Appendix E
Selenium and Boron Model

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Abbreviations and Acronyms

Basin Plan	Water Quality Control Plan for the Sacramento River and San Joaquin River Basins
CalSim II	California Simulation Model II
CDEC	California Data Exchange Center
CVRWQCB	Central Valley Regional Water Quality Control Board
DMC	Delta-Mendota Canal
Drain	San Luis Drain
GBP	Grassland Bypass Project
GDA	Grassland Drainage Area
LOD	Level of Development
µg/L	microgram(s) per liter
mg/L	milligram(s) per liter
PFR	Plan Formulation Report
Reclamation	Bureau of Reclamation
SJR	San Joaquin River
TMDL	Total Maximum Daily Load
Use Agreement	Agreement for Use of the San Luis Drain, Agreement No. 01-WC-20-2075
WDR	Waste Discharge Requirement
WQO	Water Quality Objective

Appendix E
Selenium and Boron Model

E.1 Introduction

The U.S. Department of the Interior, Bureau of Reclamation (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 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 and flow standards while reducing water demands from New Melones Reservoir. This appendix provides an evaluation of potential changes in selenium and boron concentrations due to the alternative plans.

The Selenium and Boron Model for the SJR was developed to predict the concentrations and loads of selenium and boron for the DMC Recirculation Project Plan Formulation Report (PFR). The predicted water quality for selenium and boron for the alternative plans (A1, A2, B1, B2, C, and D) with a future Level of Development (LOD) are compared with each other and with existing and future conditions (the No-Project and No-Action Alternatives, respectively). Modeled concentrations are compared to Water Quality Objectives (WQOs) to predict water quality exceedance.

The geographical boundaries of the model are the SJR at Lander Avenue in the south and the SJR at Vernalis in the north. Inputs include Mud and Salt sloughs, San Luis Drain (Drain), Newman Wasteway, and the major eastside tributaries.

E.1.1 Selenium

Selenium is a naturally occurring trace element that is known to adversely affect waterfowl at elevated levels. Soils on the west side of the SJR Basin originate from geologically uplifted marine sediments that make up the Coast Range. These soils are very productive agriculturally but in certain locations these soils are high in salts and trace elements, such as arsenic, boron, molybdenum, and selenium. The salts and trace elements were concentrated in the historic marine sediments.

Tile drainage from the Grassland Drainage Area (GDA) of the Grassland watershed has elevated selenium concentrations. Subsurface return flows from the GDA contribute approximately 90% of the selenium load in the lower SJR. On the west side of the SJR, the selenium concentration of surface return flows and wetland discharges are less than subsurface return flow concentrations. Surface return flows and wetland discharges typically have selenium concentrations similar to the irrigation water (CVRWQCB 2001a).

The Grassland Bypass Project (GBP) was implemented to divert agricultural drainage water from the GDA away from Grassland Water District water supply channels. This diversion has reduced selenium concentrations in the supply water used in Grassland watershed wildlife refuges and managed wetlands. A segment of the Drain conveys agricultural drainwater from the GDA to Mud Slough (North). As a result of the use of the Drain, Salt Slough receives surface agricultural return flows and wetland discharges but no significant subsurface agricultural return flows. Upstream of the Drain confluence, Mud Slough receives primarily wetland discharges. Downstream of the Drain discharge, Mud Slough is highly influenced by subsurface agricultural drainage (CVRWQCB 2001a). During Water Year 2000, releases from the Drain contributed 97% of the selenium discharged to the SJR from the Grassland watershed (CVRWQCB 2001b).

Water Quality Objectives

The Central Valley Regional Water Quality Control Board (CVRWQCB) has adopted the U.S. Environmental Protection Agency 4-day average aquatic life criterion for total selenium, a 4-day average concentration of 5 micrograms per liter (µg/L), as the selenium WQO for the lower SJR (CVRWQCB 2001a).

The *Water Quality Control Plan for the Sacramento River and San Joaquin River Basins* (Basin Plan) has specific WQOs for selenium in segments of the SJR, Salt Slough, and Mud Slough. The selenium objectives are as follows:

- 12 micrograms per liter (µg/L) maximum concentration and 5 µg/L 4-day average concentration for the SJR from the mouth of the Merced River to Vernalis
- 20 µg/L maximum concentration and 5 µg/L 4-day average concentration for Mud Slough (North) and the SJR from Sack Dam to the mouth of the Merced River
- 20 µg/L maximum concentration and 2 µg/L 4-day average concentration for Salt Slough and specific reconstructed water supply channels in the Grassland watershed

Table E-1. Compliance Time Schedule for Meeting the 4-Day Average and Monthly Mean Water Quality Objective for Selenium

Water Body/Water Year Type	January 10, 1997	October 1, 2002	October 1, 2005	October 1, 2010
Salt Slough and Wetland Water Supply Channels listed in Appendix 40 of the Basin Plan	2 µg/L monthly mean			
San Joaquin River below the Merced River; Above Normal and Wet Water Year types		5 µg/L monthly mean	5 µg/L 4-day average	
San Joaquin River below the Merced River; Critical, Dry, and Below Normal Water Year types		8 µg/L monthly mean	5 µg/L monthly mean	5 µg/L 4-day average
Mud Slough (North) and the San Joaquin River from Sack Dam to the Merced River				5 µg/L 4-day average

Source: CVRWQCB (2007a)

Note:

The water year classification is established using the best available estimate of the 60-20-20 San Joaquin Valley water year hydrologic classification. The selenium WQOs are in bold and the performance goals are in italics.

Key:

µg/L = microgram(s) per liter

The discharge of subsurface drainwater from the Grassland watershed is regulated by selenium effluent limits established in the waste discharge requirement (WDR) (CVRWQCB 2007a).

The Basin Plan stipulates a time schedule for compliance with these selenium WQOs and performance goals. The time schedule and objectives are listed in **Table E-1**. The selenium WQOs are in bold and the performance goals are in italics.

The water quality compliance point for selenium in the SJR (prior to October 2010) is at Crows Landing. The SJR at Crows Landing is the first easily monitored site downstream of the Merced River confluence. This site is used as the compliance point because most of the selenium is discharged to the SJR upstream of the Merced River confluence. After 2010, Mud Slough (North) and the SJR from Sack Dam to the Merced River must also meet the WQOs (CVRWQCB 2001a).

Load Allocations

The *Agreement for Use of the San Luis Drain, Agreement No. 01-WC-20-2075* (Use Agreement) between Reclamation and the San Luis Delta-Mendota Water Authority describes operation conditions for the Drain for Phase II of the GBP. The Use Agreement specifies maximum monthly and annual selenium load limits for the Drain (Reclamation 2001). Work has been initiated to develop a third use agreement that will take effect once the second use agreement expires and would most likely have new load allocations. **Table E-2** lists the selenium load limits specified in the 2001 Use Agreement.

The CVRWQCB adopted *Waste Discharge Requirements; Order No. 5-01-234* for Phase II of the GBP (CVRWQCB 2001b). The WDR also specifies maximum monthly and annual selenium load limits that the GDA and Drain may discharge into Mud Slough and the SJR. From 2001 to 2004, the load limits specified in the WDR are the same as the load limits specified in the Use Agreement. Between years 2005 and 2009 the load limits for different water year types can vary by month and water year type. **Tables E-3 and E-4** list the load limits specified in the WDR from 2001 through 2009.

The load limits in the Use Agreement and the WDR are based in part upon total maximum monthly load limits developed by the CVRWQCB. The August 2001 CVRWQCB Staff Report titled *Total Maximum Daily Load for Selenium in the Lower San Joaquin River* has maximum monthly selenium load limits for the GDA (CVRWQCB 2001a). These load limits are designed to meet a 5 µg/L 4-day average selenium concentration in the SJR, downstream of the Merced River confluence, at Crows Landing. **Table E-5** lists the Total Maximum Daily Load (TMDL) load allocations for the GDA.

Table E-2. Use Agreement Selenium Load Limits (pounds) for San Luis Drain

Month	2001	2002	2003	2004	2005	2006	2007	2008		2009	
	All Year Types	All Year Types	All Year Types	All Year Types	All Year Types	All Year Types	All Year Types	Critical, Dry, and Below Normal	Above Normal and Wet	Critical, Dry, and Below Normal	Above Normal and Wet
January	–	385	359	333	289	211	211	198	211	185	211
February	–	619	571	523	440	297	297	265	297	234	297
March	–	753	685	618	496	297	297	265	297	233	297
April	–	577	538	499	433	315	315	282	315	249	315
May	–	488	464	439	400	322	322	288	322	255	322
June	–	429	397	365	308	212	212	188	212	165	212
July	–	429	397	365	310	214	214	188	214	166	214
August	–	387	363	339	299	225	225	190	225	175	225
September	–	310	303	297	291	264	264	200	264	193	264
October	315	308	301	294	260	260	260	229	260	190	260
November	315	308	301	294	260	260	260	225	260	190	260
December	353	334	316	298	211	211	211	198	211	185	211
Annual	–	5,328	4,995	4,662	3,996	3,088	3,088	2,754	3,088	2,421	3,088

Source: Reclamation (2001)

Note:

Load limits for Phase II of the GBP are designated for October 2001 to December 2009

Key:

GBP = Grassland Bypass Project

Table E-3. Waste Discharge Requirements for Selenium (pounds) for Grassland Drainage Area and San Luis Drain during Years 2001 to 2006

Month	2001	2002	2003	2004	2005				2006			
	All Year Types	All Year Types	All Year Types	All Year Types	Critical	Dry/ Below Normal	Above Normal	Wet	Critical	Dry/ Below Normal	Above Normal	Wet
January	—	385	359	333	398	398	398	211	373	390	398	211
February	—	619	571	523	472	472	472	488	434	443	472	488
March	—	753	685	618	472	472	472	488	434	443	472	488
April	—	577	538	499	490	490	490	506	451	460	490	506
May	—	488	464	439	497	497	497	512	458	467	497	512
June	—	429	397	365	212	212	212	354	198	204	212	354
July	—	429	397	365	214	214	214	356	200	206	214	356
August	—	387	363	339	225	225	225	366	210	216	225	366
September	350	310	303	297	264	264	264	332	243	261	264	332
October	315	308	301	294	260	260	260	328	240	257	260	328
November	315	308	301	294	260	260	260	328	240	257	260	328
December	353	334	316	298	398	398	398	211	373	390	398	211
Annual	-	5,328	4,995	4,662	4,162	4,162	4,162	4,480	3,853	3,995	4,162	4,480

Source: CVRWQCB(2001 b)

Note:

Load limits for Phase II of the GBP are designated for September 2001 to December 2009.

Key:

GBP = Grassland Bypass Project

Table E-4. Waste Discharge Requirements for Selenium (pounds) for Grassland Drainage Area and San Luis Drain during Years 2007 to 2009

Month	2007				2008				2009			
	Critical	Dry / Below Normal	Above Normal	Wet	Critical	Dry / Below Normal	Above Normal	Wet	Critical	Dry / Below Normal	Above Normal	Wet
January	349	382	398	211	324	374	398	211	270	357	398	211
February	396	415	472	488	358	386	472	488	275	323	472	488
March	396	414	472	488	358	386	472	488	274	322	472	488
April	412	431	490	506	373	401	490	506	288	336	490	506
May	419	437	497	512	379	407	497	512	293	341	497	512
June	183	196	212	354	169	187	212	354	138	169	212	354
July	185	197	214	356	171	189	214	356	139	171	214	356
August	195	207	225	366	180	199	225	366	147	179	225	366
September	223	258	264	332	202	255	264	332	156	249	264	332
October	219	255	260	328	199	252	260	328	153	246	260	328
November	219	255	260	328	199	252	260	328	153	246	260	328
December	349	382	398	211	324	374	398	211	270	357	398	211
Annual	3,545	3,829	4,162	4,480	3,236	3,662	4,162	4,480	2,557	3,296	4,162	4,480

Source: CVRWQCB 2001b

Note: Load limits for Phase II of the GBP are designated for September 2001 to December 2009.

Key:

GBP = Grassland Bypass Project

Table E-5. TMDL Selenium Load Limits (pounds) for the GDA by Water Year Type

Month	Water Year Type			
	Critical	Dry/Below Normal	Above Normal	Wet
January	151	319	398	211
February	93	185	472	488
March	92	184	472	488
April	101	193	490	506
May	105	197	497	512
June	69	130	212	354
July	70	131	214	356
August	75	137	225	366
September	57	235	264	332
October	55	233	260	328
November	55	233	260	328
December	152	319	398	211
Total	1,075	2,496	4,162	4,480

Source: CVRWQCB (2001a)

Key:

GDA = Grassland Drainage Area

TMDL = Total Maximum Daily Load

The load limits in the WDR and the Use Agreement differ from the TMDLs listed in the CVRWQCB's 2001 TMDL report. The WDR and the Use Agreement incorporate annual reductions designed to meet interim performance goals and WQOs in accordance with the compliance time schedule.

E.1.2 Boron

Boron is widely distributed in nature and is found mostly in sedimentary deposits and sediments but also in metamorphic and igneous rocks. Seawater is a source of boron, and typically has a boron concentration of 5 milligrams per liter (mg/L). The soils that are derived from marine sediments on the western side of the SJR Basin are also high in boron (CVRWQCB 2004).

According to the July 2004 CVRWQCB Staff Report, *Appendix 1: Technical TMDL Report, Amendments to the Water Quality Control Plan for the Sacramento River and San Joaquin River Basins for the Control of Salt and Boron Discharges into the Lower San Joaquin River*, the Grassland watershed contributes approximately 490 tons of boron per year to the lower SJR, which accounts for 50% of the total boron load in the SJR at Vernalis. The northwestern side contributes an additional 350 tons of boron per year to the

SJR, which accounts for 36% of the total boron load at Vernalis (CVRWQCB 2004). During Water Year 2000, releases from the Drain contributed 55% of the boron discharged to the SJR from the Grassland watershed (CVRWQCB 2001b).

Boron toxicity can occur in plants and is characterized by leaf malformation and by thickened, curled, wilted, and chlorotic leaves. Aquatic life sensitivity to boron varies widely from species to species. Some species such as rainbow trout are particularly boron sensitive (CVRWQCB 2004).

Water Quality Objectives

The Basin Plan specifies WQOs for boron in the SJR from the mouth of the Merced River to Vernalis. The boron objectives are 2.0 mg/L maximum concentration and 0.8 mg/L monthly mean from March 15 to September 15, 2.6 mg/L maximum concentration and 1.0 mg/L monthly mean from September 16 to March 14, and 1.3 mg/L monthly mean in critical water year types (CVRWQCB 2007a).

Load Allocations

The goal of the control program for salt and boron discharges into the lower SJR is to achieve compliance with the salinity and boron WQOs. Salt load allocations are determined for specific dischargers or groups of dischargers. Control actions that result in salt load reductions are also effective for boron (CVRWQCB 2007a).

The WDR for the Drain specifies selenium load limits. These selenium load limits are expected to result in reductions in salt and boron discharges (CVRWQCB 2001b).

E.2 Description of the Model

The Selenium and Boron Model propagates selenium and boron loads through the SJR system to predict selenium and boron concentrations for the alternative plans. This model requires California Simulation Model II (CalSim II) San Joaquin Extension modeling results as input flow data.

Figure E-1 shows a schematic of the elements included in the water balance model. The locations selected for analyses correspond to compliance stations and typical monitoring locations. Flows, concentrations, and loads of selenium and boron were determined for input locations and calculation nodes within the model. The load at the calculation nodes were estimated as the sum of the loads

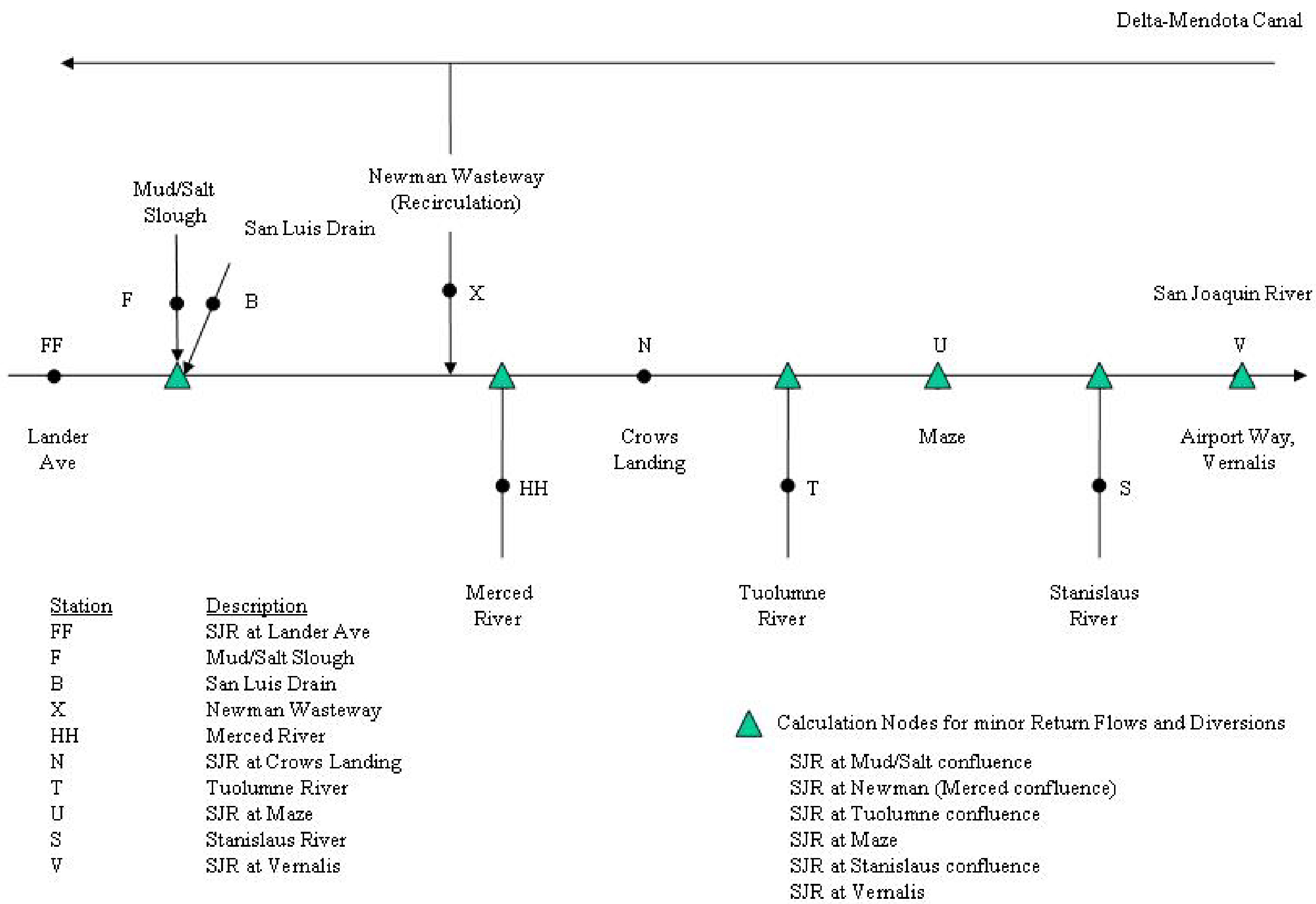

Figure E-1. Schematic of the Selenium and Boron Model

for all load inputs upstream. The concentrations for locations on the SJR were then determined from the total flows and loads.

The Selenium and Boron Model is used to determine constituent concentration in the SJR at Crows Landing (Station N) and the SJR at Vernalis (Station V). Station N is the sum of upstream contributions originating primarily from the Merced River, Newman Wasteway, Mud Slough, Salt Slough, Drain, and the SJR at Lander Avenue. Station V has contributions from the same sources as Station N as well as the Tuolumne and the Stanislaus rivers.

For example, the flow or load in the SJR at Crows Landing is the sum of the flow or load carried by the SJR at Lander Avenue, Salt Slough and Mud Slough upstream of the San Luis Drain, the Drain, Newman Wasteway, the Merced River, and minor inflows at the calculation nodes minus diversions at the calculation nodes.

$$N = FF + F + B + X + HH + \text{minor inflows} - \text{diversions}$$

Where N, FF, F, B, X, and HH are as defined on **Figure E-1.**

Similarly, the flow or load in the SJR at Vernalis is the sum of the flow or load carried by the SJR at Lander Avenue, Salt Slough, and Mud Slough upstream of the San Luis Drain, the Drain, Newman Wasteway, the Merced River, the Tuolumne River, the Stanislaus River, and minor inflows at the calculation nodes minus diversions at the calculation nodes.

$$V = FF + F + B + X + HH + T + S + \text{minor inflows} - \text{diversions}$$

Where V, FF, F, B, X, HH, T, and S are as defined on **Figure E-1.**

Diversions were calculated by summing CalSim II modeled diversion flows at each of the calculation nodes. Minor inflows are determined by the difference between the above-mentioned CalSim II modeled flows entering and exiting each of the calculation nodes. Minor inflows are primarily accounted for by local agricultural return flows.

Modeled concentrations are determined from loads and flows.

E.3 Model Inputs and Assumptions

E.3.1 Water Year Types

Five different water year types were modeled for the DMC Recirculation PFR for the No-Project/No-Action Alternatives and the alternative plans (A1, A2, B1, B2, C, and D) modeled under the future LOD. Representative years selected for alternative modeling include 1993, 1963, 2003, 2002, and 1992, which correspond to Wet, Above Normal, Below Normal, Dry, and Critical, respectively. These years were selected based on modeled recirculation flow for Alternatives B1 and B2 under the future LOD.[1]

The SJR Index from the California Department of Water Resources was used to determine water year types (DWR 2007a). **Table E-6** shows the value of the index and official water year classification for recent years (Water Years 1997 through 2007).

Table E-6. San Joaquin Valley Index Official Year Classifications for Water Years 1995–2007

Water Year	Index Value	Year Type
1997	4.2	Wet
1998	4.9	Wet
1999	3.4	Above Normal
2000	3.3	Above Normal
2001	2.3	Dry
2002	2.3	Dry
2003	2.7	Below Normal
2004	2.2	Dry
2005	4.2	Wet
2006	5.5	Wet
2007	1.9	Critical

Source: DWR 2007a

Notes:

San Joaquin Valley Water Year Index = 0.6 * Current Apr-Jul Runoff Forecast (million acre-feet [maf]) + 0.2 * Current Oct-Mar Runoff (maf) + 0.2 * Previous Water Year's Index. If the Previous Water Year's Index exceeds 4.5, then 4.5 is used.

San Joaquin River runoff is the sum of Stanislaus River inflow to New Melones Lake, Tuolumne River inflow to New Don Pedro Reservoir, Merced River inflow to Lake McClure, and SJR inflow to Millerton Lake in maf.

Water year classification is determined by the following.

San Joaquin Valley Water Year Hydrologic Classification	
Year Type	Water Year Index
Wet	Equal to or greater than 3.8
Above Normal	Greater than 3.1, and less than 3.8
Below Normal	Greater than 2.5, and equal to or less than 3.1
Dry	Greater than 2.1, and equal to or less than 2.5
Critical	Equal to or less than 2.1

[1] CalSim II modeled San Joaquin River Basin hydrology for an 82-year period, Water Years 1922 to 2003, for existing conditions, FNA, and future alternatives, prior to the selection of representative years.

E.3.2 Future Conditions

To estimate the future LOD, assumptions were made regarding the future operations of the Drain. Currently, no projects or actions are planned that would relocate the GDA discharge point, nor are treatment systems in place that can reduce the selenium concentration to levels that meet the 2010 selenium WQOs for Mud Slough (North) downstream of the Drain. Therefore, it was assumed that the Drain would no longer carry GDA discharge, and return flows from the GDA to the SJR would not occur. All discharges were assumed to be recycled, reused, or infiltrated within the boundaries of the GDA. The assumptions used for future conditions are described in **Appendix A** of the PFR, **Sections 2.3.3 and 2.3.4**.

Under the future LOD, the loads and concentrations of selenium and boron in the SJR and Mud Slough were significantly reduced due to the lack of the GDA discharge. This reduction caused a significant difference in concentrations between conditions under the No-Action Alternative and conditions under the No-Project Alternative. Reductions in selenium and boron concentrations were also assumed to occur in the DMC and Newman Wasteway under future conditions.

E.3.3 Flow

Flow output from the SJR CalSim II model (**Appendix A** of the PFR) was used as the input flow data for the Selenium and Boron Model. CalSim flow output was in a monthly time step, with April and May flow separated into pulse and nonpulse time periods. The CalSim II flow output includes existing conditions (the No-Project Alternative), future conditions (the No-Action Alternative), and all alternative plans under a future LOD. Flow data were required from the following locations for existing conditions (the No-Project Alternative), future conditions (the No-Action Alternative), and the alternative plans (**Table E-7**).

For existing conditions, the flows for the Drain were assumed to have monthly flows as described in **Table E-8**. These flows were assumed to be zero for the future LOD.

During the representative Critical year (Water Year 1992) under the future LOD, the SJR from Newman Wasteway to the Tuolumne confluence was predicted to have no flow in July and August due to diversions. Selenium and boron loads were assumed to be zero when flow was zero.

Table E-7. San Joaquin River CalSim II Flows Used in the Selenium and Boron Model

Modeled Flows	Description
C611	SJR from Lander Avenue to the Mud/Salt Slough confluence
R614West	Westside return flows from Mud and Salt sloughs
I614	Mud and Salt Slough Accretions
C614	SJR from Mud/Salt Slough confluence to Newman Wasteway
C566	Merced River from Livingston/Stevinson to the SJR confluence
D701_REC_WQ	Recirculation due to water quality
D701_REC_MIN	Recirculation due to flow requirements
D620A, D620B, D620C	Diversions in the SJR at Newman Wasteway
C620	SJR from Newman Wasteway to the Tuolumne confluence
C545	Tuolumne River from Modesto to the SJR confluence
D630A, D630B	Diversions in the SJR at the Tuolumne confluence
C630	SJR from the Tuolumne confluence to Maze
C636	SJR from Maze to the Stanislaus confluence
C528	Stanislaus River from Ripon to the SJR confluence
C637	SJR from Stanislaus confluence to Vernalis
D639	Diversions in the SJR at Vernalis
C639	SJR at Vernalis

Key:
CalSim II = California Simulation Model II
SJR = San Joaquin River

Table E-8. CalSim II Input for Grassland Bypass Project Flows (thousand acre-feet)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept
Flow	1.5	1.5	1.5	1.7	3.2	3.4	2.5	2.6	3.5	3.6	3.5	1.5

Key:
CalSim II = California Simulation Model II

E.3.4 Water Quality

Water quality data were obtained from CVRWQCB's SJR Watershed Surface Water Ambient Monitoring Program. These data represent a compilation of monitoring efforts, which include characterization of the SJR mainstem and drainage basin inflows, the GBP compliance monitoring, and the Intensive Rotational Basin program (CVRWQCB 2007b). Water quality data were obtained for locations indicated in **Table E-9**. For the majority of these sites, selenium and boron were measured on a weekly basis. The Drain and the SJR at Crows Landing were measured daily by autosampler and the major eastside tributaries were measured monthly. These data were used in model verification and calculating monthly average concentration inputs.

Table E-9. CVRWQCB Water Quality Data Monitoring Stations Used in Model Development

Site	CVRWQCB Station Code	Location	Water Years
Station FF	MER522	SJR at Lander Avenue	1997–2007
Station F	MER531	Salt Slough at Lander Avenue (Highway 165)	1997–2007
Station B	MER535S	San Luis Drain at Terminus, autosampler	1997–2007
Station HH	MER546	Merced River at River Road	1998–2006
Station N	STC504S	SJR at Crows Landing (Turlock Sports Club), autosampler	1997–2007
Station T	STC513	Tuolumne River at Shiloh Fishing Access	1998–2006
Station S	STC514	Stanislaus River at Caswell Park	1998–2006
Station V	SJC501	SJR at Airport Way	1997–2007

Key:
CVRWQCB = Central Valley Regional Water Quality Control Board
SJR = San Joaquin River

Data used to characterize selenium and boron in the recirculation flow were obtained from Reclamation's Delta-Mendota Canal Water Quality Monitoring Program (Reclamation 2008). Monthly average flow-weighted selenium concentrations were reported from daily water quality monitoring near the DMC Headworks (Milepost 3.50) and monthly boron data were reported from grab samples in the DMC at Washoe Avenue (Milepost 110.120) from July 2002 to November 2007.

Water quality data that were not detected were estimated as equal to one-half of the reporting limit. For CVRWQCB's data, typically the reporting limit for selenium was 0.4 µg/L and the reporting limit for boron was 0.05 mg/L. For the data used to estimate the water quality of the recirculation flow, the reporting limit for selenium was 0.4 µg/L, and boron was detected in every sample. Therefore nondetect selenium data were typically estimated as 0.2 µg/L and nondetect boron data were estimated as 0.025 mg/L.

Monthly average concentrations were calculated from the CVRWQCB data (Water Years 1997 to 2007) for the SJR at Lander Avenue and Salt Slough for selenium, and for the SJR at Lander Avenue, Salt Slough, and the Drain for boron. The spread of the data between different years of the same water year type was similar to the spread of the data between water year types; therefore, data were averaged across year types.

Monthly average concentrations for the recirculation flow were calculated from Reclamation data (Water Years 2002 to 2007) for alternative plans modeled with the existing LOD. Monthly selenium concentrations for the recirculation flow were similar for different water year types; therefore, selenium data were averaged across year types. Boron concentrations for the recirculation flow of wetter years differed from drier years during the late spring and early summer months. Therefore, monthly average concentrations were calculated for wet years (Wet/Above Normal) and dry years (Below Normal/Dry/Critical years). These concentrations were used for alternative plans modeled with the existing LOD (which was not presented in the PFR). Existing conditions do not include recirculation.

Under the future LOD, the selenium and boron concentrations in the SJR at Vernalis would be less than the selenium and boron concentrations under existing conditions due to the removal of GDA discharge (as described in **Section E.3-2**). When the alternative plans were modeled with the future LOD, it was assumed that the concentration of the recirculation flow was equal to the concentration of the selenium or boron in the SJR at Vernalis in the No-Action Alternative condition. The No-Action Alternative does not include recirculation.

The major eastside tributaries (the Merced, Tuolumne, and Stanislaus rivers) had data that were primarily nondetect for selenium and boron. Boron concentrations were assumed to equal 0.025 mg/L for all months and water year types, which is equivalent to one-half of the reporting limit for boron. Selenium concentrations were assumed to equal 0.1 µg/L for all months and water year types, which is equivalent to one-quarter of the reporting limit for selenium.

The selenium concentration for the major eastside tributaries was estimated at this lower concentration on the basis of monitoring data collected for the East San Joaquin Water Quality Framework (URS 2007). The selenium laboratory method used in the Eastside study was a low level method that produced reliable data. These data were from SJR Basin eastside canals and laterals that were often influenced by agricultural drainage. The results for selenium ranged from 0.031 to 1.14 µg/L, with a median of 0.082 µg/L, an average of 0.16 µg/L, and a detection frequency of 100% (URS 2007). The selenium data came from eastside channels and drains that may have higher concentrations of selenium than tributary melt water. It was assumed that the major eastside tributaries would provide dilution for these eastside canals and laterals. Therefore, the selenium concentration in the major eastside tributaries was estimated as 0.1 µg/L for the Selenium and Boron Model.

CalSim II calculates inflows and diversions at flow nodes along the SJR. Diversions were assumed to have the same concentration as the SJR at the point of the diversion. Minor eastside or westside return flows occurred at calculation nodes (see **Figure E-1**) and were included as minor inflows. Approximately one third of the minor inflows were from the westside of the SJR, and two-thirds of the minor inflows were from the eastside of the SJR. These flows were assumed to have selenium concentrations of 0.5 µg/L and boron concentrations of 0.4 mg/L with the exception of SJR at Lander Avenue inflows, which were assumed to have the same concentration as the river. The inflow at Lander

Avenue consisted primarily of Vernalis Adaptive Management Program water releases.

Tables E-10 and E-11 show the average monthly selenium and boron concentrations used in the model.

Table E-10. Monthly Average Concentration of Selenium (μg/L) Used in the Selenium and Boron Model

Month	SJR at Lander Avenue	Mud/Salt Slough[1]	Eastside Rivers[2]	Minor Inflows[2]	Recirculation Flow[3]
October	0.20	0.62	0.10	0.50	0.20
November	0.21	0.59	0.10	0.50	0.26
December	0.24	0.59	0.10	0.50	0.30
January	0.26	0.66	0.10	0.50	0.36
February	0.23[a]	0.94[a]	0.10	0.50	0.46
March	0.33	1.10	0.10	0.50	0.62
April	0.26	0.88	0.10	0.50	0.40
May	0.28	0.72	0.10	0.50	0.24
June	0.26	0.71	0.10	0.50	0.20
July	0.24	0.75	0.10	0.50	0.20
August	0.23	0.66	0.10	0.50	0.20
September	0.20	0.56	0.10	0.50	0.20

Sources: CVRWQCB, Reclamation

Notes:

Nondetect data are assumed to equal 1/2 of the reporting limit.

[1] Average monthly concentration from Salt Slough.

[2] Assumed concentrations; data were primarily non-detect for the eastside rivers.

[3] For alternative plans with the existing Level of Development; under the future Level of Development, alternative plans have concentrations equal to Vernalis under the No-Action Alternative. There is no recirculation flow for conditions under the No-Project/No-Action Alternatives.

[a] Excludes February 1998.

Key:

μg/L = microgram(s) per liter
SJR = San Joaquin River

Table E-11. Monthly Average Concentration of Boron (mg/L) Used in the Selenium and Boron Model

Month	SJR at Lander Avenue	Mud/Salt Slough[1]	Eastside Rivers[2]	Minor Inflows[2]	Grassland Drainage Area Discharge[3]	Recirculation Flow[4]	
						Wet, Above Normal	Below Normal, Dry, Critical
October	0.21	0.63	0.025	0.40	6.79	0.13	0.13
November	0.16	0.77	0.025	0.40	6.93	0.20	0.19
December	0.18	1.04	0.025	0.40	6.64	0.36	0.22
January	0.14	1.10	0.025	0.40	7.06	0.39	0.28
February	0.16	1.00	0.025	0.40	6.68	0.19	0.29
March	0.15	1.09	0.025	0.40	7.79	0.36	0.20
April	0.20	0.90	0.025	0.40	8.20	0.39	0.28
May	0.19	0.62	0.025	0.40	7.53	0.61	0.20
June	0.22	0.51	0.025	0.40	7.34	0.70	0.22
July	0.22	0.51	0.025	0.40	7.21	0.13	0.16
August	0.22	0.47	0.025	0.40	6.57	0.13	0.14
September	0.27	0.56	0.025	0.40	6.56	0.22	0.17

Key:
mg/L milligram(s) per liter

E.3.5 San Luis Drain Load Limits

Under the future LOD, the Drain is not used to transport GDA discharge to the SJR. Because a significant portion of the selenium and boron load for the SJR at Vernalis originates from the GDA, the background concentrations of selenium and boron in the lower SJR were predicted to be less than for existing conditions.

Under existing conditions, it is assumed that selenium was discharged from the Drain at the 2005 load limit. The monthly load used for existing conditions was the lesser value of the load limits specified by the WDR and the Use Agreement for Water Year 2005. **Table E-12** shows the load limit used for existing conditions.

Table E-12. Selenium Loads (pounds) for San Luis Drain Used as Existing Conditions in the Selenium and Boron Model

Month	Wet	Above Normal, Below Normal, Dry, Critical
October	294	294
November	294	294
December	298	298
January	211	289
February	440	440
March	488	472
April	433	433
May	400	400
June	308	212
July	310	214
August	299	225
September	291	264
Total	4,066	3,835

Note:

Loads represent the lower load limit of the Use Agreement and the Waste Discharge Requirements for Water Year 2005.

E.4 Model Verification, Water Year 2005

Existing conditions for the Selenium and Boron Model was verified with measured flow and measured concentrations for Water Year 2005. Flow data were downloaded for California Data Exchange Center (CDEC) stations in the project area. Concentration data compiled by the CVRWQCB were downloaded for monitoring locations in the project area (**Table E-9**). Water Year 2005 had the most complete flow and concentration data for analysis.

E.4.1 Flow Data acquired for Model Verification

Flow data were obtained from the Department of Water Resources CDEC website for Water Year 2005 for stations listed in **Table E-13**. Flow was monitored at these stations on a continuous basis, typically on a 15-minute interval, and reported as mean daily flow in cubic feet per second (DWR 2007b).

Table E-13. CDEC Stations Used for Model Verification

Site	CDEC Station	Description
Station FF	SJS	San Joaquin River near Stevinson
Station F	SSH	Salt Slough at Highway 165 near Stevinson
Adjustment to Station F[1]	MSG	Mud Slough near Gustine
Station HH	MST	Merced River near Stevinson
Inflow[2]	OCL	Orestimba Creek at River Road near Crows Landing
Station N	SCL	San Joaquin River near Crows Landing
Station T	LGN	Tuolumne River below La Grange Dam near La Grange
Station S	RIP	Stanislaus River at Ripon
Station V	VNS	San Joaquin River near Vernalis

Notes:

[1] The flow for Mud Slough upstream of the Drain was calculated as the difference between the flow at Mud Slough near Gustine (MSG) and the Drain terminus; this flow is included in Mud/Salt Slough input flow.

[2] Orestimba Creek at River Road near Crows Landing (OCL) was included as an inflow at the Merced confluence calculation node.

Key:

CDEC = California Data Exchange Center

Flow monitoring stations along the Merced, Tuolumne, and Stanislaus rivers were chosen closest to the SJR confluence. For the Tuolumne River the closest CDEC station was located near La Grange Dam.

Additional flow data were acquired from the San Francisco Estuary Institute website for the Drain (Station B). These data were reported by the Institute as daily flow in cubic feet per second (SFEI 2007).

The flow for Mud Slough upstream of the Drain was calculated as the difference between the flows at Mud Slough downstream of the Drain and the Drain terminus (Station B).

Missing data were assumed to be unmeasured rather than nondetect; therefore, the missing data were substituted using the closest measurement taken before the missing data date, except where those data were also not available. In that case the closest measurement taken after that missing datapoint was used.

E.4.2 Verification Results

Monthly concentrations described in **Tables E-10** and **E-11** and measured selenium concentrations for the Drain were used in conjunction with the flow data to compute selenium and boron loads for Water Year 2005.

Measured selenium concentrations for the Drain were used in the model verification, instead of 2005 load limits, because selenium loads were not discharged at the limit during all months. The quantities of the minor return flows were estimated from the CalSim flows for the representative Wet year. Recirculation flow was not included.

Loads were summed to predict loads at downstream locations. Flows were also summed to predict flows at downstream locations. Modeled loads and flows were then used to predict modeled concentrations. Water Year 2005 was chosen as the verification year because it had the most complete flow record for the stations described in **Table E-13**.

Figures E-2 and E-3 show predicted and measured flow in the SJR at Crows Landing and at Vernalis for Water Year 2005. **Figures E-4 and E-5** compare the measured and modeled flow directly. These figures indicate that the major sources of flow at Crows Landing and Vernalis can be accounted for by summing the inputs described in **Section E.2**.

Peak flow events may be over-represented by the modeled flow, and spring and summer flows may be under-represented; however, overall bias is minimal (less than 3% error in the slope of the best fit line). Modeled flow is slightly offset from measured flow.

Travel time is not accounted for by the model, which can be seen when modeled flow precedes measured flow. Travel time is greater at Vernalis than at Crows Landing.

Figures E-6 through E-9 show predicted and measured concentration in the SJR at Crows Landing and at Vernalis. For these figures, modeled concentrations are reported in a daily time step and measured concentrations at Crows Landing are also daily; however, measured concentrations at Vernalis are weekly. Measured concentrations have one or two significant figures and therefore appear in concentration increments. Some of the differences between measured and modeled concentrations can be accounted for by the differences in time step and measurement increments.

Model verification suggests that selenium is predicted more accurately than boron, although peak selenium concentrations may be over-represented slightly (**Figures E-6 through E-7**). Modeled boron under-represents peak boron concentrations, particularly during winter storm events (**Figures E-8 through E-9**).

Some of the differences between measured and modeled concentrations may be due to the reduction in variation that is associated with the averaged input concentrations. (The input concentrations were averaged to allow for predictive capability.) For example, monthly boron concentrations from Water Years 1997

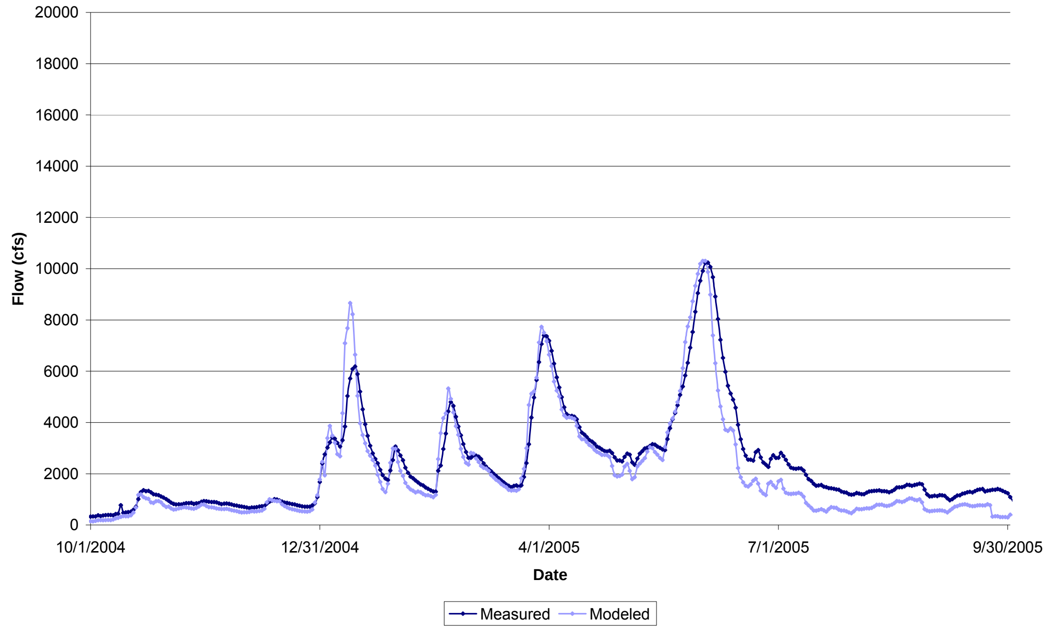

Figure E-2. Measured vs. Modeled Daily Flow in the San Joaquin River at Crows Landing for Water Year 2005

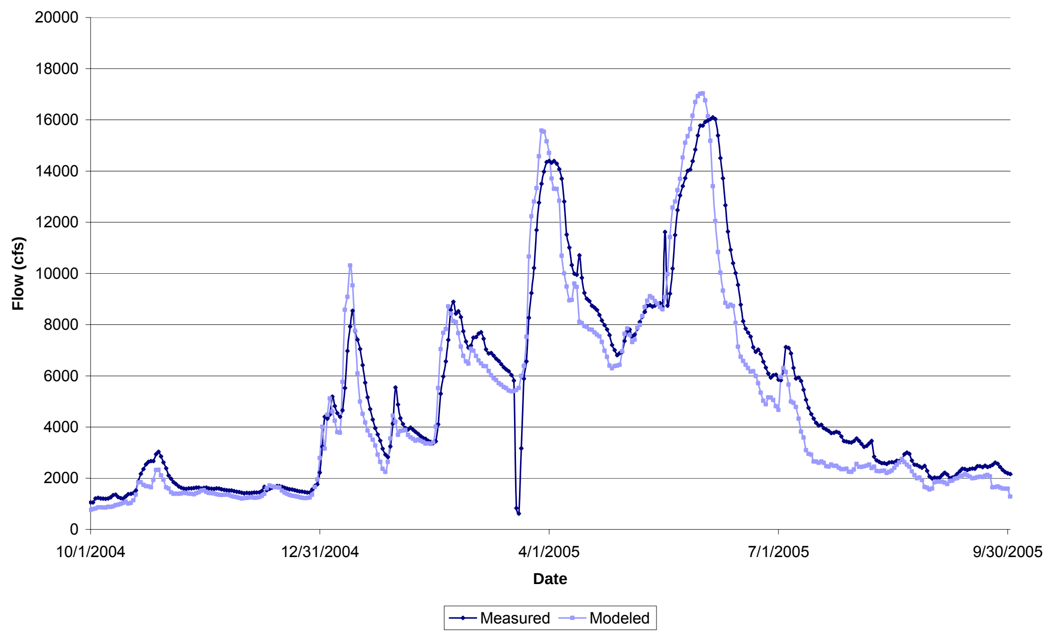

Figure E-3. Measured vs. Modeled Daily Flow in the San Joaquin River at Airport Way, Vernalis for Water Year 2005

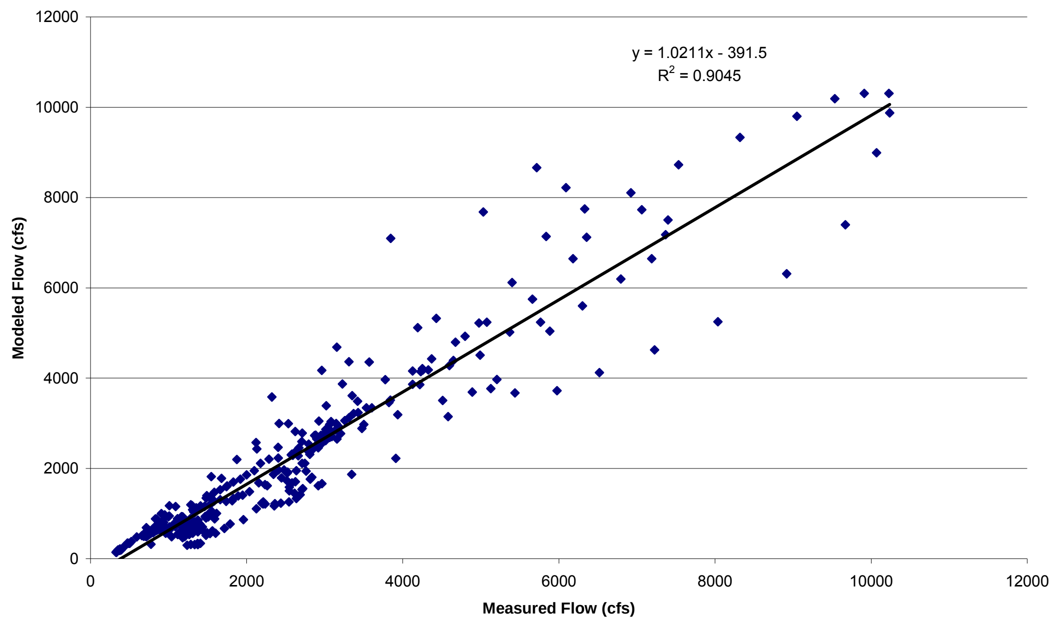

Figure E-4. Comparison of Measured and Modeled Flow in the San Joaquin River at Crows Landing for Water Year 2005

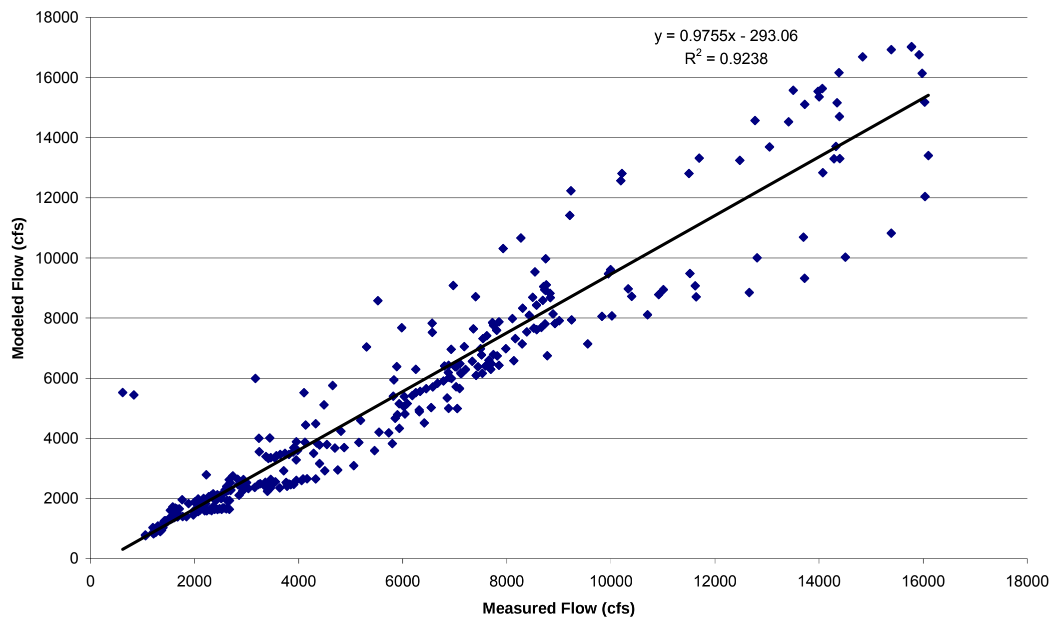

Figure E-5. Comparison of Measured and Modeled Flow in the San Joaquin River at Vernalis for Water Year 2005

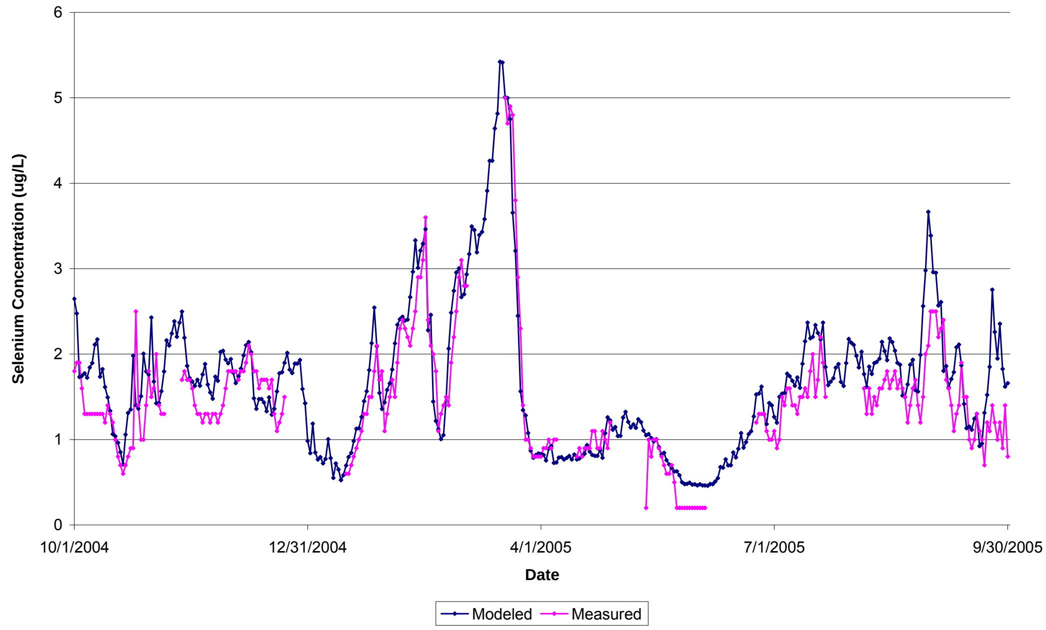

Figure E-6. Measured vs. Modeled Daily Selenium Concentration in the San Joaquin River at Crows Landing for Water Year 2005

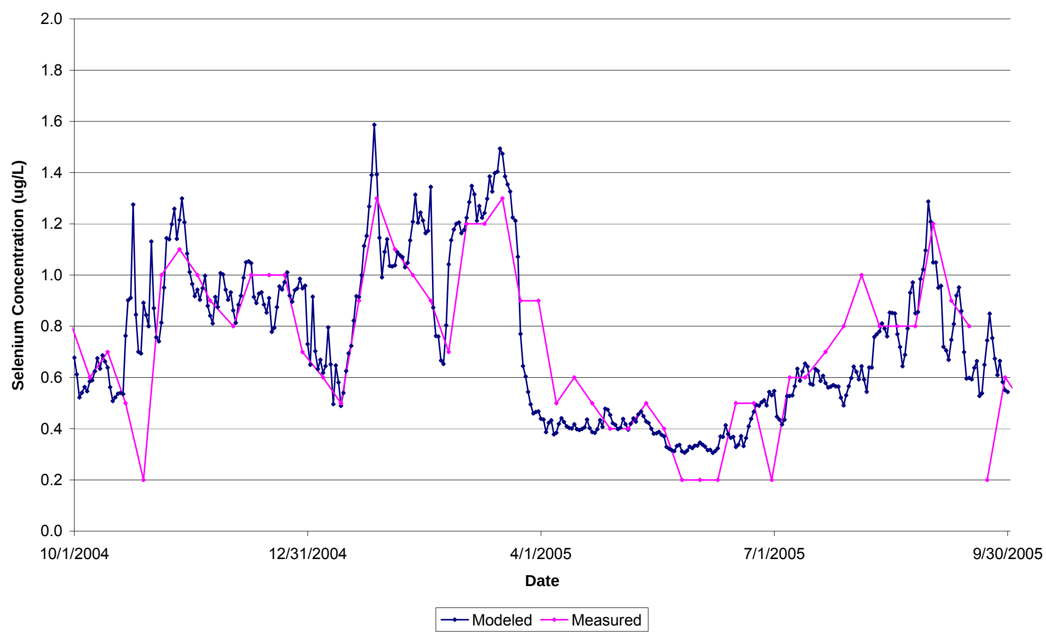

Figure E-7. Measured vs. Daily Modeled Selenium Concentration in the San Joaquin River at Vernalis for Water Year 2005

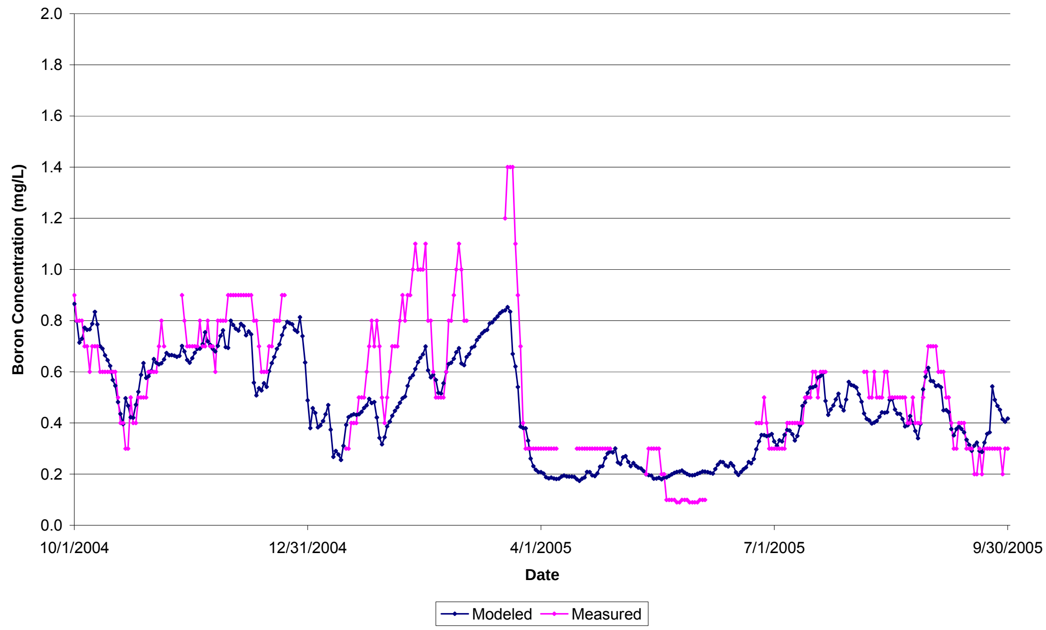

Figure E-8. Measured vs. Modeled Boron Concentration in the San Joaquin River at Crows Landing for Water Year 2005

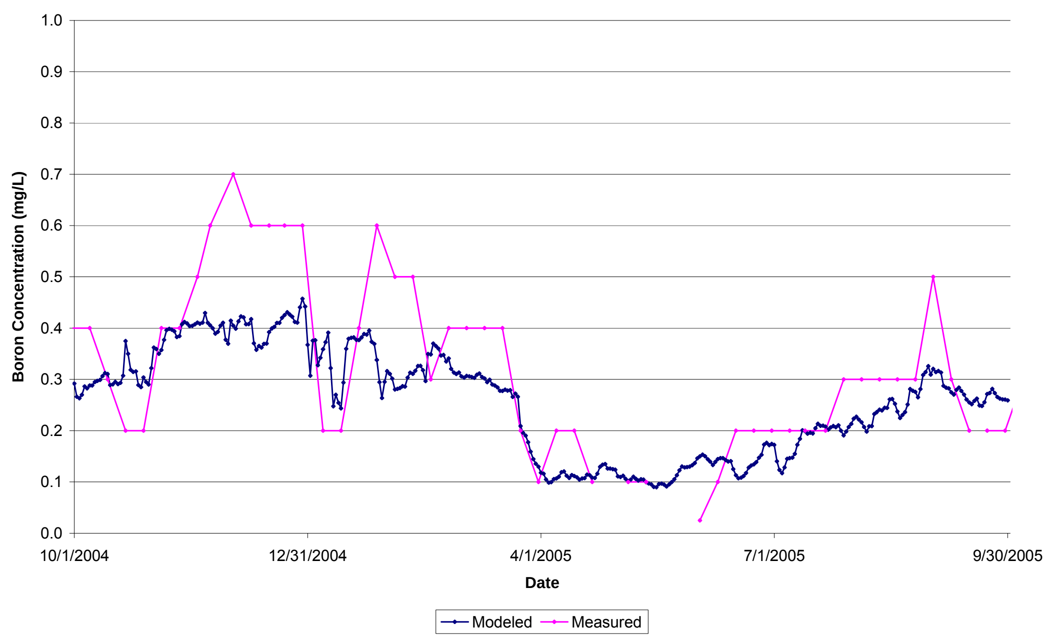

Figure E-9. Measured vs. Daily Modeled Boron Concentration in the San Joaquin River at Vernalis for Water Year 2005

to 2007 range from 4.9 to 10.2 mg/L for the GDA discharge. This variability in concentration is not reflected in the averages (**Table E-11**).

There may also be mobilization of boron within the SJR and tributaries downstream of the input locations during winter storm events.

For existing conditions, the primary source of selenium in the SJR at Crows Landing is the GDA discharge. Selenium concentrations in the Drain are approximately two orders of magnitude greater than concentrations at other inputs, such as Salt Slough. Selenium load from the GDA accounts for approximately 80% of the modeled selenium load at Crows Landing, and can account for more than 90% of the modeled load. Modeled boron load from the GDA represents approximately half of the boron load at Crows Landing for existing conditions. For the No-Action Alternative and the alternative plans modeled under the future LOD, the GDA does not discharge to the SJR.

E.5 Limitations and Uncertainties

E.5.1 Flow

The CalSim II SJR model was used to predict flow in the SJR and tributaries (**Appendix A**). The Selenium and Boron Model uses these model flows as input data. Uncertainties or limitations associated with CalSim flow are propagated into the Selenium and Boron model.

Although used to predict surface flow, CalSim also has a limited groundwater component that includes groundwater pumping, deep percolation/stream-aquifer seepage, and local inflows. Groundwater accretions are not explicitly modeled; however, accretions and depletions are lumped with local creek inflows in an “inflow” closure term (CALFED 2006). In the Selenium and Boron Model, the “minor inflow” term implicitly includes this closure term; however, flows and loads associated with groundwater accretions may not be accounted for robustly. Groundwater accretions that occur prior to the flow inputs are implicit in the input flows.

Travel time is not accounted for in the Selenium and Boron Model. Travel time can be estimated from peak flows in **Figures E-2 and E-3** (model verification). By visual inspection, travel time is approximately one day for flow inputs to reach Crows Landing and approximately two days for flow inputs to reach Vernalis. The alternative plans are predicted on a monthly or semi-monthly time step, which is much greater than estimated travel time.

E.5.2 Concentrations and Loads

Selenium and boron loads are propagated through the SJR system to predict selenium and boron concentrations. Loads and concentrations are highly dependant on the assumptions made for the concentration inputs.

The selenium concentration assumed for the Merced, Tuolumne, and Stanislaus Rivers was low (0.1 µg/L) because detected concentrations in these eastside tributaries were rare and because these tributaries were assumed to have lower concentrations than detected concentrations in eastside canals and laterals. Flow contributions from the eastside tributaries would be relatively high in the SJR at Vernalis, particularly during winter storm events. Model verification indicated that peak selenium concentrations may be over-predicted at Vernalis in the fall and winter. This suggests that the assumed input concentration level for the eastside tributaries was conservative. The concentrations assumed for minor inflows (0.5 µg/L selenium and 0.2 mg/L boron) represent estimated values that were weighted by the relative contribution of the CalSim modeled eastside return flows, westside return flows, and inflows. These concentrations were adjusted to improve the model fit.

The concentration of the recirculation flow for the alternative plans modeled under the future LOD was assumed to be equivalent to the concentration of selenium or boron in the SJR at Vernalis in the No-Action Alternative condition. Vernalis was the northern extent of this model; propagating selenium and boron concentrations through the Sacramento-San Joaquin Delta would have introduced complexity without increasing accuracy because the concentration data for Sacramento-San Joaquin Delta inflows is limited.

E.6 Model Results

E.6.1 Four-Day Average Selenium Concentration vs. Monthly Average

The WQO for selenium in the SJR at Crows Landing is expressed as a 4-day average concentration. To relate monthly average concentrations to a 4-day average concentration, the CVRWQCB daily monitoring data from Crows Landing (Station STC504S) was used to calculate monthly and 4-day average concentrations to determine the monthly average concentration that resulted in the exceedance of the 5 µg/L 4-day average. **Figure E-10** presents the relationship.

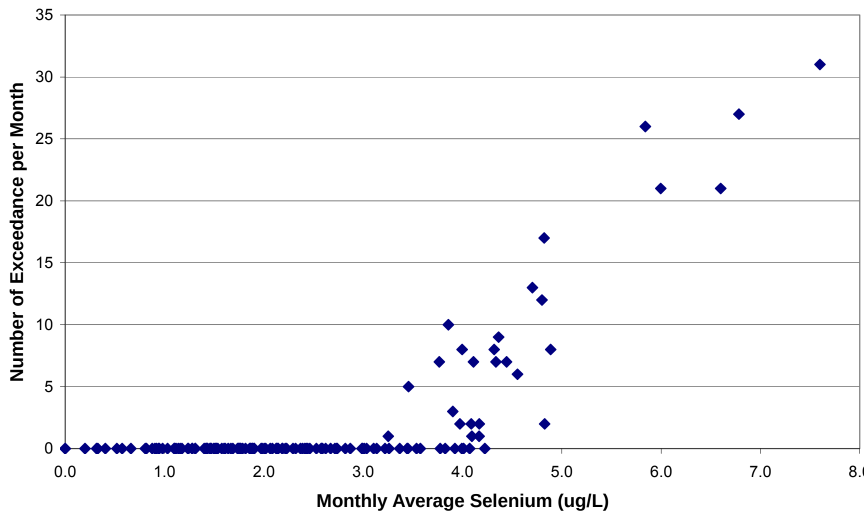

Figure E-10. Relationship between Monthly Average Selenium at Crows Landing and Exceedance of 4-Day Average Water Quality Criteria

The data indicate that exceedances of the 5 µg/L 4-day average have occurred in some months that had monthly averages greater than or equal to 3.3 µg/L and in all months that had monthly averages greater than 4.2 µg/L. Therefore, for purposes of establishing when the selenium WQO is likely to be exceeded, a monthly average selenium concentration of 3.3 to 4.2 µg/L is used as a benchmark.

E.6.2 Comparison of Alternative Plans

Results for the Selenium and Boron Model are shown below. The input flow was on a monthly time step, with April and May flow separated into pulse and nonpulse time periods. The output concentrations use the same time intervals.

Tables E-14 to E-17 show the predicted selenium and boron concentrations for Stations N and V for five water year types (Wet, Above Normal, Below Normal, Dry, and Critical) for existing conditions (No-Project Alternative), future conditions (No-Action Alternative), and the alternative plans (A1, A2, B1, B2, C, and D) under the future LOD.

The differences between the selenium and boron concentrations for alternative plans are minor compared to the differences between the selenium and boron concentrations for existing conditions and future conditions. WQOs are met for selenium and boron under the No-Action Alternative and the alternative plans in the SJR at Crows Landing and Vernalis and under existing conditions at Vernalis; however, WQOs for selected months are not met for existing conditions at Crows Landing.

The alternative plans modeled under the future LOD do not help to meet WQOs because WQOs are already met in the No-Action Alternative. The monthly average concentrations of boron for the No-Action Alternative and the alternative plans are below the WQO of 0.8 mg/L monthly mean from March to September and 1.0 mg/L monthly mean from October to February. The monthly average concentrations of selenium for the No-Action Alternative and the alternative plans are below 1 μg/L. Because the predicted concentrations for selenium in the No-Action Alternative and the alternative plans were below the benchmark values, selenium would not be expected to exceed the 4-day average water quality criteria.

Table E-14. Modeled Monthly Average Selenium Concentration (μg/L) for the San Joaquin River at Crows Landing (Station N)

Water Year Type	Month	No-Project Alternative	No-Action Alternative	A1	A2	B1	B2	C	D
Wet	1992OCT	**4.4**	0.4	0.4	0.4	0.4	0.4	0.4	0.3
	1992NOV	3.0	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	1992DEC	2.8	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	1993JAN	0.7	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	1993FEB	1.7	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	1993MAR	2.0	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	1993APR	3.6	0.4	0.4	0.4	0.4	0.4	0.3	0.3
	1993APR-P	1.8	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	1993MAY-P	2.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	1993MAY	**4.2**	0.5	0.5	0.5	0.5	0.5	0.4	0.4
	1993JUN	1.0	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	1993JUL	1.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	1993AUG	1.4	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	1993SEP	1.7	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Above Normal	1962OCT	3.1	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	1962NOV	2.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	1962DEC	2.6	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	1963JAN	2.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	1963FEB	2.0	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	1963MAR	2.7	0.5	0.4	0.4	0.4	0.4	0.4	0.4
	1963APR	1.9	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	1963APR-P	1.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	1963MAY-P	1.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	1963MAY	2.6	0.3	0.3	0.3	0.3	0.3	0.4	0.4
	1963JUN	1.6	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	1963JUL	2.2	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	1963AUG	2.8	0.4	0.4	0.4	0.4	0.4	0.4	0.4

Table E-14. Modeled Monthly Average Selenium Concentration (µg/L) for the San Joaquin River at Crows Landing (Station N)

Water Year Type	Month	No-Project Alternative	No-Action Alternative	A1	A2	B1	B2	C	D
	1963SEP	2.4	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Below Normal	2002OCT	3.9	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	2002NOV	2.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	2002DEC	2.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	2003JAN	2.7	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	2003FEB	3.6	0.6	0.5	0.5	0.5	0.5	0.5	0.5
	2003MAR	4.1	0.6	0.6	0.6	0.6	0.6	0.5	0.5
	2003APR	**4.9**	0.4	0.4	0.4	0.4	0.4	0.4	0.3
	2003APR-P	2.0	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	2003MAY-P	2.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	2003MAY	3.3	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	2003JUN	2.5	0.5	0.5	0.5	0.4	0.4	0.4	0.4
	2003JUL	3.0	0.5	0.5	0.5	0.5	0.5	0.5	0.5
	2003AUG	3.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5
	2003SEP	2.8	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Dry	2001OCT	3.8	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	2001NOV	2.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	2001DEC	2.1	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	2002JAN	2.1	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	2002FEB	3.4	0.6	0.5	0.5	0.5	0.5	0.5	0.5
	2002MAR	3.7	0.6	0.6	0.6	0.5	0.5	0.5	0.5
	2002APR	**6.5**	0.5	0.5	0.5	0.5	0.5	0.4	0.4
	2002APR-P	2.4	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	2002MAY-P	3.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	2002MAY	4.1	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	2002JUN	2.7	0.5	0.5	0.5	0.4	0.4	0.4	0.4
	2002JUL	3.2	0.5	0.5	0.5	0.5	0.5	0.5	0.5
	2002AUG	3.7	0.5	0.5	0.5	0.5	0.5	0.5	0.5
	2002SEP	2.9	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Critical	1991OCT	3.9	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	1991NOV	3.1	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	1991DEC	3.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	1992JAN	3.5	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	1992FEB	2.6	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	1992MAR	3.9	0.5	0.5	0.5	0.5	0.5	0.5	0.5
	1992APR	**5.6**	0.4	0.3	0.3	0.3	0.3	0.3	0.3
	1992APR-P	**5.6**	0.4	0.4	0.4	0.4	0.4	0.3	0.3
	1992MAY-P	**5.9**	0.4	0.4	0.4	0.3	0.3	0.3	0.3

Table E-14. Modeled Monthly Average Selenium Concentration (µg/L) for the San Joaquin River at Crows Landing (Station N)

Water Year Type	Month	No-Project Alternative	No-Action Alternative	A1	A2	B1	B2	C	D
	1992MAY	**5.9**	0.4	0.4	0.3	0.4	0.3	0.3	0.3
	1992JUN	3.4	0.5	0.4	0.4	0.4	0.4	0.4	0.4
	1992JUL	3.7	0.5	0.5	0.5	0.5	0.5	0.5	0.5
	1992AUG	**4.6**	0.5	0.5	0.5	0.5	0.5	0.5	0.5
	1992SEP	3.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6

Note:

Concentrations greater than or equal to 4.2 µg/L are indicated in bold.

Key:

µg/L = microgram(s) per liter

Table E-15. Modeled Monthly Average Selenium Concentration (µg/L) for the San Joaquin River at Vernalis (Station V)

Water Year Type	Month	No-Project Alternative	No-Action Alternative	A1	A2	B1	B2	C	D
Wet	1992OCT	1.5	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	1992NOV	1.6	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	1992DEC	1.6	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	1993JAN	0.5	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	1993FEB	1.1	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	1993MAR	1.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	1993APR	1.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	1993APR-P	0.7	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	1993MAY-P	0.6	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	1993MAY	1.0	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	1993JUN	0.4	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	1993JUL	0.5	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	1993AUG	0.8	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	1993SEP	0.9	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Above Normal	1962OCT	1.0	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	1962NOV	1.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	1962DEC	1.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	1963JAN	1.1	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	1963FEB	1.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	1963MAR	1.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	1963APR	1.0	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	1963APR-P	0.5	0.2	0.2	0.2	0.2	0.2	0.2	0.2

Table E-15. Modeled Monthly Average Selenium Concentration (µg/L) for the San Joaquin River at Vernalis (Station V)

Water Year Type	Month	No-Project Alternative	No-Action Alternative	A1	A2	B1	B2	C	D
	1963MAY-P	0.5	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	1963MAY	1.0	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	1963JUN	0.6	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	1963JUL	0.6	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	1963AUG	0.6	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	1963SEP	0.9	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Below Normal	2002OCT	1.1	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	2002NOV	1.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	2002DEC	1.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	2003JAN	1.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	2003FEB	1.8	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	2003MAR	1.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	2003APR	1.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	2003APR-P	0.7	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	2003MAY-P	0.6	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	2003MAY	1.1	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	2003JUN	0.7	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	2003JUL	0.6	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	2003AUG	0.6	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	2003SEP	1.0	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Dry	2001OCT	1.0	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	2001NOV	1.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	2001DEC	1.1	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	2002JAN	1.0	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	2002FEB	1.8	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	2002MAR	1.6	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	2002APR	1.0	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	2002APR-P	0.8	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	2002MAY-P	0.7	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	2002MAY	1.0	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	2002JUN	0.6	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	2002JUL	0.5	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	2002AUG	0.6	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	2002SEP	1.0	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Critical	1991OCT	1.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	1991NOV	1.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	1991DEC	1.6	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	1992JAN	1.9	0.3	0.3	0.3	0.3	0.3	0.3	0.3

Table E-15. Modeled Monthly Average Selenium Concentration (μg/L) for the San Joaquin River at Vernalis (Station V)

Water Year Type	Month	No-Project Alternative	No-Action Alternative	A1	A2	B1	B2	C	D
	1992FEB	1.5	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	1992MAR	1.7	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	1992APR	1.2	0.2	0.2	0.3	0.2	0.3	0.3	0.3
	1992APR-P	1.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	1992MAY-P	0.7	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	1992MAY	1.0	0.2	0.2	0.3	0.2	0.3	0.3	0.3
	1992JUN	0.5	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	1992JUL	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	1992AUG	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	1992SEP	1.1	0.4	0.4	0.4	0.4	0.4	0.4	0.4

Note:

Concentrations greater than or equal to 4.2 μg/L are indicated in bold.

Key:

μg/L = microgram(s) per liter

Table E-16. Modeled Monthly Average Boron Concentration (mg/L) for the San Joaquin River at Crows Landing (Station N)

Water Year Type	Month	No-Project Alternative	No-Action Alternative	A1	A2	B1	B2	C	D
Wet	1992OCT	0.7	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	1992NOV	0.7	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	1992DEC	0.7	0.5	0.5	0.5	0.5	0.5	0.5	0.5
	1993JAN	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	1993FEB	0.5	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	1993MAR	0.5	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	1993APR	0.7	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	1993APR-P	0.4	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	1993MAY-P	0.5	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	1993MAY	**0.8**	0.4	0.4	0.4	0.4	0.4	0.3	0.3
	1993JUN	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	1993JUL	0.3	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	1993AUG	0.4	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	1993SEP	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Above Normal	1962OCT	0.5	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	1962NOV	0.6	0.4	0.4	0.4	0.4	0.4	0.4	0.4

Table E-16. Modeled Monthly Average Boron Concentration (mg/L) for the San Joaquin River at Crows Landing (Station N)

Water Year Type	Month	No-Project Alternative	No-Action Alternative	A1	A2	B1	B2	C	D
	1962DEC	0.7	0.5	0.5	0.5	0.5	0.5	0.5	0.5
	1963JAN	0.6	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	1963FEB	0.6	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	1963MAR	0.7	0.4	0.3	0.3	0.3	0.3	0.3	0.3
	1963APR	0.4	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	1963APR-P	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	1963MAY-P	0.3	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	1963MAY	0.5	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	1963JUN	0.6	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	1963JUL	**0.8**	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	1963AUG	**0.9**	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	1963SEP	0.6	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Below Normal	2002OCT	0.7	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	2002NOV	0.6	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	2002DEC	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5
	2003JAN	0.7	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	2003FEB	1.0	0.6	0.5	0.5	0.5	0.5	0.5	0.5
	2003MAR	**1.0**	0.5	0.5	0.5	0.5	0.5	0.4	0.4
	2003APR	**0.9**	0.4	0.4	0.4	0.4	0.4	0.3	0.3
	2003APR-P	0.4	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	2003MAY-P	0.4	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	2003MAY	0.7	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	2003JUN	**1.0**	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	2003JUL	**1.2**	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	2003AUG	**1.2**	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	2003SEP	0.7	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Dry	2001OCT	0.6	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	2001NOV	0.6	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	2001DEC	0.6	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	2002JAN	0.5	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	2002FEB	0.9	0.6	0.5	0.5	0.5	0.5	0.5	0.5
	2002MAR	**0.9**	0.5	0.5	0.5	0.4	0.4	0.4	0.4
	2002APR	**1.2**	0.5	0.5	0.5	0.5	0.5	0.3	0.3
	2002APR-P	0.4	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	2002MAY-P	0.7	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	2002MAY	0.8	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	2002JUN	**1.0**	0.3	0.3	0.3	0.3	0.3	0.3	0.3

Table E-16. Modeled Monthly Average Boron Concentration (mg/L) for the San Joaquin River at Crows Landing (Station N)

Water Year Type	Month	No-Project Alternative	No-Action Alternative	A1	A2	B1	B2	C	D
	2002JUL	**1.2**	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	2002AUG	**1.2**	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	2002SEP	0.8	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Critical	1991OCT	0.6	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	1991NOV	0.7	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	1991DEC	0.8	0.5	0.5	0.5	0.5	0.5	0.5	0.5
	1992JAN	0.8	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	1992FEB	0.7	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	1992MAR	0.9	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	1992APR	1.0	0.3	0.3	0.2	0.3	0.2	0.2	0.2
	1992APR-P	1.0	0.3	0.3	0.3	0.3	0.3	0.2	0.2
	1992MAY-P	1.1	0.4	0.4	0.4	0.2	0.2	0.2	0.2
	1992MAY	1.1	0.4	0.4	0.2	0.4	0.2	0.2	0.2
	1992JUN	1.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	1992JUL	**1.4**	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	1992AUG	**1.5**	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	1992SEP	0.8	0.5	0.5	0.5	0.5	0.5	0.5	0.5

Note:

Concentrations greater than 0.8 mg/L in March through September, 1.0 mg/L in October through February, and 1.3 mg/L in the critical year are indicated in bold.

Key:

mg/L = milligram(s) per liter

Table E-17. Modeled Monthly Average Boron Concentration (mg/L) for the San Joaquin River at Vernalis (Station V)

Water Year Type	Month	No-Project Alternative	No-Action Alternative	A1	A2	B1	B2	C	D
Wet	1992OCT	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	1992NOV	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	1992DEC	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	1993JAN	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	1993FEB	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	1993MAR	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	1993APR	0.4	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	1993APR-P	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	1993MAY-P	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	1993MAY	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	1993JUN	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	1993JUL	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	1993AUG	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	1993SEP	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Above Normal	1962OCT	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	1962NOV	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	1962DEC	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	1963JAN	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	1963FEB	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	1963MAR	0.5	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	1963APR	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	1963APR-P	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	1963MAY-P	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	1963MAY	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	1963JUN	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	1963JUL	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	1963AUG	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	1963SEP	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Below Normal	2002OCT	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	2002NOV	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	2002DEC	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	2003JAN	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	2003FEB	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	2003MAR	0.5	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	2003APR	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	2003APR-P	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	2003MAY-P	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	2003MAY	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2

Table E-17. Modeled Monthly Average Boron Concentration (mg/L) for the San Joaquin River at Vernalis (Station V)

Water Year Type	Month	No-Project Alternative	No-Action Alternative	A1	A2	B1	B2	C	D
	2003JUN	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	2003JUL	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	2003AUG	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	2003SEP	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Dry	2001OCT	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	2001NOV	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	2001DEC	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	2002JAN	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	2002FEB	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	2002MAR	0.5	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	2002APR	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.3
	2002APR-P	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	2002MAY-P	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	2002MAY	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	2002JUN	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	2002JUL	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	2002AUG	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	2002SEP	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Critical	1991OCT	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	1991NOV	0.4	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	1991DEC	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	1992JAN	0.5	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	1992FEB	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	1992MAR	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	1992APR	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	1992APR-P	0.3	0.1	0.1	0.1	0.1	0.1	0.2	0.2
	1992MAY-P	0.2	0.1	0.1	0.1	0.2	0.2	0.2	0.2
	1992MAY	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	1992JUN	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	1992JUL	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	1992AUG	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	1992SEP	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3

Note:

Concentrations greater than 0.8 mg/L in March through September, 1.0 mg/L in October through February, and 1.3 mg/L in the critical year are indicated in bold.

Key:

mg/L = milligram(s) per liter

E.7 References

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