. The Basin Plan 4-day average WQO is 0.1 µg/L and the 1-hour average WQO is 0.16 µg/L (CVRWQCB 2007). In addition, the California Department of Public Health (CDPH) gives a Drinking Water

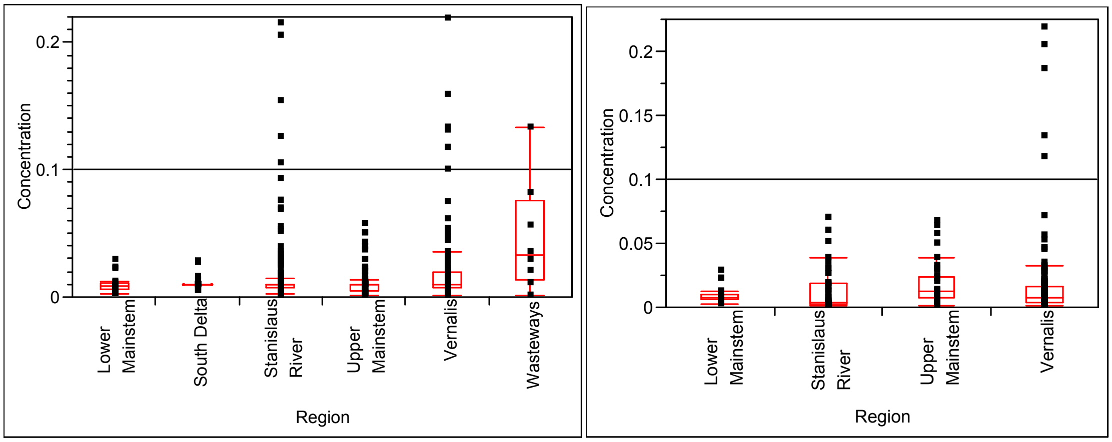
Notification Level of 6 µg/L. Diazinon has an EPA IRIS Reference Dose of 1 µg/L and an EPA Drinking Water Health Advisory level of 14 µg/L. The EPA recommended AWQC for the protection of freshwater aquatic life is 0.17 µg/L (4-day average and 1-hour average). Diazinon is toxic to humans and birds and is highly toxic to fish (EXTOXNET 2008).

Figure F2-23 shows the measured total and dissolved diazinon concentrations by region relative to the Basin Plan WQO (chronic criteria). The box plot on the left shows total diazinon concentrations and the box plot on the right shows dissolved diazinon concentrations. The detection rate for total diazinon was 25%, or less, in the south Delta and the Stanislaus River; the visual representations of the concentrations may be influenced by the reporting limits of the data. Although data for the wasteways were limited, the median concentration for total diazinon in the wasteways was higher than median concentration in the SJR and south Delta. The median total diazinon concentration in the south Delta is similar to the median concentrations in the upper mainstem, Vernalis, and the Stanislaus River, but greater than the median concentration in the lower mainstem. The Stanislaus River has data outliers for total diazinon with concentrations greater than the WQO.

Recirculation would introduce a relatively large volume of water to the wasteway agricultural drainage, which may dilute concentrations within the wasteway. The wasteways may contribute higher concentrations of diazinon during the initial stages of recirculation, but, in general, the water quality of the recirculation flow would be characterized by the south Delta. Diazinon concentrations in the lower mainstem may increase and concentrations in the upper mainstem and Vernalis may remain the same (as seen by comparison of median concentrations between the south Delta and SJR). Because the median concentrations in the south Delta and the Stanislaus River are similar, recirculation may provide a similar level of dilution at Vernalis as New Melones releases.

Diazinon was analyzed in the 2004 and 2007 recirculation pilot studies but was not detected at concentrations equal to the reporting limit and the Basin Plan WQO (0.1 µg/L) (Reclamation 2005, 2008). Although the pilot study data cannot be used to describe relative changes in diazinon concentrations during recirculation, concentrations found during these studies were below the water quality criteria.

Pesticide=Diazinon, Unit=µg/L **Pesticide=Diazinon, Dissolved, Unit=µg/L**



Notes:

Criteria (1)=0.1 µg/L, Criteria (1) Source=Basin Plan WQO for the SJR and Delta

Data sources and regional groupings are described at the beginning of **Section F2.**

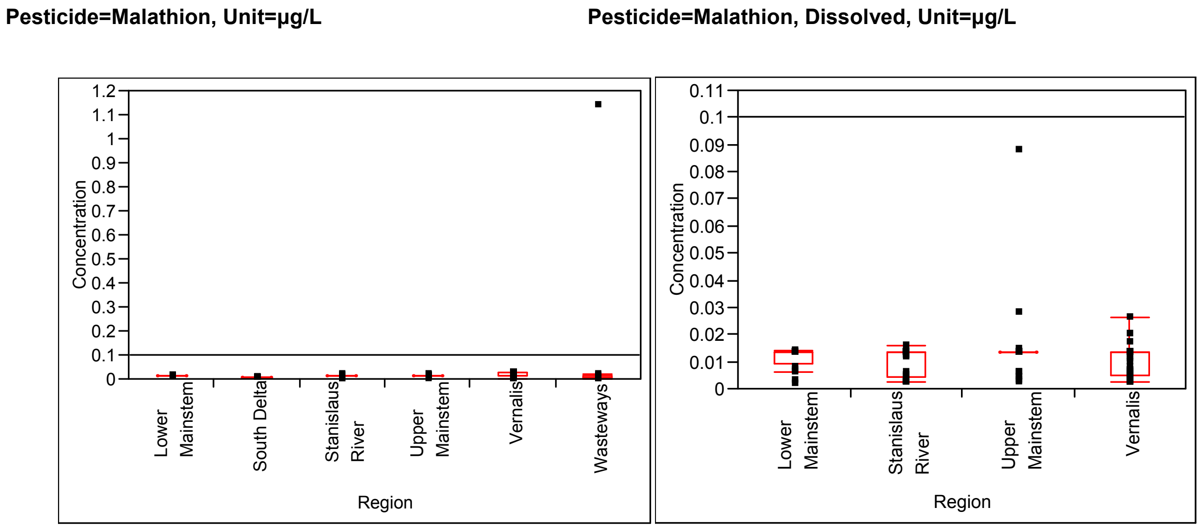
Figure F2-23. Measured Total and Dissolved Diazinon Concentrations by Region

Malathion. Malathion is commonly applied to alfalfa and wheat, but it has also been used in public health and residential settings to control mosquitoes (Newhart 2006). Malathion is considered to be among the least toxic and least persistent organophosphorus insecticides and its half-life decreases as surface water pH increases (Newhart 2006). The CDPH Drinking Water Notification Level is 160 µg/L, the EPA IRIS Reference Dose is 100 µg/L, and the EPA Drinking Water Health Advisory level is 160 µg/L. In addition, the EPA recommended AWQC for the protection of freshwater aquatic life is 0.1 µg/L (instantaneous maximum). Malathion is slightly toxic to humans, moderately toxic to birds, and slightly to very highly toxic to fish depending on the species (EXTOXNET 2008).

Figure F2-24 shows the measured total and dissolved malathion concentrations by region relative to the EPA AWQC of 0.1 µg/L. The box plot on the left shows total malathion concentrations and the box plot on the right shows dissolved malathion concentrations. Total malathion was detected at low rates (0 to 3%) in the SJR, Stanislaus River, and south Delta regions. The detection rate was higher in the wasteways, but the amount of data was limited. Detection rates for dissolved malathion were higher than total malathion, with a median concentration of dissolved malathion of approximately 0.01 µg/L throughout all the regions. Except for one major outlier in each of the total and dissolved malathion datasets, none of the measured concentrations approach the AWQC.

Since concentrations of malathion are below the AWQC in the SJR, the south Delta, and the Stanislaus River, and distinctions between south Delta and Stanislaus River concentrations are minimal, recirculation may not have a significant effect on malathion concentrations in the SJR.

Malathion was analyzed during the 2004 and 2007 recirculation pilot studies but was not detected at concentrations equal to the reporting limit (0.1 µg/L) (Reclamation 2005, 2008). The reporting limit for the malathion data was at or below the water quality criteria; therefore, the pilot study data support the conclusion that changes in malathion concentrations due to recirculation may not be significant.



Notes:
Criteria (1)=100 µg/L, Criteria (1) Source=EPA Drinking Water Health Advisory
Criteria (2)=0.1 µg/L, Criteria (2) Source=EPA AWQC for Aquatic Life
Data sources and regional groupings are described at the beginning of **Section F2.**

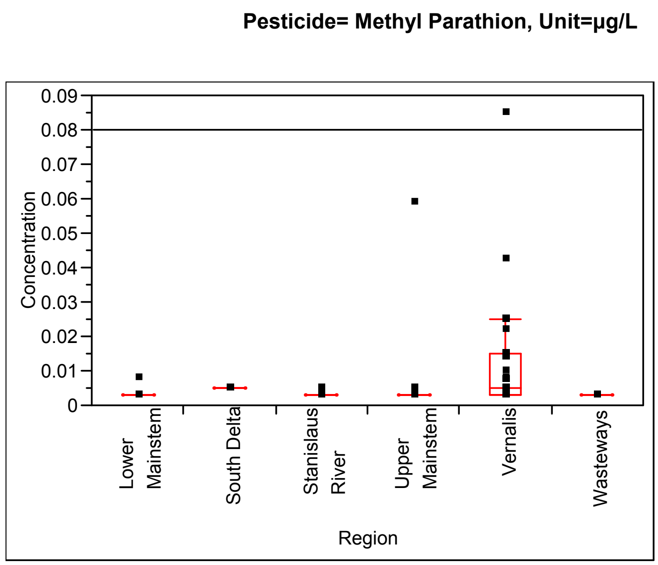
Figure F2-24. Measured Total and Dissolved Malathion Concentrations by Region

Methyl Parathion. Methyl parathion is used primarily to control boll weevils and other insect pests on cotton (EPA 2006b). The CDPH Drinking Water Notification Level is 2 µg/L, the EPA IRIS Reference Dose is 1.8 µg/L, and the EPA Drinking Water Health Advisory level is 1 µg/L. In addition, the CDFG interim criterion for the protection of freshwater aquatic life is 0.08 µg/L (instantaneous maximum). Methyl parathion can be highly toxic to humans and birds, and is moderately toxic to fish and its predators (EXTOXNET 2008).

Figure F2-25 shows the measured methyl parathion concentrations by region relative to the CDFG aquatic life criterion. The detection rates were low, and median concentrations were primarily driven by reporting limits. Except for one outlier at Vernalis, none of the measured concentrations were greater than the CDFG aquatic life criterion.

Methyl parathion was not analyzed in the recirculation pilot studies.

Since concentrations of methyl parathion are typically much less than the CDFG aquatic life criterion in the SJR, the south Delta, and the Stanislaus River, and distinctions between south Delta and Stanislaus River concentrations are minimal, recirculation may not have a significant effect on methyl parathion concentrations in the SJR.



Notes:
Criteria (1) = 1 µg/L, Criteria (1) Source = EPA Drinking Water Health Advisory
Criteria (2) = 0.08 µg/L, Criteria (2) Source = CDFG Interim Criteria
Data sources and regional groupings are described at the beginning of **Section F2.**

Figure F2-25. Measured Methyl Parathion Concentrations by Region

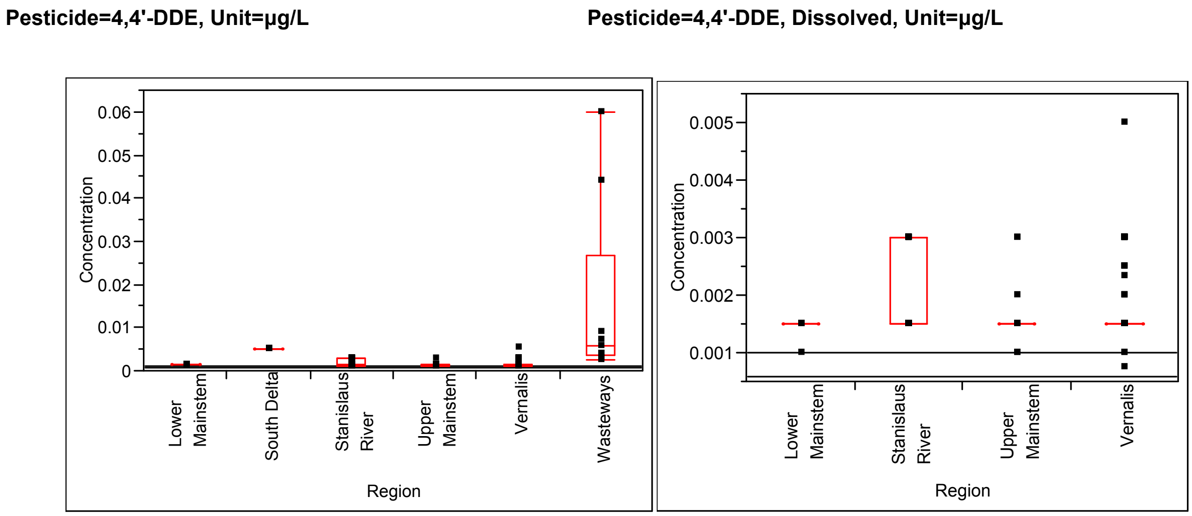
Organochlorine Pesticides

4,4′-DDE. The compound 4,4′-DDE is a degradation product of 4,4′-DDT. It is no longer registered for use in the U.S. but had been used to control vectors carrying diseases, such as mosquitoes carrying malaria (EXTOXNET 2008). The Basin Plan states that no total identifiable persistent chlorinated hydrocarbons are to be detected in the water column (CVRWQCB 2007). The EPA recommends AWQCs of 0.001 µg/L (4-day average) and 1.1 µg/L (instantaneous maximum) for freshwater aquatic life protection. In addition, the EPA California Toxics Rule criterion for 4,4′-DDE is 0.00059 µg/L (30-day average) for human health. The compound 4,4′-DDE is very persistent in aquatic systems, adsorbing strongly to sediments and bioconcentrating in aquatic organisms including fish and other organisms (EPA 2008b). It tends to bioconcentrate in lower-trophic levels and will accumulate in food webs. This pesticide has been observed to be moderately toxic to rodents; however, toxicity increases as 4,4′-DDE bioaccumulates.

Figure F2-26 shows the measured total and dissolved 4,4′-DDE concentrations by region relative to the California Toxics Rule criterion and the EPA AWQC for aquatic life. The box plot on the left shows total 4,4′-DDE concentrations and the box plot on the right shows dissolved 4,4′-DDE concentrations. The detection rates for both total and dissolved 4,4′-DDE in the south Delta, upper and lower mainstem, Vernalis, and Stanislaus River regions ranged from 0 to 11%. The various reporting limits for 4,4′-DDE were greater than criteria; therefore, the data are largely inconclusive. The detection rate for total 4,4′-DDE was 89% in the wasteways with a count of 9 and a median concentration of 0.006 μg/L. These data indicate that 4,4′-DDE is frequently detectable in the wasteways.

Recirculation would introduce a relatively large volume of water to the wasteway agricultural drainage, which may dilute 4,4′-DDE within the wasteway; however, the wasteways may contribute higher concentrations of 4,4′-DDE during the initial stages of recirculation at concentrations above the water quality criteria. Given the low detection frequency of the available data, it is uncertain whether or not recirculation would adversely affect 4,4′-DDE concentrations in the SJR.

The compound 4,4′-DDE was analyzed in the 2004 and 2007 recirculation pilot studies but was not detected at concentrations equal to the reporting limit (0.1 μg/L) (Reclamation 2005, 2008). Because the reporting limit was substantially greater than the water quality criteria, the pilot study data do not provide additional insights into relative changes in 4,4′-DDE concentrations that are due to recirculation.



Notes:
Criteria (1)=0.00059 µg/L, Criteria (1) Source=CTR Human Health Criteria
Criteria (2)=0.001 µg/L, Criteria (2) Source=EPA AWQC for Aquatic Life
Data sources and regional groupings are described at the beginning of **Section F2.**

Figure F2-26. Measured Total and Dissolved 4,4′-DDE Concentrations by Region

Carbamate Pesticides

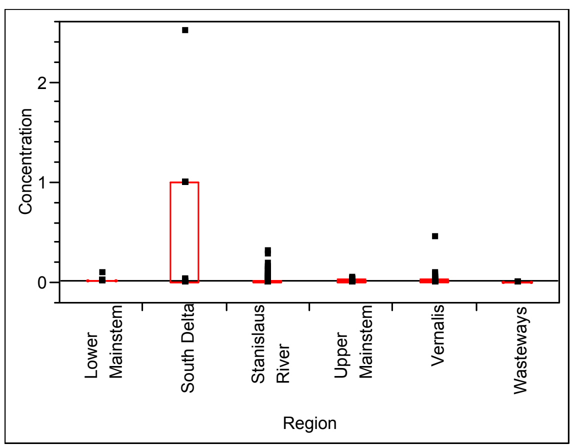
Carbaryl. Carbaryl is a carbamate insecticide that can substitute for some organochlorine pesticides and controls a broad spectrum of insects. It is the second most widely detected insecticide in surface waters of the U.S. (Gunasekara 2007). The CDPH Drinking Water Notification Level is 700 µg/L, the EPA IRIS Reference Dose is 700 µg/L, and the EPA Drinking Water Health Advisory level is 70 µg/L. In addition, the EPA has recommended an AWQC for freshwater aquatic life of 0.02 µg/L (instantaneous maximum) (EPA 1973); this 1972 criterion does not appear in the current list of recommended criteria. The CDFG recommends a 4-day and 1-hour average of 2.53 µg/L for freshwater aquatic life protection. As with carbamates in general, carbaryl does not persist in the environment, but it is moderately to very toxic to humans and moderately toxic to aquatic organisms (EXTOXNET 2008).

Figure F2-27 shows the measured carbaryl concentrations by region relative to the EPA AWQC of 0.02 µg/L. The detection rate ranged from 6 to 33% for the SJR, the south Delta, and Stanislaus River; however, the detection rate was 0% in the wasteways. The visual representation of the carbaryl concentrations for the south Delta is primarily the result of higher reporting limits. The wasteways data are limited to four datapoints with no detections, but the south Delta shows a median carbaryl concentration that is similar to the median concentration in the upper mainstem and the Stanislaus River, and less than the median concentration in the lower mainstem and Vernalis. The lower mainstem has median concentrations slightly above the AWQC of 0.02 µg/L.

Although wasteway concentrations are uncertain, the quality of the recirculation may have a beneficial effect on carbaryl concentrations for the lower mainstem and Vernalis (as seen by a comparison of the median concentrations in the SJR and south Delta). The south Delta data had a lower median concentration than some portions of the SJR even with relatively high reporting limits and a low detection frequency. Carbaryl concentrations are likely to be less than the 4-day and 1-hour average CDFG criteria of 2.53 µg/L.

Carbaryl was analyzed in the 2004 recirculation pilot study but was not detected at concentrations equal to the reporting limit (2 µg/L) (Reclamation 2005). This reporting limit for the carbaryl data is below some water quality criteria but above the EPA aquatic-life criterion. Although recirculation effects are inconclusive, the pilot study data support the conclusion that concentrations in the SJR are likely to be less than the CDFG criteria of 2.53 µg/L.

Pesticide=Carbaryl, Unit=µg/L



Notes:
Criteria (1)=70 µg/L, Criteria (1) Source=EPA Drinking Water Health Advisory
Criteria (2)=0.02 µg/L, Criteria (2) Source=EPA AWQC for Aquatic Life
Data sources and regional groupings are described at the beginning of **Section F2.**

Figure F2-27. Measured Carbaryl Concentrations by Region

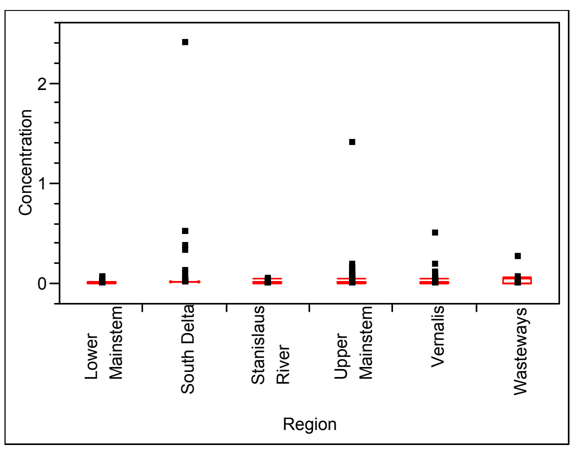
Herbicides

EPTC. EPTC (aka Eptam) is a thiocarbamate herbicide commonly applied to corn, potatoes, beans, and alfalfa to control weeds (EPA 1999b). No regulatory water quality limits exist for EPTC. However, EPTC has an EPA IRIS

Reference Dose of 180 µg/L. According to the ECOTOX database, the LOEC for algae is 6,250 µg/L; the LOEC for plants is 10,000 µg/L; the LC50 for invertebrates is 23,000 µg/L; and the LC50 for fish ranges from 11,500 to 26,670 µg/L depending on the test species (EPA 2008c). The available water quality data are all substantially less than these LOECs and LC50s. Persistence of EPTC in soil is low, making it unlikely to enter surface waters. EPTC is slightly to moderately toxic to humans, slightly toxic to relatively nontoxic to birds, and slightly toxic to aquatic organisms (EXTOXNET 2008).

Figure F2-28 shows the measured EPTC concentrations, which are all significantly less than the IRIS Reference Dose, by region. The detection rate was high along the SJR (50 to 100%), but lower in the Stanislaus River (2%), south Delta (21%), and wasteways (38%). Median concentration in the south Delta is similar to median concentration on the upper mainstem, but greater than median concentration in the lower mainstem or at Vernalis. Data for the wasteways were limited; however, the median concentration was lower than the SJR or south Delta. Recirculation may increase EPTC concentrations in the lower mainstem and Vernalis (as seen by comparison of the median concentrations). Since concentrations of EPTC in all regions are much less than the criteria, the effects from recirculation would not be significant.

Pesticide=EPTC (Eptam), Unit=µg/L



Notes:
Criteria (1)=180 µg/L, Criteria (1) Source=EPA IRIS
Data sources and regional groupings are described at the beginning of **Section F2.**

Figure F2-28. Measured EPTC Concentrations by Region

EPTC was analyzed in the 2004 and 2007 recirculation pilot studies and detected during the 2007 study in samples collected at Newman Wasteway near the confluence with the SJR (Reclamation 2005, 2008). The maximum detected concentration was 0.4 µg/L, which is several orders of magnitude less than the water quality criteria. Therefore, the pilot study data support the conclusion that the changes in EPTC concentrations that are due to recirculation would not be significant.

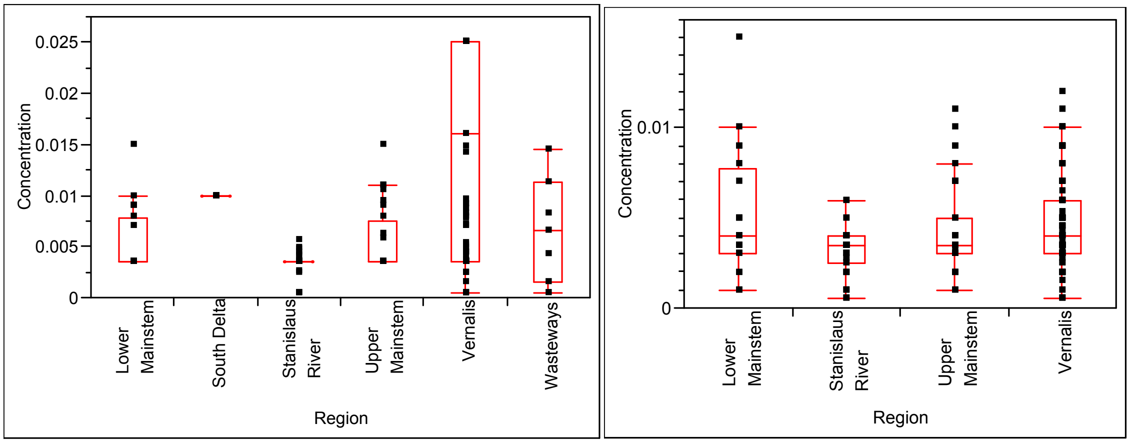
Atrazine. Atrazine is a triazine herbicide primarily applied to corn, sorghum, and sugarcane to control broadleaf and some grassy weeds. It is one of the two most widely used agricultural pesticides in the U.S. (EPA 2006c). The Primary Maximum Contaminant Levels (MCLs) for atrazine in drinking water are 1 µg/L, set by the CDPH, and 3 µg/L, set the EPA. Atrazine has an EPA IRIS Reference Dose of 25 µg/L and an EPA Drinking Water Health Advisory level of 0.15 µg/L. In addition, the EPA has an advisory AWQC of 1 µg/L (instantaneous maximum) and a provisional AWQC of 1,500 µg/L (1-hour average) for freshwater aquatic life protection. Atrazine is slightly to moderately toxic to mammals and slightly toxic to aquatic life. It is highly persistent in soil and has a long half-life, lending to its high potential for groundwater contamination despite moderate solubility in water. Atrazine is the second most common pesticide found in private and community wells (EXTOXNET 2008).

Figure F2-29 shows the measured total and dissolved atrazine concentrations, which are all less than the criteria described above, by region. The box plot on the left shows total atrazine concentrations and the box plot on the right shows dissolved atrazine concentrations. Dissolved atrazine was consistently detected along the SJR and in the Stanislaus River at a median concentration of approximately 0.004 µg/L. The detection rate of total atrazine was often lower than dissolved atrazine. The median total atrazine concentration was highest at Vernalis. Although data are limited to seven samples in the wasteways, total atrazine had a median concentration in the wasteways that was higher than the mainstem segments but lower than Vernalis. Total atrazine was not detected in the south Delta.

Because atrazine was not detected in the south Delta, and reporting limits for the south Delta data were above detected concentrations in the SJR and Stanislaus River, the relative effects from recirculation are uncertain. However, concentrations of atrazine in all regions are much less than the criteria; thus, the effects from recirculation may not be significant.

Atrazine was analyzed in the 2004 and 2007 recirculation pilot studies but was not detected at concentrations equal to the reporting limit (0.05 µg/L) (Reclamation 2005, 2008). Because the reporting limit was substantially below water quality criteria, the pilot study data support the conclusion that the changes in atrazine concentrations that are due to recirculation may not be significant.

Pesticide=Atrazine, Unit=µg/L **Pesticide=Atrazine, Dissolved, Unit=µg/L**



Notes:
Criteria (1)=1 µg/L, Criteria (1) Source=CDPH Primary MCL
Criteria (2)=1 µg/L, Criteria (2) Source=EPA AWQC for Aquatic Life
Data sources and regional groupings are described at the beginning of **Section F2.**

Figure F2-29. Measured Total and Dissolved Atrazine Concentrations by Region

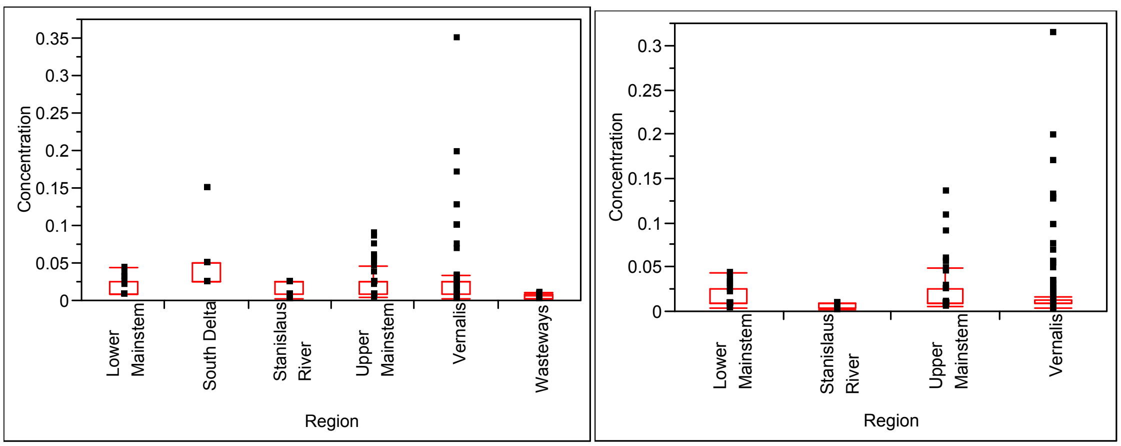
Cyanazine. Cyanazine is a triazine herbicide primarily applied to corn to control annual grasses and broadleaf weeds (EXTOXNET 2008). No regulatory water quality limits exist for cyanazine. However, cyanazine has an EPA Drinking Water Health Advisory level of 1 µg/L. According to the ECOTOX database, the LOEC for fish is 80 µg/L; for invertebrates, it is 80 µg/L; for plants, it is 600 µg/L; and for algae, it is 19 µg/L (EPA 2008c). The available data are all substantially less than these LOECs. Cyanazine is moderately toxic to mammals, and slightly to moderately toxic to birds and aquatic life. Like atrazine, cyanazine is frequently found in groundwater, though it is not as persistent in soil as atrazine (EXTOXNET 2008).

Figure F2-30 shows the measured total and dissolved cyanazine concentrations, which are all less than the EPA advisory level, by region. The box plot on the left shows total cyanazine concentrations and the box plot on the right shows dissolved cyanazine concentrations. Cyanazine was detected in up to 50% of the SJR samples from the dataset; however, the Stanislaus River and the south Delta had low detection rates (0 to 1%). The visual representations of the cyanazine concentrations in the south Delta and the Stanislaus River are due primarily to reporting limits.

Median concentrations of total cyanazine were highest in the upper mainstem and Vernalis, and although wasteway data were limited, median concentrations of total cyanazine was lower in the wasteways than in the SJR. Cyanazine was not analyzed in the recirculation pilot studies.

The effects of recirculation are unknown because of the relatively high reporting limits for the south Delta data; however, concentrations of cyanazine in all regions are much less than the water quality criteria, and the effects from recirculation may therefore not be significant.

Pesticide=Cyanazine, Unit=µg/L **Pesticide=Cyanazine, Dissolved, Unit=µg/L**



Notes:
Criteria (1)=1 µg/L, Criteria (1) Source=EPA Drinking Water Health Advisory
Data sources and regional groupings are described at the beginning of **Section F2.**

Figure F2-30. Measured Total and Dissolved Cyanazine Concentrations by Region

DCPA. DCPA is an alkyl phthalate herbicide used to control annual grasses and broadleaf weeds on ornamental turf and plants, strawberries, seeded and transplanted vegetables, cotton, and field beans (EPA 1998). DCPA has an EPA IRIS Reference Dose of 70 µg/L and an EPA Drinking Water Health Advisory level of 70 µg/L. In addition, the EPA advisory AWQC for freshwater aquatic life protection is 14,300 µg/L (instantaneous maximum). DCPA's toxicity to humans ranges from practically nontoxic to slightly toxic. It was been classified as a possible human carcinogen based on rat studies (EPA 1998). DCPA is slightly toxic to practically nontoxic to birds and aquatic organisms (EXTOXNET 2008).

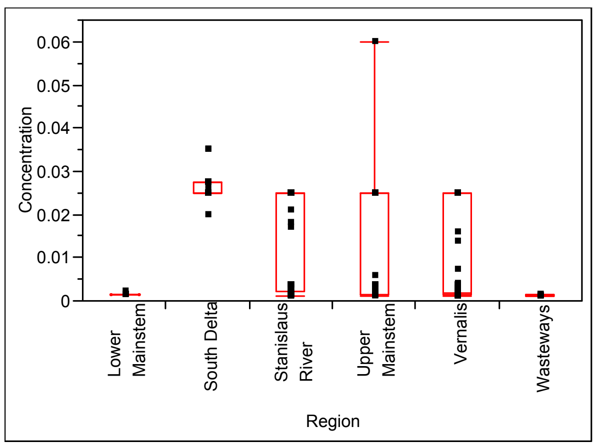
Figure F2-31 shows the measured DCPA concentrations, which are all less than the criteria described above, by region. The detection rate was relatively low throughout the regions, ranging from 0% in the wasteways to 17% at Vernalis. Median concentrations were lowest in the lower mainstem region and at

Vernalis. The median concentrations in the south Delta and Stanislaus River were similar.

Given the available data, it is uncertain whether or not recirculation would increase DCPA concentrations in the SJR; however, concentrations of DCPA in all regions are much less than the criteria and the effects from recirculation may not be significant.

DCPA was analyzed and detected in the 2004 recirculation pilot study in samples collected in the Newman Wasteway near the confluence with the SJR (Reclamation 2005). The maximum detected concentration was 0.38 µg/L, which is several orders of magnitude less than the water quality criteria. Thus, the pilot study data support the conclusion that the changes in DCPA concentrations that are due to recirculation would not be significant.

Pesticide=Dacthal (DCPA), Unit=µg/L



Notes:

Criteria (1)=70 µg/L, Criteria (1) Source=EPA Drinking Water Health Advisory

Criteria (2)=14300 µg/L, Criteria (2) Source=EPA AWQC for Aquatic Life

Data sources and regional groupings are described at the beginning of **Section F2.**

Figure F2-31. Measured DCPA Concentrations by Region

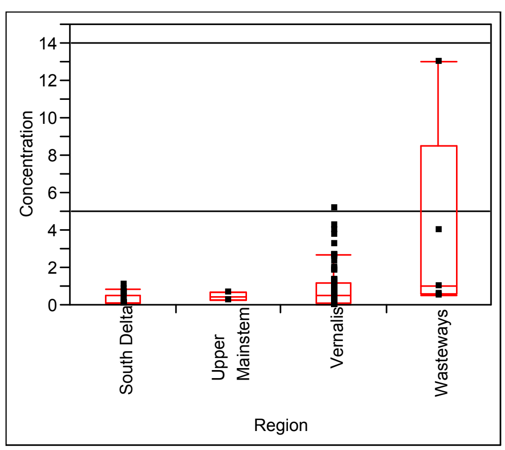
Diuron. Diuron is a urea herbicide applied in both agricultural and nonagricultural settings to control broadleaf and annual grass weeds. It is also used as an algaecide and mildewicide. In California, it is most commonly applied to rights of way, followed by alfalfa and oranges (Moncada 2004). Diuron has an EPA IRIS Reference Dose of 14 µg/L and an EPA Drinking Water Health Advisory level of 21 µg/L. According to the ECOTOX database, the LOEC for algae is 1 µg/L; for aquatic plants, it is 5 µg/L; for invertebrates, it is 3,400 to 22,800 µg/L depending on the test species; and for fish, it is

145,000 to 211,000 µg/L depending on the test species (EPA 2008c). Because of its persistence in soils and stability in neutral water, diuron is commonly detected in groundwater. Diuron is slightly toxic to mammals and birds, moderately toxic to fish, and more toxic to aquatic invertebrates (EXTOXNET 2008).

Figure F2-32 shows the measured diuron concentrations by region in relation to the IRIS reference dose and the LOEC for plants. Sample size was limited in the upper mainstem and wasteways regions. The median concentration in the south Delta was less than the median concentration in the SJR (upper mainstem and Vernalis), while the median concentration in the wasteways was higher. Diuron was not analyzed in the recirculation pilot studies.

Recirculation would introduce a relatively large volume of water to the wasteway agricultural drainage, which may dilute diuron within the wasteway. The wasteway may exhibit higher concentrations of diuron during the initial stages of recirculation, but, in general, diuron concentrations in the wasteways would be characterized by the south Delta. Because median diuron concentrations in the south Delta are less than median concentrations in the upper mainstem and Vernalis, recirculation may be beneficial for these portions of the SJR. Stanislaus River data were not included in this dataset; thus, comparisons between recirculation and additional New Melones releases cannot be evaluated.

Pesticide=Diuron, Unit=µg/L



Notes:

Criteria (1)=14 µg/L, Criteria (1) Source=EPA IRIS

Criteria (2)=5 µg/L, Criteria (2) Source=ECOTOX LOEL for Plants

Data sources and regional groupings are described at the beginning of **Section F2.**

Figure F2-32. Measured Diuron Concentrations by Region

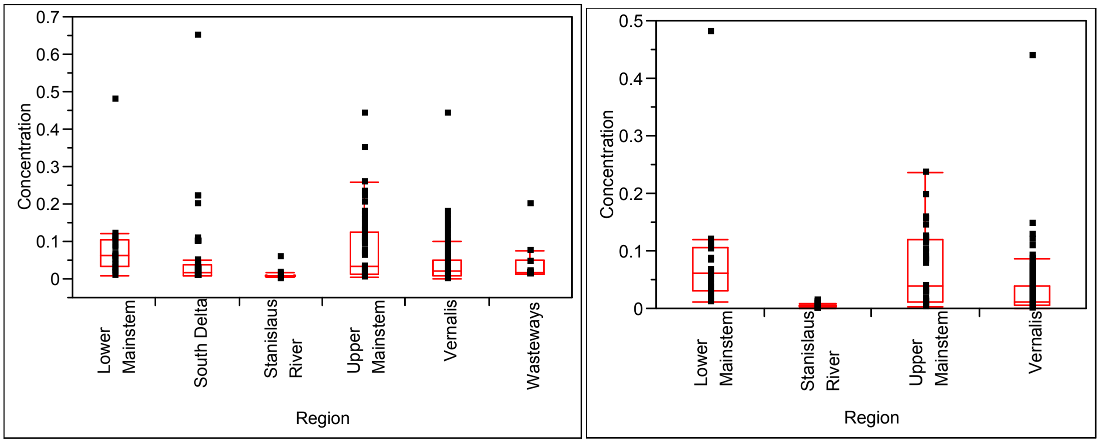
Metolachlor. Metolachlor is a chloracetanilide herbicide primarily applied to corn, soybeans, and sorghum to control weeds. It is also used on lawns and turf, ornamental plants, rights-of-way, and in forestry (EPA 1995a). Metolachlor has an EPA IRIS Reference Dose of 110 µg/L and an EPA Drinking Water Health Advisory level of 70 µg/L. In addition, the EPA has an advisory concentration of 44 µg/L metolachlor for drinking water sources (the AWQC for the protection of human health due to the consumption of water and organisms). The EPA advisory AWQC for the protection of freshwater aquatic life is 100 µg/L. Metolachlor has a very high potential to contaminate groundwater since it is relatively mobile and persistent in soil (Rivard 2003). It can be slightly toxic to humans, is slightly toxic to practically nontoxic to birds, and is moderately toxic to fish (EXTOXNET 2008).

Figure F2-33 shows the measured total and dissolved metolachlor concentrations, which are all less than the criteria described above, by region. The box plot on the left shows total metolachlor concentrations and the box plot on the right shows dissolved metolachlor concentrations. Metolachlor had a relatively high detection rate of 68 to 100% along the SJR and a lower detection rate in the south Delta and Stanislaus River. For metolachlor, median concentrations were highest in the lower mainstem and lowest in the Stanislaus River. Median concentrations for total metolachlor in the south Delta and the wasteways were less than the SJR but greater than the Stanislaus River.

Although recirculation may not be as efficient a dilution flow as additional New Melones releases, recirculation may have a beneficial effect in the upper and lower mainstem as well as at Vernalis. However, because the concentrations of metolachlor are much less than the criteria, the effects from recirculation may not be significant.

Metolachlor was analyzed and detected in the 2004 and 2007 recirculation pilot studies in samples collected from the Newman Wasteway and from the SJR (Reclamation 2005, 2008). Highest concentrations were detected at Newman Wasteway near the confluence with the SJR just prior to the start of recirculation. Concentrations in the wasteway decreased during the first day of recirculation while concentration in the SJR downstream of the wasteway remained similar to background concentrations. After the first week of recirculation, metolachlor concentrations were not detected in the wasteway or the SJR (Reclamation 2008). The maximum detected metolachlor concentration was 0.47 µg/L (Reclamation 2005), which is several orders of magnitude less than the water quality criteria. Thus, the pilot study data support the conclusion that changes in metolachlor concentrations due to recirculation may not be significant.

Pesticide=Metolachlor, Unit=µg/L **Pesticide=Metolachlor, Dissolved, Unit=µg/L**



Notes:

Criteria (1)=70 µg/L, Criteria (1) Source=EPA Drinking Water Health Advisory

Criteria (2)=100 µg/L, Criteria (2) Source=EPA AWQC for Aquatic Life

Note: Data sources and regional groupings are described at the beginning of **Section F2.**

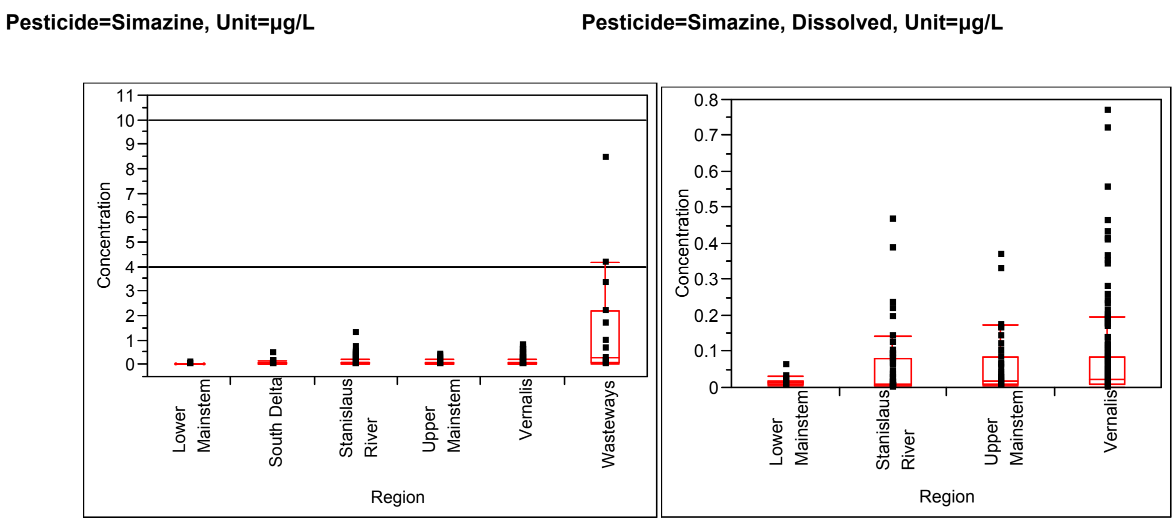
Figure F2-33. Measured Metolachlor Concentrations by Region

Simazine. Simazine is a triazine herbicide commonly applied to fruits and nuts to control broadleaf weeds and annual grasses (EPA 2006d). It is also used as an algaecide (Gunasekara 2004). The Primary MCL for simazine in drinking water is 4 µg/L, set by both the CDPH and the EPA. Simazine has an EPA IRIS Reference Dose of 3.5 µg/L and an EPA Drinking Water Health Advisory level of 140 µg/L. The EPA recommends an AWQC of 10 µg/L (instantaneous maximum); this 1972 criterion does not appear in the current list of recommended criteria. Simazine is slightly toxic to practically nontoxic to mammals, birds, and aquatic life in general, but is moderately toxic to freshwater fish and highly toxic to freshwater invertebrates (EXTOXNET 2008; EPA 2006d). Like the other triazine herbicides atrazine and cyanazine, simazine is often detected in groundwater (Gunasekara 2004).

Figure F2-34 shows the measured total and dissolved simazine concentrations by region relative to the Primary MCL and recommended AWQC for aquatic life. The box plot on the left shows total simazine concentrations and the box plot on the right shows dissolved simazine concentrations. Detection rates for total and dissolved simazine were relatively high for all regions. Except for total simazine in the Stanislaus River, each region detected simazine at rates above 50%. The Stanislaus River had a lower median concentration of dissolved simazine than the SJR; however, the median concentration for total simazine was higher than for the SJR. The median concentrations for total simazine in the south Delta were higher than median concentrations in the SJR (upper mainstem, lower mainstem, and Vernalis). The wasteways had the highest median concentration of total simazine.

Recirculation may dilute simazine within the wasteway but simazine concentrations in the recirculation flow may be greater than the SJR (as seen by comparison of the median concentrations in the SJR and south Delta) and possibly may degrade water quality. The wasteways may also exhibit higher concentrations of simazine during the initial stages of recirculation. However, simazine concentrations in the SJR would not likely be greater than the Primary MCL or recommended AWQC for aquatic life because of recirculation; therefore, the effects from recirculation may not be significant.

Simazine was analyzed in the 2004 and 2007 recirculation pilot studies but was not detected at concentrations equal to the reporting limit (0.05 µg/L) (Reclamation 2005 and 2008). The simazine reporting limit was substantially less than the water quality criteria. Thus, the pilot study data support the conclusion that changes in simazine concentrations due to recirculation may not be significant.



Notes:

Criteria (1)=4, Criteria (1) Source=CDPH Primary MCL

Criteria (2)=10, Criteria (2) Source=EPA AWQC for Aquatic Life

Data sources and regional groupings are described at the beginning of **Section F2.**

Figure F2-34. Measured Total and Dissolved Simazine Concentrations by Region

Trifluralin. Trifluralin is a dinitroaniline herbicide that is commonly applied to tree fruit, nut, vegetable, and grain crops to control annual grasses and broadleaf weeds (EXTOXNET 2008). It is also used in residential settings (EPA 1996). No regulatory water quality limits exist for trifluralin. It has an EPA IRIS

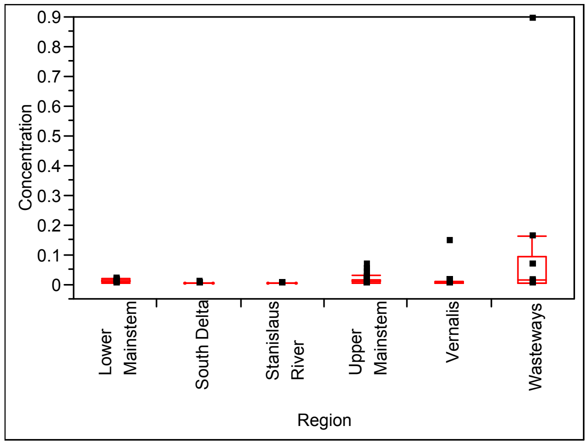
Reference Dose of 5.3 µg/L and an EPA Drinking Water Health Advisory level of 10 µg/L. According to the ECOTOX database, the LC50 for invertebrates ranges from 37 to 50,000 µg/L depending on the test species; for fish, it ranges from 8.4 to 2,000 µg/L depending on the test species; and for amphibians, it is 100 µg/L. The LOEC is 300 µg/L for algae and 150 µg/L for plants (EPA 2008c). The available water quality data are all substantially less than these LOECs and LC50s. Trifluralin is practically nontoxic to mammals and birds, and moderately to highly toxic to aquatic life. It has been classified as a possible human carcinogen (EPA 1996). Trifluralin is nearly insoluble in water and can likely be found adsorbed to particulates in the water column (EXTOXNET 2008).

Figure F2-35 shows the measured trifluralin concentrations, which are all less than the criteria described above, by region. The detection rates were generally high; however, detection rates in the south Delta and Stanislaus River regions were lower at 5 and 23%, respectively. Median concentrations were higher in the upper mainstem and the wasteways and lower in the Stanislaus River, south Delta, and at Vernalis. The south Delta had a median concentration greater than Vernalis but less than the upper and lower mainstem; however, some uncertainty exists in south Delta concentrations due to the low detection frequency and higher reporting limits.

Recirculation would introduce a relatively large volume of water to the wasteway agricultural drainage, which may dilute contaminants within the wasteway. The wasteways may exhibit higher concentrations of trifluralin concentrations during the initial stages of recirculation, but, in general, trifluralin concentrations in the SJR would not be expected to substantially increase. Because concentrations of trifluralin are much less than the water quality criteria, the effects from recirculation may not be significant.

Trifluralin was analyzed in the 2004 and 2007 recirculation pilot studies but was not detected at concentrations equal to the reporting limit (0.1 µg/L) (Reclamation 2005 and 2008). The trifluralin reporting limit was substantially less than the water quality criteria. Thus, the pilot study data support the conclusion that changes in trifluralin concentrations due to recirculation may not be significant.

Pesticide=Trifluralin, Unit=µg/L



Notes:

Criteria (1)=5.3 µg/L, Criteria (1) Source=EPA IRIS

Data sources and regional groupings are described at the beginning of **Section F2.**

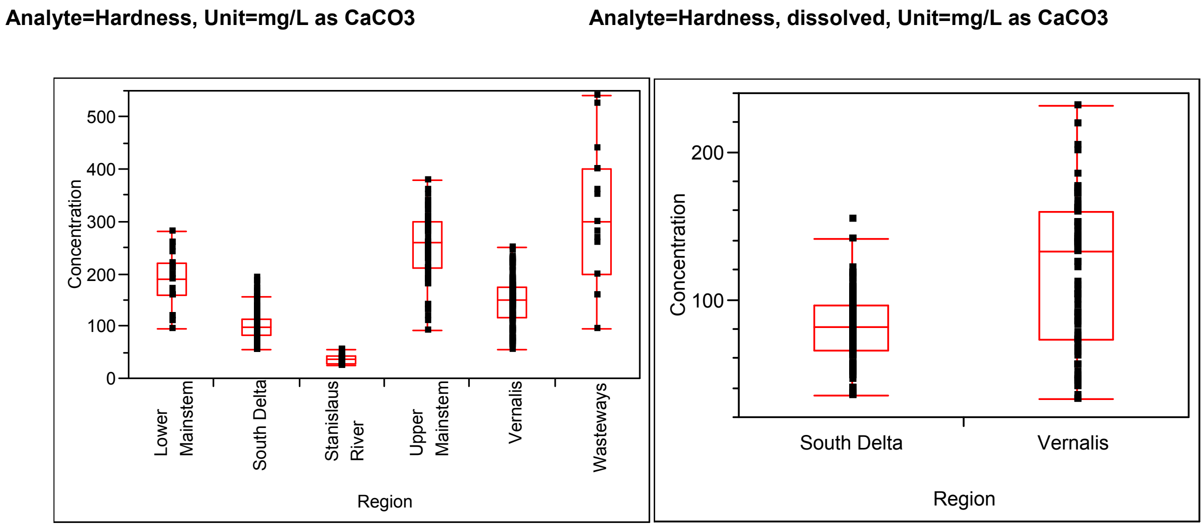
Figure F2-35. Measured Trifluralin Concentrations by Region

Trace Metals

Metals are a possible source of aquatic toxicity within the SJR and Delta. Metals may adsorb strongly to clays, muds, humic, and organic materials; however, they may also be very mobile in the environment. Depending upon the pH, hardness, salinity, oxidation state of the element, soil saturation, and other factors, metals are readily soluble (EPA 2008b).

The EPA recommended AWQC for the protection of freshwater aquatic life for cadmium, chromium, copper, lead, nickel, and zinc are expressed as a function of hardness in the water column. As hardness increases, the toxicity of these metals tends to decrease and the AWQC increases. The lowest AWQC associated with these parameters correspond to a hardness of 25 mg/L as calcium carbonate ($CaCO_3$).

The hardness in the SJR varies, but is typically greater than the hardness in the south Delta or the Stanislaus River (**Figure F2-36**). The median hardness in the Stanislaus River is 36 mg/L, the median hardness in the south Delta is approximately 100 mg/L, and the median hardness at Vernalis is 150 mg/L. The AWQC associated with 25 mg/L hardness and with 100 mg/L hardness are used as a basis of comparison to the data. As conservative estimate, an AWQC based on a hardness of 25 mg/L $CaCO_3$ is used for the Stanislaus River and the south Delta and an AWQC based on a hardness of 100 mg/L $CaCO_3$ is used for the SJR (upper mainstem, lower mainstem, and Vernalis).



Note: Data sources and regional groupings are described at the beginning of **Section F2**.

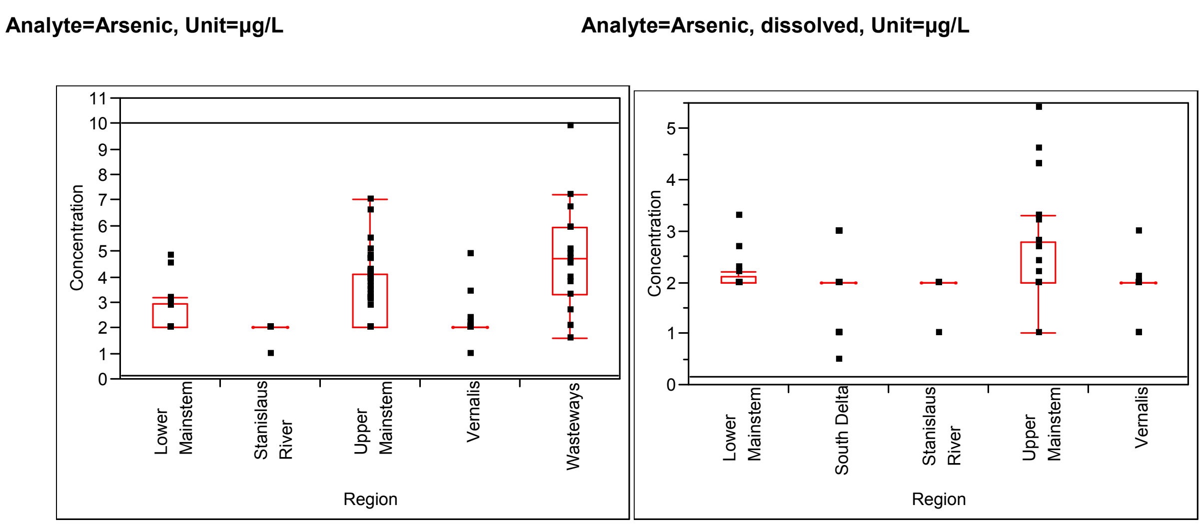
Figure F2-36. Measured Hardness by Region

Arsenic The Basin Plan objective for arsenic and the EPA Primary MCL for arsenic in drinking water is 10 µg/L, due to human health effects associated with chronic exposure to arsenic. The EPA recommended AWQC for human health due to effects associated with the consumption of contaminated water and organisms is 0.018 µg/L inorganic fraction, and the criterion for human health effects due to the consumption of organisms alone is 0.14 µg/L. These recommended criteria are based on a 10^{-6} cancer risk. The EPA AWQC for the protection of freshwater aquatic life is higher than the human health criteria. The chronic criterion for dissolved arsenic is 150 µg/L and the acute criterion is 340 µg/L. Health effects from chronic arsenic exposure include skin damage, problems with circulatory systems, and increased cancer risk. Arsenic has been linked to cancer of the bladder, lungs, skin, kidney, nasal passages, liver, and prostate (EPA 2008e).

Figure F2-37 shows measured arsenic concentrations by region in the lower San Joaquin basin and Delta. The box plot on the left shows total arsenic concentrations and the box plot on the right shows dissolved arsenic concentrations. Median concentrations are similar throughout the SJR (Vernalis, lower mainstem, and upper mainstem) and the south Delta; however, median concentrations in the wasteways are higher. The detection rates for total and dissolved arsenic in the Stanislaus River are 0%. The visual representation of the arsenic concentrations in the Stanislaus River corresponds to half of the reporting limit of the data.

Recirculation would introduce a relatively large volume of water to the resident agricultural drainage within the wasteway, which may dilute contaminants within the wasteway. Although the wasteway may exhibit higher concentrations of arsenic in the initial stages of recirculation, the majority of the recirculation flow is expected to have concentrations similar to the south Delta. Detected concentrations in the south Delta and SJR are above the EPA AWQC for human health (0.018 µg/L, 0.14 µg/L), but below the Basin Plan WQO and the EPA Primary MCL (10 µg/L). Recirculation is not expected to help the SJR in achieving the EPA AWQC, but it is expected that the SJR would continue to meet the Basin Plan and EPA drinking water standards.

Dissolved arsenic was analyzed in the 2004, 2007, and 2008 recirculation pilot studies and was consistently detected at concentrations less than the Basin Plan WQO but greater than the EPA human health AWQC (Reclamation 2005, 2008, and in press). During recirculation, dissolved arsenic concentrations tended to decrease in the SJR immediately downstream of Newman Wasteway relative to the SJR location upstream of the wasteway. Thus, the pilot study data indicate that recirculation was beneficial for this portion of the river and support the conclusion that the SJR would continue to meet Basin Plan WQO.



Notes:
Criteria (1)=10 µg/L, Basis for Criteria (1)=Basin Plan WQO
Criteria (2)=0.14 µg/L, Basis for Criteria (2)=EPA AWQC for Human Health
Data sources and regional groupings are described at the beginning of **Section F2**.

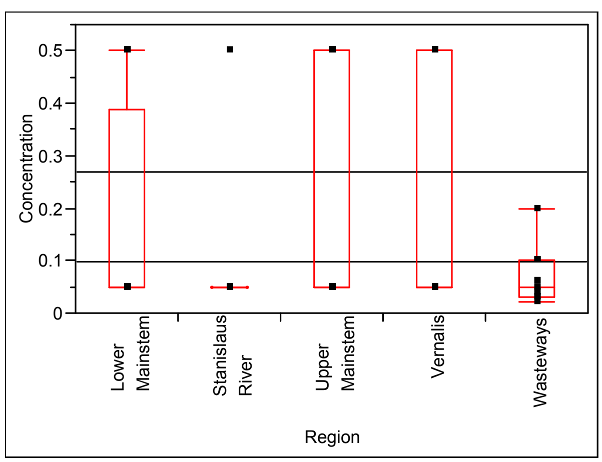
Figure F2-37. Measured Arsenic by Region

Cadmium. The EPA recommended AWQC for cadmium for the protection of freshwater aquatic life is expressed as a function of hardness. The AWQC is a 4-day average of 0.097 µg/L and 0.094 µg/L for total and dissolved cadmium respectively, when hardness is 25 mg/L $CaCO_3$. The 4-day average AWQC changes to 0.27 µg/L and 0.25 µg/L for total and dissolved cadmium, when hardness is 100 mg/L $CaCO_3$. Cadmium is cancer-causing with severe sublethal and lethal effects at low environmental concentrations. It bioaccumulates at all trophic levels and accumulates in the livers and kidneys of fish (EPA 2008b).

Figure F2-38 shows measured cadmium concentrations by region in the lower San Joaquin basin and Delta. The box plot shows total cadmium concentrations; dissolved cadmium was not detected. Cadmium was not detected in the Stanislaus River, south Delta, and the SJR (Vernalis, upper mainstem, and lower mainstem). The concentrations seen in the box plot for these regions represent values equal to half of the reporting limit. Although data were limited, the detection rate in the wasteways was 93% with a median concentration of 0.05 µg/L. Detected wasteway concentrations are below the AWQC that is based on hardness of 100 mg/L $CaCO_3$. Due to the low detection rates of cadmium, the effects of recirculation are inconclusive.

Dissolved cadmium was analyzed in the 2004 recirculation pilot study but was not detected at concentrations greater than the reporting limit (0.25 µg/L) (Reclamation 2005). This reporting limit is similar to the aquatic life criterion based on 100 mg/L hardness. Cadmium concentrations were likely below the criteria during the pilot study; however, the relative effects that were due to recirculation were inconclusive.

Analyte=Cadmium, Unit=µg/L



Notes:
Criteria (1)=0.097 µg/L, Basis for Criteria (1)=EPA AWQC for Aquatic Life (25 mg/L hardness),
Criteria (2)=0.27 µg/L, Basis for Criteria (2)=EPA AWQC for Aquatic Life (100 mg/L hardness)
Data sources and regional groupings are described at the beginning of **Section F2**.

Figure F2-38. Measured Cadmium by Region

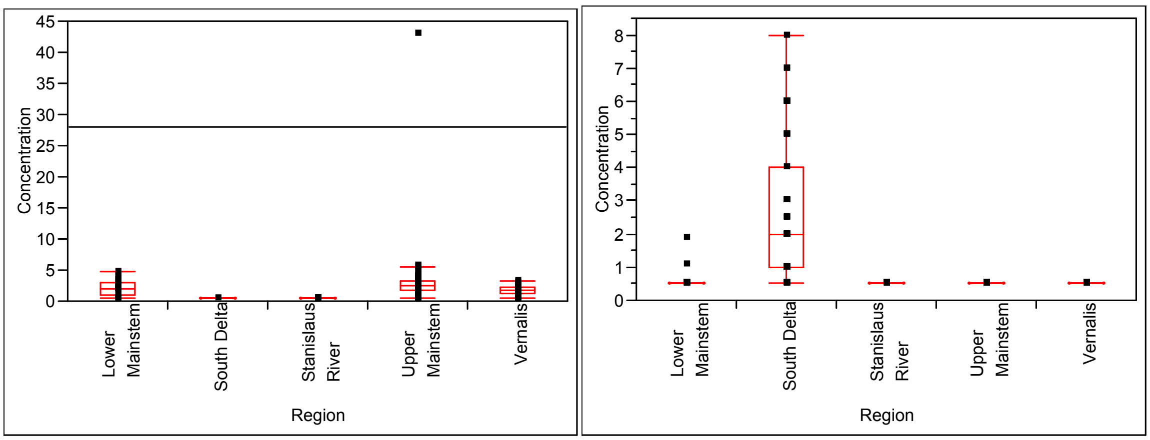
Chromium. The EPA recommended AWQC for chromium for the protection of freshwater aquatic life is expressed as a function of hardness. The AWQC is a 4-day average of 28 μg/L and 24 μg/L for total and dissolved chromium respectively, when hardness is 25 mg/L $CaCO_3$. The 4-day average AWQC changes to 86 μg/L and 74 μg/L for total and dissolved chromium, when hardness is 100 mg/L $CaCO_3$. The acute toxicity of chromium to aquatic life decreases as hardness and pH increase. No significant biomagnification of chromium occurs in aquatic food webs; however, a wide range of adverse effects exists in aquatic organisms such as algae, benthic invertebrates, and embryos and fingerlings of freshwater fish and amphibians (EPA 2008b).

Figure F2-39 shows measured chromium concentrations by region in the lower San Joaquin basin and Delta. The box plot on the left shows total chromium concentrations and the box plot on the right shows dissolved chromium concentrations. The detection rates for dissolved chromium in the SJR and for total and dissolved chromium in Stanislaus River are low (0 and 8%). The sample size for total chromium in the south Delta is too low to be a reliable indicator of concentration. Chromium concentrations in the wasteways were not measured. The median concentration of dissolved chromium in the south Delta is greater than in the lower mainstem (the upper mainstem and Vernalis are undetected). Concentrations of dissolved chromium in the south Delta are greater than the concentration associated with the nondetected level in the Stanislaus River. Except for one total chromium sample from the upper mainstem, detected concentrations do not approach the EPA AWQC. All detected concentrations are below the AWQC based on 100 mg/L hardness.

If relative concentrations between regions show a similar pattern for total and dissolved constituents, then the median concentration for total chromium in the south Delta may be higher than the SJR. Recirculation may degrade water quality for chromium in the SJR (as seen by concentrations of dissolved chromium in the south Delta); however, chromium concentrations are less than the criteria and, therefore, the effects from recirculation would not be significant.

Dissolved chromium was analyzed in the 2004 recirculation pilot study but was infrequently detected at concentrations greater than the reporting limit (0.5 μg/L) (Reclamation 2005). Detected concentrations were substantially less than the aquatic life criteria. Thus, the pilot study data support the conclusion that changes in cadmium concentrations may not be significant.

Analyte=Chromium, Unit=µg/L **Analyte=Chromium, dissolved, Unit=µg/L**



Notes:

Criteria for Total (1)=28 µg/L, Basis for Criteria (1)=EPA AWQC for Aquatic Life (25 mg/L hardness)

Criteria for Total (2)=86 µg/L, Basis for Criteria (2)=EPA AWQC for Aquatic Life (100 mg/L hardness)

Criteria for Dissolved (1)=24 µg/L, Basis for Criteria (1)=EPA AWQC for Aquatic Life (25 mg/L hardness)

Criteria for Dissolved (2)=74 µg/L, Basis for Criteria (2)=EPA AWQC for Aquatic Life (100 mg/L hardness)

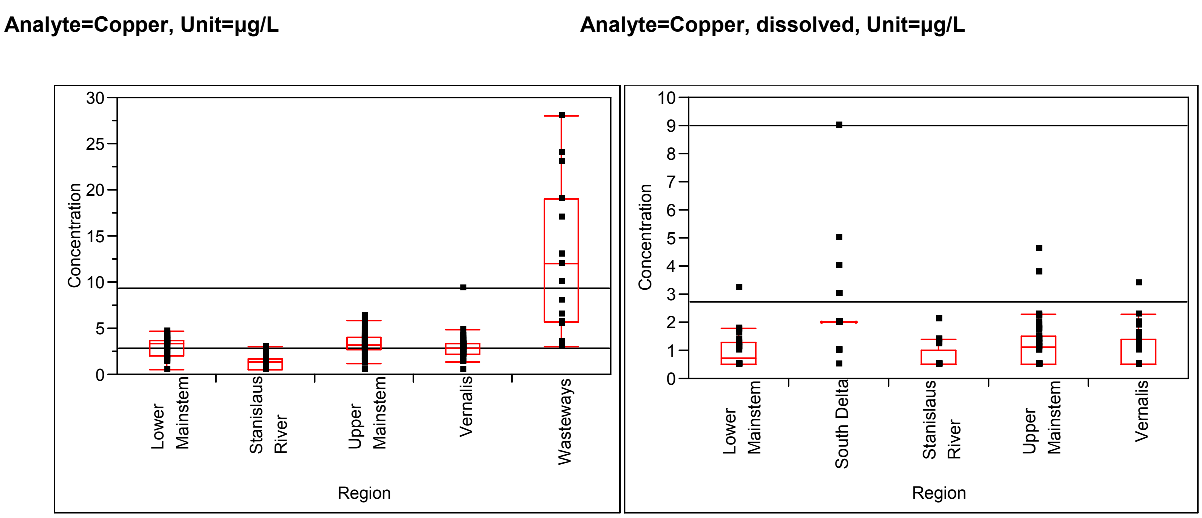
Data sources and regional groupings are described at the beginning of **Section F2**.

Figure F2-39. Measured Chromium by Region

Copper. California Toxics Rule criteria and the EPA recommended AWQC for the protection of freshwater aquatic life is a 4-day average of 2.9 µg/L and 2.7 µg/L for total and dissolved copper respectively, when hardness is 25 mg/L $CaCO_3$. The 4-day average AWQC is 9.3 µg/L and 9 µg/L for total and dissolved copper, when hardness is 100 mg/L $CaCO_3$. In the aquatic environment, the bioavailability of copper depends on how much of the copper is dissolved and ready for uptake in the water column. At lower alkalinity, copper is generally more toxic to wildlife. The main cause of copper toxicity to aquatic organisms is through rapid binding to the gill membranes, which causes damage and interferes with osmoregulatory processes (EPA 2006e).

Figure F2-40 shows measured copper concentrations by region in the lower San Joaquin basin and Delta. The box plot on the left shows total copper concentrations and the box plot on the right shows dissolved copper concentrations. The detection rates for total and dissolved copper are relatively high. Median concentrations of dissolved copper are higher in the south Delta than in the SJR. Median concentrations of total copper are highest for the wasteway agricultural drainage. The median concentrations for total copper in the lower mainstem and the upper mainstem of the SJR are above the AWQC that is based on 25 mg/L hardness but below the AWQC based on 100 mg/L hardness. The wasteway is the only region that has detections consistently greater than the AWQC that is based on 100 mg/L hardness.

Although the concentration of total copper in the south Delta is not measured by this dataset, if relative concentrations between regions show a similar pattern for total and dissolved constituents, then the median concentration for total copper in the south Delta may be greater than the SJR segments. Recirculation would introduce a relatively large volume of water to the wasteway agricultural drainage, which may dilute copper within the wasteway. Recirculation may initially contribute higher concentrations of wasteway copper to the SJR, but copper concentrations for the majority of the recirculation flow should be similar to concentrations in the south Delta. Recirculation may degrade water quality in the SJR during portions of the year; however, copper concentrations may be less than the AWQC based on 100 mg/L hardness. If concentrations are below the criteria, changes in copper concentrations that are due to recirculation would not be significant



Notes:
Criteria for Total (1)=2.9 µg/L, Basis for Criteria (1)=EPA AWQC for Aquatic Life (25 mg/L hardness)
Criteria for Total (2)=9.3 µg/L, Basis for Criteria (2)=EPA AWQC for Aquatic Life (100 mg/L hardness)
Criteria for Dissolved (1)=2.7 µg/L, Basis for Criteria (1)=EPA AWQC for Aquatic Life (25 mg/L hardness)
Criteria for Dissolved (2)=9 µg/L, Basis for Criteria (2)=EPA AWQC for Aquatic Life (100 mg/L hardness)
Data sources and regional groupings are described at the beginning of **Section F2**.

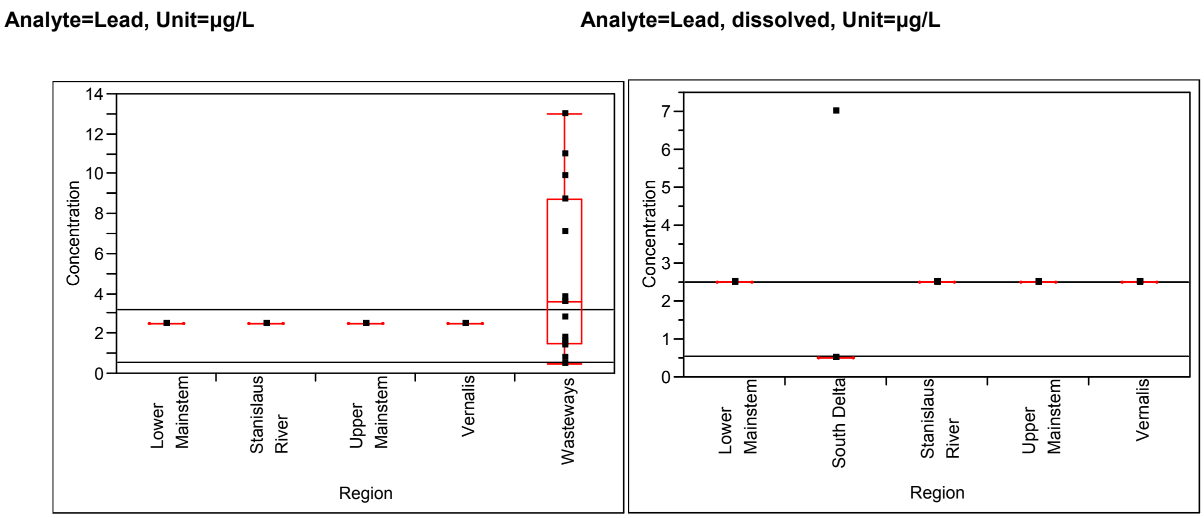
Figure F2-40. Measured Copper by Region

Dissolved copper was analyzed in the 2004, 2007, and 2008 recirculation pilot studies and was consistently detected (Reclamation 2005, 2008, and in press). Dissolved copper concentrations were generally lower in the wasteway than in the SJR. During recirculation, dissolved copper concentrations tended to decrease in the SJR immediately downstream of Newman Wasteway relative to the SJR location upstream of the wasteway. Dissolved copper concentrations in the SJR were below the aquatic life criterion based on 100 mg/L hardness, and during the 2008 study concentrations were also below the aquatic life criterion based on 25 mg/L hardness. These observations contrast with the conclusions based on comparison of the median value of the regional data. Dissolved copper concentrations in the SJR, south Delta, and wasteway may be seasonal, and the pilot study data indicate that during late summer, recirculation may be beneficial. However, concentrations were likely to be below the aquatic life criteria and changes in copper concentrations due to recirculation may not be significant.

Lead. Both a WQO for drinking water and an AWQC for aquatic life exist for lead. The Basin Plan stipulates that water designated for use as a domestic or municipal supply should have lead concentrations less than 15 µg/L. The EPA Primary MCL for lead is also 15 µg/L. The EPA recommended AWQC for lead for the protection of freshwater aquatic life is expressed as a function of hardness. The AWQC is a 4-day average of 0.54 µg/L for both total and dissolved lead when hardness is 25 mg/L $CaCO_3$. The AWQC is 3.2 µg/L and 2.5 µg/L for total and dissolved lead when the hardness is 100 mg/L $CaCO_3$.

Lead can cause a variety of adverse human health effects. At relatively low levels of exposure, these effects may include interference with red blood cell chemistry, delays in normal physical and mental development in babies and young children, slight deficits in the attention span, hearing, and learning abilities of children, and slight increases in the blood pressure of some adults. It appears that some of these effects may occur at blood lead levels so low as to be essentially without a threshold. Chronic exposure to lead has been linked to cerebrovascular and kidney disease. Lead also has the potential to cause cancer from a lifetime of exposure (EPA 1995b). Fish exposed to high levels of lead exhibit a wide range of effects including muscular and neurological degeneration and destruction, growth inhibition, mortality, reproductive problems, and paralysis. In invertebrates, lead can adversely affect reproduction. In algae, growth can be affected by lead (EPA 2008b).

Figure F2-41 shows measured lead concentrations by region in the lower San Joaquin basin and Delta. The box plot on the left shows total lead concentrations and the box plot on the right shows dissolved lead concentrations. Lead is undetected in all regions with the exception of the wasteways (for total lead) and one sample in the south Delta (for dissolved lead). The reporting limits for total and dissolved lead for samples from the SJR, Stanislaus River, and the south Delta are above the AWQC based on 100 mg/L hardness (the visual representation on the box plots represent half of the reporting limit). The wasteways have a median concentration above the AWQC based on 100 mg/L hardness. Recirculation would introduce a relatively large volume of water to the wasteway agricultural drainage, which may dilute lead concentrations within the wasteway; however, higher concentrations of lead may occur during the initial stage recirculation. The relative effects of recirculation on SJR concentrations and possible trade-offs between recirculation and additional New Melones releases cannot be evaluated because the data are inconclusive.



Notes:
Criteria for Total (1)=0.54 µg/L, Basis for Criteria (1)=EPA AWQC for Aquatic Life (25 mg/L hardness)
Criteria for Total (2)=3.2 µg/L, Basis for Criteria (2)=EPA AWQC for Aquatic Life (100 mg/L hardness)
Criteria for Dissolved (1)=0.54 µg/L, Basis for Criteria (1)=EPA AWQC for Aquatic Life (25 mg/L hardness)
Criteria for Dissolved (2)=2.5 µg/L, Basis for Criteria (2)=EPA AWQC for Aquatic Life (100 mg/L hardness)
Data sources and regional groupings are described at the beginning of **Section F2**.

Figure F2-41. Measured Lead by Region

Dissolved lead was analyzed in the 2004 recirculation pilot study but was not detected at concentrations greater than the reporting limit (0.5 µg/L) with the exception of a statistical outlier (Reclamation 2005). The reporting limit is similar to the aquatic life criterion based on 25 mg/L hardness; therefore, dissolved lead concentrations are likely below the criterion. The pilot study data do not provide additional insights into relative changes in concentrations during recirculation; however, the wasteway did not contribute dissolved lead such that concentrations in the SJR were above 0.5 µg/L. Thus, the pilot study data indicate that changes in dissolved lead concentrations due to recirculation may not be significant.

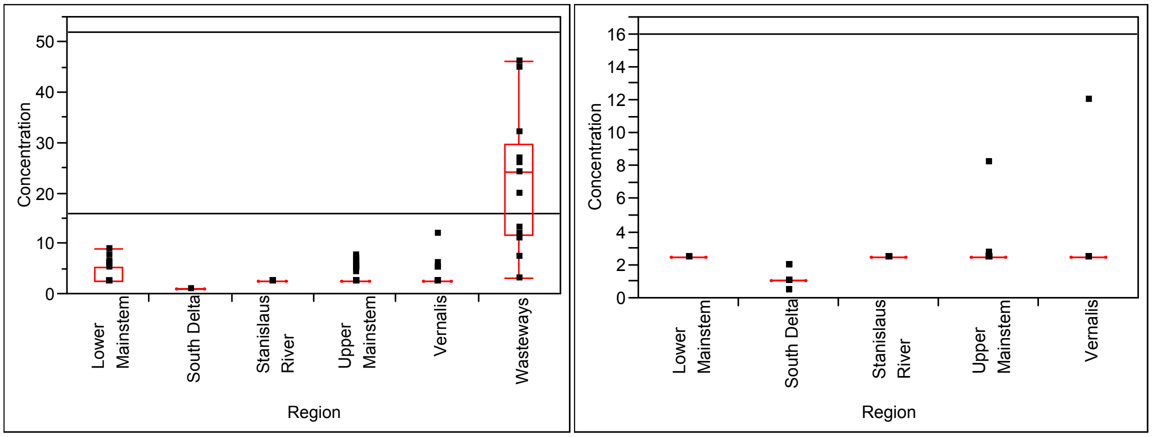
Nickel. The EPA recommended AWQC for nickel for the protection of freshwater aquatic life is expressed as a function of hardness. The AWQC is a 4-day average of 16 µg/L for both total and dissolved nickel when hardness is at 25 mg/L $CaCO_3$. The 4-day average AWQC is 52 µg/L for total and dissolved nickel when hardness is 100 mg/L $CaCO_3$. Nickel is a carcinogen and a mutagen. Effects of nickel in aquatic environments can include tissue damage, genotoxicity, and growth reduction (EPA 2008b).

Figure F2-42 shows measured nickel concentrations by region in the lower San Joaquin basin and Delta. The box plot on the left shows total nickel concentrations and the box plot on the right shows dissolved nickel concentrations. Detection rates for dissolved nickel in the SJR and the Stanislaus River are low (0 to 4%). Total nickel in the Stanislaus is undetected. The sample size for total nickel in the south Delta is too low to be a reliable indicator of concentration. Median concentrations for dissolved nickel in the south Delta are lower than median concentrations in the SJR. Total and dissolved nickel concentrations in the south Delta and SJR (lower mainstem, upper mainstem, and Vernalis) are well below the AWQC. Detected concentrations in the wasteways are below the AWQC based on 100 mg/L hardness.

Recirculation would introduce a relatively large volume of water to the wasteway agricultural drainage, which may dilute contaminants within the wasteway. During recirculation, the wasteways may exhibit higher concentrations of nickel concentrations in the initial stages of recirculation, but recirculation is not expected to result in concentrations greater than the AWQC in the SJR because of dilution in the wasteway and the hardness in the SJR. Recirculation may have a beneficial effect on nickel concentrations in the SJR (as seen by comparison of median concentrations of dissolved nickel in the south Delta and the SJR). However, nickel concentrations may be less than the AWQC and the effects from recirculation may not be significant.

Dissolved nickel was analyzed in the 2004 recirculation pilot study and was consistently detected at concentrations below the aquatic life criterion based on 25 mg/L hardness (Reclamation 2005). During recirculation, dissolved nickel concentrations tended to decrease in the SJR immediately downstream of Newman Wasteway relative to the SJR location upstream of the wasteway. Because concentrations were likely less than the aquatic life criteria, the pilot study data support the conclusion that changes in nickel concentrations due to recirculation may not be significant.

Analyte=Nickel, Unit=µg/L **Analyte=Nickel, dissolved, Unit=µg/L**



Criteria for Total (1)=16 µg/L, Basis for Criteria (1)=EPA AWQC for Aquatic Life (25 mg/L hardness)
Criteria for Total (2)=52 µg/L, Basis for Criteria (2)=EPA AWQC for Aquatic Life (100 mg/L hardness)
Criteria for Dissolved (1)=16 µg/L, Basis for Criteria (1)=EPA AWQC for Aquatic Life (25 mg/L hardness)
Criteria for Dissolved (2)=52 µg/L, Basis for Criteria (2)=EPA AWQC for Aquatic Life (100 mg/L hardness)
Data sources and regional groupings are described at the beginning of **Section F2**.

Figure F2-42. Measured Nickel by Region

Zinc. The California Toxics Rule criteria for inland surface water and the EPA recommended AWQC for zinc for the protection of freshwater aquatic life have the same values and are expressed as a function of hardness. The AWQC is a 4-day average of 37 and 36 µg/L, for total and dissolved zinc, respectively, when hardness is 25 mg/L $CaCO_3$. The 4-day average AWQC is 120 µg/L for total and dissolved zinc when hardness is 100 mg/L $CaCO_3$. In aquatic environments, zinc is slightly to moderately toxic to aquatic organisms. Chronic and acute zinc toxicity decreases as hardness increases and increases as pH increases. As with other heavy metals, bioaccumulation of zinc has been observed in aquatic organisms (CVRWQCB 2007).

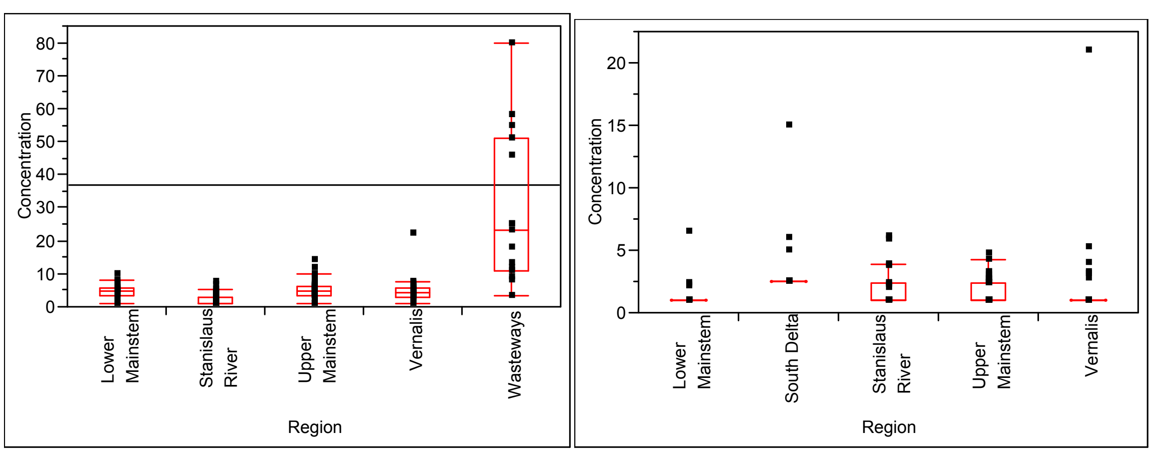
Figure F2-43 shows measured zinc concentrations by region in the lower San Joaquin basin and Delta. The box plot on the left shows total zinc concentrations and the box plot on the right shows dissolved zinc concentrations. The concentration of total zinc in the south Delta is not measured by this dataset. The detection frequency for dissolved zinc in the south Delta is low (3%). The median concentration for dissolved zinc in the south Delta is higher than the median concentration in the SJR; however, this concentration may be an artifact due to higher reporting limits. Dissolved zinc concentrations in the south Delta, the Stanislaus River, and SJR (lower mainstem, upper mainstem, and Vernalis) are well below the AWQC. Total zinc concentrations in the SJR and the Stanislaus River are also below the AWQC.

Concentrations were detected in the wasteways above the AWQC based on 25 mg/L hardness but below the AWQC based on 100 mg/L hardness.

Recirculation would introduce a relatively large volume of water to the wasteway agricultural drainage, which may dilute zinc within the wasteway. During recirculation the wasteways may exhibit higher concentrations of zinc concentrations in the initial stages of recirculation, but it is unlikely to result in concentrations greater than the AWQC in the SJR because of dilution in the wasteway and hardness in the SJR. Recirculation may degrade water quality for zinc (as seen by comparison of the median concentrations for dissolved zinc in the south Delta and SJR). Alternatively, concentrations in the SJR may remain the same (if the median concentration in the south Delta is elevated because of higher reporting limits). However, zinc concentrations may be less than the AWQC and, therefore, the effects from recirculation may not be significant.

Dissolved zinc was analyzed in the 2004 recirculation pilot study but typically was not detected at concentrations greater than the reporting limit (2.0 µg/L) (Reclamation 2005). With the exception of statistical outliers, the maximum concentration detected was 3.7 µg/L, which is substantially less than the aquatic life criterion. Thus, the pilot study data support the conclusion that changes in zinc concentrations due to recirculation may not be significant.

Analyte=Zinc, Unit=µg/L **Analyte=Zinc, dissolved, Unit=µg/L**



Notes:
Criteria for Total (1)=37 µg/L, Basis for Criteria (1)=EPA AWQC for Aquatic Life (25 mg/L hardness)
Criteria for Total (2)=120 µg/L, Basis for Criteria (2)=EPA AWQC for Aquatic Life (100 mg/L hardness)
Criteria for Dissolved (1)=36 µg/L, Basis for Criteria (1)=EPA AWQC for Aquatic Life (25 mg/L hardness)
Criteria for Dissolved (2)=120 µg/L, Basis for Criteria (2)=EPA AWQC for Aquatic Life (100 mg/L hardness)
Data sources and regional groupings are described at the beginning of **Section F2**.

Figure F2-43. Measured Zinc by Region

Mercury. The California Toxics Rule human health criterion for mercury due to the consumption of contaminated water and aquatic organisms is 0.05 µg/L calculated as a 30-day average. The EPA AWQC for the protection of freshwater aquatic life is 0.77 µg/L (4-day average) and 1.4 µg/L (1-hour average) for dissolved mercury. Mercury is found throughout the Delta as a result of widespread historical mining activities in California. Miners used mercury to extract gold from rock and abandoned gold and mercury mines in the Coast Range and the Sierra Nevada mountains continue to leach mercury. While mercury in its natural form is usually not easily transmitted into living organisms, natural processes can encourage conversion to methylmercury, which is a powerful neurotoxin that accumulates in fish tissue and is harmful to animals and humans (DWR 2005a).

Mercury was not detected in samples from the regional dataset. The dataset included 107 samples for total mercury and 180 samples for dissolved mercury with reporting limits of either 0.2 µg/L or 0.5 µg/L. Because the reporting limits for mercury were 4 to 10 times greater than the California Toxics Rule criterion, comparisons by regions to determine the effects of recirculation are not possible from this dataset.

Dissolved mercury was analyzed in the 2004, 2007, and 2008 recirculation pilot studies and was detected at concentrations substantially below the human health criterion (Reclamation 2005, 2008, and in press). Total mercury was analyzed in the 2008 pilot study (in press). During recirculation, total mercury concentrations tended to increase in the SJR immediately downstream of Newman Wasteway relative to the SJR location upstream of the wasteway; concentrations were above 0.05 µg/L during the initial stages of recirculation but dropped below this threshold after the first few days. Total mercury concentrations measured at Crows Landing were similar to, or only slightly above, concentrations measured at the SJR location upstream of the wasteway. Increases in total mercury concentrations were correlated with increased sediments (turbidity and TSS). When total mercury concentrations for samples collected at the SJR immediately downstream of Newman Wasteway were evaluated with a 30-day average, concentrations were below the human health criterion. Thus, recirculation is expected to increase total mercury concentrations in the SJR, but increased concentrations are expected to be limited both in duration and geographical extent.

Molybdenum. The Basin Plan WQOs for total molybdenum are a monthly mean of 10 µg/L and a maximum of 15 µg/L in the SJR from the Merced River to Vernalis, and a monthly mean of 19 µg/L and a maximum of 50 µg/L in the SJR from Sack Dam to the Merced River. Cattle are sensitive to molybdenum poisoning when copper and inorganic sulfate are deficient. Aquatic organisms are comparatively resistant to molybdenum salts (USFWS 1989). Molybdenum was not included in the regional dataset. Molybdenum was not analyzed in the recirculation pilot studies.

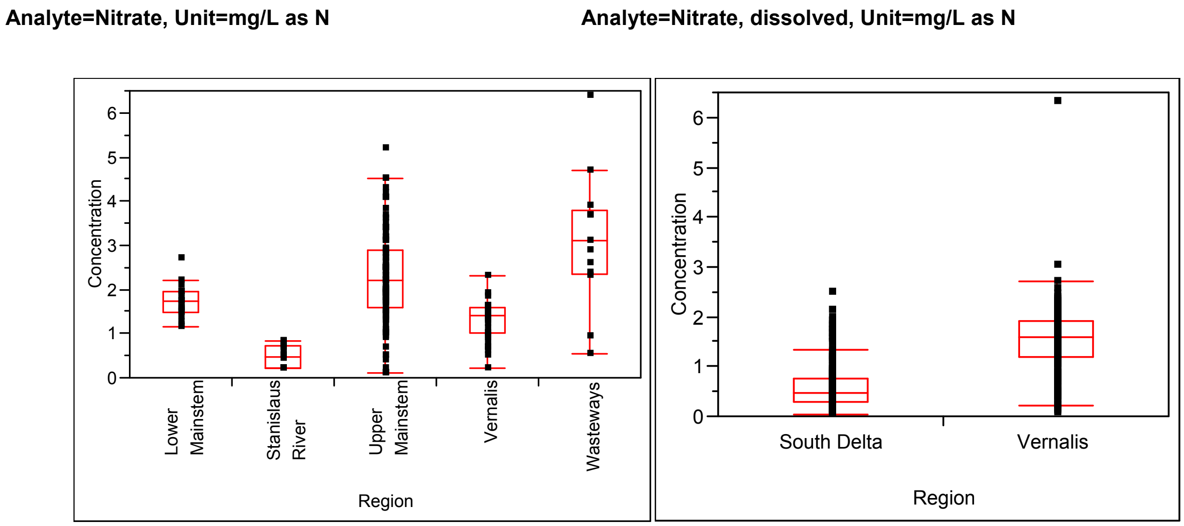
Nutrients

Nitrate as N. The CVRWQCB considers nitrate pollution to be a critical issue for beneficial use protection in the Central Valley Region, particularly for groundwater. The Basin Plan maintains that domestic, municipal, agricultural, and industrial supply waters must be protected against quality degradation. Public health standards for nitrate in drinking water supplies, such as the EPA Primary MCL, have been set at 10 mg/L nitrate as N. The CALFED WQP ROD also has a numeric target of 10 mg/L nitrate as N. Excessive levels of nitrate in drinking water can cause human health effects. Nitrate exposures above the drinking water standard have caused serious illness, and sometimes death, in infants below the age of 6 months (EPA 1995c).

Figure F2-44 shows measured nitrate concentrations by region in the lower San Joaquin basin and Delta. The box plot on the left shows total nitrate concentrations and the box plot on the right shows dissolved nitrate concentrations. The concentration of total nitrate in the south Delta is not measured in this dataset. The median concentration for dissolved nitrate in the south Delta is lower than the median concentrations at Vernalis. The data are well below the water quality criteria of 10 mg/L.

If relative concentrations between regions show a similar pattern for total and dissolved constituents, then the median concentration for total nitrate may be lower in the south Delta than the SJR and similar to median concentration in the Stanislaus River. Recirculation would introduce a relatively large volume of water to the wasteway agricultural drainage, which may dilute contaminants within the wasteway. Recirculation may improve water quality for nitrate and act as a dilution flow for the lower and upper mainstem as well as Vernalis. However, detected concentrations are lower than the water quality criteria, and therefore, the effects from recirculation may not be significant.

The combination of nitrate and nitrite was analyzed in the 2004 and 2007 recirculation pilot studies and was detected at concentrations below the EPA Primary MCL (Reclamation 2005, 2008). Nitrate/nitrite concentrations were typically lower in Newman Wasteway than in the SJR. In the 2004 study, SJR concentrations decreased slightly downstream of Newman Wasteway. In the 2007 study, SJR concentrations downstream of Newman Wasteway were similar to upstream concentrations. Because concentrations are less than the water quality criteria, the pilot study data support the conclusion that changes in nitrate/nitrite concentrations due to recirculation may not be significant.



Criteria (1)=10 mg/L as N, Basis for Criteria (1)=CALFED WQP ROD goal for municipal supply
Data sources and regional groupings are described at the beginning of **Section F2**.

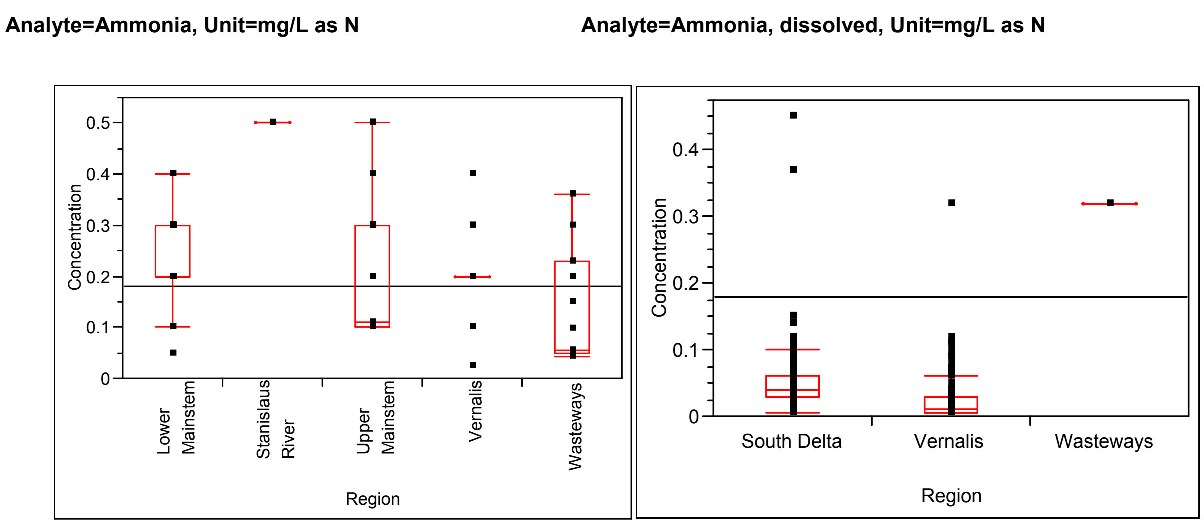
Figure F2-44. Measured Nitrate by Region

Ammonia as N The EPA has recommended AWQC for the protection of freshwater aquatic life that is pH dependent. The acute criterion is also dependent on the presence or absence of salmonids, which are particularly sensitive to ammonia. The chronic criterion is dependent both on temperature and on the presence or absence of fish early life stages. An exact value of the criterion can be calculated for a specific set of conditions. These values are in total (un-ionized plus ionized) ammonia nitrogen. In the presence of ammonia, fish have reduced growth, development, and reproductive rate. Injury can occur to gill, liver, and kidney tissues. At moderate ammonia levels, fish can suffer a loss of equilibrium, and can become hyper-excited, which increases respiratory activity, oxygen uptake, and heart rate. High ammonia concentrations can lead to convulsions, coma, and death (EPA 1999c).

Figure F2-45 shows measured ammonia concentrations by region relative to the minimum AWQC of 0.179 mg/L. The box plot on the left shows total ammonia concentrations and the box plot on the right shows dissolved ammonia concentrations. The data for total ammonia typically had less significant figures than the data for dissolved ammonia; therefore, the visual representation of the data differs. The sample size for data in the Stanislaus River and data for dissolved ammonia in the wasteways is too low to be a reliable indicator of concentration. The concentration of total ammonia in the south Delta is not measured by this dataset. The median concentration of dissolved ammonia in the south Delta is greater than the median concentration of dissolved ammonia at Vernalis. The median total ammonia concentration at Vernalis is similar to the lower mainstem and higher than the upper mainstem segment of the SJR.

If relative concentrations between regions show a similar pattern for total and dissolved constituents, then median concentrations of total ammonia in the south Delta may be higher than median concentrations in the SJR. Recirculation may degrade water quality in the SJR for ammonia. Although the SJR may exhibit ammonia concentrations greater than the lowest recommended AWQC of 0.179 mg/L, it is uncertain if concentrations would be greater than the AWQC calculated with sample specific criteria (pH, temperature, and presence/absence of salmonids or fish in early life stages).

Ammonia was analyzed in the 2004, 2007, and 2008 recirculation pilot studies and peak concentrations were detected near the aquatic life criteria (Reclamation 2005, 2008, and in press). In the 2004 and 2008 studies, ammonia concentrations in Newman Wasteway and the SJR were elevated during the first few days of recirculation; however, in the 2008 study, concentrations decreased to background levels by the second week. Ammonia concentrations in the wasteway were elevated and variable during the 2007 study, even under relatively low-flow conditions (approximately 50 cfs of recirculation). In general, ammonia concentrations increased in the SJR downstream of the wasteway. Ammonia results for the 2008 pilot study were compared to pH and temperature-specific aquatic life criteria, and all ammonia concentrations were below the criteria.



Notes:
Criteria (1)=0.179 mg/L as N, Basis for Criteria (1)=EPA Aquatic Life Criteria
Data sources and regional groupings are described at the beginning of **Section F2**.

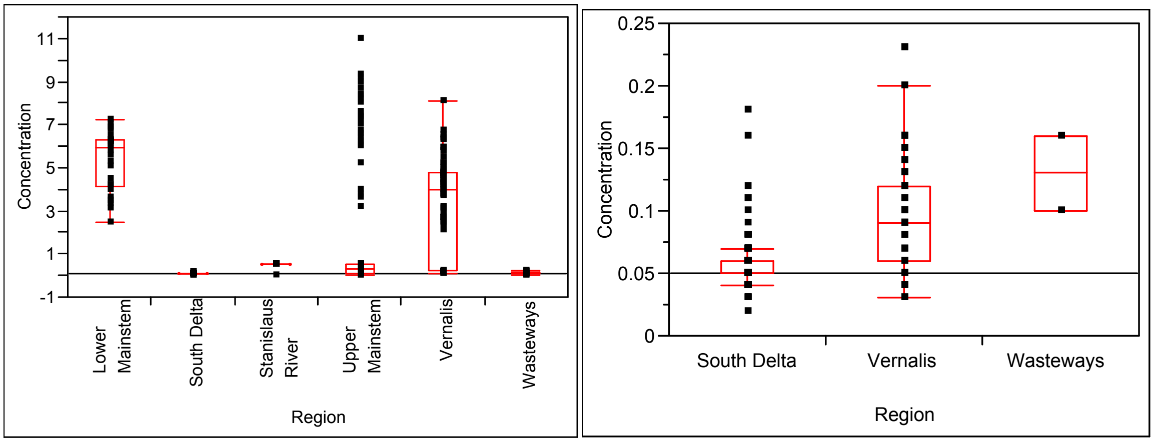
Figure F2-45. Measured Ammonia by Region

Phosphate as P. National criteria do not exist for phosphate as P; however, the EPA Water Quality Criteria (EPA 1986, also known as the Gold Book) has recommendations regarding concentrations of phosphate phosphorus for the control of nuisance aquatic growth in streams, lakes, and reservoirs. The desired goal for the prevention of plant nuisances in streams not discharging into lakes and impoundments is 100 µg/L phosphate as P, the goal for streams at the point it enters any lake or reservoir is 50 µg/L phosphate as P, and the goal for lakes and reservoirs is 25 µg/L phosphate as P. Phosphorus compounds typically found in nature are not directly toxic to plants or aquatic species; however, surface waters with high phosphorus levels can exhibit eutrophication, increased growth of undesirable algae and aquatic weeds, and subsequent decrease in DO.

Figure F2-46 shows measured orthophosphate concentrations by region in the lower San Joaquin basin and Delta. Orthophosphate represents a portion of the phosphate concentration. Orthophosphate concentrations are consistently above the water quality criteria in all regions with the possible exception of the Stanislaus River. The Stanislaus has a 0% detection rate for orthophosphate. Data are also limited in the wasteways. The south Delta has median concentrations less than the SJR for both total and dissolved orthophosphate. Recirculation would introduce a relatively large volume of water to the wasteway agricultural drainage, which may dilute concentrations within the wasteway. Recirculation may improve water quality and help decrease total orthophosphate concentrations in the upper and lower mainstem as well as Vernalis. In contrast, releases from the Stanislaus would act as a dilution flow only for Vernalis.

Orthophosphate was analyzed in the 2004 recirculation pilot study but was infrequently detected at concentrations greater than the reporting limit (0.03 mg/L) (Reclamation 2005). SJR concentrations downstream of Newman Wasteway tended to be similar or slightly reduced in comparison to upstream concentrations. The pilot study data support the conclusion that recirculation may be beneficial.

Analyte=Orthophosphate, Unit=mg/L as P **Analyte=Orthophosphate, dissolved, Unit=mg/L as P**



Notes:
Criteria (1)=0.05 mg/L as P, Basis for Criteria (1)=EPA WQ Criteria for Phosphate
Data sources and regional groupings are described at the beginning of **Section F2**.

Figure F2-46. Measured Orthophosphate by Region

F2.2.4 Constituents of Concern for Drinking Water

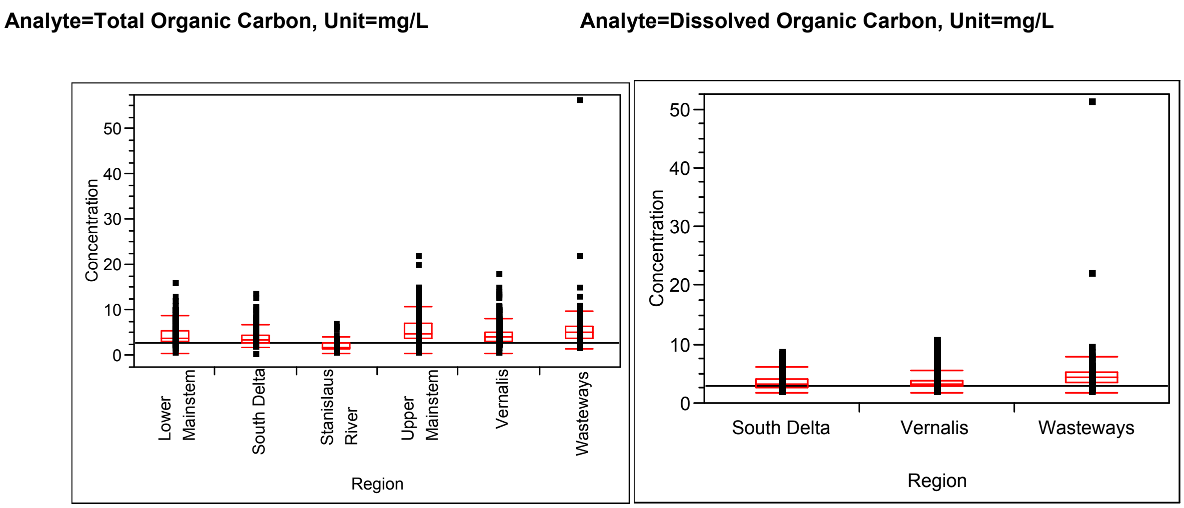
Organic Carbon. The CALFED WQP ROD has a goal of an average total organic carbon (TOC) concentration of 3 mg/L at Clifton Court Forebay and other southern and central Delta drinking water intakes, or an equivalent level of public heath protection. Organic carbon is itself not a harmful constituent; it may act as a source of food for aquatic life. Problems can occur when water containing high levels of organic carbon is treated with chemical disinfectants. Some forms of organic carbon react with chlorine and produce potentially carcinogenic disinfection byproducts (DBPs) such as trihalomethanes (DWR 2005a). Numerous researchers have documented that natural organic matter is the principal precursor of organic DBP formation during drinking water disinfection.

Figure F2-47 shows measured organic carbon concentrations by region in the lower San Joaquin basin and Delta in relation to the water quality goal of 3.0 mg/L. The box plot on the left shows TOC concentrations and the box plot on the right shows dissolved organic carbon (DOC) concentrations. Median TOC concentrations are highest in the wasteways and lowest in the Stanislaus River. The median concentration of TOC is lower in the south Delta than the SJR. For DOC, the median concentration in the wasteways is also highest and median concentrations in the south Delta and Vernalis are similar.

Recirculation would introduce a relatively large volume of water to the wasteway agricultural drainage, which may dilute the organic carbon within the wasteway. Although recirculation may reduce organic carbon concentrations at

Vernalis, the Stanislaus River would provide a more effective dilution than recirculation. An additional benefit does not occur for reducing TOC prior to drinking water intakes.

TOC was analyzed in the 2004, 2007, and 2008 recirculation pilot studies and detected at concentrations typically greater than the CALFED water quality goal for Delta municipal supply (Reclamation 2005, 2008, and in press). During the 2004 and 2008 studies, concentrations were higher at the Newman Wasteway and at the SJR downstream of the wasteway during the initial stages of recirculation; thereafter, concentrations in the SJR downstream of the wasteway were generally lower than upstream concentrations. During the 2007 study, TOC concentrations were lower in the SJR downstream of the wasteway than in the upstream site for the duration of the study. Pilot study data indicate that organic carbon from the wasteway has the potential to be mobilized during recirculation; however, aside from initial, potentially elevated concentrations, recirculation could reduce organic carbon concentrations in the SJR. Thus, the pilot study data support conclusions drawn from the analysis of the regional data.

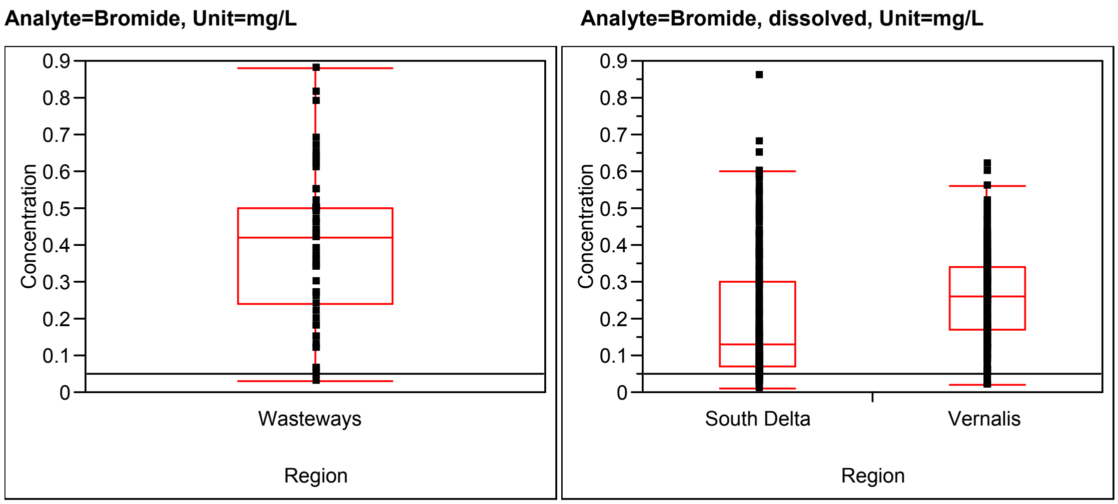


Notes:
Criteria (1)=3 mg/L, Basis for Criteria (1)=CALFED WQP ROD goal for municipal supply
Data sources and regional groupings are described at the beginning of **Section F2**.

Figure F2-47. Measured Organic Carbon by Region

Bromide. The CALFED WQP ROD has a goal of an average bromide concentration of 50 µg/L at Clifton Court Forebay and other southern and central Delta drinking water intakes, or the equivalent level of public heath protection (CALFED 2007). Bromide can play a key role in the formation of brominated DBPs during chemical oxidation and disinfection of drinking water. DBPs are known and potential human carcinogens (EPA 1999d).

Figure F2-48 shows measured bromide concentrations by region in relationship to the water quality goal of 0.05 mg/L bromide. The box plot on the left shows total bromide concentrations and the box plot on the right shows dissolved bromide concentrations. Bromide data for the lower and upper mainstem of the SJR and Stanislaus River are not included in this dataset. Median concentrations were lower in the south Delta than at Vernalis. Median concentrations in the wasteways were higher. Recirculation would introduce a relatively large volume of water to the wasteway agricultural drainage, which may dilute bromide within the wasteway. Recirculation is unlikely to degrade water quality at Vernalis because of the immediate dilution of wasteway bromide. Because bromide data for the Stanislaus River are not contained in the dataset, comparisons of recirculation flow with the Stanislaus River are not possible. Bromide was not analyzed in the recirculation pilot studies.



Notes:
Criteria (1)=0.05 mg/L, Basis for Criteria (1)=CALFED WQP ROD goal for municipal supply
Data sources and regional groupings are described at the beginning of **Section F2**.

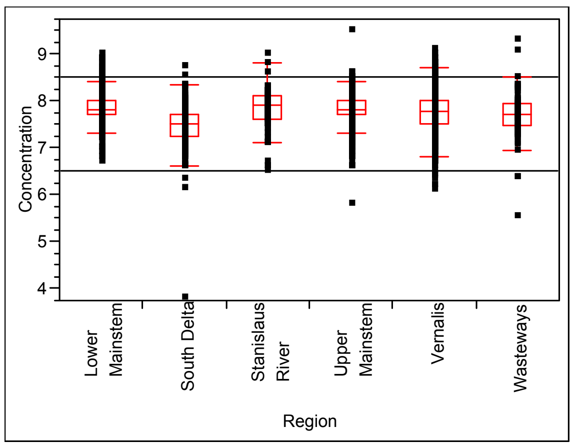
Figure F2-48. Measured Bromide by Region

Physical Parameters

pH. The Basin Plan has explicit WQOs for pH. It states, "the pH shall not be depressed below 6.5 nor raised above 8.5. Changes in normal ambient pH levels shall not exceed 0.5 in fresh waters with designated COLD or WARM beneficial uses." This pH range (6.5 to 8.5) is similar to the EPA criterion for the protection of freshwater aquatic life. pH is an important factor in the chemical and biological systems of natural waters. pH has a direct effect on organisms as well as an indirect effect on the toxicity of other pollutants in the water. The degree of dissociation of weak acids or bases is affected by changes in pH. This effect is important because the toxicity of many compounds is species dependent.

Figure F2-49 shows measured pH by region in the lower San Joaquin basin and Delta. The majority of the pH data falls within the range specified by the WQO. All of the regions have some pH detections above 8.5; however, the Stanislaus River and Vernalis may have a greater portion of samples detected above this limit. The median pH in the south Delta is 7.5 and the median pH in the Stanislaus River is 7.9. The trade-off between additional Stanislaus releases and recirculation may change pH levels in the SJR. Because the majority of the south Delta data fall within the range specified by the WQO, pH changes that are due to recirculation would likely be beneficial for SJR pH.

Analyte=pH, Unit=Std. Unit



Note:
Criteria (1)=6.5-8.5, Basis for Criteria (1)=Basin Plan WQO
Data sources and regional groupings are described at the beginning of **Section F2**.

Figure F2-49. Measured pH by Region

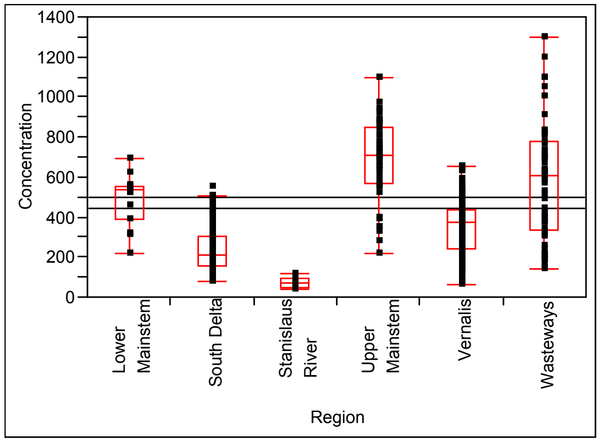
pH was analyzed in the 2007 and 2008 recirculation pilot studies (Reclamation 2008 and in press). In the 2008 study, pH was measured continuously by in-stream meters; pH varied diurnally. For both the 2007 and 2008 studies, the pH at the SJR downstream of Newman Wasteway was typically lower than the upstream measurements, with recirculation often reducing the pH below 8.5. Thus, the pilot study data indicate that pH at the SJR downstream of the wasteway may be improved as a result of recirculation.

TDS. The Basin Plan describes the memorandum of agreement between the CVRWQCB and Reclamation regarding water releases from New Melones for TDS (CVRWQCB 2007). The memorandum of agreement specifies the mean monthly TDS concentration in the SJR immediately below the mouth of the Stanislaus River to not be above 500 mg/L. The Basin Plan also includes water quality recommendations for TDS for drinking water supply. The Basin Plan recommends a 3-day average between 350 and 500 mg/L, a May to September arithmetic average between 250 and 300 mg/L, and a maximum annual average of 285 to 385 mg/L depending on the water year type. The CALFED WQP ROD has a numeric TDS target for drinking water intakes in the Delta of less than 220 mg/L for a 10-year average and less than 440 mg/L for a monthly average (CALFED 2007).

In agricultural settings, irrigation with saline water can lead to the accumulation of salts in the soil profile over a period of time. Crop yield reduction occurs when salts accumulate in the root zone of the crop to the extent that an unfavorable osmotic gradient is formed between the plant root and soil water, making it difficult for the plant to take up water and causing water stress. If water uptake is appreciably reduced, the crop plant slows its rate of growth resulting in reduction of crop yield. Symptoms of salt toxicity are similar to those for plants under drought conditions, such as wilting, or a darker bluish-green leaf color, and occasionally thicker, waxier leaves (CVRWQCB 2004b).

Figure F2-50 shows measured TDS by region compared to the CALFED WQP ROD goal for Delta drinking water intakes. Data in the Stanislaus River and lower mainstem are limited. Median TDS concentrations in the south Delta are lower than median concentrations in the SJR, but higher than median concentrations in the Stanislaus River. The median TDS concentration in the wasteways is between the median concentration in the upper and lower mainstem segments. Recirculation would introduce a relatively large volume of water to the wasteway agricultural drainage, which may dilute TDS within the wasteway. Recirculation may benefit the upper and lower mainstem as well as at Vernalis, while releases from the Stanislaus would act as a dilution flow for only Vernalis. TDS was not analyzed in the recirculation pilot studies.

Analyte=Total Dissolved Solids, Unit=mg/L



Notes:

Criteria (1)=500 mg/L, Basis for Criteria (1)=Basin Plan MOA in the SJR below the Stanislaus River

Criteria (2)=440 mg/L, Basis for Criteria (2)=CALFED WQP ROD goal for municipal supply

Data sources and regional groupings are described at the beginning of **Section F2**.

Figure F2-50. Measured Total Dissolved Solids by Region

F.3 Flow and Stage Evaluation

F.3.1 CalSim II

CalSim II Common Assumptions full system model was used in conjunction with DSM2 HYDRO and QUAL to predict flow system-wide. Existing conditions are modeled using the existing LOD; No-Action Alternative conditions and the alternative plans presented below are modeled using the 2030 future LOD (see **Appendix A**). For this project, model simulation was for an 82-year hydrologic trace (1922 through 2003) with model output during 14 periods per year. Each period represents a monthly or semimonthly average. Periods during June through March are monthly averages and periods during April and May are semimonthly averages to account for Vernalis Adaptive Management Plan pulse flow. The total number of periods during the model simulation is 1,148.

CalSim II output was used to evaluate flow against the flow objective for the SJR at Vernalis. The *Water Quality Control Plan for San Francisco Bay/Sacramento-San Joaquin Delta Estuary* flow objective for the SJR at Vernalis has flow requirements during February through June and during October (State Water Resources Control Board 1995). The flow requirement is based on the required location of "X2," the San Joaquin Basin Index water year type, and the date (see **Section 2.2.3**).

Figure F3-1 and **Table F3-1** show an analysis for the flow objective at Vernalis that is similar to the analysis for the EC objective. The differences in alternative plans are more apparent for flow than for EC. The number of periods when the flow objective is predicted to be met due to recirculation is similar in Alternatives A1 and A2 (25 or 23 occurrences), in Alternatives B1 and B2 (41 or 38 occurrences), and in Alternatives C and D (78 occurrences). Alternatives C and D are predicted to help to meet the flow objective more consistently than B1 or B2, which, in turn, are predicted to help to meet the flow objective more consistently than A1 or A2. The percentage of periods where flow at Vernalis is predicted to be less than the flow objective is reduced from 14.5% under No-Action Alternative conditions to 7.7% under Alternatives C and D. Recirculation is predicted to contribute flow at Vernalis such that the flow objective would be met almost half of the periods when it would have otherwise failed to meet the objective under No-Action Alternative conditions.

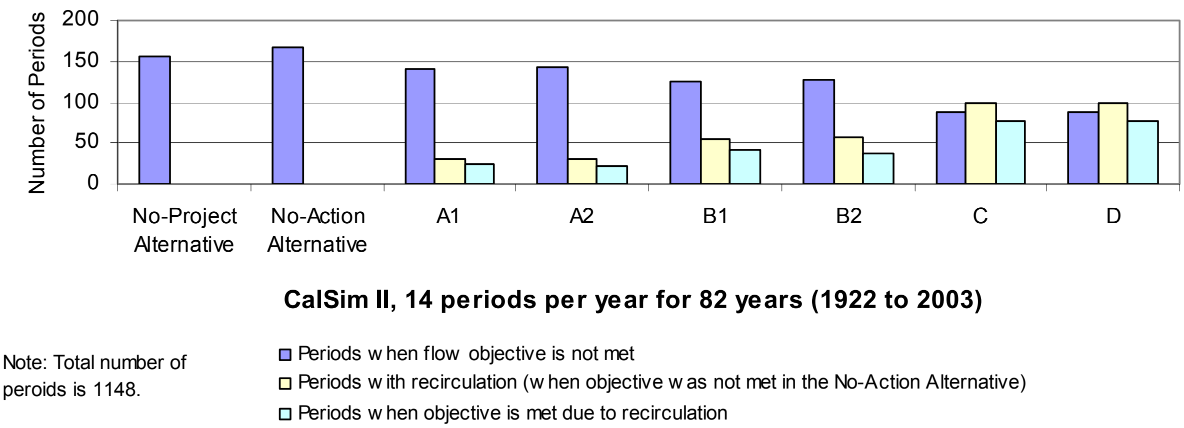


Figure F3-1. Effectiveness of Alternative Plans in Meeting the Flow Objective at Vernalis, CalSim II

Table F3-1 shows that the median magnitude below the flow objective is significantly less than the mean magnitude below the flow objective for the alternative plans. For Alternatives C and D, the median magnitude below the flow objective is relatively small (15 cfs), indicating that several instances are predicted where flow at Vernalis approaches, yet does not met, the flow objective. It can also indicate that some problematic periods for flow would be resolved by recirculation.

Table F3-1. Evaluation of the Flow Objective at Vernalis, CalSim II

Criteria	No-Project Alternative	No-Action Alternative	A1	A2	B1	B2	C	D
Periods when flow objective is predicted to not be met	155	166	141	143	125	128	88	88
Percent of periods flow objective is predicted to not be met	13.5	14.5	12.3	12.5	10.9	11.1	7.7	7.7
Periods with recirculation (when objective would not be met in the No-Action Alternative)	NA	NA	31	31	56	57	100	100
Periods when objective is predicted to be met due to recirculation	NA	NA	25	23	41	38	78	78
Median magnitude below flow objective, cfs	217	193	147	137	132	93	15	15
Mean magnitude below flow objective, cfs	458	459	458	452	453	434	345	344
Standard Deviation of the magnitude below flow objective, cfs	560	558	581	579	570	560	490	488

Notes:

Calculations account for rounding error (± 0.05 cfs).

Periods include monthly and VAMP pulse and nonpulse timesteps; the total number of periods is 1148.

Alternative plans are modeled using the 2030 future LOD.

Key:

cfs = cubic feet per second
LOD = Level of Development
VAMP = Vernalis Adaptive Management Plan

Modeled recirculation assumed the use of the Condition 1 filter (see **Appendix A, Section A3.1**). Alternate filters could be applied to recirculation that may predict a greater frequency of recirculation, and increased compliance with the flow objective, for the alternative plans.

F.3.2 DSM2

Stage, as defined by elevation in National Geodetic Vertical Datum of 1929, was modeled in the Delta using DSM2 for existing and No-Action Alternative conditions and for Alternatives B1, B2, and D. Existing conditions were modeled using the existing LOD; No-Action Alternative conditions, and the alternative plans were modeled using the future LOD. Stage was evaluated at SJR at Vernalis, Middle River at Mowery Road Bridge, Old River at Tracy Road Bridge, SJR at Brandt Bridge, and Grant Line Canal at Tracy Road Bridge.

Output for existing and No-Action Alternative conditions and the differences in mean daily stage between the alternative plans and the No-Action Alternative are shown on figures in **Attachment F3** for the 82-year model simulation. **Attachment F3** also contains histograms of the mean daily stage modeled for the alternative plans during April-through-August recirculation periods, the corresponding No-Action Alternative values during recirculation periods for each alternative plan, and change in stage (i.e., the difference between the alternative plan and the No-Action Alternative) for these periods. The histograms show the distribution of the data and the frequency of occurrence within each category.

Table F3-2 presents summary statistics of the mean daily stage and the change in stage predicted for the SJR at Vernalis during April-through-August recirculation periods. The 90th percentile value of the change in stage during agricultural season recirculation periods is similar for Alternatives B1 and B2 and higher for Alternative D. These values, which are larger stage increments, are predicted to be approximately 1.0 to 1.2 feet.

Summary statistics for stage modeled at south Delta locations are shown on **Tables F3-3 to F3-6**. The 90th percentile changes in stage during agricultural season recirculation periods are approximately 0.1 to 0.2 foot in Middle River at Mowery Road Bridge, Old River at Tracy Road Bridge, and the SJR at Brandt Bridge and less than 0.05 foot in Grant Line Canal at Tracy Road Bridge for each modeled alternative plan. At these south Delta locations, the 90th percentile stage increment was greatest for Alternative D, with the exception of Old River at Tracy Road Bridge, where Alternative B1 had the highest value.

Figures F3-2 to F3-6 display a comparison of recirculation flow and the change in stage between alternative plans and the No-Action Alternative during agricultural season recirculation periods at the SJR at Vernalis and south Delta locations. Recirculation tends to increase stage in the SJR at Vernalis, the SJR at Brandt Bridge, and the Middle River at Mowery Road Bridge; however, this effect is less pronounced at Old River at Tracy Road Bridge and Grant Line Canal.

Stage at south Delta locations is on occasion predicted to decrease during agricultural season recirculation, as seen on **Figures F3-3 to F3-6** and by the negative values for the 10th percentile stage increments in **Tables F3-3, F3-4, and F3-6**. This decrease in stage may be a result of increased exports. Maximum drawdown in water levels is predicted to be less than 0.1 foot. Decreased stage occurred most frequently at Grant Line Canal.

Table F3-2. Statistics for Stage Modeled by DSM2 in the San Joaquin River at Vernalis during Recirculation, Agricultural Season (April–August)

Periods	Alternative Plans and Change Relative to No-Action Alternative	Mean Daily Stage (ft)					
		Mean	10th percentile	25th percentile	Median	75th percentile	90th percentile
Recirculation in Alternative B1, April–August	No-Action Alternative	9.24	7.89	8.42	9.07	10.03	11.15
	Alternative B1	9.74	8.03	8.70	9.68	10.96	11.53
	Change in B1 relative to No-Action Alternative	0.50	0.06	0.14	0.41	0.7	1.05
Recirculation in Alternative B2, April–August	No-Action Alternative	9.44	7.89	8.42	9.67	10.49	11.25
	B2	9.86	8.43	8.71	9.97	11.04	11.55
	Change in B2 relative to No-Action Alternative	0.42	0	0.06	0.33	0.69	1.02
Recirculation in Alternative D, April–August	No-Action Alternative	9.74	7.95	8.42	9.39	10.71	11.55
	D	10.23	8.48	8.71	10.09	11.39	11.76
	Change in D relative to No-Action Alternative	0.48	0	0.06	0.24	0.84	1.22

Key:
DSM2 = Delta Simulation Model 2
ft= feet
SJR = San Joaquin River

Table F3-3. Statistics for Stage Modeled by DSM2 in the Middle River at Mowery Road Bridge during Recirculation, Agricultural Season (April–August)

Periods	Alternative Plans and Change Relative to No-Action Alternative	Mean Daily Stage (ft)					
		Mean	10th percentile	25th percentile	Median	75th percentile	90th percentile
Recirculation in Alternative B1, April–August	No-Action Alternative	1.64	0.99	1.30	1.66	2.00	2.27
	B1	1.71	0.99	1.34	1.73	2.09	2.37
	Change in B1 relative to No-Action Alternative	0.06	0	0.01	0.04	0.09	0.19
Recirculation in Alternative B2, April–August	No-Action Alternative	1.70	1.01	1.31	1.73	2.1	2.34
	B2	1.75	1.02	1.34	1.78	2.16	2.39
	Change in B2 relative to No-Action Alternative	0.05	-0.01	0	0.02	0.08	0.14
Recirculation in Alternative D, April–August	No-Action Alternative	1.58	0.92	1.2	1.54	1.98	2.31
	D	1.65	0.98	1.24	1.59	2.05	2.4
	Change in D relative to No-Action Alternative	0.07	0	0.01	0.03	0.07	0.23

Key:
DSM2 = Delta Simulation Model 2
ft= feet

Table F3-4. Statistics for Stage Modeled by DSM2 in Old River at Tracy Road Bridge during Recirculation, Agricultural Season (April–August)

Periods	Alternative Plans and Change Relative to No-Action Alternative	Mean Daily Stage (ft)					
		Mean	10th percentile	25th percentile	Median	75th percentile	90th percentile
Recirculation in Alternative B1, April–August	No-Action Alternative	1.50	0.90	1.18	1.54	1.85	2.09
	B1	1.54	0.89	1.21	1.58	1.93	2.15
	Change in B1 relative to No-Action Alternative	0.04	-0.01	0	0.02	0.06	0.15
Recirculation in Alternative B2, April–August	No-Action Alternative	1.54	0.89	1.2	1.59	1.92	2.13
	B2	1.57	0.89	1.22	1.62	1.96	2.17
	Change in B2 relative to No-Action Alternative	0.03	-0.02	0	0.01	0.05	0.1
Recirculation in Alternative D, April–August	No-Action Alternative	1.36	0.68	1.04	1.39	1.72	2
	D	1.39	0.71	1.06	1.41	1.77	2.06
	Change in D relative to No-Action Alternative	0.04	0	0	0.02	0.04	0.12

Key:
DSM2 = Delta Simulation Model 2
ft= feet

Table F3-5. Statistics for Stage Modeled by DSM2 in the San Joaquin River at Brandt Bridge during Recirculation, Agricultural Season (April–August)

Periods	Alternative Plans and Change Relative to No-Action Alternative	Mean Daily Stage (ft)					
		Mean	10th percentile	25th percentile	Median	75th percentile	90th percentile
Recirculation in Alternative B1, April–August	No-Action Alternative	1.57	1.14	1.35	1.55	1.82	2.04
	B1	1.63	1.18	1.39	1.61	1.90	2.11
	Change in B1 relative to No-Action Alternative	0.06	0.01	0.01	0.04	0.09	0.15
Recirculation in Alternative B2, April–August	No-Action Alternative	1.59	1.12	1.35	1.58	1.85	2.05
	B2	1.64	1.15	1.39	1.635	1.91	2.11
	Change in B2 relative to No-Action Alternative	0.05	0	0.01	0.03	0.07	0.14
Recirculation in Alternative D, April–August	No-Action Alternative	1.63	1.06	1.3	1.57	1.91	2.22
	D	1.70	1.12	1.37	1.65	1.97	2.32
	Change in D relative to No-Action Alternative	0.07	0	0.01	0.03	0.12	0.21

Key:
DSM2 = Delta Simulation Model 2
ft= feet
SJR = San Joaquin River

Table F3-6. Statistics for Stage Modeled by DSM2 in Grant Line Canal at Tracy Road Bridge during Recirculation, Agricultural Season (April–August)

Periods	Alternative Plans and Change Relative to No-Action Alternative	Mean Daily Stage (ft)					
		Mean	10th percentile	25th percentile	Median	75th percentile	90th percentile
Recirculation in Alternative B1, April–August	No-Action Alternative	0.99	0.56	0.76	0.99	1.21	1.42
	B1	0.98	0.55	0.75	0.99	1.21	1.42
	Change in B1 relative to No-Action Alternative	0.00	-0.01	-0.01	0	0	0
Recirculation in Alternative B2, April–August	No-Action Alternative	0.98	0.56	0.76	0.98	1.21	1.41
	B2	0.98	0.56	0.75	0.98	1.2	1.4
	Change in B2 relative to No-Action Alternative	-0.01	-0.02	-0.01	0	0	0
Recirculation in Alternative D, April–August	No-Action Alternative	0.94	0.49	0.7	0.94	1.18	1.41
	D	0.95	0.5	0.71	0.95	1.19	1.41
	Change in D relative to No-Action Alternative	0.01	-0.01	0	0	0.01	0.04

Key:
DSM2 = Delta Simulation Model 2
ft= feet

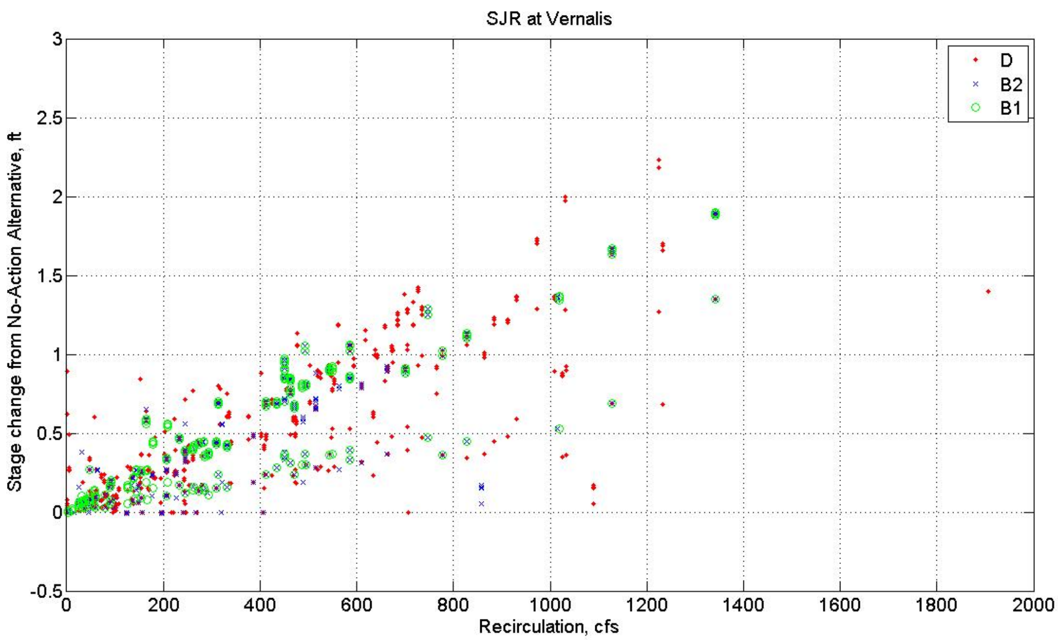


Figure F3-2. Change in Modeled Stage during Recirculation in the San Joaquin River at Vernalis, April–August

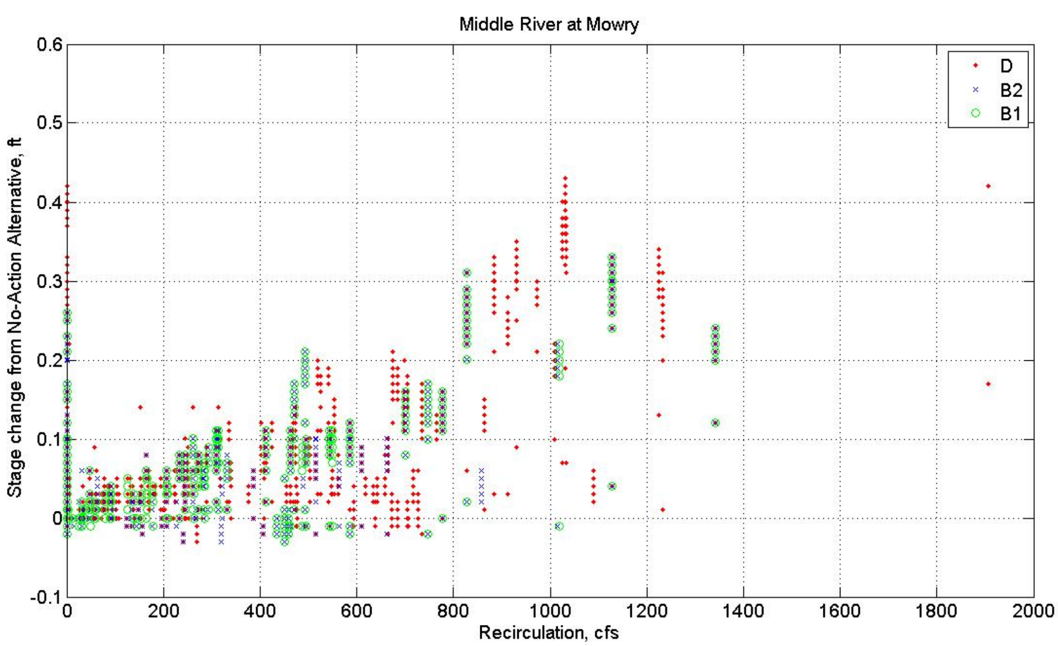


Figure F3-3. Change in Modeled Stage during Recirculation in the Middle River at Mowery Road Bridge, April–August

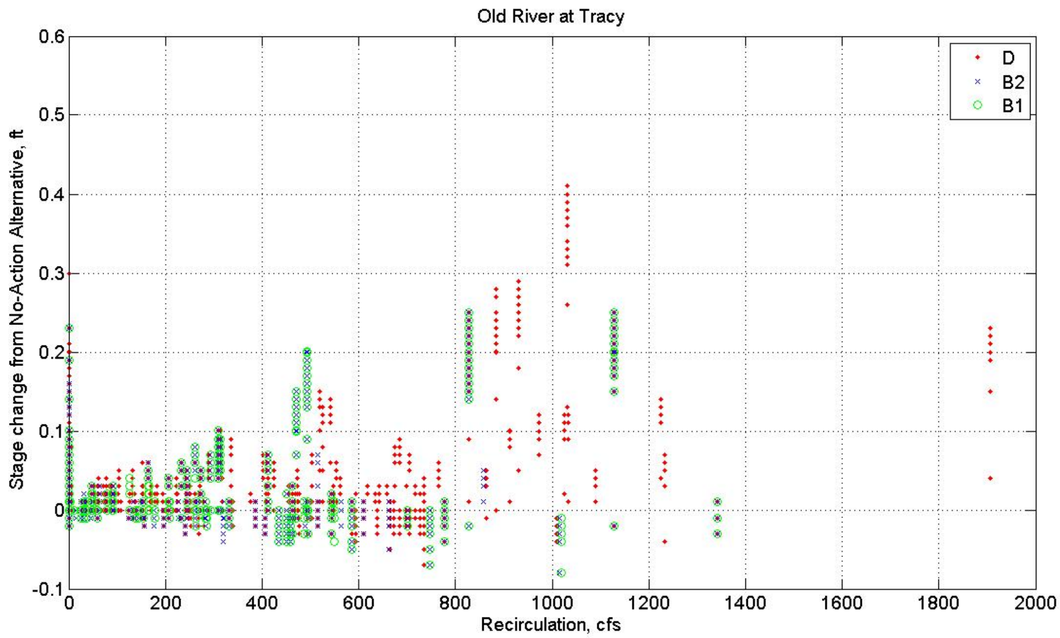


Figure F3-4. Change in Modeled Stage during Recirculation in the Old River at Tracy Road Bridge, April–August

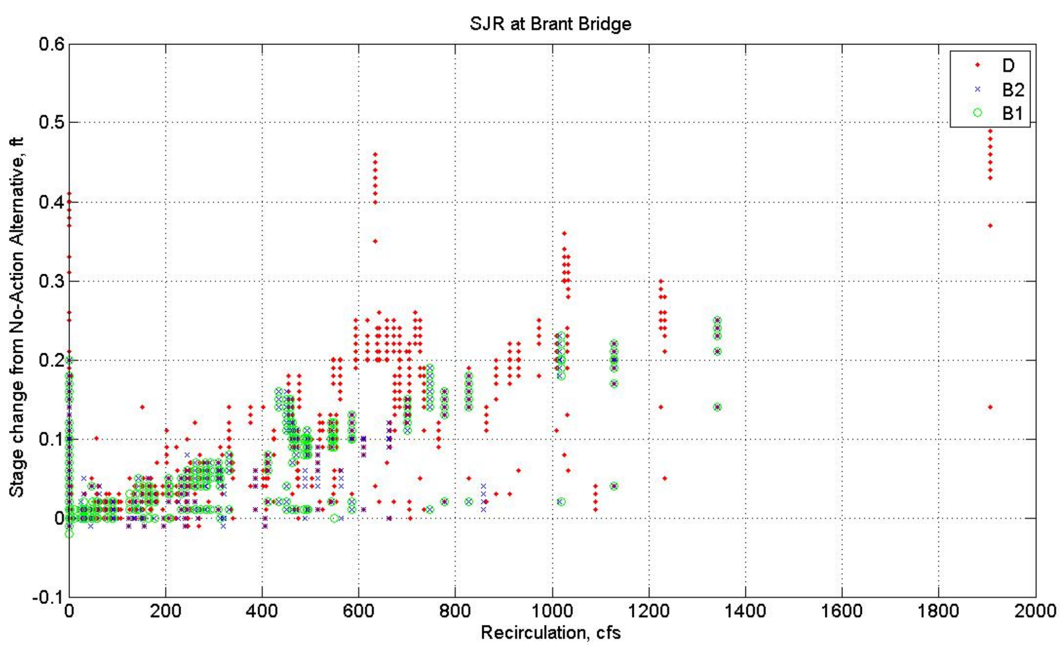


Figure F3-5. Change in Modeled Stage during Recirculation in the San Joaquin River at Brandt Bridge, April–August

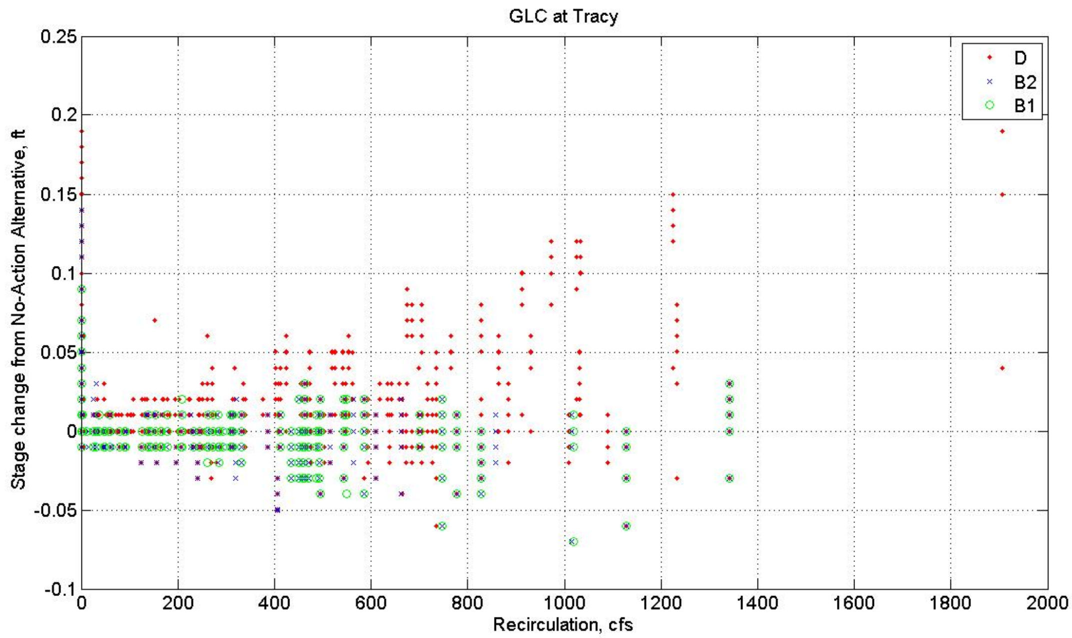


Figure F3-6. Change in Modeled Stage during Recirculation in Grant Line Canal at Tracy Road Bridge, April–August

Change in stage at south Delta locations during agricultural season recirculation periods is typically less than a few inches (as seen by the 90th percentile values), indicating that recirculation may not be an efficient method to increase water levels in the south Delta. Water levels are generally of most concern during late summer, when SJR flow decreases. During this period, recirculation to satisfy the primary planning objectives is not predicted to occur.

F.4 Conclusions

Recirculation would increase in frequency, duration, and/or intensity with each subsequent alternative plan (A to D). Likewise, modeled effects from recirculation tend to amplify with each alternative plan (**Table F4-1**). Modeled recirculation is expected to have a beneficial effect for flow, EC, and DO in relation to WQOs. Recirculation may have a detrimental effect on temperature and turbidity. Recirculation is not predicted to result in significant changes in selenium and boron concentrations.

Table F4-1. Percentage of Model Periods Water Quality Objective is Predicted to Not be Met

Objective and Location	No-Project Alternative	No-Action Alternative	A1	A2	B1	B2	C	D
Flow objective at Vernalis	13.5	14.5	12.3	12.5	10.9	11.1	7.7	7.7
EC objective at Vernalis	3.6	1.8	1.4	1.5	1.4	1.5	1.3	1.1
EC objective in Middle River at Mowery (Old River near Middle River)	7.4	2.8	--	--	2.5	2.5	--	2.3
EC objective in Old River at Tracy Road	9	4.9	--	--	4.4	4.4	--	4.1
EC objective in SJR at Brandt Bridge	7.4	2.8	--	--	2.5	2.5	--	2.3
Temperature objective at Vernalis	NA	NA	--	0.9	--	1.1	1.2	1.4
Temperature objective in the Stanislaus River at Orange Blossom Bridge	NA	NA	--	0.003	--	0.23	0.19	0.04
Temperature objective in the Stanislaus River at Ripon	NA	NA	--	0.03	--	0.03	0.03	0.20
Turbidity objective in the SJR below Newman Wasteway	NA	NA	21	25	46	50	92	100
Turbidity objective in the SJR above the Tuolumne River	NA	NA	4	13	8	17	42	46
Selenium objective in the SJR at Crows Landing	11	0	0	0	0	0	0	0
Boron objective in the SJR at Crows Landing	24	0	0	0	0	0	0	0
Dissolved Oxygen in the Stockton Deep Water Ship Channel	--	17	--	--	8.6	8.6	--	2.8

Note: Dashes occur where alternative plans are not modeled, “NA” occurs when WQO is not applicable.

Key:

EC = electrical conductivity
NA = not applicable
SJR = San Joaquin River
WQO = water quality objective

The wasteway agricultural drainage is often lower in quality than that found in the south Delta or the SJR (**Tables F4-2 and F4-3**). Recirculation would introduce a relatively large volume of water to the wasteway agricultural drainage, which may dilute wasteway contaminants. Without sufficient dilution, an initial pulse of contaminants to the SJR may occur. The water quality of the recirculation would otherwise be characterized by the water quality in the south Delta. When concentrations in the south Delta or the SJR approach water quality criteria, the effects of recirculation may become significant.

Table F4-2. Median Value of the Existing Data by Region

Analyte	Unit	South Delta	Waste-ways	Upper Mainstem	Lower Mainstem	Stanislaus River	Vernalis
Ammonia	mg/L as N	--	0.06	0.11	0.2	ND	0.2
Ammonia, Dissolved	mg/L as N	0.04	0.32	--	--	--	0.01
Nitrate	mg/L as N	--	3.1	2.2	1.7	0.5	1.4
Nitrate, Dissolved	mg/L as N	0.5	--	--	--	--	1.6
Orthophosphate	mg/L as P	0.06	0.1	0.3	5.9	ND	4
Orthophosphate, Dissolved	mg/L as P	0.05	0.13	--	--	--	0.09
Total Organic Carbon	mg/L	3.45	5.2	5	3.7	1.9	4.05
Dissolved Organic Carbon	mg/L	3.1	4.45	--	--	--	3.15
Bromide	mg/L	--	0.42	--	--	--	--
Bromide, Dissolved	mg/L	0.13	--	--	--	--	0.26
pH	Std. Unit	7.5	7.7	7.8	7.8	7.9	7.8
Total Dissolved Solids	mg/L	207	605	710	540	67	370
Hardness	mg/L as $CaCO_3$	98	300	260	190	35.5	150
Hardness, Dissolved	mg/L as $CaCO_3$	81	--	--	--	--	132
Arsenic	µg/L	--	4.7	2	2	ND	2
Arsenic, Dissolved	µg/L	2	--	2	2	ND	2
Cadmium	µg/L	--	0.05	ND	ND	ND	ND
Cadmium, Dissolved	µg/L	ND	--	ND	ND	ND	ND
Chromium	µg/L	ND	--	2.6	2.1	ND	1.7
Chromium, Dissolved	µg/L	2	--	ND	0.5	ND	ND
Copper	µg/L	--	12	3.2	3.3	1.4	2.9
Copper, Dissolved	µg/L	2	--	1.1	0.75	0.5	0.5
Lead	µg/L	--	3.6	ND	ND	ND	ND
Lead, Dissolved	µg/L	0.5	--	ND	ND	ND	ND
Nickel	µg/L	1	24	2.5	2.5	ND	2.5
Nickel, Dissolved	µg/L	1	--	2.5	ND	ND	2.5
Zinc	µg/L	--	23	4.8	4.9	1	4.2
Zinc, Dissolved	µg/L	2.5	--	1	1	1	1
Mercury	µg/L	--	--	ND	ND	ND	ND
Mercury, Dissolved	µg/L	ND	--	ND	ND	ND	ND
Bifenthrin	µg/L	ND	--	0.025	--	0.025	0.025
Bifenthrin, Dissolved	µg/L	--	--	--	--	--	ND
Azinphos Methyl (Guthion)	µg/L	ND	ND	0.025	0.025	ND	0.025
Chlorpyrifos	µg/L	0.005	0.017	0.005	0.003	0.005	0.006
Chlorpyrifos, Dissolved	µg/L	--	--	0.003	0.005	0.003	0.004
Diazinon	µg/L	0.01	0.033	0.01	0.008	0.01	0.01
Diazinon, Dissolved	µg/L	--	--	0.012	0.008	0.004	0.008
Malathion	µg/L	ND	0.0089	ND	ND	0.0135	0.015
Malathion, Dissolved	µg/L	--	--	0.0135	0.0135	0.0135	0.0135
Parathion, Methyl	µg/L	ND	ND	0.003	0.003	0.003	0.005

Table F4-2. Median Value of the Existing Data by Region

Analyte	Unit	South Delta	Waste-ways	Upper Mainstem	Lower Mainstem	Stanislaus River	Vernalis
4,4'-DDE	µg/L	ND	0.0057	ND	ND	ND	0.0013
4,4'-DDE, Dissolved	µg/L	--	--	0.0015	0.0015	ND	0.0015
Carbaryl	µg/L	0.01	ND	0.01	0.0205	0.01	0.0191
EPTC (Eptam)	µg/L	0.025	0.0018	0.0250	0.0115	0.025	0.0094
Atrazine	µg/L	ND	0.0065	0.0035	0.0035	0.0035	0.0161
Atrazine, Dissolved	µg/L	--	--	0.0035	0.004	0.0035	0.004
Cyanazine	µg/L	ND	0.0054	0.025	0.009	ND	0.025
Cyanazine, Dissolved	µg/L	--	--	0.009	0.009	0.009	0.009
Dacthal (DCPA)	µg/L	0.025	ND	0.025	0.0015	0.025	0.0018
Diuron	µg/L	0.125	0.96	0.458	--	--	0.499
Metolachlor	µg/L	0.0165	0.0158	0.035	0.062	0.01	0.021
Metolachlor, Dissolved	µg/L	--	--	0.038	0.062	0.0065	0.012
Simazine	µg/L	0.029	0.295	0.023	0.013	0.1	0.025
Simazine, Dissolved	µg/L	--	--	0.017	0.013	0.009	0.021
Trifluralin	µg/L	0.005	0.012	0.013	0.008	0.0045	0.0045

Notes:

For the purpose of evaluation, nondetect data were assumed to equal ½ of the reporting limit.

When sample data had a 0% detection frequency, "ND" was indicated.

When sample data were absent from the dataset, "--" was indicated.

Data sources and regional groupings are described at the beginning of **Section F2**.

Key:

CaCO3 = calcium carbonate
DDE = dichlorodiphenyldichloroethylene
µg/L = microgram(s) per liter
mg/L = milligram(s) per liter
ND = not detected
Std. = standard

Table F4-3. Percentage of Samples for Which Water Quality Criteria are Not Met by Region

Analyte	Criteria	Unit	Basis for Criteria	South Delta	Waste-ways	Upper Mainstem	Lower Mainstem	Stanislaus River	Vernalis
Ammonia	0.179	mg/L as N	EPA Aquatic Life Criteria	--	33	45	92	0	81
Ammonia, dissolved	0.179	mg/L as N	EPA Aquatic Life Criteria	1	100	--	--	--	1
Boron (3/15 - 9/15)	0.8	mg/L	Basin Plan WQO	--	14	45	2	0	0.5
Boron (9/16 - 3/14)	1	mg/L	Basin Plan WQO	--	25	10	1	0	0
Boron, dissolved (3/15 - 9/15)	0.8	mg/L	Basin Plan WQO	0	--	--	--	--	0
Boron, dissolved (9/16 - 3/14)	1	mg/L	Basin Plan WQO	0	--	--	--	--	0
Bromide	0.05	mg/L	CALFED WQP ROD goal	--	85	--	--	--	--
Bromide, dissolved	0.05	mg/L	CALFED WQP ROD goal	84	--	--	--	--	97
Dissolved Organic Carbon	3	mg/L	CALFED WQP ROD goal	51	88	--	--	--	58
Dissolved Oxygen	5	mg/L	Basin Plan WQO for WARM	0.9	12	0	0.3	0	0.5
Dissolved Oxygen	7	mg/L	Basin Plan WQO for COLD	6	35	1	0.9	0	1
Electrical Conductivity (EC) (4/1 - 8/31)	700	µmhos/cm	Basin Plan WQO	1	52	76	55	0	21
Electrical Conductivity (EC) (9/1 - 3/31)	1000	µmhos/cm	Basin Plan WQO	0	45	68	28	0	10
Nitrate	10	mg/L as N	CALFED WQP ROD goal	--	0	0	0	0	0
Nitrate, dissolved	10	mg/L as N	CALFED WQP ROD goal	0	--	--	--	--	0
Orthophosphate	0.05	mg/L as P	EPA WQ Criteria	81	79	69	100	0	100
Orthophosphate, dissolved	0.05	mg/L as P	EPA WQ Criteria	47	100	--	--	--	79
pH	6.5 - 8.5	Std. Unit	Basin Plan WQO	1	7	0	7	3	7
Selenium	5	µg/L	Basin Plan WQO	0	0	2	0	0	0
Selenium, dissolved	5	µg/L	Basin Plan WQO	0	--	--	--	--	--
Total Dissolved Solids	440	mg/L	CALFED WQP ROD goal	4	60	84	73	0	23
Total Dissolved Solids	500	mg/L	Basin Plan MOA	1	58	84	67	0	12
Total Organic Carbon	3	mg/L	CALFED WQP ROD goal	66	93	92	77	17	79
Turbidity	50	NTU	CALFED WQP ROD goal	0.8	48	39	19	2	5
Turbidity	150	NTU	Basin Plan WQO	0	13	2	0	0	0
Arsenic	0.14	µg/L	EPA AWQC for Human Health	--	100	48	29	0	23
Arsenic	10	µg/L	Basin Plan WQO	--	0	0	0	0	0
Arsenic, dissolved	0.14	µg/L	EPA AWQC for Human Health	99	--	36	24	0	11
Arsenic, dissolved	10	µg/L	Basin Plan WQO	0	--	0	0	0	0
Cadmium	0.097	µg/L	EPA AWQC for Aquatic Life (25 mg/L hardness)	--	33	0	0	0	0
Cadmium	0.27	µg/L	EPA AWQC for Aquatic Life (100 mg/L hardness)	--	0	0	0	0	0
Cadmium, dissolved	0.094	µg/L	EPA AWQC for Aquatic Life (25 mg/L hardness)	0	--	0	0	0	0

Table F4-3. Percentage of Samples for Which Water Quality Criteria are Not Met by Region

Analyte	Criteria	Unit	Basis for Criteria	South Delta	Waste-ways	Upper Mainstem	Lower Mainstem	Stanislaus River	Vernalis
Cadmium, dissolved	0.25	µg/L	EPA AWQC for Aquatic Life (100 mg/L hardness)	0	--	0	0	0	0
Chromium	28	µg/L	EPA AWQC for Aquatic Life (25 mg/L hardness)	0	--	1	0	0	0
Chromium	86	µg/L	EPA AWQC for Aquatic Life (100 mg/L hardness)	0	--	0	0	0	0
Chromium, dissolved	24	µg/L	EPA AWQC for Aquatic Life (25 mg/L hardness)	0	--	0	0	0	0
Chromium, dissolved	74	µg/L	EPA AWQC for Aquatic Life (100 mg/L hardness)	0	--	0	0	0	0
Copper	2.9	µg/L	EPA AWQC for Aquatic Life (25 mg/L hardness)	--	100	61	55	3	48
Copper	9.3	µg/L	EPA AWQC for Aquatic Life (100 mg/L hardness)	--	60	0	0	0	2
Copper, dissolved	2.7	µg/L	EPA AWQC for Aquatic Life (25 mg/L hardness)	18	--	4	4	0	4
Copper, dissolved	9	µg/L	EPA AWQC for Aquatic Life (100 mg/L hardness)	0	--	0	0	0	0
Lead	0.54	µg/L	EPA AWQC for Aquatic Life (25 mg/L hardness)	--	93	0	0	0	0
Lead	3.2	µg/L	EPA AWQC for Aquatic Life (100 mg/L hardness)	--	53	0	0	0	0
Lead, dissolved	0.54	µg/L	EPA AWQC for Aquatic Life (25 mg/L hardness)	1	--	0	0	0	0
Lead, dissolved	2.5	µg/L	EPA AWQC for Aquatic Life (100 mg/L hardness)	1	--	0	0	0	0
Mercury, dissolved	0.05	µg/L	CTR Human Health Criteria	0	--	0	0	0	0
Nickel	16	µg/L	EPA AWQC for Aquatic Life (25 mg/L hardness)	0	62	0	0	0	0
Nickel	52	µg/L	EPA AWQC for Aquatic Life (100 mg/L hardness)	0	0	0	0	0	0
Nickel, dissolved	16	µg/L	EPA AWQC for Aquatic Life (25 mg/L hardness)	0	--	0	0	0	0
Nickel, dissolved	52	µg/L	EPA AWQC for Aquatic Life (100 mg/L hardness)	0	--	0	0	0	0
Zinc	37	µg/L	EPA AWQC for Aquatic Life (25 mg/L hardness)	--	33	0	0	0	0
Zinc	120	µg/L	EPA AWQC for Aquatic Life (100 mg/L hardness)	--	0	0	0	0	0
Zinc, dissolved	36	µg/L	EPA AWQC for Aquatic Life (25 mg/L hardness)	0	--	0	0	0	0
Zinc, dissolved	120	µg/L	EPA AWQC for Aquatic Life (100 mg/L hardness)	0	--	0	0	0	0
4,4'-DDE	0.00059	µg/L	CTR Human Health Criteria	0	89	0	0	0	1
4,4'-DDE	0.001	µg/L	EPA AWQC for Aquatic Life	0	89	0	0	0	1
4,4'-DDE, Dissolved	0.00059	µg/L	CTR Human Health Criteria	--	--	11	5	0	8
4,4'-DDE, Dissolved	0.001	µg/L	EPA AWQC for Aquatic Life	--	--	6	0	0	7
Atrazine	1	µg/L	CDPH Primary MCL	0	0	0	0	0	0
Atrazine	1	µg/L	EPA AWQC for Aquatic Life	0	0	0	0	0	0
Atrazine, Dissolved	1	µg/L	CDPH Primary MCL	--	--	0	0	0	0
Atrazine, Dissolved	1	µg/L	EPA AWQC for Aquatic Life	--	--	0	0	0	0
Azinphos Methyl (Guthion)	0.01	µg/L	EPA AWQC for Aquatic Life	0	0	1	5	0	1
Bifenthrin	0.02	µg/L	ECOTOX LOEL for Invertebrates	0	--	2	--	0	2
Bifenthrin	110	µg/L	EPA IRIS	0	--	0	--	0	0
Carbaryl	0.02	µg/L	EPA AWQC for Aquatic Life	3	0	5	20	15	6

Table F4-3. Percentage of Samples for Which Water Quality Criteria are Not Met by Region

Analyte	Criteria	Unit	Basis for Criteria	South Delta	Waste-ways	Upper Mainstem	Lower Mainstem	Stanislaus River	Vernalis
Carbaryl	70	µg/L	EPA Drinking Water Health Advisory	0	0	0	0	0	0
Chlorpyrifos	0.015	µg/L	Basin Plan WQO	6	60	10	0	8	3
Chlorpyrifos, Dissolved	0.015	µg/L	Basin Plan WQO	--	--	0	0	4	4
Cyanazine	1	µg/L	EPA Drinking Water Health Advisory	0	0	0	0	0	0
Cyanazine, Dissolved	1	µg/L	EPA Drinking Water Health Advisory	--	--	0	0	0	0
Dacthal (DCPA)	70	µg/L	EPA Drinking Water Health Advisory	0	0	0	0	0	0
Dacthal (DCPA)	14300	µg/L	EPA AWQC for Aquatic Life	0	0	0	0	0	0
Diazinon	0.1	µg/L	Basin Plan WQO	0	13	0	0	3	2
Diazinon, Dissolved	0.1	µg/L	Basin Plan WQO	--	--	0	0	0	4
Diuron	5	µg/L	ECOTOX LOEL for Plants	0	20	0	--	--	1
Diuron	14	µg/L	EPA IRIS	0	0	0	--	--	0
EPTC (Eptam)	180	µg/L	EPA IRIS	0	0	0	0	0	0
Malathion	0.1	µg/L	EPA AWQC for Aquatic Life	0	11	0	0	0	0
Malathion	100	µg/L	EPA Drinking Water Health Advisory	0	0	0	0	0	0
Malathion, Dissolved	0.1	µg/L	EPA AWQC for Aquatic Life	--	--	0	0	0	0
Malathion, Dissolved	100	µg/L	EPA Drinking Water Health Advisory	--	--	0	0	0	0
Metolachlor	70	µg/L	EPA Drinking Water Health Advisory	0	0	0	0	0	0
Metolachlor	100	µg/L	EPA AWQC for Aquatic Life	0	0	0	0	0	0
Metolachlor, Dissolved	70	µg/L	EPA Drinking Water Health Advisory	--	--	0	0	0	0
Metolachlor, Dissolved	100	µg/L	EPA AWQC for Aquatic Life	--	--	0	0	0	0
Parathion, Methyl	0.08	µg/L	CDFG Interim Criteria	0	0	0	0	0	0
Parathion, Methyl	1	µg/L	EPA Drinking Water Health Advisory	0	0	0	0	0	0
Simazine	4	µg/L	CDPH Primary MCL	0	13	0	0	0	0
Simazine	10	µg/L	EPA AWQC for Aquatic Life	0	0	0	0	0	0
Simazine, Dissolved	4	µg/L	CDPH Primary MCL	--	--	0	0	0	0
Simazine, Dissolved	10	µg/L	EPA AWQC for Aquatic Life	--	--	0	0	0	0
Trifluralin	5.3	µg/L	EPA IRIS	0	0	0	0	0	0

Notes:

Only detected samples can be considered above the water quality criteria.

When sample data were absent from the dataset, “- -“ was indicated.

The criteria for hardness-dependent metals are based on 25-mg/L hardness for the Stanislaus River and the south Delta and 100-mg/L hardness for the SJR and the wasteways.

Data sources and regional groupings are described at the beginning of **Section F2**.

Key:

AWQC = ambient water quality criteria
Basin Plan = Water Quality Control Plan for the Sacramento River and San Joaquin River Basins (CVRWQCB 2007)
CDPH = California Department of Public Health
COLD = cold freshwater habitat
CTR = California Toxics Rule
CDFG = California Department of Fish and Game
EPA = U.S. Environmental Protection Agency
IRIS = Integrated Risk Information System
LOEL = lowest observed effects level
MCL = Maximum Contaminant Level
MOA = memorandum of agreement
µg/L = microgram(s) per liter
µmhos/cm = micromhos per centimeter
mg/L = milligram(s) per liter
WARM = warm freshwater habitat
WQO = water quality objective
WQP ROD = Water Quality Program Record of Decision

When the median concentration of the existing regional data for the south Delta is less than or equal to the median concentrations in the SJR, recirculation can potentially improve water quality. When the median concentration in the south Delta is greater than or equal to the median concentrations in the SJR, recirculation can potentially degrade water quality.

Median concentrations in the south Delta were compared to median concentrations in different segments of the SJR for parameters with concentrations in the SJR or south Delta near or above the water quality criteria. A summary of this comparison is as follows:

- Median concentrations in the south Delta are equal to or less than the median concentrations in all segments of the SJR for carbaryl, arsenic, orthophosphate, TOC, DOC, dissolved bromide, and TDS. Recirculation may be beneficial for these parameters.
- Median concentrations for chlorpyrifos in the south Delta are above median concentrations in the upper mainstem, but below other segments of the SJR. Recirculation may increase chlorpyrifos concentrations in the SJR between the Merced River and the Tuolumne River.
- Median concentrations in the south Delta are equal to or above the median concentrations in all segments of the SJR for diazinon, dissolved copper, and dissolved ammonia. Recirculation may degrade water quality in the SJR for these parameters.

Many of the other parameters are either not detected in the south Delta, measured data are much less than the water quality criteria, or the effects from recirculation are inconclusive (**Table F4-2**). The percentages of data above the water quality criteria show a similar pattern for many parameters (**Table F4-3**). Recirculation pilot study data often supported conclusions drawn from the analysis of the regional data.

The recirculation pilot study data provided additional insights into changes in mercury and dissolved copper concentrations from recirculation. In the pilot studies, the SJR benefited from recirculation with respect to dissolved copper concentrations and was degraded with respect to total mercury concentrations (see **Section F2.2.2**). Although dissolved copper concentrations in the SJR decreased during the studies, concentrations were likely below the water quality criteria. Total mercury concentrations at the SJR downstream of Newman Wasteway increased during recirculation, but increases in concentrations were limited both in duration and geographical extent. Dissolved mercury concentrations were substantially below water quality criteria.

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