Testimony on Recent Salinity and Selenium Science and Modeling for the Bay-Delta Estuary

Submitted by
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for

Workshop #1
Ecosystem Changes and the Low Salinity Zone
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The State Water Resources Control Board called for workshops to receive information from and discuss with participating parties the scientific and technical bases for considering potential changes to the 2006 Water Quality Control Plan for the San Francisco/Sacramento-San Joaquin Delta Estuary for Phase II of the Board's comprehensive review of this plan.

According to the State Board's public notice for these workshops, the prompts for Workshop 1 testimony are:

1. What additional scientific and technical information should the State Water Board consider to inform potential changes to the Bay-Delta Plan relating to ecosystem changes and the low salinity zone that was not addressed in the 2009 Staff Report and the 2010 Delta Flow Criteria Report? For large reports or documents, what pages or chapters should be considered? What is the level of scientific certainty or uncertainty regarding the foregoing information? What changes to the Bay-Delta Plan should the State Water Board consider based on the above information to address existing circumstances and changing circumstances such as climate change and BDCP?

2. How should the State Water Board address scientific uncertainty and changing circumstances, including climate change, invasive species and other issues? Specifically, what kind of adaptive management and collaboration (short, medium, and long-term), monitoring, and special studies programs should the State Water Board consider related to ecosystem changes and the low salinity zone as part of this update to the Bay-Delta Plan?

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First I examine persistent salinity violations by the California Department of Water Resources and the US Bureau of Reclamation in the South Delta and describe studies they performed and submitted to comply with the State Water Resources Control Board's 2010 modified Cease and Desist Order (State Water Resources Control Board 2010: Condition 7, 24). Their results point to the need for dramatic changes in how Bay-Delta and San Joaquin River water diversions occur. Background information provides context for the studies performed by the Bureau and the Department. Supporting evaluation of Board inaction on salinity issues relating to the South Delta is presented in Appendix A to this testimony.

Next, I describe recent studies by US Geological Survey researchers of selenium behavior under a variety of flow regimes and hydrologic environments, and applies these various regimes to how selenium fate manifests over time in specimens of *Corbula* clams near Chipps Island in eastern Suisun Bay. Our findings strongly suggest that the Board consider its proposed new inflow objectives for tributaries from a water quality and anti-toxics contamination perspective, as well as integrating selenium-focused water quality regulation into the next Bay-Delta Plan. Supporting selenium uptake, hydrologic flow, and X2 (isohaline) data are presented in Appendix B of this testimony. There is not only a reasonable scientific basis for increased San Joaquin and Sacramento River flows to the Bay-Delta Estuary to benefit fish, there is reasonable basis as well for prevention of selenium contamination associated with local and region-scale slow or slack water environments in the Estuary.

Past Bay-Delta Estuary Water Quality Control Plans have failed to incorporate and evaluate the Board's efforts to study and acknowledge salinity and selenium problems that affect the Bay-Delta Estuary. In our scoping comments from April 25, 2012, C-WIN urges the State Board to carefully and thoroughly evaluate each of its salinity and selenium control programs as well as those of the Central Valley Regional Water Quality Control Board. (California Water Impact Network 2012: "Program of Implementation," pp. 10-14) Appendices C and D provide chronologies of salinity and selenium regulation in the watershed of the Bay-Delta Estuary and its Central Valley watershed.

Increased Delta inflow regimes from both the Sacramento and San Joaquin Rivers will do much to combat salinity problems and prevent uptake of toxic selenium by invasive species such as *Corbula*, and in aquatic food webs of the lower San Joaquin River and the Bay-Delta Estuary generally. Other actions on salinity and selenium will be needed to complement increased flow regimes. By using inflow increases to complement other strengthened regulatory and implementation actions the Board will find it possible to solve salinity and selenium problems in the Bay-Delta Estuary watershed.

I. South Delta Salinity and the Central Valley Project

In 1960, California voters approved State Water Project which included funds for San Joaquin Valley drainage service, although specific facilities were not identified for the voters. Congress required of the Bureau of Reclamation that construction of the San Luis Unit would hinge on the provision of drainage services to the San Luis Unit service area.[1] The State backed out of the San Joaquin Valley Master Drain in 1967 when irrigators balked at its cost. The US Bureau of Reclamation stopped further construction of the San Luis Drain at Kesterson Reservoir when it could not complete the Drain to the Delta.

No one—particularly federal and state agencies—with the power to decide made the hard choice to stop water deliveries to the San Luis Unit as Congress originally intended in 1960, since construction was well under way by 1967. Instead, the drainage problems of the San Luis Unit service area have been allowed to fester to the point that the State Water Resources Control Board itself found that:

> ...the actions of the [Central Valley Project, CVP] are the principal cause of the salinity concentrations exceeding the objectives at Vernalis. The salinity problem at Vernalis is the result of saline discharges to the [San Joaquin] river, principally from irrigated agriculture, combined with low flows in the river due to upstream water development. The source of much of the saline discharge to the San Joaquin River is from lands on the west side of the San Joaquin Valley which are irrigated with water provided from the Delta by the CVP, primarily through the Delta-Mendota Canal and the San Luis Unit. The capacity of the lower San Joaquin River to assimilate the agricultural drainage has been significantly reduced through the diversion of high quality flows from the upper San Joaquin River by the CVP at Friant. (State Water Resources Control Board 2000: 83)

The State Water Resources Control Board then designated the US Bureau of Reclamation as "responsible for significant deterioration of water quality in the southern Delta," adding that the Bureau's actions "have caused reduced water quality of the San Joaquin River at Vernalis." (State Water Resources Control Board 2000: 86) This chapter describes how the activity of the Central Valley Project causes water quality to deteriorate in the San Joaquin River Basin and the South Delta, and the continuing record

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[1] See Appendix A and Appendix C to this testimony for additional information about the background of drainage services and salinity problems in the watershed of the Bay-Delta Estuary. Public Law 86-488 states in pertinent part that:

> "...Construction of the San Luis unit shall not be commenced until the Secretary has (1) secured, or has satisfactory assurance of his ability to secure, all rights to the use of water which are necessary to carry out the purposes of the unit and the terms and conditions of this Act, and (2) received satisfactory assurance from the State of California that it will make provision for a master drainage outlet and disposal channel for the San Joaquin Valley, as generally outlined in the California water plan, Bulletin Numbered 3...which will adequately serve, by connection therewith, the drainage system for the San Luis unit or has made provision for constructing the San Luis interceptor drain to the delta designed to meet the drainage requirements of the San Luis unit as generally outline in the report of the Department of the Interior, entitled "San Luis Unit, Central Valley Project," dated December 17, 1956."

of inaction by the State Water Resources Control Board to reduce salt drainage problems along the lower San Joaquin River and in the South Delta.

Importing and Recirculating Salts

In the San Joaquin River Basin, the salinity (the salt concentration in water) of its water bodies was historically very low, and in some of its water bodies continues to be of high quality. This is because the Basin's river flows were dominated by higher quality runoff from the snowpack of the Sierra Nevada, while natural flows on the west side were low as a result of the Coast Range rain shadow. Prior to 1951, according to the California Department of Water Resources, salt concentrations in the upper San Joaquin River near Mendota were typically less than 50 parts per million (sea water salt concentrations are generally about 3.5 percent salt or about 35,000 parts per million). (California Department of Water Resources 1965: 8) On the Stanislaus River, a 1953 pollution study found chloride concentrations ranging between 1 to 10 parts per million of chloride in that river. (Central Valley Regional Water Pollution Control Board 1953: Table ST-1) However, additional salts are imported to the San Joaquin River Basin as a result of mixing with salty tidal flows with water in the western Delta before being exported by large pumps located near Tracy. These saltier supplies arrive in the western San Joaquin Valley via the Delta Mendota Canal.

The conveyance of water through the Delta Mendota Canal is made possible legally by State Water Board-issued water rights permits to the US Bureau of Reclamation to operate the Central Valley Project and by the Exchange Contract by which senior San Joaquin River water rights holders "exchange" their upper San Joaquin River water rights for imported Sacramento River water delivered to them via the Delta Mendota Canal. The "Exchange Contract" for this imported water recognized from the outset that salinity in the imported water would be greater than salts naturally occurring in San Joaquin River water. The original Exchange Contract stated that it should not exceed a five-year mean salt concentration of 400 parts per million (see Table A-1 in Appendix 1). Thus, planned importation of water into the San Joaquin River Basin would allow as much as a *nine-fold increase in salt concentration* in water applied to western San Joaquin Valley lands. This is the direct water quality impact of the exchange arrangement at the heart of the creation of the Central Valley Project's Friant Division, the Delta Mendota Canal, and the Jones Pumping Plant. Large amounts of imported water brought large loads of salt to the Basin as well.

Central Valley water regulators acknowledge that "salinity impairments" of the state's water bodies "are occurring with greater frequency and magnitude. Such impairments in the past have led to the fall of civilizations." (Central Valley Regional Water Quality Control Board 2006: 5) The Central Valley Regional Water Quality Control Board estimates that the Delta Mendota Canal imports about 900,000 to 1 million tons of salt each year into the San Joaquin River Basin while the San Joaquin River returns about 922,000 tons of salt to the Delta annually. (California Regional Water Quality Control Board 2006: Tables 2 through 5) The Central Valley Regional Board is clearly concerned about salts building up in western San Joaquin Valley soils, but it has estimated no timetable by which the productivity of these soils would be exhausted from salinization. See Appendix C for a chronology of State Water Resources Control Board inaction on salinity problems.

However, in 1981 the White House Council on Environmental Quality offered an estimate. The Council found at that time that some 400,000 acres of land in the San Joaquin Valley were poorly drained, and that crop yields had declined 10 percent since 1970. The Council stated that with no action the amount of poorly drained land would increase to about 700,000 acres by 2000. The Council reported too that "over the next 100 years" (or by about 2080) "about 1 million acres of agricultural land in the San Joaquin will undergo desertification" if groundwater salinization is not addressed. (Sheridan, 1981: 42-43)

The salinization of the western San Joaquin Valley keeps pace with the Council on Environmental Quality's projection: From sworn testimony it received in preparing its Water Rights Decision 1641 (D-1641) in 2000, the State Water Resources Control Board found that "the total acreage of lands impacted by rising water tables and increasing salinity is approximately 1 million acres. (State Water Resources Control Board 2000: 82) The San Joaquin Valley Drainage Monitoring Program reported to the Department of Water Resources for 2005 that there are about 1.324 million acres of land with present and potential drainage problems. About three-tenths (30.4 percent) of these lands (about 403,000 acres similar to findings of the Council on Environmental Quality in 1981) has very shallow groundwater levels of between 0 to 5 feet. These lands can be considered to have current drainage problems, while another 857,000 acres have water tables between 5 and 15 feet below the surface, or about 65 percent of lands. These lands can be considered to have present and potential drainage problems. (California Department of Water Resources, 2010: Table 1)

The Central Valley Project's importation of Delta water establishes a vicious cycle of cropland salinization. The lands of the western San Joaquin Valley (on which Delta Mendota Canal water is applied largely for irrigation) seldom experience a net leaching of salts out to the ocean through the Delta because the imported water applied to it always has a relatively high salt content. And irrigating with that water serves to further concentrate salts in the soils and return flows. The Central Valley Regional Water Quality Control Board describes this as "recirculation":

> Such recirculation can have a large effect on salt fluxes [i.e., movement] because rather than completely leaving the system, such recirculated salts continued to contribute to any impairments and costs associated with elevated salinity in supply water. (California Regional Water Quality Control Board 2006: 36)

Echoing the State Water Resources Control Board's finding in 2000, salts in the Delta Mendota Canal are found by the Central Valley Regional Board to be the primary source of salt circulating in the San Joaquin River Basin. While the Canal supplies most of the surface irrigation water to this part of the Basin, the Board states that "the quality of this supply may be impaired by the recirculation of salts from the San Joaquin River to the [Canal's] Delta pumping plant." (California Regional Regional Water Quality Board 2006: 41) In addition to 1 million tons per year of salt recirculating through the San Joaquin River and the Delta Mendota Canal, the Board estimates that application of salts from soil amendments and groundwater pumping for irrigation in the River Basin adds an *additional 500,000 tons of salt per year* to the River.

Table 1 summarizes how the degree to which the San Joaquin River Basin's hydrology has been dramatically altered by water development over the period 1984-2009. It does this in two key ways.

Table 1
Changes in Flows of San Joaquin River Basin Tributaries, Unimpaired and Observed Conditions, 1984 to 2009

Statistics for 1984-2009	Stanislaus River	Tuolumne River	Merced River	San Joaquin River	Chowchilla, Fresno, Valley Floor, Tulare Combined	San Joaquin River at Vernalis (Sum of flows)
Median Unimpaired Flows	922	1,514	721	1,311	231	4,699
Percent of Flow at Vernalis	20%	32%	15%	28%	5%	
Median Observed flows	429	398	271	137	416	1,651
Percent of Flow at Vernalis	26%	24%	16%	8%	25%	
Percent Flow Change from Unimpaired Conditions	**-53%**	**-74%**	**-62%**	**-90%**	**80%**	**-65%**

Source: State Water Resources Control Board 2011: Tables 2.9 through 2.14); California Water Impact Network.

First, when comparing unimpaired with observed (that is, actually measured) flow conditions for the Basin's rivers, it is apparent that the unimpaired flow conditions have been greatly reduced on the major tributaries by water project operations. For the Stanislaus, actual median flow has fallen relative to unimpaired flows by about 53 percent; on the Tuolumne, by 74 percent; on the Merced by 62 percent; and on the Upper San Joaquin River (above the Merced River confluence) by 90 percent. (Median flows are employed for this analysis to avoid the skewing effects of the statistical averages.)

For the Chowchilla, Fresno, Valley floor, and Tulare (e.g., Fresno Slough and Kings River) streams combined, observed flow conditions *dramatically increased* over their unimpaired conditions—*by 80 percent* during this 25-year period. Table 1 includes median unimpaired and observed flow conditions for an aggregation of the flows of the much smaller Chowchilla, Fresno, Valley floor, and Tulare (Fresno Slough) streams in the San Joaquin River Basin. According to US Geological Survey data available online, the largest Valley floor sources of median observed annual flows were from Salt Slough, Mud Slough, the Fresno River, and Chowchilla River, from largest to smallest. Median annual flows for other west side creeks (Pacheco, Orestimba, and Del Puerto) are only about about one-eighth of Mud and Salt Slough observed flows. Median observed flows along the James Bypass to Fresno Slough are likewise small.

The median observed annual flow of the San Joaquin River at Vernalis during 1984 to 2009 is just 1.65 million acre-feet, just 35 percent of median unimpaired annual flow of

4.7 million acre-feet at Vernalis. (Table 1 sums the flows from only the major tributaries in the table as an approximation of unimpaired and observed flow conditions at Vernalis.)

Second, Table 1 shows that the composition (or stream source) of flows reaching Vernalis, (unimpaired compared with actual observed flows) also changed dramatically. (Keep in mind that observed flows are actually *decreasing* from unimpaired conditions.) The Stanislaus River's *share of flow* at Vernalis increases under water development from 20 percent of unimpaired flow to 26 percent of observed flow. The Tuolumne decreases from 32 percent of unimpaired flow to 24 percent of observed flow conditions under water development. The Merced River's *share of flow* at Vernalis barely changes (15 percent of unimpaired; 16 percent of observed), while the Upper San Joaquin River's share of Vernalis flow decreases dramatically from 28 percent under unimpaired conditions, to just 8 percent under developed flow conditions. The Valley floor sources, however, represent a sharply increased share of flow at Vernalis, rising from just 5 percent of unimpaired flow conditions to 25 percent of actual observed flows under developed conditions.

This radically changed flow pattern from unimpaired to observed flow in the San Joaquin River Basin change the Basin's handling of salt circulation as well. According to the California Department of Water Resources, the sources of salt loads recirculating through the San Joaquin River measured at Vernalis as shown in Table 2. Agriculture's use of both surface and groundwater sources is the largest source by which salt is mobilized. Adding together groundwater, and surface and subsurface return flows, these sources account for 71 percent of the salt load in the San Joaquin River as measured at Vernalis.

Table 2
Sources of Salt in the San Joaquin River as Measured at Vernalis

Approximate Sources of Salt	Share of Load
Sierra Nevada Tributaries	18%
Groundwater	28%
Agricultural Surface Return Flow	26%
Agricultural Subsurface Return Flow	17%
Managed Wetlands	9%
Municipal and Industrial Discharges	2%

Source: California Department of Water Resources, 2006: Table C-3; California Water Impact Network.

The geographic origins of the river basin's salt loads are illustrated in Figure 1 and summarized in Table 3. This figure shows the "effective" drainage area of the San Joaquin River Basin and its subbasins while tacitly acknowledging the export of upper San Joaquin River flows from the Basin via the Friant-Kern Canal. For the "San Joaquin River upstream of Salt Slough" subregion in Table 3, Figure 1 indicates that the "effective drainage area" for this watershed is a handful of creeks together with the Chowchilla River area. Flows in this area amount to just 9 percent of all salt contributions to total flows at Vernalis. In dark blue-green are "East Valley Floor" creeks that drain the plains between the Merced, Tuolumne, and Stanislaus rivers, which in turn drain the Sierra Nevada. The East Valley Floor creeks contribute just 5 percent of the salt detected at Vernalis on an annual basis. The combined salt loads of the Merced, Tuolumne, and Stanislaus rivers are also just 19

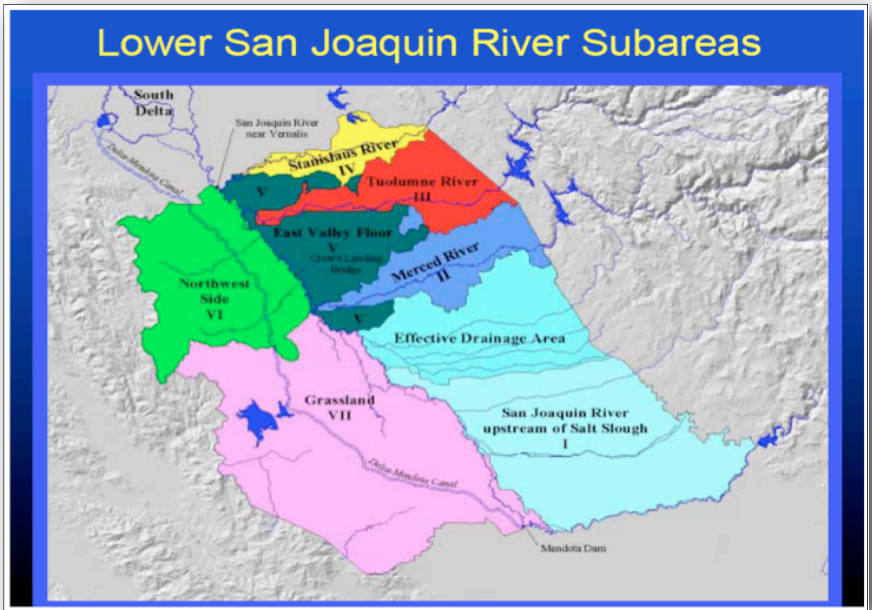

Figure 1: Geographical sources of salt in the San Joaquin River Basin. Source: California Department of Water Resources, 2006.

percent of the total salt load measured at Vernalis. Combined, the streams that "effectively" drain the east side of the San Joaquin River Basin contribute just 33 percent of the total salt load at Vernalis.

Meanwhile, the two west side subareas (the Northwest Side and Grasslands) contribute 67 percent—*two-thirds*—of the salt load measured at Vernalis on an annual basis. Recall from Table 1 above that the Valley floor streams entering the San Joaquin River above the Merced River confluence contribute just 25 percent of observed flow at Vernalis (essentially accounting for much of "Grasslands" flows in Table 2). ***This means that just one-quarter of flows reaching Vernalis carries about two-thirds of the salt load of the San Joaquin River as measured at Vernalis***.

Table 3
Sources of Salt in the San Joaquin River Basin as Measured at Vernalis by Contributing Geographic Area of the Basin

Approximate Source of Salt	Share of Load by Contributing Area
I. San Joaquin River upstream of Salt Slough	9%
II. Merced River III. Tuolumne River IV. Stanislaus River	19%
V. East Valley Floor Streams	5%
VI. Northwest Side	30%
VII. Grasslands	37%

Source: California Department of Water Resources, 2006: Table C-4; California Water Impact Network.

Historical data, illustrated in Figure 2, strongly suggest that higher proportions of unimpaired fresh water flows in the San Joaquin River earlier in the 20th century maintained lower salinity conditions before completion and operation of the Central Valley Project in the 1950s and 1960s. The 1930s and 1940s had lower average annual and monthly salinities than the 1950s and 1960s when the Central Valley Project facilities of the San Joaquin Valley were completed and began operating. Figure 2 shows that while total dissolved solids (or TDS, a measure of salinity in units of milligrams per liter [mg/L]) generally declined in high flow spring months when snowmelt runoff is peaking, there occurred across-the-board increases in average salinity conditions on the timescale of decades as Central Valley Project development reached full operation. The average salinity for the 1930s was 228 mg/L; for the 1940s it increased about 13 percent to 257 mg/L. But with the advent of Friant Dam and Friant-Kern Canal exports of low salinity San Joaquin River water to Kern and Tulare counties, and the arrival of saltier Delta imported water to the west side of the San Joaquin Valley in the 1950s, average salinity of the River in the 1950s jumped 23 percent over the 1940s to 315 mg/L (38 percent higher than the 1930s salinity levels). By the end of the 1960s, the average salinity level for that decade was 427 mg/L, an 87 percent increase in salinity levels over the 1930s (and the 1930s had five drought years in it, 1930-1934; US Water and Power Resources Service and South Delta Water Agency 1980: Table VI-17, 107). ***In other words, salinity conditions in the San Joaquin River at Vernalis nearly doubled in 30 years, a period in which export of high quality and low salinity San Joaquin River water coincided with import of similar quantities of saltier Delta Mendota Canal imports from the Delta, which were, in turn, applied to lands heavily burdened with salts.***

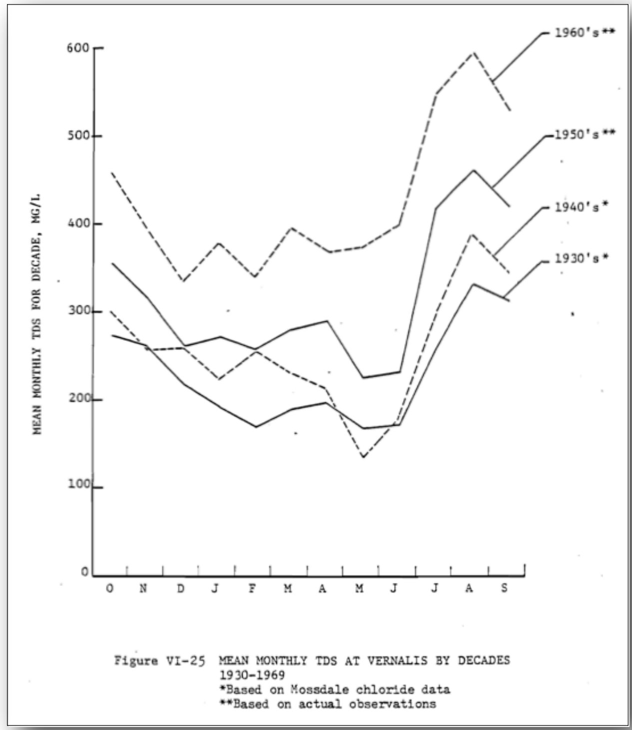

Figure 2: Decadal changes in salinity conditions for the San Joaquin River as measured at Vernalis, 1930s through 1960s. Source: US Water and Power Resources Service and South Delta Water Agency, 1980.

The burdens of salt loads increased over time. Salinity is a function of both available salt load and the river flows available to carry it. The share of salinity effects attributable to reduced flows declined relative to the growth of salt loads in return flows in the San Joaquin River:

> Comparing the average monthly TDS (over the entire year), load-flow regressions show a 1950-1969 increase of 43 percent—from 259 mg/L to 371 mg/L. For the 1950s alone the percentage increase is about 22 percent and for the 1960s, 65 percent....Thus, according to this analysis, in this first decade after the CVP went into operation, about 56 percent of the increase in average TDS was caused simply by a reduction in flow from upstream sources; the remaining 44 percent was a result of increased salt burden, perhaps associated with an expansion of irrigated lands in the basin. Similarly in the 1960s (compared to thee 1930s and

> 1940s) about 27 percent of the average increase in TDS...can be accounted for by a reduction in flow and 73 percent attributed to increased salt burden. It is of interest to note here that the absolute change apparently caused by reduction in flow changed relatively little from the 1950s to the 1960s...while that charged to an increase in salt burden increased about four times [...]. This is consistent with other analyses that indicate a progressive buildup in salt load in the San Joaquin system. (US Water and Power Resources Service and South Delta Water Agency 1980: 126)

Salt concentrations in the San Joaquin River reaching the Delta are greatly increased by the loss of San Joaquin River Basin fresh water flows to exports. The major exports of water from the San Joaquin River basin are from the Upper San Joaquin River via the Friant-Kern Canal to Tulare and Kern counties, and via San Francisco's Hetch Hetchy Aqueduct to the San Francisco Bay Area. (By far, the larger of the two exports is that of the Friant-Kern Canal.)

What if water now exported from the San Joaquin River Basin was brought back to flow into the Delta? The Central Valley Regional Water Quality Control Board explored this question briefly in 2006. If the City and County of San Francisco's exports of 250,000 acre-feet of Tuolumne River flows and 17,000 tons of salt were hypothetically reintroduced to the San Joaquin River, it would "have a large cumulative effect," according to the Central Valley Regional Board:

> Removal of this high quality, low salinity, water has a relatively large impact on water quality in the San Joaquin River. If this 250,000 acre-feet of water per year were added to the mean annual discharge for the San Joaquin River from 1985-to 1994, mean annual [electrical conductivity, a direct measure of the presence of salts in water] would have been reduced from 570 to 506 [microSiemens, the unit of electrical conductivity]. Similar results could be expected with flow augmentation from other high quality sources or reduced consumptive use of water in the Basin. (California Regional Water Quality Control Board 2006: 44-45)[2]

The reduction in salinity concentration is significant: the Central Valley Regional Board finds it would result in an 11 percent average decrease in salinity from the addition of 250,000 acre-feet annually of high quality water during a hydrologic period in which 7 of 10 years were dry or critically dry (1985, 1986 and 1993 were the exceptions).

What if Upper San Joaquin River flows could be returned to the San Joaquin River Basin, the Bay-Delta Estuary, and San Francisco Bay? Returning an average of over 800,000 acre-feet of Upper San Joaquin River flows that are exported under the Bureau's Friant Dam water rights via the Friant-Kern Canal would also reduce salinity concentrations from imports substantially. Assuming a linear extrapolation of the electrical conductivity relationship the Regional Board identifies above (that is, for every 250,000 acre-feet of fresh water returned to the river, an 11 percent decrease in salinity would result), a cumulative 46 percent reduction in average annual salinity concentration would result

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[2] C-WIN presents this example to illustrate the effect of returning a large bloc of dilution flows on San Joaquin River salinity conditions; we do not advocate this specific action for the City and County of San Francisco's Tuolumne River supplies at this time.

from returning about 800,000 acre-feet of Upper San Joaquin River water from Friant Dam to the Delta from this extrapolation, a decrease from 570 to about 307 microSiemens of salinity. *Such an action would reduce salinity by nearly one-half in the San Joaquin River.*

In addition to such water quality improvements from returning unimpaired flows from the Upper San Joaquin River to the Delta, other gains in salinity reduction would occur from retiring saline irrigated lands in the western San Joaquin Valley and ending Delta imports of salty water there.

II. Interior South Delta Salinity Objectives

The federal Clean Water Act states America's most basic water quality goals: 1) to ensure that no activity will lower water quality to support existing uses, and 2) to maintain and protect high quality waters. If the SED proceeds with the proposed relaxation of salinity objectives, both the Bay-Delta Water Quality Control Plan and its Supplemental Environmental Document must state how the proposed relaxation complies with this long-established and venerable policy.

The State Water Resources Control Board's "Statement of Policy with Respect to Maintaining High Quality of Waters in California," provides in relevant part, that:

> Any activity which produces or may produce a waste or increased volume or concentration of waste and which discharges or proposes to discharge to existing high quality waters will be required to meet waste discharge requirements which will result in the best practicable treatment or control of the discharge necessary to assure that (a) a pollution or nuisance will not occur and (b) the highest water quality consistent with maximum benefit to the people of the State will be maintained. (State Water Resources Control Board 1968)

In Water Rights Decision 1641 (D-1641) the Board placed responsibility for meeting South Delta salinity objectives to protect South Delta agricultural beneficial uses on the US Bureau of Reclamation and the California Department of Water Resources. In addition to the compliance point at Vernalis on the San Joaquin River, there are three other compliance points in the interior Delta: Old River at Tracy Boulevard Bridge, Middle River at Old River, and the San Joaquin River mainstem station at Brandt Bridge, not far from the head of Old River. Between April 1 and August 31, the salinity standard for each of these compliance points is 0.7 EC, and the rest of the year it is 1.0 EC. The Board proposes to relax these standards at the compliance points below Vernalis to 1.0 EC between April 1 and August 31 and 1.4 EC the rest of the year. The Board propose that the salinity objectives at Vernalis would remain unchanged at these same levels.

Figure 3 illustrates that the salinity concentrations of water flowing in South Delta channels exceeded D-1641 salinity objectives every year since 2007, through the winter of 2010. Figure 3 shows that the Bureau and the Department violated *both* the winter and summer salinity standards repeatedly during this four-year period (violation regions are shown in yellow). These D-1641 salinity objectives are applied at interior south Delta monitoring stations, where the specific characteristics of flow can be quite complex (and their study is referred to as "hydrodynamics").

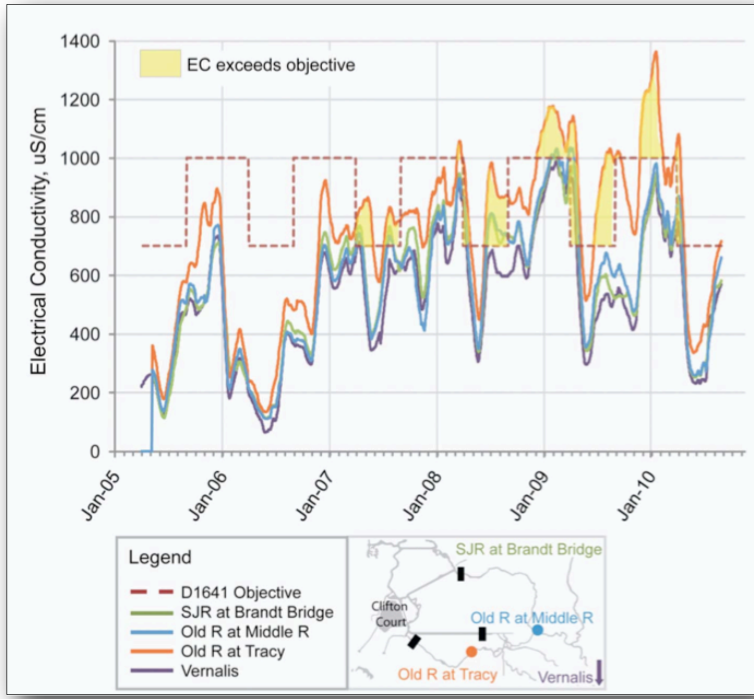

Figure 3: Salinity objective exceedences at South Delta compliance stations by the California Department of Water Resources and the US Bureau of Reclamation shown in yellow. Source: California Department of Water Resources, 2011.

In the wake of assigning responsibility in D-1641 to the Department and the Bureau for meeting interior south Delta salinity objectives, the Department and the Bureau's attention focused on the quality of the waters immediately around the three monitoring and compliance sites rather than on addressing squarely the largest sources of salinity entering the Delta from the San Joaquin River from upstream. In 2007, the Board held a workshop on salinity in the south Delta, specifically how salt sources within the south Delta could be reduced and controlled near the interior South Delta compliance points. The logic of this seemed to be that if the Department and the Bureau were going to be responsible for not violating the salinity objectives at these sites, then there better not be any other point sources of salinity being discharged within the Delta for which they might be otherwise held responsible.

How Important are In-Delta Salinity Sources?

Not very. The State Water Resources Control Board, as the state's steward of the public trust on water quality matters, in 2007 paid attention to small polluters rather than also devise and implement strategies that create compliance by major upstream dischargers of saline agricultural drainage to the San Joaquin River, the major source of both water and salts entering the south Delta from Vernalis. Most of the discharges revealed by a Department of Water Resources study of in-Delta salinity sources have extremely low, if saline, discharges compared with the sources upstream of Vernalis. Some appear to be natural in origin, as shown in Table 4. (California Department of Water Resources 2007: 3-12) Table 4 suggests that these in-Delta saline flows of about 72,900 acre-feet annually are about four percent of observed Delta inflow at Vernalis and would be about one percent of unimpaired flow.

The State Water Board's determination to police salinity discharges interior to the south Delta on behalf of the Projects does not make the upstream region-scale problems of saline agricultural drainage go away.

The Board's in-Delta enforcement distraction in this period ignores conscious Delta farmer practices that manage salt and keep their lands sustainable for cultivation. The Department studied application of irrigation water and associated drainage in the Delta in the 1954 and 1955 prior to the State Water Project. It found that salt in Delta lowlands (a substantial portion of which occur in the South Delta) varied widely by month, with most of it accruing in Delta island soils during the irrigation season. By applying water to Delta island fields during winter months, however, farmers leached salts out of Delta soils. Department engineers concluded at the time that:

> The Delta Lowlands act as a salt reservoir, storing salts obtained largely from the channels during the summer, when water quality in such channels is most critical and returning such accumulated salts to the channels during the winter when water quality there is least important. Therefore agricultural practices in that area enhanced rather than degraded the good quality Sacramento River water enroute [*sic*]to the [Central Valley Project's] Tracy Pumping Plant. (California Department of Water Resources 1956: 30)

The 2006 Cease and Desist Order

The need to reduce salt-laden flow in the San Joaquin River is also evident from the State Board's experience prosecuting a Cease and Desist Order against the Bureau and the Department for their violations of the interior south Delta salinity objectives, and its subsequent modification in 2010. In 2005, the Department and the Bureau informed the State Water Resources Control Board they would not be able to comply with the salinity objectives in the South Delta. The Board adopted a Cease and Desist Order in 2006, giving the Department and the Bureau until July 1, 2009, to comply or face additional enforcement actions.

The State Water Resources Control Board allows the Bureau and the Department to divide the responsibilities of complying with these salinity objectives. The Department has three main facilities in or directly affecting the San Joaquin River Basin: the San Luis Reservoir, the California Aqueduct's northern reach, and the Banks Pumping Plant, which exports Delta water into the Basin through the Aqueduct's northern reach (ultimately to some water contractors along the way and to the San Luis Reservoir for later export out of the Basin). Consequently, the Department's activities directly concerning the San Joaquin River occur mainly in the Delta where it operates Banks Pumping Plant. In the Delta itself, the Department attempts to manage the hydrodynamics of Delta flow and salinity conditions, some of which are caused by Banks Pumping Plant. Delta channel hydrodynamics affect:

- The salinity of the water exported at Banks.

Table 4
South Delta Discharges as Sources of Salinity

Source	Estimated Discharge	General Location	Salinity Reported
22 discharges of either stormwater or agricultural origin	None provided.	Vernalis to Head of Old River	None provided.
Reclamation District No. 2075	25 cfs (up to 18,112 AF/year)	Vernalis to Head of Old River	"above 2,000 µS/cm"
Watershed of unknown size drained by Walthall Slough	None provided.	Vernalis to Head of Old River	None provided.
Cities of Manteca and Lathrop	5.72 million gallons per day (up to 6,407 AF/year)	Vernalis to Head of Old River	"Averaging above 1,000 µS/cm."
Brown Sand, Inc.	6.2 million gallons per day (between January 2001 and December 2004) (up to 6,950 AF/year)	Vernalis to Head of Old River	None provided; groundwater seepage and excess stormwater discharge from historical mining pit operation.
Four sump pumps at Clifton Court Forebay	None provided.	Head of Old River to Export Sites	None provided; considered "relatively minor" though "they do contribute to the cumulative influence of all sources of salt in the South Delta."
City of Tracy	7.09 million gallons per day (up to 7,947 AF/year	Head of Old River to Export Sites	Conductivities range from 1,000 to 2,400 µS/cm
Deuel Vocational Institution	0.589 million gallons per day (up to 660 AF/year)	Head of Old River to Export Sites	Conductivities range from 1,000 to 2,400 µS/cm
Mountain House Community Services District	3.0 million gallons per day, increasing to 5.4 million gallons per day when Phase III completed. (up to 6,053 AF/year)	Head of Old River to Export Sites	None provided.
Three urban/ agricultural drains reaching dead end sloughs connected to Old River	1 to 2 cfs each in December 2006 "before any appreciable rainfall had fallen during water year 2007" (up to 1,449 AF/year)	Head of Old River to Export Sites	2,100 and 2,600 µS/cm during December 2006 inspections.

Table 4
South Delta Discharges as Sources of Salinity

Source	Estimated Discharge	General Location	Salinity Reported
Groundwater effluence to drainage channels - Westside Irrigation District	"agreement with City of Tracy to pump as much as 35 cfs (22.6 mgd)" but no firm estimate of regular discharge (up to 25,333 AF/year)	Head of Old River to Export Sites	None provided.
Wastewater ponds next to Sugar Cut	"may be one specific source of saline groundwater accretion to Old River" but no firm estimate of regular discharge	Head of Old River to Export Sites	None provided.
Estimated Maximum Total Discharge, In-Delta Sources	up to 72,910 AF/year		

Source: California Department of Water Resources 2007; California Water Impact Network.

- Water levels in neighboring channels that are used by Delta farmers to divert water to irrigate their fields. (If water levels are too low, their pumps may not connect and they cannot divert.) Many of these farmers are water right holders whose rights are either paramount (that is, riparian) or senior (that is have earlier appropriation dates) to those of the Department for Banks Pumping Plant and must not be harmed.
- Finally, the Department has obligations to minimize impacts to fish and wildlife from its diversions and their effects on neighboring channels.

When the salinity objective violations at interior South Delta monitoring stations were reported to the State Water Resources Control Board, the Department of Water Resources and the Bureau of Reclamation were completing planning and environmental documents for a "South Delta Improvement Program" which would, among other things, install permanent operable tidal barriers intended to influence hydrodynamics and interior South Delta salinity conditions. Through operation of the barriers, it was hoped that salinity, water level, and fish passage issues could be addressed.

The Board issued draft Cease and Desist Order, held evidentiary hearings led by Board prosecution team, and adopted the Order in February 2006. The Order required, among other things, that:

- The Department and the Bureau "obviate the threat of non-compliance with the 0.7 EC [electrical conductivity] interior southern Delta salinity objectives by July 1, 2009.

- The two agencies prepare within 60 days of issuing the Order a "detailed plan and schedule" for the Board that would obviate the threat of salinity violations by providing for "equivalent measures" that "will provide salinity control at the three compliance stations equivalent to the salinity control that would be achieved by permanent barriers."
- The two agencies were also to prepare "an operations plan that will reasonably protect southern Delta agriculture" for Board approval no later than January 1, 2009.
- Corrective actions may include "but are not limited to additional releases from upstream Central Valley Project facilities or south of the Delta State Water Project or Central Valley Project facilities, modification in the timing of releases from Project facilities, reduction in exports, recirculation of water through the San Joaquin River, purchases or exchanges of water under transfers from other entities, modified operation of temporary barriers, reductions in highly saline drainage from upstream sources, or alternative supplies to Delta farmers (including overland supplies)." (State Water Resources Control Board 2006: 29, 30)

Even the State Board's Cease and Desist Order could not help noticing the absurd delays by the Department and the Bureau in achieving compliance with south Delta salinity objectives:

> Considering that the objectives were first adopted in the water quality control plan in 1978 [in D-1485], and there is evidence that salinity is a factor in limiting crop yields for southern Delta agriculture, the State Water Board will not extend the date for removing the threat of non-compliance beyond July 1, 2009. (State Water Resources Control Board 2006: 27)

Despite the array of "corrective actions" the Board suggested in the Cease and Desist Order to the Department and the Bureau, the two water agencies fixed on the permanent operable barriers of the South Delta Improvement Program serve as their solution to their salinity control problems near the export pumps. The Department informed the State Board in February 2007 that its consultation process with US Fish and Wildlife Service and National Marine Fisheries Service was delayed due to the fishery agencies' concerns about the interrelatedness of the South Delta Improvement Program and the long-term operation of the CVP and SWP. Ultimately, neither the Bureau nor the Department would lift a finger for any other "corrective action" available to them to try to address south Delta salinity objective compliance. Figure 3 above records the extent of violations the two water agencies allowed to occur during dry years.

The Modified Cease and Desist Order of 2010

By June 2009, less than 30 days before deadlines in the 2006 Cease and Desist Order were to lapse, the Department on behalf of the Bureau announced to the State Water Board that the agencies were about to violate interior south Delta salinity objectives once again, and requested that the Board hold hearings to modify the Order.

The Board hastily convened an evidentiary hearing to modify the Cease and Desist Order. (The California Water Impact Network participated as a protestant in the Cease and Desist Order proceeding in the summer of 2009.) As part of compliance with a modified

Cease and Desist Order that the Board issued in January 2010, the State Board required the Department and the Bureau to "study the feasibility of controlling salinity by implementing measures other than the temporary barriers project, recirculation of water through the San Joaquin River, and construction of permanent operable gates." (State Water Resources Control Board 2010: Condition 7, 24)

The Department of Water Resources' South Delta Low Head Pumping Study

The Department agreed to study "low head pumping" as a method for controlling salinity at key compliance monitoring stations in the South Delta (shown in the inset to Figure 3). The Bureau evaluated dilution flow needs and the potential for achieving interior South Delta salinity objectives. The goal for the study was to determine what flows and at which locations low head pumping would significantly reduce or eliminate the salinity objective violations by the Department and the Bureau. Water years 2007, 2008 and 2009 were dry or critically dry years, and so as time went on, fresh water flows with low salinity became harder to come by, and exceedances piled up. These "low head pumps" would in theory shunt high quality Sacramento River water upstream (eastward) around the temporary rock barriers with culverts through them that the Department installs each year in key interior Delta channels. It was hoped that low head pumping might improve the Department and the Bureau's compliance record on salinity objectives with little cost of high quality fresh water from upstream sources.

The Department's study results indicate that low head pumping could increase the dilution effects on salinity in south Delta channels by shifting higher quality Sacramento River water upstream of the barriers where the compliance points are. However, their effects appear to be small at best, even at pumping rates of from 500 to 1,000 cubic feet per second. (California Department of Water Resources 2011: 25-31) *The most important factor in South Delta salinity, the Department acknowledged, was the sources of water reaching each south Delta compliance monitoring site.* From modeling results, the Department found that 83 to 93 percent of the salty water reaching the interior South Delta compliance monitoring sites originated from the San Joaquin River. While low head pumping at one location could move large proportions of Sacramento River water upstream of the barriers and improve water quality there, salinity concentrations at other (non-pumped) compliance points saw little or no improvement; the salty flows of the San Joaquin River continued to predominate elsewhere in the South Delta. Even joint low head pumping at both Old and Middle River sites (see inset of Figure 3) would not result in significant reductions in the likelihood of continued salinity violations by the Bureau and the Department. After trying almost 60 different modeling scenarios, the Department concluded that, while low head pumping can reduce salinities on the upstream side of the Delta's temporary barriers near salinity compliance points, this approach's ability to reduce salinity objective violations was minimal, and posed high costs for fish screens. Cost estimates also had very high ranges of uncertainty in the absence of more definite engineering designs. (California Department of Water Resources 2011: Tables III.3 through III.6 and Figures III.5 and III.6; cost data shown in Tables ES.1 and ES. 2)

The Bureau's Dilution Flow Study

The Bureau of Reclamation's 2011 study for the State Water Resources Control Board addresses the ability of such upstream dilution flows to attain salinity control and compliance at the interior South Delta monitoring sites. Recall from Table 1 above that fresh water flows from the major east side tributaries to the San Joaquin River exhibit sharp declines in flow from unimpaired to observed conditions, ranging from 53 percent on the Stanislaus River to 90 percent on the Upper San Joaquin River (State Water Resources Control Board 2011). Higher unimpaired fresh water flows would contribute larger volumes of low salinity water that would help to dilute salinity concentrations from west side and Valley Floor drainage sources.

The Bureau acknowledges in its dilution flow study that the best watersheds from which to get ideal dilution flows would have salinity conditions that are "60% or lower" than the salinity targets with which the Bureau wants to comply. In other words, the Bureau recognizes in the study's methodology that the lower the salinity and hence the better the water quality of the dilution flows to be used for compliance, the more likely the Bureau could use less water to achieve compliance with the State Board's salinity objectives.

For its study, the Bureau assumed that the salinity of dilution flow would be 60 micro-mhos per centimeter of electrical conductivity, a very low salt concentration "representing eastside reservoir water quality." (US Bureau of Reclamation 2011: 39) (This salinity is equal to about 38.4 mg/L (milligrams per liter) of salt as Total Dissolved Solids.[3]) This would approximate the salinity of water originating from snowmelt in the High Sierra.

The Bureau found that the tributaries with the best water quality for dilution flows are the Stanislaus and the Tuolumne rivers. While the Merced River's flows are of better quality than the those of the Bureau's recirculation scenario (in which Delta water is imported into the Delta Mendota Canal, then released down eastbound "wasteways" to the San Joaquin River without being used for irrigation), its water quality is not as good as the Stanislaus and the Tuolumne and would therefore require greater volumes of water to achieve compliance.

The recirculation scenario would continue importing some Delta salt loads and yielded results in critically dry, dry, and below normal water years where compliance could not be achieved by the Bureau for weeks and months at a time. The Bureau effectively rejected recirculation as a feasible option for salinity compliant dilution flows.

The Bureau found that using high quality water from an eastside reservoir (as yet unnamed), it would take about 100,000 to 200,000 acre-feet to comply with the most lenient of water quality objectives, and as much as 1.4 million acre-feet in dry years to meet "the most stringent" water quality objectives at Vernalis, which of course are years when such a supply of water is unlikely to be available. (US Bureau of Reclamation 2011: 40)

At this time, the National Marine Fisheries Service in its just-issued biological opinion on the coordinated operations of the State Water Project and the Central Valley Project,

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[3] Conversion from micromhos per centimeter to total dissolved solids (expressed in mg/L) is based on criteria conversions provided in Bauder et al 2011.

rejected permanent operable barriers as essentially magnets for predators consuming juvenile salmon and salmon smolts migrating to the ocean. Throughout this hearing, the Department and the Bureau held to their belief that pursuing the permanent operable barriers, and won from the State Water Board a modified Cease and Desist Order that postpones any enforcement action by the Board against them until at least 2014. There is no prospect at this time that National Marine Fisheries Service will alter its opinion of the permanent operable barriers, but by 2014, at least nine years will have elapsed during which the Department and the Bureau are and are not held responsible for complying with interior South Delta salinity objectives of the 1995 Bay-Delta Water Quality Control Plan, D-1641, and the subsequent 2006 Bay-Delta Water Quality Control Plan.

Salinity violations continue during 2012 in the South Delta. Figure 4 shows the trends in actual electrical conductivity at monitoring station P-12 (Old River at Tracy Boulevard), the calculated 30-day average of EC values at this location, and the salinity objective of 1000 microSiemens per centimeter (mS/cm) through March 31 and the 700 mS/cm from April 1 through August 31. The red curve in Figure 4 shows that the 30-day running average for electrical conductivity exceeded the P-12 EC objective for 84 consecutive days between March 4 and May 26, nearly three months of compromised water rights for South Delta diverters.

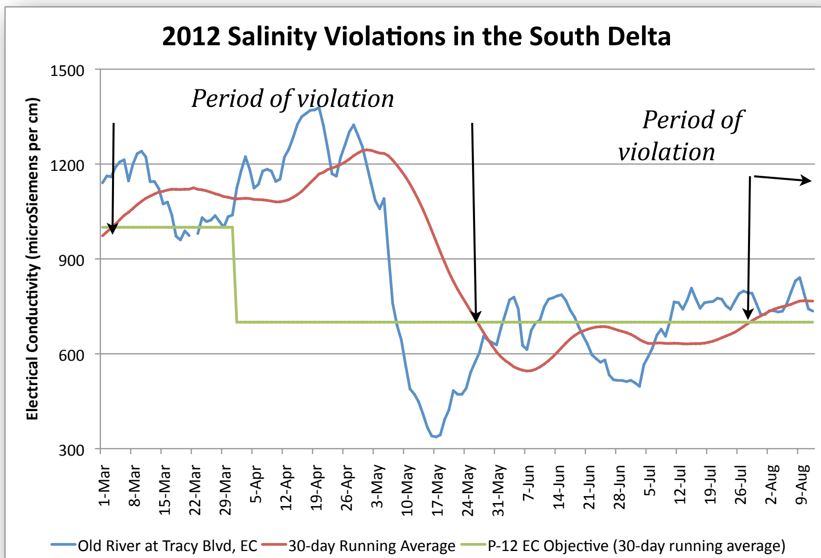

Figure 4: Salinity violations in the South Delta between March 1 and August 12, 2012. Source: California Data Exchange Center, California Water Impact Network. See Appendix E for supporting data.

The western San Joaquin Valley is the logical place to focus the State Water Resources Control Board's source control enforcement efforts, and has been the logical place for decades, rather than in the South Delta. Salts from this area contribute significantly to the compliance problems in the interior South Delta, as DWR's Low Head Pump and the Bureau's dilution flow studies show. They also compromise water rights of Delta farmers.

The South Delta salinity objectives are intended to protect South Delta agricultural beneficial uses, which includes protection of the water rights of South Delta agricultural water users. The current objectives protect these water rights by providing that level of salinity (as measured in terms of electrical conductivity) that meets the quality requirements of those rights. To relax these objectives would be a conscious State Water Resources Control Board choice to directly reduce and injure water rights and agricultural beneficial uses in the South Delta. C-WIN believes this proposed action would violate the federal Clean Water Act's antidegradation policy and the Board's own 1968 resolution protecting against antidegradation of the state's waters.

The efficacy of water rights and the quality of agricultural beneficial uses in the South Delta are determined largely by salinity of Delta inflows from the San Joaquin River. Studies and reports by the Department, the Bureau, and the Central Valley Regional Board confirm this.

Dilution flows are already part of the overall strategy the State Water Resources Control Board relies on to address South Delta salinity issues. The Board's existing dilution flow strategy in the Bay-Delta Plan to date has focused almost exclusively on releases from New Melones Reservoir, owned by the Bureau of Reclamation, on the Stanislaus River. (This strategy accounts for the increase in the Stanislaus River's share of flows at Vernalis from unimpaired to observed, developed conditions, as shown in Table 1, above.) Water Rights Decision 1422, which governs operation of New Melones, called for water quality releases amounting to 98,000 acre-feet of releases for fish and wildlife beneficial uses and such releases as necessary to maintain 500 parts per million of salinity at Vernalis. Given the Bureau's continuing lack of compliance with D-1641's South Delta salinity objectives, these releases are neither enough to maintain compliance by the Bureau at interior South Delta salinity compliance points, nor do they provide sufficient instream flow protection to listed aquatic species in South Delta channels.

The Board's past willingness to regulate New Melones Reservoir operations dates back to the 1970s. It clearly demonstrates the Board's authority and capacity to regulate upstream inflows to the Delta to protect beneficial uses downstream. Hence the State Water Resources Control Board's apparent interest in looking to additional sources of dilution flows from other San Joaquin River tributaries has both merit and precedent.

III. The Toxicity of Selenium

The problem of salt loading in flows returning to the Delta via the San Joaquin River is compounded by the presence of selenium. Selenium is typically found as a very small component of total dissolved solids (TDS), a commonly used measure of salinity and salts. But the larger the salt load the larger the selenium load.

Selenium occurs naturally in mineral deposits like coal and oil, as well as other marine-derived sediments. (Presser 1999) Wastes from agriculture, industry, mining, and gas and oil refineries can increase selenium contamination in estuaries and bays.

Selenium is necessary to the health of most vertebrate species and for human health when provided in small doses. Adequate amounts of selenium are found in a well-balanced human diet. But at just slightly elevated levels, selenium becomes actively poisonous. As concentrations rise further, selenium can cause embryonic defects, reproductive problems, and death in vertebrate animals.

As a chemical element, selenium is chemically similar to sulfur in how they both react with both mineral and organic compounds. Selenium can readily substitute for sulfur in salts (such as selenates for sulfates) as well as in certain amino acids (e.g., seleno-cysteine and seleno-methionine; Presser 1999; Presser and Luoma 2006: 40), the building blocks of proteins. Selenium's ability to substitute chemically for sulfur in both salt chemistry and organic amino acids clears pathways to toxicity, increased gene mutation, and ecological damage.

At higher tissue concentrations, selenium can substitute for sulfur in amino acids, altering the structure of proteins in metabolic and reproductive systems of the body. When proteins in predator species mutate from excessive exposure to selenium, it can lead to sterility and suppression of the immune system "at critical development stages when rapid cell reproduction and morphogenic movement are occurring." Changes in the structure of many antibodies (such as from substitution of selenium atoms for sulfur atoms) can compromise the organism's immune defenses, making it more susceptible to disease.(Presser 1999: 555).

In the spring of 1983, federal wildlife biologists found that a majority of birds nesting at Kesterson National Wildlife Refuge had deformed embryos and chicks. Nearly two-thirds of Refuge birds had missing eyes and feet, protruding brains, and twisted beaks, legs and wings. The number of breeding birds able to reproduce collapsed. These birds had been poisoned and the reservoir at Kesterson became synonymous with "toxic disaster," a western Love Canal.

The direct culprit for these disfiguring effects on wildlife was selenium. (Ohlendorf 1985; Saiki 1985; Sylvester 1985; Barnes 1985; Kilness and Simmons 1985) This contaminant was brought to Kesterson by agricultural drain water from a wastewater canal called the San Luis Drain, which was constructed by the US Bureau of Reclamation.

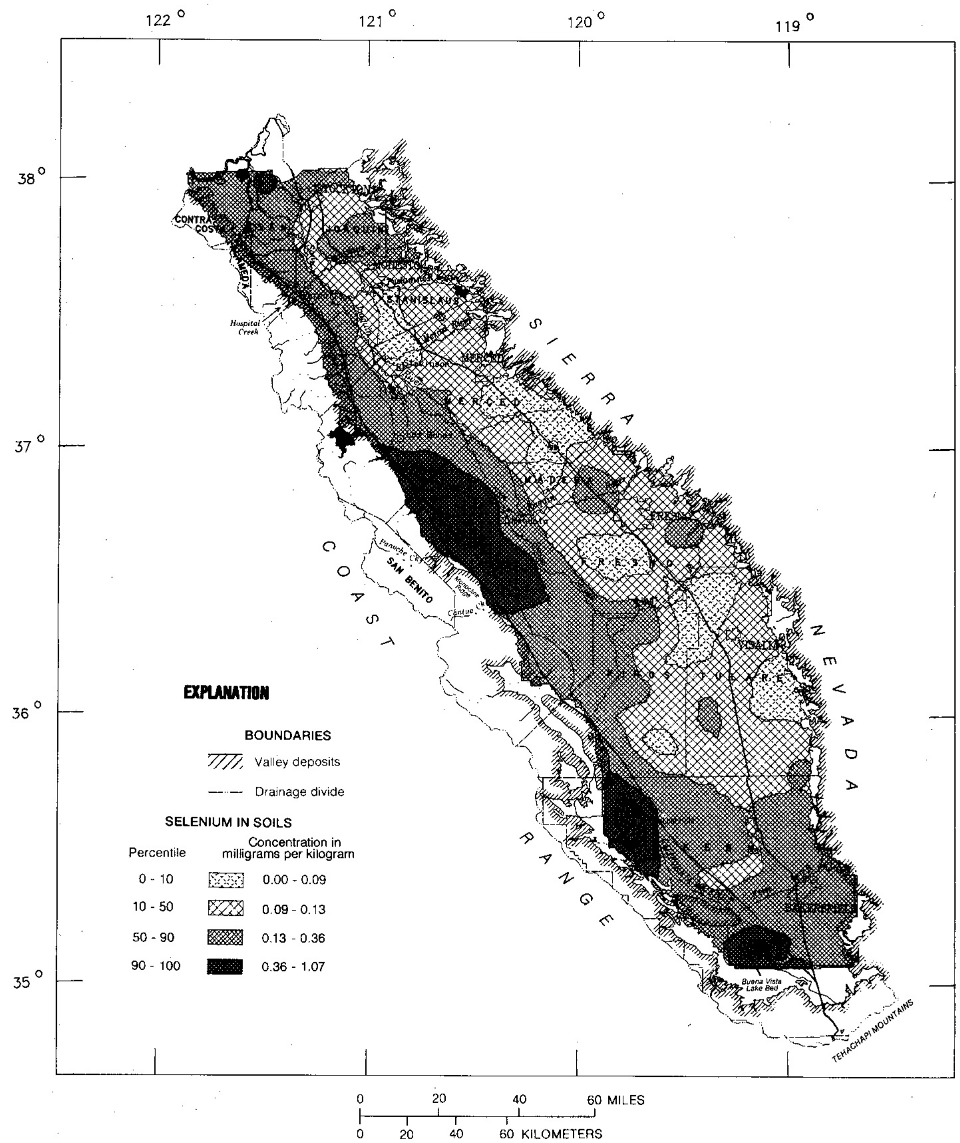

FIGURE 2.— Areal distribution of estimated total selenium concentrations for the 0- to 12-inch depth interval in soils of the San Joaquin Valley. (Adapted from Tidball and others, 1986a.)

Figure 5: Selenium concentrations in San Joaquin Valley soils. The darkest areas contain the highest selenium concentration in soils. Source: Gilliom 1988.

The "Unlimited Reservoir" of Selenium

The western San Joaquin Valley and its Coast Range foothills have naturally high levels of selenium in the rocks and soils. (Tidball et al 1986; Gilliom 1988) Three areas of the western San Joaquin Valley have the highest soil selenium concentrations:

- The alluvial fans near Panoche and Cantua creeks in the central western valley (near Gustine and Firebaugh; see Figure 5).

- An area west of the town of Lost Hills.
- The Buena Vista Lake Bed Area, west of Bakersfield. (San Joaquin Valley Drainage Monitoring Program 2010)

The disaster at Kesterson National Wildlife Refuge was the earliest and most vivid example of the western San Joaquin Valley's toxic legacy due to selenium. It was caused by the west side growers' obtaining and applying a large supply of irrigation water from Delta imports to lands of the San Luis Unit. Presser and Luoma (2006) identify a unit of measure they refer to as the "kesterson." It is equivalent to 17,400 pounds of selenium, the load of selenium that is believed to have accumulated at Kesterson reservoir between 1981 and 1985, the period when the Westlands Water District's drain water was connected to the reservoir. This is the mass of selenium loading from agricultural drainage water to which scientists attribute the deformities and deaths affecting 64 percent of waterfowl there in 1983.

Other parts of the San Joaquin Valley are also naturally contaminated with salts, selenium, and high levels of other toxic elements like boron, arsenic, and molybdenum (Figure 5; San Joaquin Valley Drainage Program 1990: 58-63). Because of the extent of the geologic deposits and rocks containing selenium in the western San Joaquin Valley, it is important to recognize that at time scales relevant to society, "there are, for all practical purposes, unlimited reservoirs of selenium and salt stored within the aquifers and soils of the valley and upslope in the Coast Ranges." (Presser and Schwarzbach 2008: 2) The selenium reservoir will be with Californians for a very long time to come.

Presser and Luoma (2006) quantify this reservoir by conceiving the reservoir of selenium as a stream of yearly time-step flows that can be modeled using reasonable assumptions about drainage projections, selenium concentrations and loadings from recognized plans and studies (such as San Joaquin Valley Drainage Program 1990; US Bureau of Reclamation 2005a, 2006, California Regional Water Quality Control Board, Central Valley Region 2000, 2001).

Their projections of selenium loads over time are shown in Table 5. Their scenarios are as follows:

- Existing discharges from the Grassland subarea (the northern part) through extension of the San Luis Drain to the Delta.[4]
- Westlands Water District subarea-only use of a San Luis Drain extension to the Delta or San Joaquin River.
- Grassland subarea plus Westlands subarea, both carried to the Bay-Delta.[5]
- Drainage is collected valleywide from all five subareas (Northern; Grassland, Westlands; Tulare, and Kern subareas).[6]

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[4] "It seems unlikely that demand [for use of the San Luis Drain] would remain at this level once an out-of-valley conveyance was available. Increasing acreages of saline soils, rising ground water tables, and the availability of a conveyance facility are likely to generate strong pressures from other areas to use the facility." (Presser and Luoma 2006: 31)

[5] "This seems a likely outcome if a conveyance is constructed." (Presser and Luoma 2006: 31)

[6] "This would require extensions of the San Luis Drain into Kern and Tulare subareas, in addition to an extension to the Bay-Delta." (Presser and Luoma 2006: 31-32)

- Two other scenarios that include all potential problem lands estimated for the year 2000. The first shows the range of selenium loads expected if drainage management follows the 1990 Rainbow Report of the San Joaquin Valley Drainage Program (1990). The second of the two forecasts lists load targets of the Total Mean Monthly (TMML) management plans for discharge to the San Joaquin River from the Grassland subarea, which ramp down over time.

Using load targets (Table 5's bottom scenario) as the basis for the future stream of selenium drainage results in the lowest loading (about 1,400 to 6,500 pounds per year, or 0.08 to .38 "kestersons" per year) selenium discharges could be heavily regulated. By comparison, encouraging drainage of selenium and salts to the Bay-Delta either via a San Luis Drain extension or use of the San Joaquin River would result in a far larger range of nearly 15,000 to 42,800 pounds per year (or about 0.86 to 7.36 "kestersons" per year).

Table 5
Projections of Selenium Loads from the Western San Joaquin Valley for Different Drainage Scenarios

[A kesterson (kst) is defined here as 17,400 lbs selenium, the cumulative load that caused ecological damage when released to Kesterson National Wildlife Refuge, California) (Presser and Piper, 1998)].

Scenario (subarea(s) discharging to a proposed San Luis Drain extension)	Selenium load (lbs/year)	Selenium load (kestersons/ year)	Cumulative 5-year selenium load (kestersons)
Grassland (based on current data)	6,960 – 15,500	0.4 – 0.89	2.0 – 4.45
Westlands (based on 50 – 150 µg selenium in drainage and 60,000 acre-feet)	8,000 – 24,500	0.46 – 1.41	2.3 – 7.05
Grassland and Westlands (from above)	14,960 – 40,000	0.86 – 2.30	4.3 – 11.5
Valleywide Drain (current conditions and Westlands from above)	16,490 – 42,785	0.95 – 2.46	4.75 – 12.3
Valleywide Drain (all potential problem lands with management of drainage quantity and quality)	19,584 – 42,704	1.12 – 2.45	5.6 – 12.2
Valleywide Drain (all potential problem lands with minimum management of quality and quantity)	42,704 – 128,112	2.45 – 7.36	12.2 – 36.8
Total Maximum Daily or Monthly Load Model management (load *targeted* for environment safeguards, Grassland subarea or drainage basin)	1,394 – 6,547	0.08 – 0.38	0.4 – 1.9

Source: Presser and Luoma 2006: Table 8, 33.

Presser and Luoma also examine scenarios in which constant concentrations of selenium in drainage flows (either in the San Luis Drain or in the San Joaquin River) are maintained. In Table 6, these projections show that at high flows selenium loads may differ significantly depending on the concentration maintained either in the river or the drain. At the current Total Mean Monthly Load (TMML) level for the lower San Joaquin River (California Regional Water Quality Control Board 2000) of 5 micrograms per liter (µg/L) can yield large loads in high flows (up to 40,800 pounds during a 3 million acre-feet wet year) or small loads in low flows (or nearly 3,000 pounds during low flow in the San Joaquin River or capacity flow of the San Luis Drain).

Table 6 also shows that relaxing selenium concentration assumptions in the drainage flows to the Bay-Delta for purposes of carrying larger loads in the San Luis Drain from 50 to 300 µg/L can enable the Drain to carry much more selenium out of the San Joaquin Valley to the Delta (from nearly 30,000 pounds pear year to nearly 180,000 pounds per year, thereby easing the buildup of stored selenium in western San Joaquin Valley soils and groundwater (the "reservoir" alluded to earlier). Yet these cumulating loads would likely be highly toxic, especially in dry and drought years, of which more are expected as

California's climate changes. Expressed in kestersons, these load projections by Presser and Luoma convert to *1.7 to 10.3 kestersons per year* in the San Luis Drain under relaxed assumptions of selenium concentration.

Table 6
Selenium Loads Conveyed to the Bay-Delta Under Different Flow Conditions by Maintaining Constant Concentration in Either San Joaquin River or San Luis Drain

[Flow conditions: high flow (3.0 million acre-feet/year); low flow (1.1 million acre-feet/year); and annual flow assumed for a proposed San Luis Drain extension at maximum capacity or a small San Joaquin River input in a dry year (approximately 220,000 acre-feet/year)].

Selenium concentration in river or drain extension (µg/L)	Selenium load (lbs/year)		
	3.0 million acre-feet/ year	1.1 million acre-feet/ year	216,810 acre-feet/year (300 ft³/s)
0.1	816	299	60
1.0	8,160	2,990	598
2.0	16,320	5,980	1,197
5.0	40,800	14,960	2,992
50	–	–	29,920
150	–	–	89,760
300	–	–	179,520

Source: Presser and Luoma 2006: Table 9, 33.

Selenium Behavior Across Aquatic Environments

Selenium concentrates naturally in the depositional environments of estuaries and marshes. Hydrologic conditions provide important reasons for this. Selenium dissolved in water represents only a small proportion of exposures. (Presser and Luoma 2006; Presser and Luoma 2009: 8485; Schlekat et al 2004; Roditi et al 1999; Alquezar et al 2008) Selenium can undergo "partitioning" reactions in the water column that determine whether selenium remains dissolved or enters what chemists refer to as its "particulate phase." (Presser and Luoma 2006: 41; Presser and Luoma 2010)

Selenium in the water column of a flowing river can become problematic when flows slow down due to changing geomorphology of the stream channel, or at conclusion of a runoff event. (Presser and Luoma 2006: 6) Incorporated into detritus or suspended sediments, selenium may then get deposited to the bed of the quiet water body. Incorporated into bacteria or phytoplankton, selenium gains immediate entry into an aquatic food web when these organisms are consumed by their immediate predators (such as zooplankton and other open water or bottom-dwelling consumers).

Presser and Luoma (2010: 703) catalog a range of hydrologic environments and selenium's partitioning behavior, summarized in Table 7. The relative calm of water in marshes, wetlands and estuaries facilitate this partitioning process by which selenium finds its way from the water column, aquatic organisms and animals connected by predation to aquatic food webs. Once consumed by prey organisms, predators can then bioaccumulate selenium at varying rates that depend on the assimilative efficiencies of prey in their diet choices.

Table 7
Examples of Ecosystem and Hydrologic Environment-Specific Selenium Criteria in Tissue and in Water Column

Hydrologic Environment	Selenium Partitioning Factor (K_d)	Target Selenium Concentration in Tissue (µg/g, dry wt)	Hypothetical Selenium Concentration in Water Column (µg/L)	Protected Fish or Birds in Hydrologic Environment
Mainstream River	150	5 (fish tissue)	10.8 to 34	Bluegill; Trout
Backwater	350	5 (fish tissue)	4.6 to 14.4	Bluegill; Trout; Bass
Reservoir	1,800	5 (fish tissue)	0.89 to 1.7	Blackfish; Redear
Estuary	3,000	5 (fish tissue)	0.24 to 1.2	Starry Flounder; White Sturgeon
Estuary	3,000	8 (bird tissue)	0.24	Scaup
Wetland	900	8 (bird tissue)	1.8	Grebe
Stream	350	8 (bird tissue)	4.5	Dipper
Saline Lake or Pond	1,500	8 (bird tissue)	0.70 to 1.8	Blacknecked Stilt

Source: Presser and Luoma (2010a: Figure 6, 703); California Water Impact Network.

Selenium and the Invasive Clam, *Corbula*

One such food web is based on predators consuming large quantities of bottom dwelling (benthic) organisms. Once deposited at the bottom of the water column, benthic organisms may consume selenium-containing detritus or sediments as part of their grazing behaviors. Filter-feeding behavior by clams in the water column can also be an important pathway by which bottom-dwelling organisms consume and incorporate selenium into their tissues directly from the water column before particulates fall into sediments. The invasive Asian clam, *Corbula amurensis,* assimilates selenium into its tissues with high efficiency. (Linville, et al 2002; Stewart et al 2004)

C-WIN examined this relationship between flow rate and selenium uptake by benthic organisms. Field research by Kleckner, *et al* (2010) measured selenium uptake in *Corbula* tissues over a 15-year span (1996-2010) from several sites in Suisun Bay and Carquinez Strait immediately west of the Delta. Kleckner *et al*'s data on selenium uptake by these clams is used to illustrate the relationship to Delta outflow and the position of the X2 isohaline (which scientists use as the western boundary of the Delta estuary's "low salinity zone").

By comparing the selenium uptake of Kleckner's clams near Chipps Island to various flow indicators, C-WIN hoped to provide empirical corroboration of selenium behavior in slower moving aquatic environments as found by Presser and Luoma (2010a). C-WIN identified three flow and salinity indicators to compare with the selenium uptake by clams. These indicators included: net Delta outflow; the ratio of San Joaquin flows at Jersey Point to net Delta outflow; and the position of X2, an isohaline marking the position of water with a salinity concentration of 2 parts per thousand (2 ppt). C-WIN chose Chipps Island as the site for comparison purposes because the island is located at a bathymetric and geographic transition in flow from more narrow channels of the Sacramento and San Joaquin River confluence into the eastern edge of the widening of Suisun Bay. (Kleckner et al 2010: Site 4.1 in Figure 1, Table 3) Such a location is presumed to exhibit where flow velocities for a given volume of water will slow down as the underlying channel bathymetry flattens and widens. Streams and rivers at such transitions lose their competence to hold sediment. Deposition of suspended particles occurs readily.

Net Delta outflow is a calculated estimate of flow at the confluence of the Sacramento and San Joaquin Rivers at the east end of Suisun Bay. These calculations are done at daily time-steps as part of the output of the Interagency Ecological Program's Dayflow model of Delta flows. As with Net Delta outflow, San Joaquin River flows and the position of X2 are also obtained from Dayflow.

Approximately monthly samples of *Corbula* were taken by Kleckner's team between 2002 and 2010 to study selenium concentrations in the clams' tissues. Weighted average monthly selenium loads were calculated from Kleckner et al's data by C-WIN based on the number of individual clams in each sample for each respective month in Kleckner, et al's dataset (that is, the data in the next few charts are "sample-weighted"). (C-WIN's sample weighting of the selenium uptake data by *Corbula* and Dayflow hydrology data for Net Delta Outflow, San Joaquin River at Jersey Point, Sacramento River at Rio Vista, and X2 are all presented in Appendix B to this testimony.)

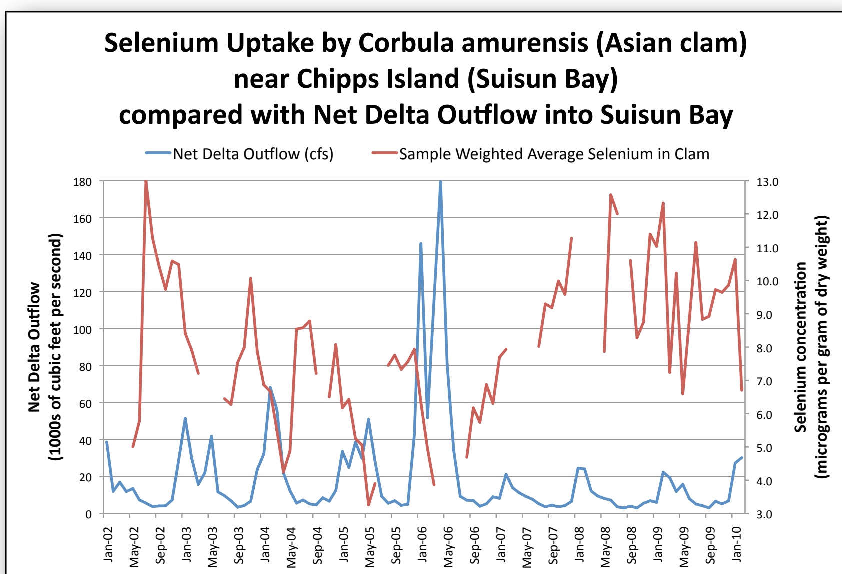

Figure 6
Sources: Kleckner, et al, 2010; Dayflow; California Water Impact Network.

Figure 6 presents a side-by-side comparison of *Corbula*'s selenium uptake with the time series of net Delta outflow at monthly time-steps. There is an observable inverse relationship between these datasets, but it does not appear strong. But the comparison does reveal that when net Delta outflow is high as in the winter of 2006, tissue concentrations of selenium in *Corbula* appear to fall. At lower net Delta outflows, selenium tissue concentrations conversely appear to climb.

A significant rise in selenium uptake occurred during critically dry and dry years of 2007 through 2009. This three year interval was an extended drought period in California. Selenium loads in clam tissues there at Chipps Island rose in 2006 from about 4.5 µg/g (dry weight) to levels approaching 13 µg/g (dry weight) by 2009. With the onset of early storms in water year 2010, an above normal year, selenium in the tissues of Chipps Island *Corbula* clams decreased to about 6.5 µg/g (dry weight), as shown in Figure 6. In these years, extended periods of low flows and relatively low wintertime floods seem to correlate with persistent and chronic elevated levels of selenium uptake by *Corbula* at Chipps Island.

Net Delta outflow, however, does not directly reflect the relative presence or absence of salts and selenium in source waters reaching the Chipps Island *Corbula* clams. As shown earlier, however, the San Joaquin River is a major source of salts (including selenium) reaching the South Delta, and at higher flows, beyond.

Figure 7 shows the same data on selenium uptake by *Corbula* compared with tracking of the monthly ratio of San Joaquin River at Jersey Point to the sum of Sacramento and San Joaquin River flows. This comparison shows selenium uptake in *Corbula* varying more directly with the relative volume of San Joaquin river flows making it to Suisun Bay. Figure 7 reveals a similar inverse relationship as with net Delta outflow, but the signal from the San Joaquin River in this inverse relationship appears stronger than the signal for net Delta outflow alone. C-WIN suggests this is likely because the ratio captures the oscillating signal of San Joaquin River flows (which are well-known to be of far saltier concentration than those of the Sacramento River). The San Joaquin River's salt loads thus would figure more prominently than it would in net Delta outflow by itself. Seasonal variation in selenium uptake by *Corbula* also is visible in Figure 7. The strong climb from 2006 through 2008 in selenium tissue

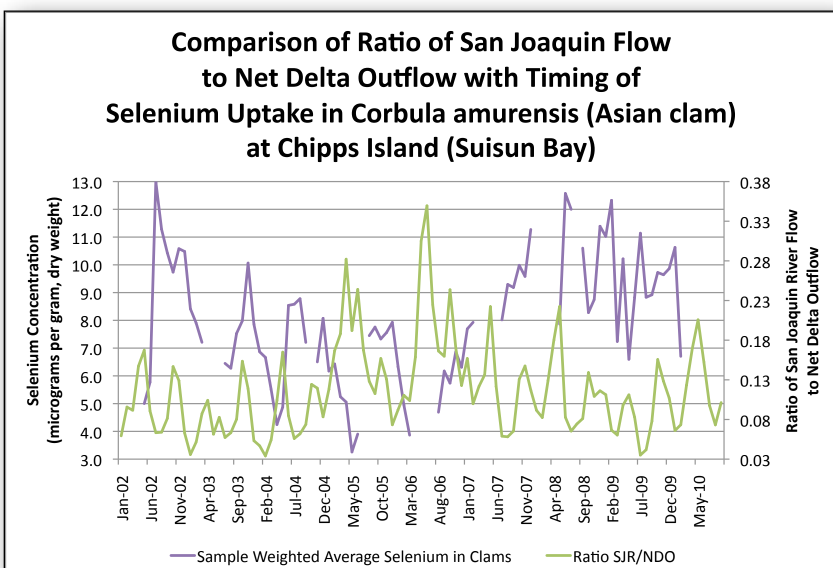

Figure 7
Sources: Kleckner et al, 2010; Dayflow; California Water Impact Network.

concentrations in *Corbula* in the wake of large loads transported by high 2006 spring flows from the San Joaquin is also evident in Figure 7.

The analysis presented from Figure 7, however, does not capture the oscillation of salinity conditions specific to Chipps Islands. So C-WIN next compared the *Corbula* clam selenium uptake data with X2 monthly data, a measure of the position of the 2 parts per thousand isohaline in the western Delta and northern San Francisco Bay Estuary.

The X2 isohaline is a region of water whose salinity is approximately 2 parts per thousand (2 ppt). Waters upstream of X2 are fresher, while those downstream are saltier. Scientists observe that this isohaline marks a distinct ecological boundary between species preferring fresher water environs and those that prefer greater salinity. This region indicates the overall size of freshwater habitat in the Delta as it oscillates its position between, generally, the east and west ends of Suisun Bay (that is, between Chipps Island and the eastern mouth of Carquinez Strait, a distance of about 20 kilometers). X2 is described as a distance (measured in kilometers) from the Golden Gate. Chipps Island is approximately 75 kilometers from the Golden Gate, while Carquinez Strait's eastern edge is about 55 kilometers from the Golden Gate. (San Francisco Estuary Project 1993: Figure 1, A-11)

X2 can thus be used as a proxy for the relative presence or absence of salinity in the Bay-Delta estuary. It marks the mobile boundary of what scientists call the "Low Salinity Zone" in the Bay Delta Estuary. Figure 8 shows that X2 has a relatively direct correlation in its movements with flow as does the uptake of selenium by *Corbula* clams at Chipps Island. Recall that selenium is a component of salinity concentrations in the water column. It follows that when X2 is further west of Chipps Island, salinities and selenium concentrations and bio-availability are reduced. Consequently, clam uptake of selenium is reduced because of elevated downstream fresh water flows with high volumes and velocities, as Figure 8 indicates. On the other hand, when flows are low, X2 recedes eastward, upstream into the separate channels of the Sacramento and San Joaquin River. The value of X2 increases as the western boundary of the low Salinity Zone moves east. This means that greater salinities and selenium uptake occur in the vicinity of Chipps Island, both seasonally and in the course of interannual dry

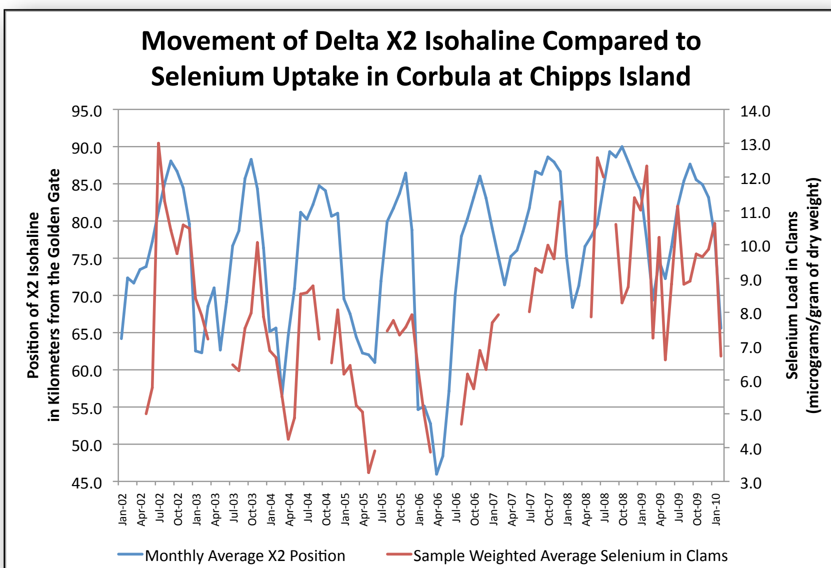

Figure 8
Sources: Kleckner, et al, 2010; Dayflow; California Water Impact Network.

spells, such as occurred in 2007 through 2009.
In Figure 8, the same selenium uptake data derived from Kleckner et al (2010) are plotted along with X2 isohaline data also provided by the Interagency Ecological Program's Dayflow output. X2 daily data were converted into monthly averages for ease of comparison with the sample-weighted monthly data on selenium uptake by the clams.

When net Delta outflow is high, the X2 isohaline is pushed west into Suisun Bay. As Figure 8 illustrates, during the wet year of 2006, spring flows pushed X2 almost to 45 kilometers from the Golden Gate, well into Carquinez Strait. On the other hand, at the low point of low flows in the fall of 2008, X2 receded to 90 kilometers upstream of the Golden Gate (or about to a point just east of Antioch on the San Joaquin River and a point midway between Collinsville and Rio Vista in southern Solano County along the Sacramento River).

The relationship of selenium in the water column of the Delta to residence time and bio-availability is further suggested by the use of temporary barriers in the South Delta. In particular, the Head of Old River Barrier is intended to close off Old River from San Joaquin flows during high flow periods such as spring (snowmelt) peak flows so that salmon smolts are diverted away from Old River and possible entrainment at the state and federal export pumps. In the fall, this barrier amplifies low flows through the Stockton Deepwater Ship Channel to help prevent sags in dissolved oxygen concentration that occur during otherwise stagnant hydraulic conditions there. Monsen *et al*'s modeling simulations of the Barrier's effects (particularly in the fall) indicate that when the Barrier is in place the "flushing time for the Stockton Ship Channel during autumn periods is on the order of days...and on the order of weeks when this barrier is removed." Without endorsing use of the Barrier, this example makes plain that when mainstem San Joaquin River flows through Stockton are greater, residence time (the obverse of "flushing time") decreases significantly. When these flows are laden with selenium, they are shunted beyond direct reaches of the South Delta into Central Delta mixing zone areas and for eventual deposition in Delta sediments or exit from the Delta past Chipps Island. (Monsen et al 2007: 11)

The relationship between selenium concentrations in the water column and invertebrate uptake of selenium is confirmed by a selenium ecological risk assessment performed for the Grassland Bypass Project for wetlands along the lower San Joaquin River. (San Luis Delta Mendota Canal Authority and US Bureau of Reclamation 2009: Appendix E2) In that assessment, the best predictor of fish selenium concentrations relative to water column selenium concentrations is provided by a logarithmic function that lags fish tissue samples 1 to 7 months after the water column concentration is measured. (Correlation coefficient [R^2] equals 0.76.) The same assessment also found that selenium levels in aquatic invertebrates in these wetlands (including crayfish) "are broadly correlated with selenium concentrations in water." The correlation was strongest (R^2 equals 0.68) when invertebrate selenium tissue concentrations were lagged 30 to 60 days after measurement of the water column selenium concentration. (San Luis Delta Mendota Canal Authority and US Bureau of Reclamation 2009: Appendix E2: E.2-10) In other words, it takes just a few weeks for selenium in the water column to become bioavailable through partitioning and deposition in sediments. This is why residence time of selenium in the water body is so important to its fate and to selenium's toxicity in aquatic food webs.

Selenium's Ecological Risks

Once consumed, selenium can quickly build up in the tissues of their predators, the fish, birds, and even humans higher up in aquatic food webs. Beckon and Maurer (2008) surveyed potential for selenium effects on a variety of fish and wildlife species in the San Joaquin River Basin and the San Joaquin Valley. They found that:

- The **San Joaquin Kit Fox** is "potentially at risk from dietary intake" of selenium by virtue of consuming small rodents (voles, mice, shrews) that may frequent evaporation ponds and selenium reuse areas (where selenium and salt-tolerant crops are grown to remove selenium from drain water).

- **Kangaroo rats** in the San Joaquin Valley are potentially at risk from consuming seeds enriched with selenium in their diets. If so, Beckon finds kangaroo rats are "likely to exceed thresholds for adverse effects" from consuming such seeds.

- **Giant Garter Snakes** are potentially at risk, though that risk is unknown because this snake is rare and endangered.

- **Blunt-Nosed Lizards** are also considered by Beckon to be at risk from feeding on aquatic insects in the vicinity of agricultural drainage ditches, evaporation ponds, reuse areas, and retired seleniferous (selenium-contaminated) lands. Beckon states that reuse areas may pose the greatest selenium-related risks for this lizard.

- **California Least Terns** have been seen at selenium-treating evaporation ponds in the San Joaquin Valley, but have as yet shown no toxic effects from exposure. However, Beckon observes that "if California least terms learn to eat brine shrimp and other invertebrates in evaporation ponds" then their exposure to selenium could dramatically increase.

- **Chinook Salmon** are among the most sensitive fish and wildlife to selenium exposure. In particular, Beckon warns there is substantial ongoing risk to juvenile salmon. For fall-run juvenile Chinook salmon, their migration commences with late winter and spring snowmelt flows along the major tributaries of the San Joaquin River (Stanisaus, Tuolumne, and Merced rivers). In low flow years on the San Joaquin River, this can mean, however, that otherwise compliant selenium concentrations in the river may prove toxic to young salmon beginning their migration. Beckon and Maurer estimate that up to 20 percent of all juvenile salmon at a tissue concentration of 2.45 μg/g dry weight reaching the San Joaquin River from the Merced River die in low flow years. (Beckon and Maurer 2008; Beckon 2009; Presser and Luoma 2010, 2011) Presser and Luoma (2006) warn that San Joaquin River Restoration Program efforts to reintroduce fall-run Chinook salmon must address the potential for selenium poisoning of reintroduced salmon between Sack Dam and reaches of the River downstream of Mud Slough (north, which releases Grassland Bypass Project drainage flows that have passed through the San Luis Drain; Presser and Luoma 2006, 2010; 2011).

- **Steelhead (Rainbow) Trout** are also believed by Beckon to be at risk from selenium exposure, which could confound efforts to restore this fish to the upper San Joaquin River as well.

- **White Sturgeon**, another migratory fish eats a major portion of its diet from bottom-dwelling (benthic) organisms, such as clams, which predominate in their diet (Beckon 2008). Beckon expresses hope that the exposure of white sturgeon to selenium will diminish as the State Water Resources Control Board's Total Monthly Mean Load regulations for selenium are implemented.

- **Sacramento Splittail**, of which some 7 million individuals were killed after being entrained by state and federal pumps in the Delta during 2011, face important risks of selenium exposure. They reside mainly in slow-water estuarine habitat and rely on the Asian clam and other mollusks as about one-third of their diet. Beckon expresses hope that the exposure of Sacramento splittail to selenium will diminish as the State Water Resources Control Board's Total Monthly Mean Load regulations for selenium are implemented.

Beckon and Maurer included the Delta smelt in their survey of selenium exposure to listed species. In the case of Delta smelt, there is disagreement in the literature about the role selenium exposure may play in the decline of Delta smelt abundance in the last decade or so. Beckon and Maurer (2008: 31) characterize the risk of selenium exposure by Delta smelt to be low. Delta smelt adults reach a maximum of about 4.7 inches in length. They feed on zooplankton, primarily which is not a significant selenium partitioning pathway into Delta food webs, but Delta smelt also consume aquatic insect larvae when available (McGinnis 2006: 197). Moreover, their spawning takes place in April and May in slow-water environments (e.g., side channels and sloughs) of the upper Delta and the lower Sacramento River in periods of low tidal activity. Beckon and Maurer (2008) report that Delta smelt larvae are "ecologically similar to larval and juvenile striped bass" in that they are not motile, but instead float in the water column where feeding occurs through random particle interactions.[7] (Bennett 2005: 18) Beckon and Maurer further note that Delta smelt obtained from the area of Chipps Island during the springs of 1993 (a wet year) and 1994 (a dry year, the seventh out of the previous eight) had whole body selenium concentrations of 1.5 μg/g dw (n=41, range from 0.7 to 2.3 μg/g dw; Beckon and Maurer 2008: 32), which are substantially lower than concentrations found in clams in the same region.

Delta smelt are known to prefer low salinity environments of from 2 to 7 parts per thousand salinity, such as is found in Suisun Bay and the northern and central Delta (McGinnis 2006). In drier years, the low salinity zone of the Delta estuary shrinks, however, and consequently Delta smelt habitat shrinks accordingly. Delta smelt eggs are spawned, fertilized, and attach initially during the April and May spawning season to the bottoms of slow-water hydrologic environments (e.g., backwaters in Table 7) prior to developing into larvae that then float in the water column in open water. These stages of Delta smelt life history take place in intimate proximity to hydrologic locations that are typical of selenium chemical speciation and partitioning, especially in lower flow

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[7] Bennett has observed directly that in the water column Delta smelt larvae "swim continuously, and feeding success requires practically bumping into prey items rather than a coordinated attack behavior."

regimes. Beckon states that Delta smelt spawning sites are now found largely in the north Delta channels associated with "the selenium-normal Sacramento River." However, Beckon appears to base his assessment of Delta smelt risk on a 1996 US Fish and Wildlife Delta smelt recovery plan, stating that Delta smelt "are nearly absent from the south-Delta channels associated with the selenium-contaminated San Joaquin River." This assessment appears to ignore at least two consecutive years (2000 and 2001) in which thousands of Delta smelt were killed at the state and federal project's pumping plants in the south Delta during the winter. (Swanson 2001; Swanson 2002) Beckon does not report on what if any selenium sensitivity studies have been done on Delta smelt in the field or in laboratory conditions.

Presser and Luoma (2010b) and Beckon and Maurer (2008) both consider the Delta smelt to be at risk of selenium exposure in the Bay-Delta estuary. Presser and Luoma cite as reasons for its at-risk classification that its overall threatened status as an endemic Delta fish species, and the fact that it feeds on insect larvae that may take up selenium (2010b: Table 4, 8). They agree with Beckon that it does not feed in a clam-based food web since zooplankton are the more important component of Delta smelt diets. They write, "the sensitivity of delta smelt to selenium is unknown; population numbers are alarmingly low, so this species is particularly vulnerable to any adverse effect." (Presser and Luoma 2010b: Table 4, 8, footnote 10)

Presser and Luoma (2006) earlier concluded from their selenium loading projections that white sturgeon (an Endangered Species Act-listed species) and greater and lesser scaup, surf and black scoters are at risk of significantly elevated selenium exposure given these selenium loading projections. (Presser and Luoma 2006: Table 33: 93; 2010a; 2010b) White sturgeon is a migratory fish, while the scaups and scoters are migratory estuary-based water birds that dive to prey on clams and other bottom-dwelling organisms.

IV. Regulation and the Future of the "Selenium Reservoir"

Presser and Luoma (2010a and 2010b) continue to develop a modeling methodology by which regulators may reasonably set protective water column selenium concentrations that are appropriate to the ecosystems and hydrologic environments that need protection. They examine a broad spectrum of environments and identify partitioning factors (K_d) that characterize the relative rates of selenium partitioning (wherein selenium comes out of solution into particulate phase, available for bioaccumulation into food webs). Their broad characterizations of hydrologic environments and food webs is summarized in Table 7 (above).

Their method links the detailed biogeochemistry of selenium in different environments to their food web relationships. Using these relationships, they expect to derive water column-based selenium criteria that link ecological relationships and hydrologic environments through which selenium moves. (Presser and Luoma 2010a: 704, 707) Selenium has multiple routes through which it can expose fish and wildlife to its toxicity.

Policy choices are critical when applying Presser and Luoma's selenium model to the setting of protective selenium criteria. See Appendix D for a chronology of selenium regulation in the Bay Delta Estuary and its Central Valley watershed.

> Policy choices such as 1) the predator species [meant] to represent an ecosystem (e.g., toxicologically sensitive, ecologically vulnerable based on food web, resident or migratory, commercially or esthetically valuable) and 2) the food web [used] to represent an ecosystem (e.g., potentially restored food webs in addition to current food webs) also serve as important initial inputs into the development of protective scenarios for a site or watershed. (Presser and Luoma 2010a: 707)

These potential policy choices illustrate some of the many options for key species and ecosystems needing protection. There are many sensitive species for whom selenium exposures and possible food web pathways to selenium exposure have not been identified. Two key listed species in the Delta for which either no or limited data are available are the Delta smelt and Chinook salmon, discussed above. They deserve consideration by the State Water Resources Control Board and the US Environmental Protection Agency as sensitive listed species whose protection should be an important foundation on which selenium regulation should be revised in the San Joaquin River Basin and the Bay-Delta Estuary. The Bay-Delta Water Quality Control Plan has not yet had specific criteria pertaining to toxic contaminants. C-WIN believes the time is long past due for the State Water Resources Control Board to integrate the management of toxic contaminant threats such as selenium into its Bay-Delta estuary regulatory framework.

A great risk to the Delta's future health and quality are systemic changes that are likely to lengthen the residence time of waters passing through the Bay-Delta Estuary on their way to the Pacific Ocean, and in so doing increase risks of selenium poisoning and ecological damage in the Bay-Delta Estuary (Presser and Luoma 2006, 2010). These risks originate with agricultural drainage accumulating in the San Joaquin River Basin due to irrigation of lands with soils impregnated with naturally occurring high selenium, salt, and other toxic contaminant concentrations and loads that must eventually be disposed of, else cultivation of western San Joaquin Valley lands will eventually go out of production.

There are three principal large-scale changes that each contribute to the prospect of increasing residence time in the Delta:

1) Construction and operation of a peripheral canal or tunnel that would change the point of diversion for the south Delta pumping plants of the state and federal projects to the inflows of the Sacramento River at a north Delta diversion.
2) Rising sea level in the Delta; and
3) Climate change affecting the volume, timing, and amount of inflows to the Bay-Delta Estuary from its major tributary watersheds, the Sacramento River Basin (including the Trinity River) and the San Joaquin River Basin

Under current hydrologic regimes, residence times of water in the south Delta and the North Bay can last from 16 days to three months in Suisun Bay during low flow, depending on levels of through-Delta discharge and mixing activity. (Presser and Luoma 2006: 17; Smith 1987; Presser and Luoma 2010: 707) Removal of Sacramento River flows from the Delta will result in less overall fresh water reaching central Delta channels, such as through Georgiana Slough (or via the Delta Cross Channel, a Central Valley Project facility that serves the same purpose to get fresh water across the central Delta to the pumping plants in the south Delta). To compensate, far more water would have to flow into the Delta from the San Joaquin River, but this river on average has the capability of delivering only a fraction of Sacramento River flows under unimpaired conditions.

While San Joaquin flows need to be increased from its major tributaries to provide dilution flows (discussed above and in the Instream Flows chapter below), the San Joaquin can never fully replace Sacramento river flow volumes or timing. As a result, longer residence times should be expected for water containing selenium even in current selenium Total Mean Monthly Load (TMML)-compliant concentrations. The longer the residence time of flows from the San Joaquin River, the more opportunity there is for selenium to transfer chemically from its dissolved phase to particulate forms and become "bio-available." Once it becomes bio-available, selenium is readily accumulated by aquatic food webs in low- or no-flow areas of the Delta and Suisun Bay. If San Joaquin River Restoration Program activities restoring floodplain and riparian habitat where slow-water environments are created for rearing juvenile salmon and steelhead and Sacramento splittail, these environments may also become sites for growing selenium exposure and its damaging ecological effects. It will be vital to keep flows moving to avoid selenium toxicity exposures in the lower San Joaquin River and south and central Delta regions.

Mud Slough (north) on the west side, the lower San Joaquin River, and Suisun Bay are hydrologically connected. Rising selenium levels threaten many species, including salmon, white sturgeon, green sturgeon, and migratory birds that feed on bottom-dwelling organisms like clams and worms burrowing through sediments where selenium collects. As Figure 9 shows[8], selenium concentrations in subsurface drain water in the San Joaquin River Basin exceed US Environmental Protection Agency aquatic selenium criterion for rivers and streams by 13 to 20 times (depending on whether the arithmetic or geometric mean is compared); by 32 to 50 times the aquatic criterion for westlands in California, and 130 to 200 times the level recommended as non-toxic in animal tissues by the US Geological Survey in recent research. (Presser and Luoma 2010, 2011; California Department of Water Resources 2010: see data in Table B-3, Appendix B, this testimony) This is the reservoir of selenium toxicity that builds up. Selenium regulation needs to catch up with this reality.

Sea level rise also poses toxic challenges to the Delta's future. With the water in Delta channels at present sea level, direct concerns focus on additional hydrostatic pressures that rising sea levels will place on Delta levees. For this discussion, however, sea level rise is likely to result in two other aspects of hydraulic pressures upstream of the Delta:

- Larger and deeper (hence heavier) volumes of tidally influenced sea water reaching the Delta is expected to slow the rate at which subsurface flows into the Delta from both the Sacramento and San Joaquin River Basins can drain into the Delta.
- Larger volumes of tidally influenced sea water in the Delta will also slow the rate at which surface inflows to the Delta from major tributary watersheds will reach the Delta. (This potential effect could be compounded if the Sacramento River is diverted in the North Delta for direct delivery to the south Delta pumps.) (Hanson, et al, 2012: Slide 42)

Slowing the escape of subsurface flows from the tributary valleys may result in slowed

[8] See Appendix B, Table B-3 for supporting data for Figure 8.

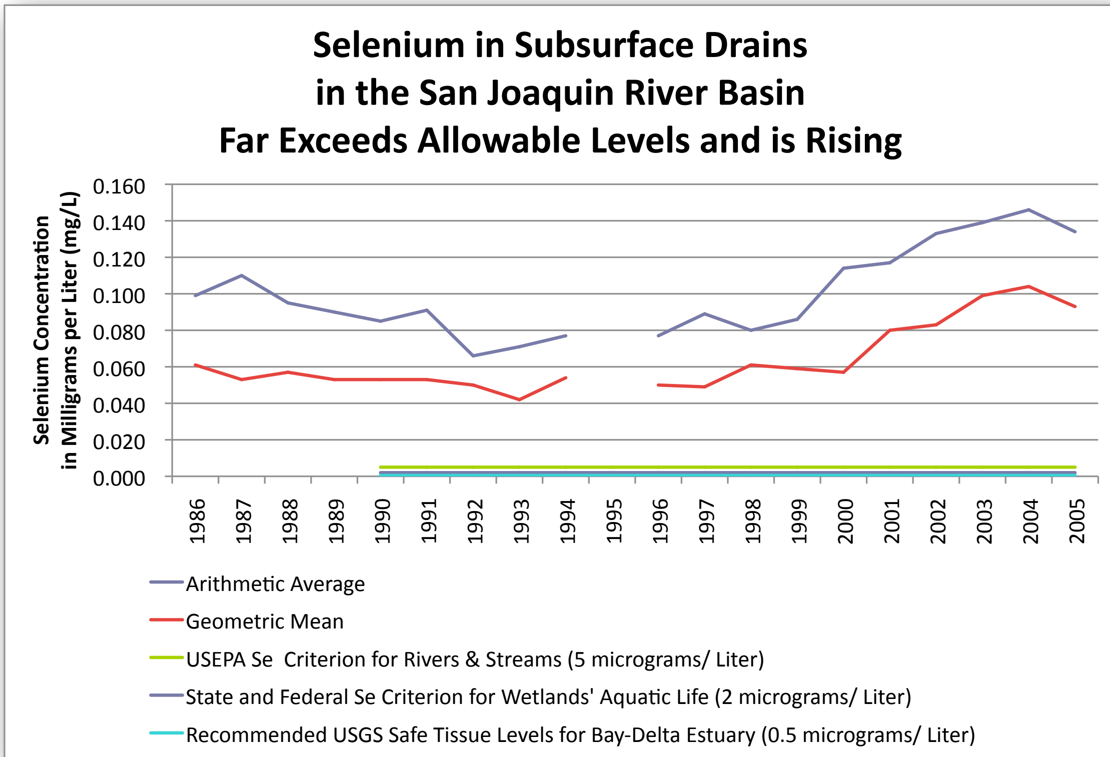

Figure 9
Sources: California Department of Water Resources 2010; Presser and Luoma 2010, 2011.

subsurface flow in both valleys, which could contribute to rising water table elevations. If groundwater elevations get to close to root zones, agricultural production can be disrupted. In areas where groundwater tables may be relatively deep, however, having them rise could be a benefit to some groundwater pumpers.

But in the San Joaquin River Basin, west side groundwater elevations are already very close to the surface, as discussed above. Having them rise further, with their saline and selenium-tainted water quality could be detrimental to irrigated cultivation in this part of the Basin.

This potential impact of climate change in the San Joaquin River Basin and the Delta would be further compounded by the trend, now seen in reduced snowpack and spring snowmelt, and increased rainfall and runoff. While extreme events like flooding and droughts may occur with greater frequency in the future in California, it is also anticipated that overall water supplies will decrease. In that event, residence time of waters in the Delta can be expected to increase as well with its implications of toxic damage in slow-water environments of the lower reaches of the San Joaquin River Basin and the Bay-Delta Estuary.

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Appendix A
Drainage, Salt and Selenium in the San Joaquin Valley

Millions of years ago, the lands of the western San Joaquin Valley and Coast Range were an ancient seabed. As the shallow seas and wetlands of that epoch dried up and folded into mountains, elements such as selenium, boron, molybdenum, mercury, arsenic, and various other salts and minerals concentrated in the marine mud, from which soils and rocks later formed.

Summary of Major Salts, Minerals, and Trace Elements in Western San Joaquin Valley (Central Area) Drains:

- **Arsenic**
- **Boron**
- **Calcium**
- **Chloride**
- **Magnesium**
- **Molybdenum**
- **Nitrate**
- **Potassium**
- **Selenium**
- **Sodium**
- **Sulfate**

Source: California Department of Water Resources 2010.

Today, many San Joaquin Valley growers irrigating orchards, vineyards and field crops along Interstate 5 face a vicious cycle of salty irrigation water and drainage pollution that threatens the productivity of their lands and the ecological and economic health of the San Joaquin River and the Delta estuary downstream.

As their crops take up irrigation water, they filter out salts. The salts build up in the soil. To continue cultivating these areas, growers must apply extra water just to leach salts from the root zone in order to keep the land producing. The leaching also mobilizes the selenium, boron, mercury, molybdenum, arsenic, and other elemental toxins that occur naturally in the soils. This toxic brew of irrigation drainage percolates down to a shallow impermeable layer called "Corcoran Clay." The water pools and collects on top of the Corcoran Clay. The more irrigation water is applied, the higher the toxic brew in the groundwater rises. In reaching the root zone, the brew threatens to harm plant growth and turn once productive fields into lifeless salt-encrusted wastelands.

The Valley growers' water supply problems and their drainage problems are inextricably linked and of their own making: the more they seek to expand irrigated production, the more surface water they use and then the more their drainage problems compound. The more that drainage collects underground the more its pollution drains into the west side creeks and sloughs of the San Joaquin Valley that ultimately reach the Delta, completing a vicious cycle of pollution.

Since the 1870s irrigation has been practiced widely in the San Joaquin Valley, and drainage problems have occurred ever since. Historians Kelley and Nye characterize the history of drainage problems in the Valley as having three distinct periods (Kelley and Nye 1984). Between the late 1870s and about 1915, there occurred rapid growth in irrigated acreage and salinity and drainage problems emerged. Individual irrigators experienced ponding and soil salinization. Experts from University of California agricultural experiment stations and federal soils agencies sought solutions, but by 1915, at least 80,000 acres of land in Fresno County were found to have subsurface water lying 6 feet or less from the surface. Kelley and Nye also report that "similar conditions existed in Stanislaus, Kings, and Kern counties" as well. (Kelley and Nye 1984: 5)

Between 1915 and the 1950s, agricultural production and irrigated acreage continued to expand in the San Joaquin Valley and irrigation and water districts proliferated. As statewide coordinated water development brought a shared understanding of the need for water supplies as a community undertaking, the recognition of shared drainage problems came to the fore as well, according to Kelley and Nye. "Hundreds of miles of ditches and tile lines installed by districts lying east of the Valley trough, however, proved insufficient to lower the water tables enough to prevent salt accumulation," they wrote.

Pressure to continue expanding irrigated agriculture in the San Joaquin Valley helped drive the approval and construction of the federal Central Valley Project between the 1930s and 1950s. The Delta Mendota Canal was completed in 1951 to import water from the south Delta at Tracy to lands along the west side of the San Joaquin River from approximately Patterson all the way to Mendota in northern Fresno County. The Canal's planners recognized that Delta imports would add salts to Valley soils. For instance, the original 1939 Exchange Contract by which the Bureau of Reclamation and four key water rights holders in the Firebaugh and Mendota vicinity committed the Bureau to delivering imported water with salinity concentrations that were equivalent to the quality of the Sacramento River at the head of Snodgrass Slough in the Delta (a point on the river where in most years salt concentrations were below 200 parts per million in total dissolved solids, except in drought years; California Department of Public Works 1930: Table 233, Isleton Bridge salinity gage for 1924 through 1928). The 1939 Exchange Contract also required that total dissolved solids in fall, winter, and spring seasons was not to exceed 200 parts per million, and that total dissolved solids in imported water for the summer irrigation season was not to exceed 300 parts per million. (US Department of the Interior 1939: ¶7(e) "Substitute Waters", 4) The Exchange Contract was amended in 1956 and relaxed the salinity requirements for waters the Exchange Contractors would receive from the Bureau substantially as shown in Table A-1. These salinity requirements were continued in the 1968 second amendatory Exchange Contract, and remain in effect today. (US Department of Interior 1956: ¶17; US Department of Interior 1968: ¶9)

Table A-1
San Joaquin River Exchange Contract Water Quality Provisions

Contract Version	Total Dissolved Solids (parts per million)	Season/ Time Step
1939 Exchange Contract	200	Fall, winter, spring
	300	Summer
1956 Amendatory Exchange Contract	800	Daily maximum
	600	Monthly maximum
	450	Annual maximum
	400	5-year maximum
1968 Second Amendatory Exchange Contract	800	Daily maximum
	600	Monthly maximum
	450	Annual maximum
	400	5-year maximum

Sources: Central California Irrigation District 2011; US Bureau of Reclamation 2011; California Water Impact Network

Beyond the 1950s, there emerged serious drainage problems in the western San Joaquin Valley, as well as support for a regional or valley-wide salt disposal solution.

As additional political and economic pressure grew to expand irrigated agriculture further south along the Valley's west side toward the Tulare Lake Basin, a new set of water facilities called the San Luis Unit was planned. Its projects would consist of San Luis Reservoir, and San Luis Canal/ California Aqueduct, and associated pumping plants which would be jointly owned by the state and federal governments. South of Mendota, however, there is no consistent or direct path for drainage water to reach the ocean by gravity; these lands drain mainly to Tulare Lake. Only from Fresno Slough draining the Lake and the Kings River in high runoff years do excess surface water flows reach the Pacific Ocean.

Appendix A
Drainage, Salt, and Selenium in the San Joaquin Valley

In the 1950s, growers and government officials recognized that a drainage canal would be needed to rid the western and southern San Joaquin Valley of its salt-laden drainage return flows. State planning was undertaken for a San Joaquin Master Drain (see Figure A-1) as an "integral part of the State Water Project draining lands as far south as near Bakersfield, and which was authorized by California voters in 1960s through Proposition 1. A federally-owned drain, the San Luis Drain, would serve the lands of the San Luis Unit in western Fresno County and link with the state's master drain to convey salty and polluted drain water all the way to the western Delta where it would be discharged into either the Carquinez Strait or San Pablo Bay. Beginning in the late 1940s, farmers installed on-farm tile drains to relieve drainage from the root zones of their fields, and by the mid-1970s, the Bureau had installed about 120 miles of collector drains that connected to the San Luis Drain.

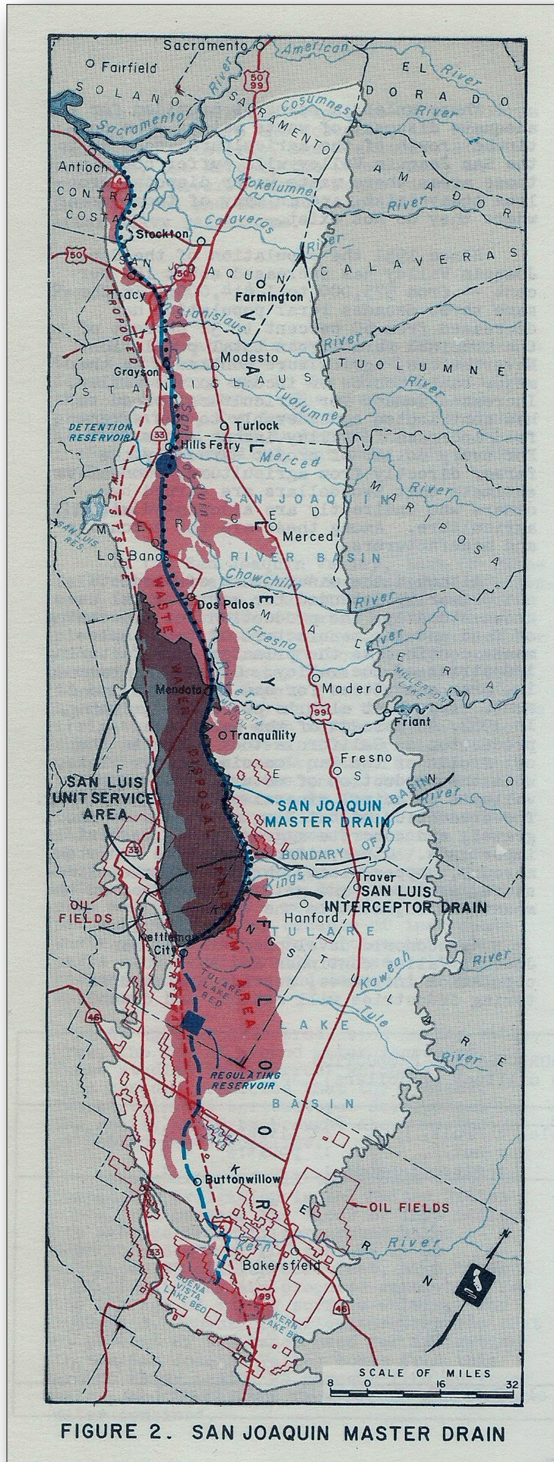

Figure A-1: Map of the San Joaquin Master Drain and the extent of drainage problem lands it was to serve. Source: California Department of Water Resources 1965.

However, in 1965 strong concerns from the San Francisco Bay Area and Delta regions about the quality and potential environmental effects of conveying agricultural drain water to the Delta and the Bay led Congress to make it national policy that "...the final point of discharge for the interceptor drain for the San Luis Unit shall not be determined until development by the Secretary of the Interior and the State of California of a plan which shall conform to the water quality standards of the State of California" and is approved by the Administrator of the US Environmental Protection Agency (US Bureau of Reclamation 1991: 6). Such joint approval has yet to occur.

The State of California withdrew from development of the San Joaquin Master Drain when the State failed to receive assurances in 1967 from irrigators in the State Water Project service area that they would repay the State's expenses for drainage service. Since 1968, the US Bureau of Reclamation, as required by the San Luis Unit authorization act in 1960, proceeded alone with construction of the San Luis Drain. Originally, this drain would have been 188 miles long from Kettleman City to the Delta, but only 85 miles were completed between Five Points and Gustine (US Bureau of Reclamation 1991: 5). In the mid-1970s, the Drain was connected to Kesterson Reservoir. This reservoir was a series of shallow ponds that was to store and evaporate drainage water until the rest of the Drain could be built to the Delta where drainage flows would be disposed of. During the 1981 to 1985 period that Westlands Water District discharged agricultural drain water to the San Luis Drain and Kesterson Reservoir, about 42,000 acres of Westlands service area were served by the Drain. After the contamination of wildlife was discovered in 1983, however, the State Water Resources Control Board issued a clean-up and abatement order for Kesterson reservoir against the Bureau of Reclamation (State Water Resources Control Board 1985) and the Department of the Interior closed Kesterson Reservoir in 1986. Upon closure, Westlands Water District lands that had received service from the Drain began storing irrigation drainage underground. Between 1986 and 1996, the San Luis Drain went unused until the growers in the Grassland area between Firebaugh and Gustine (in what is the northern portion of the San Luis Unit service area) contracted with the Bureau to use the San Luis Drain as part of a system through which their drainage would be routed around the wildlife refuges and wetlands of the Grassland region, a project called the Grassland Bypass Project (discussed in the chapter on Government Actions). For now, this section of the San Luis Drain empties effluent from the Grassland Bypass Project into Mud Slough (North) which drains into the San Joaquin River.

The cost of providing drainage facilities from these lands is high and and the difficulty of finding funding contributes to delays in providing some kind of drainage service there. A 2008 feasibility study of San Luis Drainage alternatives found that neither of the "in-valley" alternatives were economically justified nor financially feasible within existing authorizations by Congress. The cost of these alternatives was $2.24 to $2.69 billion at the time. The feasibility study had to rely on large contingency allowances to account for the cost of unproven reverse osmosis treatment plants for removing salts and selenium from drainage water. The lower cost alternative involves retiring more land (a total of about 200,000 acres) and more imported water from the San Luis Unit, while the higher cost alternative calls for greater use of reverse osmosis treatment of drainage water, as well as other treatment methods (but also including about 100,000 acres of land retired from applying imported water to crops).

Moreover, the feasibility study found that the three northern water districts can afford to pay neither the capital nor annual operating, maintenance, research, and engineering costs of both drainage service alternatives. Westlands Water District was found to be unable to pay a portion of the capital repayment obligation if either alternative is implemented. (US Bureau of Reclamation 2008: 95-96) The Bureau's preferred alternative is also the more expensive one that relies on greater use of reverse osmosis treatment and less land retirement. This means greater taxpayer subsidies would be needed to sustain San Luis Unit lands in privately controlled production. To address the contractors' inability to pay the Bureau's feasibility report recommends expansion by Congress of subsidies to the San Luis Unit through:

- Authorizing federal appropriations to pay the operating and maintenance charges needed to implement the preferred alternative *for which the northern water districts (Panoche, Pacheco, and San Luis Water Districts) are unable to pay*.
- Authorizing the Interior Secretary to *defer without interest each San Luis Unit contractor's obligation to repay all capital and operating and maintenance costs for the preferred alternative* "until the Secretary determines that such contractor has the independent ability to repay its share of such costs without unduly burdening its water users, provided such determinations are made at not more than 5-year intervals." (US Bureau of Reclamation 2008: 99; emphasis added)

The Bureau and Westlands Water District (the largest water district in need of drainage service in this region) have long had difficulty coming to terms on the District's long-term water service contract due in part to the cost of repaying the federal government for all federally-constructed drainage facilities (Kelley and Nye 1984: 6). According to Westlands, the District pays about $7.50 per acre-foot of water it receives for irrigation service and another $0.50 per acre-foot for drainage service. (United States Court of Federal Claims 2012: 12, 14)

Neither the Bureau nor Westlands Water District have adequately taken responsibility for the lack of drainage service to date for the San Luis Unit service area. Matters seem to be at a standstill on both sides. It has been five years since the Bureau adopted an alternative from its San Luis Drainage Feature Re-Evaluation process of the decade of the 2000s. The drainage problems of the Valley continue to mount.

State Board Inaction

The State Water Resources Control Board is also involved in this drainage fiasco for its inaction. While the Bureau of Reclamation's Central Valley Project operations are the primary cause of the salinity problems, the State Water Resources Control Board has so far been timid about trying to design and enforce regulatory solutions for this portion of the San Joaquin River Basin.

Historians Jackson and Paterson reported in 1977 that the California Department of Water Resources initiated the San Joaquin Valley Drainage Investigation in 1957 after legislative hearings on drainage and water quality issues associated with the 1957 California Water Plan. (Jackson and Paterson 1977: 136-139) The Burns Porter Act, authorized by the California voters in November 1960, contained language calling for the California Department of Water Resources to build "facilities for removal of drainage water from the San Joaquin Valley." (California Department of Water Resources 1974: Appendix B, 123)

C-WIN offers a chronology of the State Water Resources Control Board's treatment (and those of its predecessor agencies) of southern Delta salinity standards in Appendix C of this report. The Board's own 2006 Cease and Desist Order states regarding this period of State Water Rights Board regulation:

> During a twelve-year period the State Water Board adopted six difference decisions (Decisions 893, 990, 1020, 1250, 1308, and 1356) approving permits for various components of the federal CVP operated by USBR. The permits issued as a result of the decisions included a term by which the Water Board reserved jurisdiction to revisit salinity control requirements. (Decision 893, p. 71, Condition 12; Decision 990, p. 86, Condition 25; Decision 1020, p. 21, Condition 9; Order Extending Time in Which to Formulate Terms and Conditions Relative to Salinity Control Pursuant to Decision 990 and Decision 1020, p. 2; Decision 1250, p. 5, Condition 9; Decision 1308, p. 11-12, Condition 8; Decision 1356, p. 17, Condition 21.)[1]

Beginning with its Decision 893 in 1958, and extending through its Decision 1379 in 1971, the State Water Resources Control Board (and its predecessor the State Water Rights Board) declined to establish southern Delta salinity standards even though salinity data available to the 1980 South Delta Water Agency study of the San Joaquin River existed at that time. The State Water Boards of the past, however, preferred instead to reserve jurisdiction in the matter of salinity control (and fish protection in several decisions) to some unspecified future date.

In Water Rights Decision 1020 (which addressed water rights on Old River in the South Delta; State Water Rights Board 1961), adopted by the State Water Rights Board in 1961, the Board acknowledges a warning from the Delta Water Users' Association and the San Joaquin County Flood Control and Water Conservation District that water quality in the San Joaquin River was deteriorating, and had since 1950 (and presaging the water quality results identified in the joint SDWA/USWPRS 1980 study). These parties pointed out in 1961 that (in the words of D-1020):

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[1] These water rights decisions are all referenced in the bibliography to this report and are accessible online at http://www.waterboards.ca.gov/waterrights/board_decisions/adopted_orders/decisions/ where they may be searched by order or decision number.

> …the development of the San Luis Unit will further degrade water quality in the San Joaquin River and in the Delta. It is contended that return flow from the San Luis service area will contain high concentrations of salts and if added to those already found in the San Joaquin River northward from Mendota Pool, will adversely affect the water quality for diverters along the stream and in the Delta. At the same time, the parties [the Delta Water Users Association and the flood control district] point out that the construction of a master drainage system envisioned as one possible solution to the problem...will intercept all return flows for conveyance northward to San Francisco Bay, thereby reducing the flow of water in the lower San Joaquin River. (State Water Rights Board 1961: 15)

The Board took note in D-1020 of the 1960 Burns-Porter Act's proposed San Joaquin Valley drainage water facilities and dismissed the Delta and San Joaquin County water users' concerns by observing that reduced San Joaquin River flows from drainage return water being diverted to the "drainage facilities":

> will result in the interception of drainage water north of Mendota Pool rather than the interception of the drainage water from the San Luis Unit [north of the expected route of the San Luis Drain]. [citation] Therefore the contention that the construction of a master drainage system will reduce the quantity of water available in the lower San Joaquin River is clearly outside of the issues under consideration in connection with [D-1020]. (State Water Rights Board 1961: 15-16)

Six years later, California withdrew from the San Joaquin Valley master drain. The State Water Rights Board did reserve its continuing jurisdiction concerning salinity control in Term 9 of D-1020, but it would be another 17 years before south Delta salinity concerns would be addressed in the water quality objectives of the 1978 Water Quality Control Plan. The Board continued to reserve its jurisdiction on salinity control matters in water right decisions through 1970. (State Water Resources Control Board 2006: Figure 2, 8-9) It would be another 27 years before the State Water Board attempted to enforce them in D-1641.

This record of delay in establishing salinity control policy is compounded by a lack of accountability of regional boards to the State Water Board, again in the area of salinity control. The State Water Resources Control Board in WQ 85-1 (relating to selenium pollution of Kesterson National Wildlife Refuge in the early 1980s) directed the Central Valley Regional Water Quality Control Board to "initiate a process to develop specific water quality objectives for the San Joaquin River basin that will result in the adoption of appropriate basin plan amendments by the Regional Board and the development of a program to regulate agricultural drainage discharges." (State Water Resources Control Board 2000: 85; State Water Resources Control Board 1985: Conclusion 11, 63) The Board's order characterizes the drain water that accumulated at Kesterson Reservoir as meeting the definition of "hazardous waste" and that the Bureau had created a "public nuisance" there. (State Water Resources Control Board 1985: Conclusion 1, 61)

Unfortunately, in 1985 the State Board allowed the Central Valley Regional Board to consider using not just waste discharge requirements to regulate drainage discharges from irrigated lands, but also "waivers of discharge requirements in appropriate circumstances" which C-WIN and others believe has been used by the Central Valley Regional Board to excess in allowing heavily saline (and other problem constituents like selenium, discussed below) drainage discharges in the San Joaquin River basin to continue. The State Board in 1985 required no preparation of a plan for ending the degradation of San Joaquin River and west side tributaries' water quality by agricultural drainage flows, only monthly "progress reports."

In D-1641, adopted by the State Water Board in 2000, the Board recalled that it had directed the Central Valley Regional Board to "initiate a process to develop specific water quality objectives for the San Joaquin River basin that will result in the adoption of appropriate basin plan amendments by the Regional Board and the development of a program to regulate agricultural drainage." The Board also acknowledges in D-1641 that a long-term solution for drainage management in the San Joaquin River Basin remains to be developed.

Also in D-1641, the Board described salinity problems of the San Joaquin River system as having two principal causes: lack of sufficient diluting flows, and drainage discharges largely from western San Joaquin Valley agricultural irrigators. The Board continued:

> Although releases of dilution water could help meet the southern Delta objectives, regional management of drainage water is the preferred method of meeting the objectives. The Central Valley RWQCB is currently in the process of setting salinity objectives for the San Joaquin River. [cite] The Central Valley RWQCB is hereby directed promptly to develop and adopt salinity objectives and a program of implementation for the main stem of the San Joaquin River upstream of Vernalis. (State Water Resources Control Board 2000: 84)

The Board offers no explanation as to what "regional management of drainage water" means exactly, or why it is the preferred method. *Twenty-seven years after WQ 85-1, California still awaits this important basin plan amendment.* It is over twelve years since the State Water Board issued its directive in D-1641 to the Central Valley Regional Water Quality Control Board. The Central Valley Regional Board appears still to hold committee meetings to gather stakeholder input for the basin plan amendment. Meanwhile, the San Joaquin River continues delivering an average of 922,000 tons of salt to the southern Delta each year. (Central Valley Regional Water Quality Control Board 2006: 30) There are additional instances of inaction by the State Water Resources Control Board and its Central Valley Regional Water Quality Control Board on selenium issues detailed in the next section, and in Appendix C. We could find no schedule or work plan on the Regional Board's CV-SALTS website indicating when an effective basin plan amendment is to be accomplished by the Central Valley Regional Board and delivered to the State Water Resources Control Board for imminent consideration.

Rather, the State Water Resources Control Board in D-1641 gives support for a San Luis Drain without endorsing it overtly as its preferred method of regional drainage management. D-1641 reports that Central Valley Regional Board staff testified in support of extending the San Luis Drain to the Delta, and that Board's water quality control plan for the Central Valley Region "states that a valley-wide drain will be the only feasible long-term solution to drainage problem *[sic]*," concluding that "the drain has numerous benefits including the maintenance of productivity and the export of salts." (State Water Resources Control Board 2000: 85) The Board expressed dismay towards the Bureau that Public Law 86-488 "required assurance that the San Luis Drain would be constructed. In 1963 and 1967, the SJREC [the Exchange Contractors] filed suit against the US Bureau of Reclamation. The Bureau assured the judge that a drain would be constructed. Nevertheless, the USBR continues to delay making progress on an out-of-valley plan." (State Water Resources Control Board 2000: 86) However, a Bureau witness in the D-1641 evidentiary hearings testified that the Bureau has no specific plans to "improve quality of the river upstream of Vernalis." The Board in D-1641 then prods the Bureau:

> The USBR has been directed by the court to initiate activities to resolve the drainage problems in the San Joaquin Valley. It should proceed promptly to initiate such activities and file any necessary applications.

In its 2006 Water Quality Control Plan, the State Water Resources Control Board reported that among the "emerging issues" of the Bay-Delta Estuary was "Delta and Central Valley Salinity." The Board announced there was "broad stakeholder support" for a new Salinity Management Plan for the Central Valley and Delta to protect beneficial uses of both surface and ground waters. How this process is supposed to relate to the Department of Water Resources ongoing San Joaquin Valley Drainage Monitoring Program was not stated. The process, the Board reported,

> ***is expected to take 40 to 50 years*** and to reduce economic hardship related to managing salinity. The Board will develop regulations and provide regulatory encouragement to ensure that infrastructure is developed that improves and maintains Central Valley and Delta salinity while providing certainty to local and regional planners, municipalities, agriculture, water suppliers, food processors and others." (State Water Resources Control Board 2006: 6; emphasis added)

The 2006 Water Quality Control Plan makes clear that elevated salinity in the South Delta has many large and small sources, including low flows, salts imported to the San Joaquin River Basin in irrigation water, municipal discharges, subsurface accretions from groundwater, tidal action; local, state, and federal water diversions, channel capacity, and "discharges from land-derived salts, primarily from agricultural drainage." The Plan makes no attempt to assign portions to these various sources, but the shares associated with these sources were analyzed by the Department of Water Resources in 2006 and reported here in Tables 2 and 3 in the body of our testimony above. The vast majority of salt sources in the San Joaquin River originate from agricultural irrigation practices that flush salts from the soils, increase surface and subsurface return flow to the River, and raise the elevation and hydraulic head of groundwater tainted with salts. The Plan itemizes a number of methods for addressing salinity problems of the River and the South Delta, but enforcement actions are not contemplated. Its recommended projects, studies and actions omit enforcement, but include a committee to "address salinity issues" through a committee-designated "task force" that will "conduct meetings" to "gather public input" and produce an economic study that will "highlight the major salinity-related issues and their statewide impacts. (State Water Resources Control Board 2006: 32; Howitt et al 2009)

To implement South Delta salinity objectives, the Board's actions focus on

> the need for an updated independent scientific investigation of irrigation salinity needs in the southern Delta….The scientific investigation should address whether the agricultural beneficial uses in the southern Delta would be reasonably protected at different salinity levels, whether management practices are available that would allow for protection of the beneficial uses at a higher salinity level in the channels of the southern Delta, and whether such management practices are technically and financial feasible. The investigation could address the feasibility of providing an alternative method of delivering fresh water to agricultural water users in the southern Delta. The scientific investigation must be specific to the southern Delta. (State Water Resources Control Board 2006: 32; Hoffman 2010)

In the same plan, the Board continues its implicit support for completing the San Luis Drain, stating almost in passing that "The salinity objectives at Vernalis can be attained by releasing dilution water from New Melones [Reservoir on the Stanislaus River] and other sources, *completing a drain to remove the salts generated by agricultural drainage and municipal discharges from the San Joaquin Valley*, and conducting measures in the San Joaquin Valley such as...state regulatory actions, state funding of projects and studies, regulation of water diversions, pollutant discharge controls, improvements in water circulation, and long-term implementation of best management practices to control saline discharges." (State Water Resources Control Board 2006: 28)

Planning for More Delay

The State Water Resources Control Board wrote a Strategic Work Plan for the Delta Estuary in 2008 that laid out five year work plans Delta and San Joaquin Valley related programs, "characterizing discharges from Delta islands," and south Delta salinity. These Work Plan elements are a road map for further delay addressing salinity issues that entwine the fates of the San Joaquin River Basin and the Bay-Delta Estuary. (California Water Impact Network et al 2008; California Sportfishing Protection Alliance et al 2010)

The Irrigated Lands Regulatory Program is perhaps the single most graphic example of the failure of the State and Central Valley Boards to protect water quality in the San Joaquin River and Delta. Monitoring data collected by the Central Valley Regional Water Quality Control Board, UC Davis and agricultural coalitions, among others, established that discharges from irrigated lands represent the largest source of toxic and other pollutants to Central Valley waters. In 2006, the Central Valley Board released a landmark draft report presenting the first region-wide assessment of data collected pursuant to the Irrigated Lands Program since its inception in 2003. Data collected from some 313 sites throughout the Central Valley reveals that: 1) toxicity to aquatic life was present at 63 percent of the monitored sites (50 percent were toxic to more than one species); 2) pesticide water quality standards were exceeded at 54 percent of sites (many for multiple pesticides); 3) one or more metals violated criteria at 66 percent of the sites; 4) human health standards for bacteria were violated at 87 percent of monitored sites and 5) more than 80 percent of the locations reported exceedances for general parameters (dissolved oxygen, pH, salt and TSS). While the adequacy of monitoring varied dramatically from site to site, the report presents a dramatic panorama of the epidemic of pollution caused by the uncontrolled discharge of agricultural wastes.

Since conditional waivers were originally adopted in 1982, and subsequently in 2003 and 2006, the Central Valley Regional Board has been unable to identify a single improvement in water quality or, indeed, a single pound reduction in the mass loading of agricultural pollutants that has been achieved by the Program (other than a reduction in application of organophosphate pesticides as farmers switched to more potent and less expensive pyrethroids). Under the agricultural waivers, the Central Valley Board does not know who the major polluters in the Central Valley are because it has required no farm-level water quality management plans, preferring instead to organize and rely on a regional monitoring approach. The Board has misinterpreted the state's "Statement of Policy with Respect to Maintaining High Waters in California" which provides that

> Any activity which produces or may produce a waste or increased volume or concentration of waste and which discharges or proposes to discharge to existing high quality waters will be required to meet waste discharge requirements which will result in *the best practicable treatment or control of the discharge necessary to assure that (a) a pollution or nuisance will not occur and (b) the highest water quality consistent with maximum benefit to the people of the State will be maintained.* (State Water Resources Control Board, 1968; emphasis added)

To comply with this policy, the Central Valley Regional Board must require the discharger to demonstrate that their manner of compliance is the best practicable treatment and control for the discharge. Not one irrigated lands discharger has complied with the State Board's resolution. Because it requires no farm water quality management plans, the Regional Board is entirely in the dark regarding what, if any, measures have been implemented let alone whether they amount to the best practicable treatment and control methods. (California Sportfishing Protection Alliance 2010)

The same problem with the Board's Irrigated Lands Regulatory Program clouds the prospects for its planned effort to "characterize discharges from Delta islands" called for in the Strategic Work Plan. The discharge of some 430,000 acre-feet of return flow from approximately 680,000 acres of Delta farmland clearly presents a serious problem. "Characterization" of the pollutants in these discharges is fundamental to any serious effort to protect Delta water quality. However, the State Board's proposal is a searing indictment of both the Central Valley Regional Board and the Irrigated Lands Regulatory Program. *Had requirements to submit Reports of Waste Discharge not been waived for agricultural dischargers, outflow from Delta islands would have been "characterized" years ago.* Similarly, had the State Board insisted that agricultural dischargers, coalitions, and water districts comply with the same monitoring requirements it routinely demands from virtually every other segment of societey (that is, cities, industries, and businesses), then discharges would have already been "characterized" by now. Indeed, had the Board complied with its regulatory responsibility to protect the water quality of Delta and San Joaquin River water ways, the receiving waters would have also been fully "characterized" by now. While the State Board seems focused on agricultural discharges in the Delta, it inexplicably ignores the agricultural discharges from millions of acres of farmland along water ways upstream of the Delta. Targeting Delta farmers while ignoring those who discharge upstream is simply hypocritical. The State Board should direct the Central Valley Board to immediately issue California Water Code Section 13267 letters requiring all agricultural dischargers to "characterize" their discharges. The time is long past due.

This critique of the State and Central Valley Regional Boards records a consistent pattern of delay and inaction that favors process and voluntary compliance over results. Both methods have been ineffective if not actively harmful to the San Joaquin River Basin and the Bay-Delta Estuary. As the State Water Resources Control Board is well aware, the Bureau and the Department have great difficulty achieving compliance with salinity standards at interior South Delta compliance stations. We see in the State Board's proposal to relax interior South Delta salinity objectives an implicit admission that all other State and Regional Board activity to control and reduce salinity has been an abject failure and that the only option left is for the State Board to "move the goalposts" or "lower the bar" in order to help the Bureau and the Department to get over a lower regulatory hurdle. Before adopting this change, however, the Board must justify this proposed relaxation in light of the Board's longstanding antidegradation policy. This policy is required under the federal Clean Water Act. Our organizations do not believe that the proposed relaxation of South Delta salinity objectives is consistent with Board antidegradation policy and with the requirements of the federal Clean Water Act.

These proposed revisions to South Delta salinity objectives will not solve South Delta water quality problems. Null zones (areas where net stream flow in channels stagnates and residence times are lengthy) occur near each of the interior compliance points. Positive (net downstream) flows over time and during key seasonal periods are needed to improve water quality conditions in these zones. Temporary barriers (and proposed permanent operable gates) impede such flows, as do exports from the Banks and Jones pumping plants. In the absence of sufficient net downstream flows, reverse flows occur and interior South Delta water levels fall to where Delta irrigators cannot divert their flows.

A key mitigation for the Board to consider in the Bay-Delta Water Quality Control Plan is reduction or cessation of Delta pumped exports to allow instream flows to facilitate fish migration and turbid open water conditions needed by Delta smelt. The State Water Resources Control Board must determine through the Plan whether and how operational and flow options would create internal Delta hydrodynamics that more closely mimic natural flow conditions that benefit fish and reduce residence times, exposure to toxic stressors, and predation while in transit.

The Bureau's chronic salinity objective violations result from its continued adherence to the terms of the Exchange Contract and its failure to use any method of source control in order to comply with the D-1641 condition to reduce salinity discharges at Vernalis and in the South Delta. In 2006, the Board imposed a cease and desist order, but the Board then relaxed the order in 2010. It now offers in the April 2011 Notice of Preparation proposed language that would permanently relax the interior South Delta salinity objectives themselves. The proposed new, relaxed interior South ?Delta objectives are a sorry perpetuation of the Board's backpedaling and delay.

The proposal to relax salinity standards appears to be based upon a January 2010 report (Hoffman 2010) about *Salt Tolerance of Crops in the Southern Sacramento-San Joaquin Delta*. The report was not peer reviewed. Repeated State Water Resources Control Board orders directing the Central Valley Regional Water Quality Control Board to develop and implement upstream salinity objectives have been ignored for many years. Had the State Board not condoned the Regional Board's continued inaction on regional salinity and drainage management, meaningful source controls for the massive salt loading from West Side sources would likely now be in place. Proposing to relax long-existing standards by using seriously inadequate and flawed data while continuing to ignore and excuse the primary source of salt loading is inexcusable.

Selenium Regulation, Unproven Technology

Grassland Bypass Project

The Grasslands Bypass Project was started in 1996 as a means of preventing discharge of selenium-contaminated subsurface agricultural drainage water into wildlife refuges and wetlands in the Grasslands Basin, tributary to the San Joaquin River. The Grassland Bypass Project is operated by the Bureau of Reclamation and the San Luis & Delta-Mendota Water Authority. The drainage water is "bypassed" around the refuges, wetlands and Salt Slough, and is conveyed into a segment of the San Luis Drain where it discharges to Mud Slough (north), a tributary of the San Joaquin River a few miles from the former Kesterson evaporation ponds. (See Figures A-2 and A-3.)

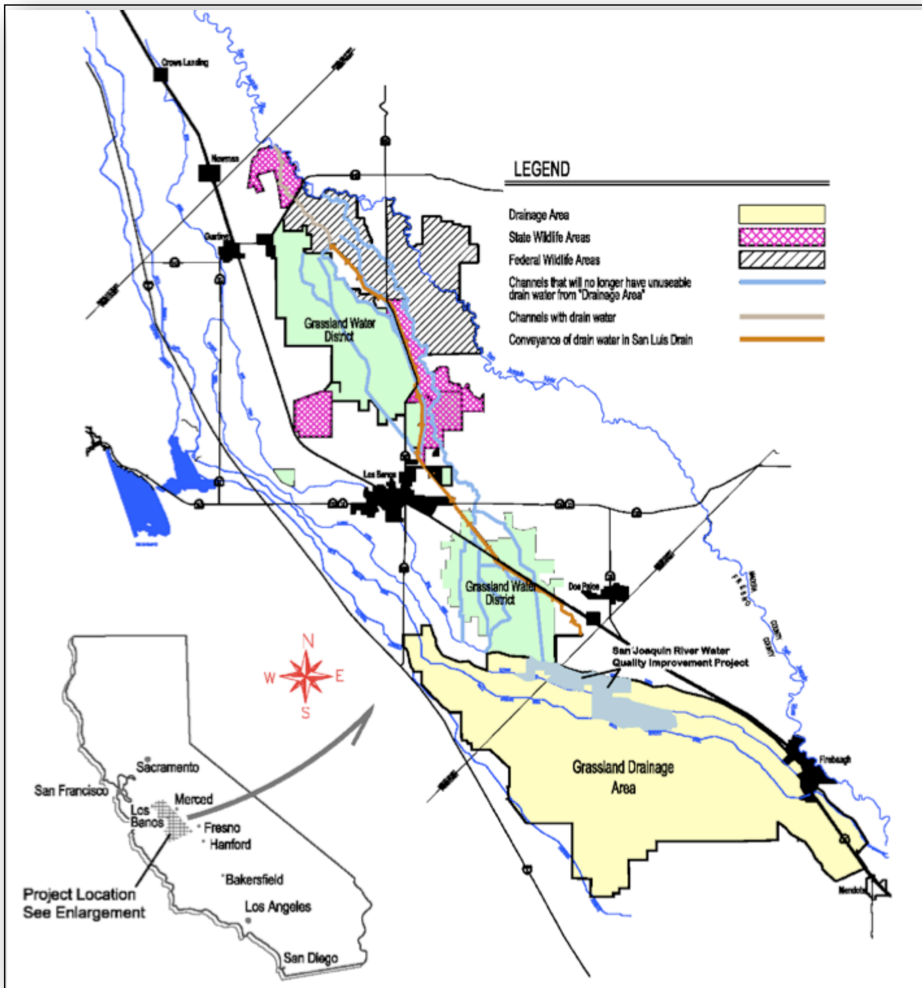

Figure A-2: Location of the Grassland Bypass Project. Source: San Luis Delta-Mendota Water Authority and US Bureau of Reclamation 2009.

The Grasslands Drainage Area is primarily in the northerly area of the San Luis Unit, but also includes lands within the Delta Mendota Canals Unit of the CVP as well as a portion of the San Joaquin River Exchange Contractors. Figure A-2 shows the geographic location of the Grassland Drainage Area in relation to the service areas of the local water providers.

> The GDA is located on the western side of the San Joaquin River roughly between Los Banos to the north and Mendota to the south. The GDA consists of Charleston Drainage District,

Pacheco Water District, Panoche Drainage District, a portion of the Central California Irrigation District (CCID) known as Camp 13 drainage area, Firebaugh Canal Water District, Broadview Water District (acquired by Westlands Water District following retirement from irrigation), and Widren Water District.
The In- Valley drainage reuse area, called the San Joaquin River Water Quality Improvement Project (SJRIP), is owned and operated by Panoche Drainage District. (US Bureau of Reclamation and San Luis Delta-Mendota Water Authority 2009)

The principal features of the Grassland Bypass Project are drainage collection and drainage reduction. A portion of the federally owned San Luis Drain is the conveyance structure to discharge the drainage to areas outside of the Grassland Bypass Project service area at Mud Slough (north; see Figure A-3). Grassland Bypass Project proponents claim that the reductions in drainage volume, selenium, salt and boron are a direct result of source control (lining ditches, reducing seepage, irrigation system improvements, etc.), groundwater management, dust control using drainage water, and reuse at the San Joaquin River Improvement Project. Land retirement must also play a role (see below)

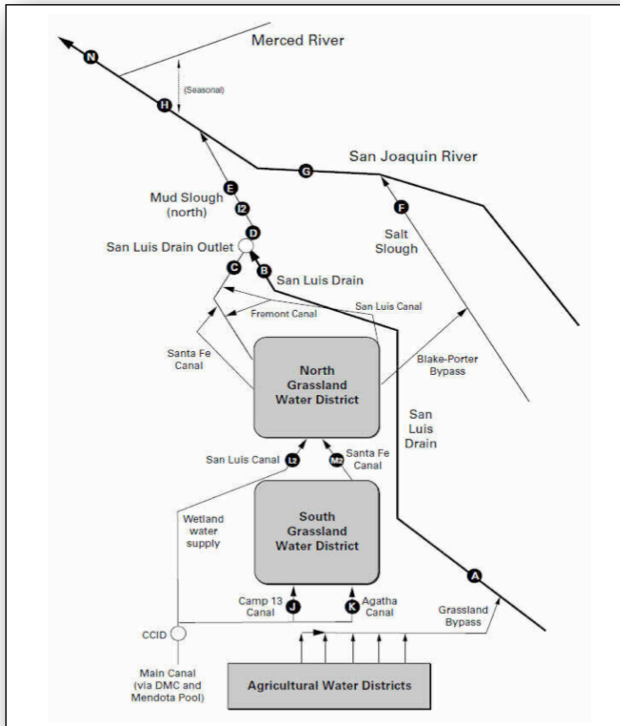

Figure A-3: Schematic Map of the Grassland Bypass Project. Source: US Bureau of Reclamation.

The Grassland Bypass Project is facilitated by a Use Agreement signed by Reclamation and the San Luis Delta Mendota Water Authority on behalf of the Grassland Drainers to establish conditions for use of a portion of the San Luis Drain to discharge selenium and other pollutants from the Grassland Drainage Area. The first Use Agreement was signed in 1996 and was renewed and amended in 2009. The Use Agreement includes monitoring provisions, penalties for selenium discharges in excess of Waste Discharge Requirements and limitations on the volume of drainage water that can be conveyed in the San Luis Drain.

While the Grassland Bypass Project has improved water quality in Salt Slough, the wildlife refuges and wetlands, the Project discharges pollutants directly into Mud Slough and the San Joaquin River, thereby increasing pollution there. It has sustained the productivity of 97,000 acres of irrigated acres, mostly in the northerly area of the San Luis Unit at the expense of water quality in Mud Slough and the San Joaquin River. The Grassland drainers do not have the same problems with high salty groundwater that the Westlands irrigators have because they are able to export their salty drainage water via Mud Slough and the San Joaquin River. The Grassland Bypass Project is the de facto San Luis Drain, emptying pollution into Mud Slough and the San Joaquin River. Salt, selenium and boron are the major sources of pollution from the Grassland Bypass Project, but nutrients and other pollutants are also discharged. Excessive nutrients from Mud and Salt Sloughs have been linked to dissolved oxygen water quality problems in the San Joaquin River deepwater ship channel. (Lee and Jones-Lee 2003)

The selenium control program described in the Central Valley Regional Water Quality Control Plan for the Sacramento River and San Joaquin River Basins (Basin Plan) includes a prohibition of discharge of agricultural subsurface agricultural drainage unless the discharge is regulated by Waste Discharge Requirements or water quality objectives for selenium are met. Selenium water quality objectives are 5 μg/L (4 day mean) for the San Joaquin River and 2 μg/L (4 day mean) for Salt Slough and wetland water supply channels identified in the Basin Plan. The Basin Plan amendment in 1996 included a compliance time schedule establishing October 1, 2010, as the effective date of the prohibition of discharges for Mud Slough (north) and the San Joaquin River above the mouth of the Merced River. Waste Discharge Requirements (California Regional Water Quality Control Board, 2001a) were issued by the Central Valley Regional Board allowing selenium discharges in excess of the Basin Plan selenium objective and larger than the allowable monthly and annual selenium loads at Vernalis contained in the San Joaquin River TMDL (California Regional Water Quality Control Board 2001b) until October 1, 2010. The Waste Discharge Requirements includes monthly monitoring for molybdenum and nutrients (nitrate, ammonia, total Kjedahl nitrogen, total phosphate, and ortho-phosphate) as well as weekly analyses of salinity, selenium, boron, and other parameters, and chronic toxicity testing. The Waste Discharge Requirements also outline a program to monitor storm water releases from the Grassland Drainage Area into the Grassland wetland supply channels should they occur.

State Board Also Delays Selenium Protections

The 1996 Grassland Bypass Project Basin Plan Amendment and waste discharge requirements were originally approved by the Central Valley Regional Board to establish an end to seleniferous discharges into Mud Slough North by October 1, 2010. The intent was to have zero selenium discharges by that time as a result of treatment through source control and reuse, with reverse osmosis and biotreatment for the remaining volume of drainage. However, by 2007 it became apparent that there was no "Best Practicable Treatment and Control" option to treat the selenium pollution, so the Grassland Drainers and Reclamation requested and received a time extension in 2010 from the Central Valley Regional Water Quality Control Board and the State Water Resources Control Board to delay implementation of selenium water quality objectives in the San Joaquin River and Mud Slough North until December 31, 2019. An unenforceable "performance goal" of 15 μg/L monthly mean has been established for December 31, 2015 by the CVRWQCB. (California Regional Water Quality Control Board 2010) The U.S. Environmental Protection Agency declined to approve or disapprove of the Basin Plan Amendment, claiming that it was not subject to federal jurisdiction. (Strauss 2011)

The two main reasons given for the delay are the lack of effective drainage treatment options and lack of funding. Reclamation and the San Luis Delta Mendota Water Authority had originally anticipated that effective drainage treatment technology could be identified prior to 2010, but it did not occur. Several technologies were tested but results have not been positive, with no clear Best Practicable Treatment and Control option identified. Prior to full-scale implementation, treatment technology must still be tested and validated. Over $100 million in state, federal and private monies have been spent on the Grassland Bypass Project. (Water Education Foundation n.d.) The Grassland Drainers were spending a $25 million grant award when the State Department of Finance issued Budget Letter 08-33 stopping payment of awarded grant funds and forcing the Grassland Drainers to stop work. The "halt work" order came when the project had completed a series of local source control projects and the SJRIP drainage reuse area had been constructed, but before treatment technology could be identified, constructed, tested and used.

The rationale for the Central Valley Regional Board's action to extend the compliance date for the 5 μg/L (4 day mean) selenium water quality objective can be summed up in the following paragraphs from its Resolution R5-2010-0046 approving the Basin Plan amendment:

> 8. In a 13 December 2006 letter to the US Bureau of Reclamation, the GAF [Grassland Area

> Farmers] informed the Bureau and Central Valley Water Board staff that the GBP [Grassland Bypass Project] would be unable to eliminate all surface water discharges of agricultural subsurface drainage by 30 October 2010 without increased risks of loss of soil productivity; accelerated loss of beneficial use of groundwater due to salinization; a significant decrease in farm profitability stemming from a rising water table if irrigation continues; or low or no returns if fields are dryland farmed or fallowed. Rising groundwater would also increase groundwater seepage to surface water channels and open ditches, potentially increasing selenium in channels now protected by the monitoring and management of the regional drainage program. Continued farm productivity and profitability is necessary to fund ongoing regional drainage management in this area; and continued wildlife protection is consistent with state, federal, local and GBP priorities.
>
> 9. The GBP [Grassland Bypass Project] operators anticipate that the project area will be able to achieve full control of agricultural subsurface drainage if an additional nine years, three months beyond the existing compliance date is granted." (California Regional Water Quality Control Board 2010a, 2010b)

The Central Valley Regional Board Final Staff Report for the Basin Plan Amendment also justified the requested delay as follows:

> The compliance time schedule currently in the Basin Plan includes compliance dates prior to 2010 for other channels and other reaches of the River. The Grassland Area Farmers (GAF), the subset of local agencies within the Authority participating in the GBP, have met the interim milestones of the selenium control program, complying with the prohibition of discharge or meeting the selenium objective in the channels where these requirements are now in effect (see Figures 3, 4 and 6 in Section 1 of this report). Given this history, it is reasonable to expect that if the Board approves the requested time extension by adopting the proposed amendment, the GAF will develop full drainage management capacity in the project area. In this context, "full drainage management capacity" means that, consistent with the Grassland Bypass Project's dual goals of water quality and environmental protection and maintaining the viability of farming in the area, the dischargers are able to control all agricultural subsurface drainage generated in the drainage area without discharge. The Grassland Area Farmers expect to achieve this by further development of the source control measures and drainage reuse strategies in current use and by treating drainage to remove selenium and/or salt. Expanded source control and reuse alone could potentially increase the Project's drainage management capacity sufficiently to achieve water quality and environmental goals, but at a cost. If the Board adopts the proposed amendments, dischargers will need to weigh those costs and determine whether drainage treatment is truly feasible for this area; and report their decision to the Board in 2013."

Currently, the Bureau of Reclamation is funding a selenium demonstration treatment plant in the Panoche Drainage District. The project, estimated to cost $37 million (United States District Court, Eastern District 2011), will treat 200 gallons per minute constantly for 18 months (470 AF). At that treatment rate, the cost of treating agricultural drainage only for selenium (excluding salt and boron treatment) is $78,723 per acre-foot, not counting transportation and disposal of the processed solid waste to a hazardous waste facility. Even at that cost, the potential for economic feasibility is at best low. A 2010 Report by CH2M Hill for the North American Metals Council determined the following:

> While these physical, chemical and biological treatment technologies have the potential to remove selenium, there are very few technologies that have successfully and/or consistently removed selenium in water to less than 5 µg/L at any scale. There are still fewer technologies that have been demonstrated at full-scale to remove selenium to less than 5 µg/L, or have been in full-scale operation for sufficient time to determine the long-term feasibility of the selenium removal technology. There are no technologies that have been

> demonstrated at full-scale to cost-effectively remove selenium to less than 5 µg/L for waters associated with every one of the industry sectors." (CH2M Hill 2010)

The Grassland Bypass Project has resulted in a reduction of the volume of drainage water and pollutants as follows for Water Years 1997 through 2010:

- Discharge volume (Acre-Feet) reduced by 64% (39,856 AF to 14,529 AF)
- Selenium load reduced by 77% (7,096 lbs. to 1,601 lbs.)
- Salt load reduced by 61% (172,608 tons to 67,661 tons)
- Boron load reduced by 58% (753,000 lbs. to 315,000 lbs.) (McGahan 2010)

These improvements are achieved at enormous cost relative to the economic activity it is intended to support: agriculture. The U.S. Geological Survey, in its 2008 "Technical Analysis of In-Valley Drainage Management Strategies for the Western San Joaquin Valley, California" stated in regard to the possibilities for treatment of drainage water that:

> The treatment sequence of reuse, reverse osmosis, selenium bio-treatment, and enhanced solar evaporation is unprecedented and untested at the scale needed to meet plan requirements." (Presser and Schwarzbach 2008)

Land Retirement

While drainage reduction through source control and reuse have likely led to reductions in salt, selenium and boron discharges into Mud Slough, the role of land retirement has not been adequately analyzed to determine its role in reducing the amount of pollution discharged by the Grassland Bypass Project. Land retirement policies are currently voluntary. (US Bureau of Reclamation 2005, 2006)

The 2004 Draft Environmental Assessment on Broadview Water Contract Assignment Project identified significant reductions in the volume of drainage water, salt, selenium and boron from the retirement from irrigation of 10,000 acres in the Broadview Water District, as shown in Table A-2. (Environmental Sciences Associates 2004, 4-2)

Table A-2
Drainage and Water Quality Effects of Land Retirement in the Broadview Water District Along West Side of San Joaquin River

Broadview Water District Water Quality Indicators	Existing Conditions	Under Proposed Action Conditions	Estimated Reduction Attributable to Proposed Action
Drainage to San Joaquin River	3,700	1,100	2,600
Estimated Salt Production (tons/year)	24,300	7,300	17,000
Estimated Selenium Production (pounds per year)	2,140	640	1,500
Estimated Boron Production (pounds per year)	74,000	22,000	52,000

Source: Environmental Sciences Associates 2004; California Water Impact Network.

The Northerly subarea of Westlands Water District, which drains subsurface flows to the Grassland area, has also had substantial land fallowing/retirement due to shallow salty groundwater within the root zone. (California Water Research Associates 2011) So much land has been retired in the Northerly subarea of Westlands that Westlands does not believe it is cost effective to install drainage service for the remaining acreage. (United States Court of Federal Claims 2012) It is unknown how much total land has been retired in Westlands' Northerly subarea, but it is likely to be at least 40,000 acres. (Water Education Foundation, n.d.) Based on the estimates from the Broadview Contract Assignment Project Draft Environmental Assessment, extrapolation of potential drainage, salt, selenium and boron savings from the retirement of an estimated 40,000 acres in the northerly area of Westlands and the 10,000 acres in Broadview could result in the following reduction in discharges:

Drainage to San Joaquin River (AF)	13,000
Salt (tons)	85,000
Selenium (lbs.)	7,500
Boron (lbs.)	260,000

The above sample estimated numbers could represent a significant percentage of the total reduction in drainage volume, salt, selenium and boron from inception of the Grassland Bypass Project in 1996 through 2010 and do not count other retired lands such as Widren, Eagle Field and Mercy Springs water districts, and may not include all of the retired lands within Westlands' northerly subarea. Most of the reduction in drainage, salt, selenium and boron discharged from the Grassland Bypass Project would come from retirement of irrigation from lands with drainage problems and reductions in water deliveries due to drought. Other measures may be given unwarranted credit for the savings. However, there has not been a definitive study on the issue to determine the specific reason for reductions in pollution.

As of early 2012, significant new grants and subsidies have been awarded to the Grassland Drainers through the Panoche Drainage District. The Selenium Demonstration Treatment Facility at Panoche is estimated to cost $37 million, averaging over $78,000 per acre-foot of treated drainage water. In September 2011, the Pacheco Water District was awarded a $262,000 CALFED water efficiency grant to line three miles of open channel (US Bureau of Reclamation 2011) in order to reduce seepage and creation of drainage water. The lowest annual volume of drainage water discharged into Mud Slough from the Grassland Bypass Project was 13,166 acre-feet in Water Year 2009. As recently as Water Year 2005, drainage volume was 29,957 AF. (McGahan 2010) The efficacy of the proposed treatment methodology has yet to be proven, as noted above.

The Bureau of Reclamation's National Economic Development feasibility analysis found that land retirement is the most cost effective solution to resolve problems associated with irrigation of these toxic soils. (US Bureau of Reclamation 2008) The Bureau's Land Retirement Demonstration Project has shown significant and immediate success in lowering contaminated groundwater levels and selenium exposure from land retirement. Presser and Schwarzbach of the US Geological Survey found that:

> When lands are retired, there is an overall reduction in water applied to a district. In general, less water applied as irrigation means less drainage produced, which in turn means less drainage requiring treatment and storage. (Presser and Schwarzbach 2008: 9)

Ceasing imported water deliveries from the Delta to these toxic lands need not preclude agriculture. The lands could return to dry farming (where growers rely on rainfall for their crops, as occurred in this area prior to the arrival of surface water supplies in the 1960s and 1970s). The west side of the San Joaquin Valley sees rainfall of between 5 and 10 inches a year. Before completion of the California Aqueduct in 1967, groundwater was the primary source of irrigation water in the area. This dependence led to land subsidence of an average of one foot across the whole region, but as much as 29 feet in some localized areas. But presently, imported supplies have shifted the groundwater budget from one of overdraft to one of surplus. Groundwater elevations in the area of

Panoche and Cantua creeks in the western San Joaquin Valley rose 100 to 200 feet between 1967 and 1984. Belitz and Phillips state that this rise in the water table "represents a recovery of nearly one half the total drawdown that had occurred" prior to development of imported water supplies. (Belitz and Phillips 1995: 1847)

The lands may also be used for other purposes compatible with adjacent land uses such as solar "farms." Solar farms would provide much needed sustainable electricity to complement the hydropower generation from the east side's dams on the San Joaquin River and its tributaries.

Land retirement already occurs here. Since the 1990s, Westlands Water District (the largest water district in California's Central Valley) has purchased outright about 100,000 acres of drainage problem lands within its limits. However, the land retirement alternative appears to have plateaued in deference to continued delivery of imported subsidized water.

Researchers have not undertaken yet to model the potential impacts of climate change for the forecasting and handling of toxic contaminants like selenium in the state's water quality regulation and policy frameworks. C-WIN urges the State Water Resources Control Board to seek such research as soon as possible. Presser and Schwarzbach have laid out the two principal scenarios, however, which state and federal regulators, and the communities of the San Joaquin Valley will increasingly have to confront:

> The draining of accumulated reservoirs of salt and selenium stored in the soils and aquifers of the valley to surface impoundment [i.e., to some form of surface storage such as evaporation ponds and other treatment processes] may have large-scale implications for the future of the valley in terms of tradeoffs of contaminated groundwater aquifers (i.e., life of the aquifer for irrigation and drinking water use) for contaminated land-surfaces (i.e., creation of salt waste dumps and landfills for designated bio-treatment waste). (Presser and Schwarzbach 2008: 14)

There is hazardous agricultural drainage water collecting in aquifers year after year in the western San Joaquin Valley. There is already a significant unaddressed backlog of seleniferous hazards waiting to be addressed. C-WIN believes that California's water regulators should act now to stop creation of yet more hazardous wastewater by retiring lands from irrigation with imported surface supplies in areas known to contain high selenium concentrations, under the prohibition on waste and unreasonable use of water in the California Constitution, Article X, Section 2.

San Luis Drainage Feature Re-Evaluation

As a result of years of litigation regarding drainage issues and a Ninth Circuit Court of Appeals decision on the responsibility of Reclamation to provide drainage service to Westlands and other San Luis Unit contractors, Reclamation issued a final Environmental Impact Statement and Record of Decision (ROD) for the San Luis Drainage Feature Re-Evaluation. The Final Environmental Impact Statement was issued in 2006, with the Record of Decision issued in 2007. (US Bureau of Reclamation 2005, 2006)

While the environmentally preferred alternative in the San Luis Drainage Feature Re-Evaluation Environmental Impact Statement was the "In Valley/Drainage Impaired Land Retirement" alternative which would have retired all 298,000 acres of drainage impaired lands in Westlands, Reclamation selected the "In-Valley Water Needs Land Retirement" alternative to retire just 194,000 acres of impaired lands, which also includes existing land that is retired.

The San Luis Drainage Feature Re-Evaluation Record of Decision called for a combination of land retirement, reuse, reverse osmosis, biotreatment and evaporation ponds to reduce the formation of drainage and to treat drainage that remains. It includes continuation of the Grassland Bypass Project, with little or no additional land retirement in that area. The U.S. Fish and Wildlife Service recommended that Reclamation consider an alternative retiring all of the 379,000 acres of drainage impaired lands in the San Luis Unit (including the Grassland area), but Reclamation did not consider retirement of the portion of the San Luis Unit within Grassland Drainage Area. (US Bureau of Reclamation 2005: Appendix M)

The National Economic Development Act (NED) analysis for the San Luis Drainage Feature Re-Evaluation Environmental Impact Statement showed that the "In Valley/Drainage Impaired Land Retirement" alternative was the most cost effective, with a $5 million/year benefit. However, Reclamation requested and received a waiver of the National Economic Development Act requirement to adopt the most cost effective alternative and instead adopted the "In-Valley Water Needs Land Retirement" alternative, which would lose approximately $10 million/year. (US Bureau of Reclamation 2005: Appendix N, Cost-Benefit Analysis, Table N-10, p. N-17)

The Environmental Working Group report, "Throwing Good Money at Bad Land" estimated that crop subsidies provided to the drainage impaired lands in the San Luis Unit are approximately $10 million per year. (Environmental Working Group 2011) Environmental Working Group estimated that adding the crop subsidies to the drainage subsidies for San Luis Drainage Feature Re-Evaluation would result in a $20 million loss to the taxpayers, and concluded that land retirement would be the most cost effective solution to resolving drainage problems.

As of early 2012, resolution of drainage issues within the San Luis Unit remains problematic. The ceiling of appropriations for the San Luis Unit is lower than the projected cost of a drainage collection and treatment system for all drainage impaired lands, and Reclamation has identified and recommended increases in federal subsidies will be necessary to allow the project to proceed. (US Bureau of Reclamation 2008) Westlands Water District filed a lawsuit in the federal claims court in January 2012 asking for damages from Reclamation's lack of progress in providing drainage service. (Unites States Federal Court of Claims 2012)

Presser and Schwarzbach (2008) recommended a "Decision Analysis" process to resolve San Luis Drainage problems, but to date no action has been taken to initiate such a process. They also recommended as much land retirement as possible, noting, "Land retirement is a key strategy to reduce drainage because it can effectively reduce drainage to zero if all drainage-impaired lands are retired." (Presser and Schwarzbach 2008) However, despite land retirement recommendations from them and the Bureau's San Luis Drainage Feature Re-Evaluation ROD's inclusion of 194,000 acres of retired land, there has been no additional land retirement within the San Luis Unit since 2007 (Lee 2012).

Presser and Schwarzbach (2008) identified several problems for implementation of the San Luis Drainage Feature Re-Evaluation Record of Decision as follows:

- "Regardless of what drainage plan is implemented, the amount of salt in groundwater will increase. Based on projections of future total dissolved solids in groundwater of the Westland and Northerly Areas, the useable life of the aquifer under various irrigation and drainage management goals is estimated to be between 25 and 220 years." (Presser and Schwarzbach 2008: 2)

- They recommend a "program that substitutes groundwater pumping for surface water delivery, thus helping to shift the groundwater budget from large surplus to small deficit and to stem any expansion of the drainage problem through time with continued irrigation." (Presser and Schwarzbach 2008: 3)

- A Decision Analysis process would allow objective and scientific analysis of different treatment options, but it would require stakeholder participation. (Presser and Schwarzbach 2008: 3)

- "A drainage alternative that exports wastewaters outside of the valley may slow the degradation of valley resources, but drainage alone cannot alleviate the selenium build-up in the valley, at least within a century, even if influx of selenium from the Coast Ranges could be curtailed." (Presser and Schwarzbach 2008: 6)

- "If the goal is to create a sustainable integrated production/habitat system, then up-gradient land retirement emerges as the most logical strategy. Implementation of a successful land retirement program may require an approach that weighs independently the benefits of drainage reduction, selenium reduction, habitat creation, water acquisition and removal of lands that are no longer productive. Such an approach would also serve to identify target lands within each category that might not be considered for land retirement under a voluntary land retirement program." (Presser and Schwarzbach 2008: 10)

- "The stream of RO [Reverse Osmosis] treated water produced would be available for other uses, but some water- quality issues (e.g., boron and mercury) remain for the product water. For example for planning for agricultural use of RO product water, it would be necessary to dilute the concentration of boron in the product water by up to 36-fold with CVP water to obtain a boron concentration that would not impair plant growth (San Luis Drainage Feature Re-EvaluationE Environmental Impact Statement, 2007, Response to Comments)." (Presser and Schwarzbach 2008: 15)

- "A review of treatment technologies in 2004, evaluated the advantages and disadvantage of a number of technologies specifically tested on agricultural drainage waters from the valley. Some initial reduction of selenium concentration is possible (e.g., from 400 µg/L to 100 µg/L), but achieving levels low enough to meet regulatory requirements (2-5 µg/L) to protect the environment were found difficult and expensive." (Presser and Schwarzbach 2008: 25)

- "The concentration of selenium in liquids associated with the sludge bio-waste in the scenarios illustrated in figures 6-12 may be as high as 1,068 µg/L if a two-fold concentrating factor is assumed. The final concentration of selenium in the bio-waste would depend on an assumed density, but the potential exists for the production of liquids and solids that would be designated or hazardous selenium wastes. The selenium criteria for a hazardous waste are 1,000 µg/L for a liquid and 100 µg/g wet weight for a solid (U.S. Department of Health and Human Services, 1996)." (Presser and Schwarzbach 2008: 27)

- "If 100,000 acres of land is retired under the *Groundwater Quality* alternative, then 412,772 tons salt/year are available for storage at the end of the evaporation process. Assuming a bulk dry density of 1 g/cm3, then 13.24 million feet^3 [cubic feet of] salt are produced per year. At one-foot depth, this amount would cover 311 acres. In 50 years, the salt waste pile would rise to 50 ft. on the assumed 311 acres. This amount would be produced each 50 years into perpetuity." (Presser and Schwarzbach 2008: 27)

- "…[A]irborne particulates from salt waste piles may provide an additional pathway of exposure to wildlife and humans. Air quality problems may arise from wind-driven salt particles containing selenium." (Presser and Schwarzbach 2008)

- "A scenario that successfully scales-up drainage water reuse, selenium bio-treatment, and evaporation of water to concentrate salt to magnitudes effective in treating planned volumes of drainflow may create new selenium exposure pathways that pose potential risks at levels that are currently undefined. However, selenium risk may be greatest at reuse areas." (Presser and Schwarzbach 2008: 28)

A September 1, 2010, letter from the Michael Conner, Commissioner of Reclamation to Senator Dianne Feinstein identified numerous problems with implementation of the San Luis Drainage Feature Re-Evaluation ROD. Reclamation had attempted to negotiate a legislative settlement with the San Luis Unit contractors and interested public in 2007 and 2008, but no consensus could be reached. The letter identifies the inadequate authorization ceiling of appropriations for San Luis Drainage Feature Re-Evaluation implementation and also states that while the 2008 Feasibility Report identified that the San Luis Drainage Feature Re-Evaluation Record of Decision is financially and economically infeasible "*because the costs exceed the national economic benefits and are beyond the ability of the beneficiaries to repay*."

Despite the recommendation from Reclamation to increase the authorized ceiling of appropriations for the San Luis Unit and increase allowable subsidies, Congress has taken no action. There is only adequate funding authorization remaining to construct drainage collection and treatment facilities in one subarea of Westlands. Reclamation and Westlands continue to negotiate which area that will be (northerly sub-area or central sub-area of Westlands). Meanwhile, Reclamation continues to deliver hundreds of thousands of acre-feet, sometimes over a million acre-feet of water to the San Luis Unit. Each acre-foot of clean water delivered to that area results in creation of highly seleniferous drainage water that either goes into shallow or deep aquifers, and/or the Grassland Bypass Project for discharge into Mud Slough and the San Joaquin River. As long as irrigation deliveries continue to these poisoned lands, pollution will occur.

Conclusion

The State Water Resources Control Board has the authority to bring order, economic sanity, and environmental protection to drainage, salinity, and selenium problems of the Bay-Delta Estuary and the western San Joaquin Valley by acting through the Bay-Delta Water Quality Control Plan to prioritize land retirement as the most economically feasible option for reducing saline and seleniferous drainage to the lower San Joaquin River and the Bay-Delta Estuary. The time for Board action is long past due.

Appendix B
Selenium Uptake, Flow, and X2 (Isohaline) Data

Table B-1
Concentrations of Selenium (Se) in *Corbula amurensis* at USGS Benthic Station 4.1 near Chipps Island, Suisun Bay

Date	Individuals in Sample	Average shell length (mm)	Total dry weight (g)	Average dry weight (g)	Se concentration (micrograms/gram)	Weighted Monthly Average of Se in Clams (micrograms/gram)
01-Nov-01						16.0
27-Nov-01	71	9.970	0.318	0.004	16.0	
27-Nov-01	58	11.600	0.388	0.007	16.0	
01-Dec-01						13.1
18-Dec-01	85	10.000	0.322	0.004	14.0	
18-Dec-01	73	11.820	0.435	0.006	12.0	
01-Jan-02						
01-Feb-02						
01-Mar-02						7.9
23-Mar-02	56	9.970	0.358	0.006	8.0	
23-Mar-02	6	19.980	0.268	0.045	6.6	
01-Apr-02						
01-May-02						5.0
08-May-02	74	8.550	0.408	0.006	5.0	
08-May-02	45	9.490	0.332	0.007	5.0	
01-Jun-02						5.8
05-Jun-02	50	9.510	0.218	0.004	6.0	
05-Jun-02	38	10.460	0.221	0.006	5.9	
05-Jun-02	34	11.440	0.256	0.008	5.3	
01-Jul-02						13.0
17-Jul-02	35	10.580	0.177	0.005	13.0	
17-Jul-02	28	11.410	0.177	0.006	13.0	
17-Jul-02	21	12.450	0.172	0.008	13.0	

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Date	Individuals in Sample	Average shell length (mm)	Total dry weight (g)	Average dry weight (g)	Se concentration (micrograms/gram)	Weighted Monthly Average of Se in Clams (micrograms/gram)
01-Aug-02						11.3
22-Aug-02	32	11.400	0.257	0.008	11.0	
22-Aug-02	19	13.530	0.211	0.011	12.0	
22-Aug-02	17	14.450	0.228	0.013	11.0	
01-Sep-02						10.4
11-Sep-02	21	13.490	0.269	0.013	10.2	
11-Sep-02	14	15.580	0.250	0.018	10.8	
11-Sep-02	10	17.350	0.245	0.024	10.4	
01-Oct-02						9.7
09-Oct-02	21	12.450	0.253	0.011	10.1	
09-Oct-02	18	13.570	0.209	0.012	10.1	
09-Oct-02	17	14.440	0.220	0.013	8.9	
01-Nov-02						10.6
14-Nov-02	28	14.990	0.459	0.016	11.0	
14-Nov-02	20	16.970	0.377	0.019	10.0	
01-Dec-02						10.5
11-Dec-02	12	17.550	0.315	0.026	11.0	
11-Dec-02	7	19.180	0.221	0.032	10.0	
11-Dec-02	6	20.470	0.227	0.038	10.0	
01-Jan-03						8.4
08-Jan-03	18	13.800	0.223	0.012	8.9	
08-Jan-03	10	17.600	0.228	0.023	7.9	
08-Jan-03	6	20.290	0.190	0.032	7.8	
01-Feb-03						7.9
20-Feb-03	6	16.500	0.098	0.016	7.8	

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Date	Individuals in Sample	Average shell length (mm)	Total dry weight (g)	Average dry weight (g)	Se concentration (micrograms/ gram)	Weighted Monthly Average of Se in Clams (micrograms/ gram)
20-Feb-03	6	17.440	0.107	0.018	8.0	
20-Feb-03	6	19.270	0.145	0.024	7.9	
01-Mar-03						7.2
19-Mar-03	33	10.980	0.225	0.007	7.6	
19-Mar-03	10	16.400	0.207	0.021	6.0	
19-Mar-03	4	19.390	0.111	0.028	7.0	
01-Apr-03						
01-May-03						
01-Jun-03						
01-Jul-03						6.5
16-Jul-03	35	11.490	0.234	0.007	6.2	
16-Jul-03	20	12.530	0.180	0.009	6.7	
16-Jul-03	15	13.550	0.179	0.012	6.7	
01-Aug-03						6.3
13-Aug-03	22	11.520	0.179	0.008	6.2	
13-Aug-03	26	12.560	0.268	0.010	6.4	
13-Aug-03	22	13.520	0.247	0.011	6.2	
01-Sep-03						7.5
10-Sep-03	21	12.550	0.219	0.010	7.5	
10-Sep-03	17	13.560	0.222	0.013	7.7	
10-Sep-03	10	17.510	0.243	0.024	7.3	
01-Oct-03						8.0
16-Oct-03	14	16.520	0.300	0.021	8.0	
16-Oct-03	10	17.370	0.242	0.024	8.4	
16-Oct-03	5	20.380	0.216	0.043	7.1	

Appendix B
Selenium Uptake, Flow, and X2 (Isohaline) Data

Table B-1
Concentrations of Selenium (Se) in *Corbula amurensis*
at USGS Benthic Station 4.1 near Chipps Island, Suisun Bay

Date	Individuals in Sample	Average shell length (mm)	Total dry weight (g)	Average dry weight (g)	Se concentration (micrograms/ gram)	Weighted Monthly Average of Se in Clams (micrograms/ gram)
01-Nov-03						10.1
19-Nov-03	47	10.500	0.244	0.005	10.7	
19-Nov-03	37	11.380	0.245	0.007	9.7	
19-Nov-03	7	16.590	0.178	0.025	7.7	
01-Dec-03						7.9
17-Dec-03	8	15.450	0.161	0.020	7.9	
17-Dec-03	10	17.680	0.270	0.027	7.9	
17-Dec-03	10	18.510	0.289	0.029	7.8	
01-Jan-04						6.9
13-Jan-04	22	17.350	0.151	0.007	7.1	
13-Jan-04	13	12.450	0.205	0.016	6.2	
13-Jan-04	15	13.570	0.318	0.021	7.1	
01-Feb-04						6.7
11-Feb-04	35	14.440	0.234	0.007	6.8	
11-Feb-04	19	14.990	0.223	0.012	6.4	
11-Feb-04	10	16.970	0.203	0.020	6.7	
01-Mar-04						5.5
10-Mar-04	47	17.550	0.299	0.006	5.5	
10-Mar-04	33	19.180	0.262	0.008	5.5	
01-Apr-04						4.2
21-Apr-04	49	20.470	0.377	0.008	4.4	
21-Apr-04	44	13.800	0.539	0.012	3.9	
21-Apr-04	14	17.600	0.404	0.029	4.8	
01-May-04						4.9
19-May-04	83	20.290	0.423	0.005	4.8	

Appendix B
Selenium Uptake, Flow, and X2 (Isohaline) Data

Table B-1
Concentrations of Selenium (Se) in *Corbula amurensis* at USGS Benthic Station 4.1 near Chipps Island, Suisun Bay

Date	Individuals in Sample	Average shell length (mm)	Total dry weight (g)	Average dry weight (g)	Se concentration (micrograms/ gram)	Weighted Monthly Average of Se in Clams (micrograms/ gram)
19-May-04	45	16.500	0.345	0.008	4.9	
19-May-04	23	17.440	0.321	0.014	5.1	
01-Jun-04						8.5
23-Jun-04	63	19.270	0.337	0.005	9.1	
23-Jun-04	34	10.980	0.251	0.007	8.2	
23-Jun-04	27	16.400	0.248	0.009	8.7	
23-Jun-04	21	19.390	0.230	0.011	7.8	
23-Jun-04	17	11.490	0.252	0.015	7.8	
01-Jul-04						8.6
27-Jul-04	28	12.530	0.207	0.007	8.3	
27-Jul-04	27	13.550	0.243	0.009	9.3	
27-Jul-04	17	11.520	0.222	0.013	7.9	
01-Aug-04						8.8
25-Aug-04	29	12.560	0.211	0.007	8.2	
25-Aug-04	27	13.520	0.237	0.009	9.5	
25-Aug-04	31	12.550	0.339	0.011	8.7	
01-Sep-04						7.2
15-Sep-04	19	13.560	0.248	0.013	7.3	
15-Sep-04	11	17.510	0.207	0.019	7.3	
15-Sep-04	7	16.520	0.162	0.023	6.8	
01-Oct-04						
01-Nov-04						6.5
04-Nov-04	17	17.370	0.249	0.015	6.8	
04-Nov-04	11	20.380	0.248	0.023	6.7	
04-Nov-04	8	10.500	0.239	0.030	5.6	

Appendix B
Selenium Uptake, Flow, and X2 (Isohaline) Data

Table B-1
Concentrations of Selenium (Se) in *Corbula amurensis* at USGS Benthic Station 4.1 near Chipps Island, Suisun Bay

Date	Individuals in Sample	Average shell length (mm)	Total dry weight (g)	Average dry weight (g)	Se concentration (micrograms/ gram)	Weighted Monthly Average of Se in Clams (micrograms/ gram)
01-Dec-04						8.1
14-Dec-04	13	11.380	0.195	0.015	8.0	
14-Dec-04	11	16.590	0.179	0.016	8.3	
14-Dec-04	9	15.450	0.175	0.019	7.9	
01-Jan-05						6.2
12-Jan-05	14	17.680	0.221	0.016	6.4	
12-Jan-05	11	18.510	0.208	0.019	6.3	
12-Jan-05	8	17.410	0.187	0.023	5.6	
01-Feb-05						6.4
24-Feb-05	24	13.250	0.221	0.009	6.3	
24-Feb-05	14	15.570	0.200	0.014	7.0	
24-Feb-05	15	16.790	0.266	0.018	6.1	
01-Mar-05						5.2
23-Mar-05	25	12.370	0.220	0.009	5.0	
23-Mar-05	10	15.910	0.156	0.016	5.6	
23-Mar-05	6	17.880	0.133	0.022	5.7	
01-Apr-05						5.1
13-Apr-05	28	11.940	0.272	0.010	5.1	
13-Apr-05	18	15.390	0.307	0.017	5.2	
13-Apr-05	11	16.270	0.281	0.026	4.7	
01-May-05						3.3
11-May-05	70	5.500	0.388	0.006	3.3	
11-May-05	50	9.510	0.379	0.008	3.1	
11-May-05	37	10.450	0.359	0.010	3.4	
01-Jun-05						3.9

Appendix B
Selenium Uptake, Flow, and X2 (Isohaline) Data

Table B-1
Concentrations of Selenium (Se) in *Corbula amurensis* at USGS Benthic Station 4.1 near Chipps Island, Suisun Bay

Date	Individuals in Sample	Average shell length (mm)	Total dry weight (g)	Average dry weight (g)	Se concentration (micrograms/ gram)	Weighted Monthly Average of Se in Clams (micrograms/ gram)
22-Jun-05	75	9.190	0.382	0.005	3.8	
22-Jun-05	40	10.960	0.348	0.009	4.0	
22-Jun-05	20	13.020	0.268	0.013	4.1	
01-Jul-05						
01-Aug-05						7.4
10-Aug-05	34	12.100	0.326	0.010	7.8	
10-Aug-05	21	14.150	0.301	0.014	7.2	
10-Aug-05	9	17.770	0.246	0.027	6.7	
01-Sep-05						7.8
08-Sep-05	21	14.020	0.355	0.017	7.7	
08-Sep-05	14	15.490	0.287	0.021	8.2	
08-Sep-05	9	17.710	0.266	0.030	7.2	
01-Oct-05						7.3
13-Oct-05	15	14.090	0.258	0.017	7.7	
13-Oct-05	10	16.390	0.226	0.023	7.2	
13-Oct-05	8	17.570	0.210	0.026	6.8	
01-Nov-05						7.6
09-Nov-05	19	14.380	0.351	0.018	7.8	
09-Nov-05	10	17.510	0.266	0.027	7.5	
09-Nov-05	7	18.960	0.244	0.035	7.0	
01-Dec-05						7.9
08-Dec-05	16	16.190	0.360	0.022	8.3	
08-Dec-05	10	17.430	0.264	0.026	7.6	
08-Dec-05	8	18.470	0.242	0.030	7.6	
01-Jan-06						6.3

Appendix B
Selenium Uptake, Flow, and X2 (Isohaline) Data

Table B-1
Concentrations of Selenium (Se) in *Corbula amurensis* at USGS Benthic Station 4.1 near Chipps Island, Suisun Bay

Date	Individuals in Sample	Average shell length (mm)	Total dry weight (g)	Average dry weight (g)	Se concentration (micrograms/ gram)	Weighted Monthly Average of Se in Clams (micrograms/ gram)
11-Jan-06	22	11.220	0.146	0.007	6.5	
11-Jan-06	11	16.480	0.235	0.021	6.1	
11-Jan-06	6	18.480	0.159	0.026	6.1	
01-Feb-06						5.0
15-Feb-06	46	10.180	0.258	0.006	4.9	
15-Feb-06	24	13.190	0.291	0.012	5.3	
15-Feb-06	8	17.460	0.201	0.025	4.2	
01-Mar-06						3.9
16-Mar-06	32	10.930	0.302	0.009	3.9	
16-Mar-06	8	16.940	0.223	0.028	3.7	
16-Mar-06	5	19.560	0.218	0.044	3.9	
01-Apr-06						
01-May-06						2.8
10-May-06	45	9.080	0.273	0.006	2.9	
10-May-06	21	11.590	0.287	0.014	2.9	
10-May-06	8	13.680	0.185	0.023	2.0	
01-Jun-06						
01-Jul-06						
01-Aug-06						4.7
16-Aug-06	14	13.570	0.285	0.020	4.4	
16-Aug-06	9	16.570	0.243	0.027	4.9	
16-Aug-06	7	17.470	0.215	0.031	5.0	
01-Sep-06						6.2
13-Sep-06	43	9.940	0.258	0.006	6.2	
13-Sep-06	14	15.500	0.233	0.017	6.0	

Appendix B
Selenium Uptake, Flow, and X2 (Isohaline) Data

Table B-1
Concentrations of Selenium (Se) in *Corbula amurensis* at USGS Benthic Station 4.1 near Chipps Island, Suisun Bay

Date	Individuals in Sample	Average shell length (mm)	Total dry weight (g)	Average dry weight (g)	Se concentration (micrograms/ gram)	Weighted Monthly Average of Se in Clams (micrograms/ gram)
13-Sep-06	10	17.340	0.221	0.220	6.3	
01-Oct-06						5.7
18-Oct-06	10	14.560	0.146	0.015	5.9	
18-Oct-06	7	17.320	0.159	0.023	5.8	
18-Oct-06	6	18.250	0.171	0.029	5.4	
01-Nov-06						6.9
15-Nov-06	21	12.800	0.202	0.010	7.4	
15-Nov-06	10	17.580	0.222	0.022	6.3	
15-Nov-06	8	18.620	0.218	0.027	6.2	
01-Dec-06						6.3
13-Dec-06	44	10.660	0.269	0.006	6.3	
13-Dec-06	13	15.230	0.236	0.018	6.5	
13-Dec-06	10	17.420	0.243	0.024	6.1	
01-Jan-07						7.7
10-Jan-07	58	9.010	0.225	0.004	8.2	
10-Jan-07	17	12.830	0.190	0.011	6.7	
10-Jan-07	9	16.710	0.199	0.022	6.3	
01-Feb-07						7.9
07-Feb-07	46	9.040	0.168	0.004	8.0	
07-Feb-07	22	11.360	0.151	0.007	8.2	
07-Feb-07	6	17.180	0.138	0.023	6.4	
01-Mar-07						
01-Apr-07						5.6
04-Apr-07	80	8.830	0.258	0.003	5.6	
04-Apr-07	30	10.970	0.167	0.006	5.9	

Appendix B
Selenium Uptake, Flow, and X2 (Isohaline) Data

Table B-1
Concentrations of Selenium (Se) in *Corbula amurensis*
at USGS Benthic Station 4.1 near Chipps Island, Suisun Bay

Date	Individuals in Sample	Average shell length (mm)	Total dry weight (g)	Average dry weight (g)	Se concentration (micrograms/ gram)	Weighted Monthly Average of Se in Clams (micrograms/ gram)
04-Apr-07	12	15.620	0.189	0.016	5.3	
01-May-07						
01-Jun-07						
01-Jul-07						8.0
17-Jul-07	79	8.530	0.216	0.003	7.2	
17-Jul-07	60	9.530	0.224	0.004	8.3	
17-Jul-07	40	10.420	0.181	0.005	9.2	
01-Aug-07						9.3
21-Aug-07	81	9.280	0.300	0.004	9.8	
21-Aug-07	40	11.420	0.258	0.006	9.6	
21-Aug-07	28	12.400	0.218	0.008	7.4	
01-Sep-07						9.2
12-Sep-07	27	10.480	0.166	0.006	9.1	
12-Sep-07	28	11.460	0.204	0.007	9.4	
12-Sep-07	21	12.380	0.188	0.009	9.0	
01-Oct-07						10.0
24-Oct-07	42	10.180	0.212	0.005	10.0	
24-Oct-07	27	12.430	0.227	0.008	10.0	
24-Oct-07	13	14.510	0.167	0.013	9.9	
01-Nov-07						9.6
15-Nov-07	35	11.480	0.232	0.007	10.0	
15-Nov-07	30	12.470	0.240	0.008	10.0	
15-Nov-07	25	13.410	0.231	0.009	8.5	
01-Dec-07						11.3
12-Dec-07	48	9.860	0.223	0.005	12.0	

Appendix B
Selenium Uptake, Flow, and X2 (Isohaline) Data

Table B-1
Concentrations of Selenium (Se) in *Corbula amurensis*
at USGS Benthic Station 4.1 near Chipps Island, Suisun Bay

Date	Individuals in Sample	Average shell length (mm)	Total dry weight (g)	Average dry weight (g)	Se concentration (micrograms/ gram)	Weighted Monthly Average of Se in Clams (micrograms/ gram)
12-Dec-07	25	12.510	0.215	0.009	11.0	
12-Dec-07	22	13.320	0.220	0.010	10.0	
01-Jan-08						
01-Feb-08						8.3
13-Feb-08	35	10.460	0.152	0.004	8.6	
13-Feb-08	30	11.500	0.171	0.006	8.4	
13-Feb-08	21	13.370	0.180	0.009	7.5	
01-Mar-08						
01-Apr-08						
01-May-08						7.9
07-May-08	58	9.470	0.390	0.007	7.4	
07-May-08	40	10.640	0.360	0.009	8.2	
07-May-08	10	14.300	0.180	0.018	9.2	
01-Jun-08						12.6
18-Jun-08	52	9.620	0.254	0.005	13.0	
18-Jun-08	31	11.820	0.261	0.008	12.0	
18-Jun-08	8	15.630	0.145	0.018	12.0	
01-Jul-08						12.0
16-Jul-08	42	10.640	0.280	0.007	12.0	
16-Jul-08	30	12.880	0.329	0.011	12.0	
16-Jul-08	18	14.180	0.267	0.015	12.0	
01-Aug-08						
01-Sep-08						10.6
17-Sep-08	75	9.930	0.452	0.006	11.0	
17-Sep-08	22	12.480	0.254	0.012	9.6	

Appendix B
Selenium Uptake, Flow, and X2 (Isohaline) Data

Table B-1
Concentrations of Selenium (Se) in *Corbula amurensis* at USGS Benthic Station 4.1 near Chipps Island, Suisun Bay

Date	Individuals in Sample	Average shell length (mm)	Total dry weight (g)	Average dry weight (g)	Se concentration (micrograms/ gram)	Weighted Monthly Average of Se in Clams (micrograms/ gram)
17-Sep-08	13	15.350	0.284	0.022	10.0	
01-Oct-08						8.3
16-Oct-08	28	12.440	0.286	0.010	8.6	
16-Oct-08	17	14.730	0.306	0.018	7.9	
16-Oct-08	9	16.300	0.216	0.024	8.0	
01-Nov-08						8.8
19-Nov-08	30	12.900	0.331	0.011	8.7	
19-Nov-08	17	14.430	0.261	0.015	9.0	
19-Nov-08	11	16.400	0.257	0.023	8.5	
01-Dec-08						11.4
17-Dec-08	60	9.890	0.304	0.005	12.0	
17-Dec-08	23	13.150	0.260	0.011	10.0	
17-Dec-08	12	15.400	0.219	0.018	11.0	
01-Jan-09						11.0
14-Jan-09	62	9.430	0.204	0.003	10.0	
14-Jan-09	42	11.100	0.225	0.005	13.0	
14-Jan-09	19	14.500	0.220	0.012	10.0	
01-Feb-09						12.3
11-Feb-09	53	8.470	0.157	0.003	13.0	
11-Feb-09	37	10.380	0.179	0.005	12.0	
11-Feb-09	18	12.500	0.148	0.008	11.0	
01-Mar-09						7.2
11-Mar-09	56	9.130	0.185	0.003	7.2	
11-Mar-09	35	11.280	0.198	0.006	7.6	
11-Mar-09	14	15.080	0.191	0.014	6.5	

Appendix B
Selenium Uptake, Flow, and X2 (Isohaline) Data

Table B-1
Concentrations of Selenium (Se) in *Corbula amurensis* at USGS Benthic Station 4.1 near Chipps Island, Suisun Bay

Date	Individuals in Sample	Average shell length (mm)	Total dry weight (g)	Average dry weight (g)	Se concentration (micrograms/ gram)	Weighted Monthly Average of Se in Clams (micrograms/ gram)
01-Apr-09						10.2
15-Apr-09	56	9.000	0.174	0.003	11.0	
15-Apr-09	37	10.460	0.176	0.005	9.3	
15-Apr-09	16	12.330	0.115	0.007	9.6	
01-May-09						6.6
20-May-09	53	8.590	0.199	0.004	6.4	
20-May-09	27	10.390	0.161	0.006	6.8	
20-May-09	16	12.820	0.156	0.010	6.9	
01-Jun-09						8.8
24-Jun-09	56	9.150	0.225	0.004	8.9	
24-Jun-09	40	10.530	0.232	0.006	8.7	
24-Jun-09	24	12.050	0.187	0.008	8.9	
01-Jul-09						11.1
22-Jul-09	63	9.090	0.245	0.004	11.0	
22-Jul-09	46	10.560	0.283	0.006	12.0	
22-Jul-09	27	12.220	0.234	0.009	10.0	
01-Aug-09						8.8
26-Aug-09	62	9.710	0.291	0.005	9.1	
26-Aug-09	40	11.930	0.314	0.008	8.9	
26-Aug-09	21	13.490	0.228	0.011	7.9	
01-Sep-09						8.9
23-Sep-09	32	12.030	0.253	0.008	10.0	
23-Sep-09	21	13.440	0.225	0.011	9.7	
23-Sep-09	158	14.910	0.217	0.014	8.6	
01-Oct-09						9.7

Appendix B
Selenium Uptake, Flow, and X2 (Isohaline) Data

Table B-1
Concentrations of Selenium (Se) in *Corbula amurensis*
at USGS Benthic Station 4.1 near Chipps Island, Suisun Bay

Date	Individuals in Sample	Average shell length (mm)	Total dry weight (g)	Average dry weight (g)	Se concentration (micrograms/ gram)	Weighted Monthly Average of Se in Clams (micrograms/ gram)
28-Oct-09	27	11.540	0.184	0.007	10.0	
28-Oct-09	26	13.210	0.263	0.010	9.9	
28-Oct-09	13	15.050	0.187	0.014	8.8	
01-Nov-09						9.6
17-Nov-09	52	10.770	0.288	0.006	9.9	
17-Nov-09	27	12.620	0.214	0.008	9.7	
17-Nov-09	20	13.890	0.211	0.011	8.9	
01-Dec-09						9.9
02-Dec-09	28	12.530	0.254	0.009	9.8	
02-Dec-09	21	13.500	0.229	0.011	10.0	
02-Dec-09	16	14.850	0.209	0.013	9.8	
01-Jan-10						10.6
06-Jan-10	27	12.480	0.226	0.008	11.0	
06-Jan-10	22	13.960	0.254	0.012	10.0	
06-Jan-10	10	15.470	0.147	0.015	11.0	
01-Feb-10						6.7
24-Feb-10	25	12.000	0.159	0.006	7.4	
24-Feb-10	17	13.600	0.152	0.009	6.2	
24-Feb-10	11	15.270	0.131	0.012	5.9	

Sources: Kleckner, *et al* 2010; California Water Impact Network. Months that are blank means no data were available from Kleckner's dataset, as shown in Table B-1, above.

Appendix B
Selenium Uptake, Flow, and X2 (Isohaline) Data

Table B-2
Flow, X2 and Selenium Sample Data in *Corbula* Clams, 2002-2010

Month/ Year	Net Delta Outflow (cfs)	San Joaquin River at Jersey Point (cfs)	Sacramento River at Rio Vista (cfs)	Ratio SJR/ (SJR+SAC)	X2 (miles from Golden Gate)	Sample Weighted Average Selenium in Clam
Jan-02	38,734	38,277	2,661	0.06501	64.19	
Feb-02	12,029	18,175	1,897	0.09452	72.35	
Mar-02	16,964	21,316	2,134	0.09099	71.67	7.9
Apr-02	11,892	14,477	2,599	0.15217	73.47	
May-02	13,483	12,963	2,739	0.17443	73.87	5.0
Jun-02	7,374	13,889	1,407	0.09200	77.24	5.8
Jul-02	5,662	18,901	1,227	0.06096	81.35	13.0
Aug-02	3,768	17,020	1,116	0.06151	85.07	11.3
Sep-02	4,108	13,563	1,175	0.07973	88.06	10.4
Oct-02	4,184	9,891	1,705	0.14702	86.68	9.7
Nov-02	7,331	11,746	1,715	0.12738	84.46	10.6
Dec-02	28,885	29,130	1,988	0.06390	79.60	10.5
Jan-03	51,440	51,935	1,913	0.03552	62.53	8.4
Feb-03	29,622	36,086	1,879	0.04949	62.29	7.9
Mar-03	15,761	22,923	2,193	0.08732	68.52	7.2
Apr-03	22,029	21,587	2,668	0.10999	71.01	
May-03	41,877	40,539	2,625	0.06082	62.67	
Jun-03	11,719	22,277	2,034	0.08365	69.11	
Jul-03	9,631	22,429	1,321	0.05561	76.67	6.5
Aug-03	6,874	19,584	1,281	0.06138	78.67	6.3
Sep-03	3,447	15,347	1,308	0.07855	85.72	7.5
Oct-03	4,288	11,005	1,999	0.15373	88.29	8.0
Nov-03	6,626	12,450	1,647	0.11683	84.34	10.1
Dec-03	23,820	27,787	1,503	0.05130	76.36	7.9
Jan-04	32,104	36,768	1,792	0.04647	65.16	6.9
Feb-04	68,091	44,421	2,201	0.04722	65.61	6.7

Appendix B
Selenium Uptake, Flow, and X2 (Isohaline) Data

Table B-2
Flow, X2 and Selenium Sample Data in *Corbula* Clams, 2002-2010

Month/ Year	Net Delta Outflow (cfs)	San Joaquin River at Jersey Point (cfs)	Sacramento River at Rio Vista (cfs)	Ratio SJR/ (SJR+SAC)	X2 (miles from Golden Gate)	Sample Weighted Average Selenium in Clam
Mar-04	56,256	46,706	3,361	0.06712	56.70	5.5
Apr-04	21,948	23,793	2,751	0.10363	64.67	4.2
May-04	12,354	12,532	2,647	0.17437	70.90	4.9
Jun-04	5,651	15,130	1,404	0.08490	81.18	8.5
Jul-04	7,317	20,442	1,147	0.05311	80.25	8.6
Aug-04	5,204	17,913	1,125	0.05911	82.22	8.8
Sep-04	4,676	14,627	1,121	0.07117	84.74	7.2
Oct-04	8,508	12,606	1,753	0.12207	84.09	
Nov-04	6,708	12,250	1,632	0.11754	80.64	6.5
Dec-04	12,449	17,745	1,578	0.08167	81.05	8.1
Jan-05	33,589	33,681	4,918	0.12742	69.54	6.2
Feb-05	24,922	24,875	5,303	0.17573	67.52	6.4
Mar-05	38,546	30,368	8,065	0.20984	64.40	5.2
Apr-05	29,876	22,133	10,061	0.31250	62.26	5.1
May-05	50,929	40,219	10,408	0.20558	62.02	3.3
Jun-05	27,838	28,653	9,922	0.25722	60.99	3.9
Jul-05	9,378	19,668	4,160	0.17460	71.92	
Aug-05	5,586	17,245	2,622	0.13196	79.93	7.4
Sep-05	6,897	17,933	2,298	0.11357	81.69	7.8
Oct-05	4,451	14,074	2,619	0.15688	83.71	7.3
Nov-05	5,006	13,387	2,038	0.13214	86.44	7.6
Dec-05	42,828	35,458	3,521	0.09034	78.80	7.9
Jan-06	145,920	66,152	13,171	0.16605	54.66	6.3
Feb-06	51,805	48,921	6,458	0.11661	55.12	5.0
Mar-06	115,393	67,413	11,705	0.14794	52.77	3.9
Apr-06	179,387	77,647	27,887	0.26425	45.97	

Table B-2
Flow, X2 and Selenium Sample Data in *Corbula* Clams, 2002-2010

Month/ Year	Net Delta Outflow (cfs)	San Joaquin River at Jersey Point (cfs)	Sacramento River at Rio Vista (cfs)	Ratio SJR/ (SJR+SAC)	X2 (miles from Golden Gate)	Sample Weighted Average Selenium in Clam
May-06	80,754	52,145	25,971	0.33247	48.40	2.8
Jun-06	34,332	27,210	15,670	0.36544	57.13	
Jul-06	9,300	18,587	5,547	0.22983	70.04	
Aug-06	7,227	18,865	3,697	0.16387	77.94	4.7
Sep-06	6,982	18,010	3,316	0.15549	80.33	6.2
Oct-06	3,970	11,722	3,851	0.24728	83.18	5.7
Nov-06	5,230	12,147	2,538	0.17283	86.03	6.9
Dec-06	9,019	16,952	2,354	0.12194	83.07	6.3
Jan-07	8,229	13,823	2,587	0.15766	79.01	7.7
Feb-07	21,230	22,700	2,534	0.10040	75.19	7.9
Mar-07	13,968	18,323	2,555	0.12237	71.42	
Apr-07	11,239	13,631	2,225	0.14034	75.24	5.6
May-07	9,311	9,363	2,898	0.23637	76.06	
Jun-07	7,777	12,290	1,745	0.12433	78.64	
Jul-07	5,292	19,065	1,138	0.05632	81.74	8.0
Aug-07	3,689	17,123	1,008	0.05557	86.66	9.3
Sep-07	4,486	15,197	1,014	0.06256	86.27	9.2
Oct-07	3,649	10,517	1,570	0.12986	88.61	10.0
Nov-07	4,290	10,007	1,711	0.14599	87.93	9.6
Dec-07	6,579	11,519	1,503	0.11539	86.63	11.3
Jan-08	24,549	22,471	2,319	0.09356	75.37	
Feb-08	24,104	26,286	2,369	0.08268	68.39	8.3
Mar-08	12,183	13,692	2,115	0.13383	71.30	
Apr-08	9,482	10,194	2,409	0.19113	76.57	
May-08	8,154	8,798	2,755	0.23850	77.92	7.9
Jun-08	7,254	11,304	1,033	0.08372	79.58	12.6

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Selenium Uptake, Flow, and X2 (Isohaline) Data

Table B-2
Flow, X2 and Selenium Sample Data in *Corbula* Clams, 2002-2010

Month/ Year	Net Delta Outflow (cfs)	San Joaquin River at Jersey Point (cfs)	Sacramento River at Rio Vista (cfs)	Ratio SJR/ (SJR+SAC)	X2 (miles from Golden Gate)	Sample Weighted Average Selenium in Clam
Jul-08	3,614	12,526	864	0.06452	84.56	12.0
Aug-08	3,031	10,823	869	0.07430	89.32	
Sep-08	4,029	10,336	902	0.08023	88.60	10.6
Oct-08	3,032	7,631	1,235	0.13927	90.00	8.3
Nov-08	5,534	9,458	1,140	0.10756	87.99	8.8
Dec-08	6,919	8,679	1,128	0.11503	85.88	11.4
Jan-09	6,034	8,870	1,105	0.11077	84.11	11.0
Feb-09	22,387	20,104	1,428	0.06630	77.36	12.3
Mar-09	19,414	22,116	1,422	0.06042	69.39	7.2
Apr-09	11,944	13,563	1,516	0.10053	74.66	10.2
May-09	15,797	16,358	2,130	0.11519	72.27	6.6
Jun-09	8,006	11,966	1,099	0.08409	76.53	8.8
Jul-09	5,151	18,616	606	0.03153	81.98	11.1
Aug-09	4,213	15,113	609	0.03872	85.38	8.8
Sep-09	3,066	11,448	948	0.07645	87.64	8.9
Oct-09	6,636	9,781	1,904	0.16296	85.54	9.7
Nov-09	5,201	9,008	1,404	0.13488	84.92	9.6
Dec-09	6,874	10,612	1,319	0.11053	83.16	9.9
Jan-10	27,303	26,809	1,955	0.06797	77.86	10.6
Feb-10	30,183	28,993	2,426	0.07721	65.58	6.7

Table B-3
Average Subsurface Selenium Concentrations in San Joaquin River Basin, 1986-2005 and Selenium Regulation Criteria

Year	Arithmetic Average	Geometric Mean	USEPA Se Criterion for Rivers & Streams (5 micrograms/ Liter)	State and Federal Se Criterion for Wetlands' Aquatic Life (2 micrograms/ Liter)	Recommended USGS Safe Tissue Levels for Estuary (0.5 micrograms/ Liter)
1986	0.099	0.061			
1987	0.110	0.053			
1988	0.095	0.057			
1989	0.090	0.053			
1990	0.085	0.053	0.005	0.002	0.0005
1991	0.091	0.053	0.005	0.002	0.0005
1992	0.066	0.050	0.005	0.002	0.0005
1993	0.071	0.042	0.005	0.002	0.0005
1994	0.077	0.054	0.005	0.002	0.0005
1995			0.005	0.002	0.0005
1996	0.077	0.050	0.005	0.002	0.0005
1997	0.089	0.049	0.005	0.002	0.0005
1998	0.080	0.061	0.005	0.002	0.0005
1999	0.086	0.059	0.005	0.002	0.0005
2000	0.114	0.057	0.005	0.002	0.0005
2001	0.117	0.080	0.005	0.002	0.0005
2002	0.133	0.083	0.005	0.002	0.0005
2003	0.139	0.099	0.005	0.002	0.0005
2004	0.146	0.104	0.005	0.002	0.0005
2005	0.134	0.093	0.005	0.002	0.0005

Sources: California Department of Water Resources 2010: Table 15, 29.

Appendix C:
Chronology of State Water Board Activities and Related Studies Concerning Salinity Control and Fish Protection

Document/ Source/ Authority	Year	Purpose	Face Value	Points of Diversion	Comments
Central Valley Project Act (Stats.1933, Ch. 1042)	1933	Design and operation of the CVP	NA	Multiple	Salinity control in the Sacramento-San Joaquin Delta is one of the primary purposes of the Central Valley Project.
Effects of the CVP on the Southern Delta Water Supply, joint study by US Water and Power Resources Service (nee USBR) and South Delta Water Agency	1980; compared historical water quality and flow data as far back as 1930s.	"Comparing the average monthly TDS (over the entire year), load-flow regressions show a 1950-1969 increase of 43 percent--from 259 mg/L to 371 mg/L. For the 1950s alone the percentage increase is about 22 percent and for the 1960s, 65 percent....Thus, according to this analysis, in this first decade after the CVP went into operation, about 56 percent of the increase in average TDS was caused simply by a reduction in flow from upstream sources; the remaining 44 percent was a result of increased salt burden, perhaps associated with an expansion of irrigated lands in the basin. Similarly in the 1960s (compared to thee 1930s and 1940s) about 27 percent of the average increase in TDS...can be accounted for by a reduction in flow and 73 percent attributed to increased salt burden. It is of interest to note here that the absolute change apparently caused by reduction in flow changed relatively little from the 1950s to the 1960s...while that charged to an increase in salt burden incrased about four times [...]. This is consistent with other analyses that indicate a progressive buildup in salt load in the San Joaquin system." (p. 126.)			
D-893	1958	USBR – Appropriate water for operating American River CVP facilities	1,000,000 AF of storage, 8,000 cfs maximum diversion rate	Multiple	During a twelve-year period the State Water Board adopted six difference decisions (Decisions 893, 990, 1020, 1250, 1308, and 1356) approving permits for various components of the federal CVP operated by USBR. The permits issued as a result of the decisions included a term by which the Water Board reserved jurisdiction to revisit salinity control requirements. (Decision 893, p. 71, Condition 12; Decision 990, p. 86, Condition 25; Decision 1020, p. 21, Condition 9; Order Extending Time in Which to Formulate Terms and Conditions Relative to Salinity Control Pursuant to Decision 990 and Decision 1020, p. 2; Decision 1250, p. 5, Condition 9; Decision 1308, p. 11-12, Condition 8; Decision 1356, p. 17, Condition 21.)
D-990	1961	USBR - Appropriate water for operating the CVP	8,022,000 AF of storage; 23,674 cfs maximum diversion rate	Multiple	Order reserved to the State Water Rights Board continuing jurisdiction over CVP permits for the purpose of formulating terms and conditions relative to salinity control in the Delta. Narrative noted 1500 cfs minimum flow needed to maintain 1000 ppm water quality at Antioch for irrigation purposes. Industrial interests preferred no more than 350 ppm at Antioch, preferred 150 to 250 ppm at Antioch. D-990 also stated that the State's water rights applications assigned to the Bureau of Reclamation for the CVP included salinity control as a purpose of the water rights.

Sources: State Water Resources Control Board, Order WR 2006-0006, Figure 2, pp. 8-9; various State Water Resources Control Board water quality control plans and water right decisions cited herein and available online at http://www.waterboards.ca.gov/waterrights/board_decisions/adopted_orders/decisions/; Jackson and. Paterson, 1977; California Water Impact Network.

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Document/ Source/ Authority	Year	Purpose	Face Value	Points of Diversion	Comments
D-1020	1961	USBR - Appropriate water for the San Luis Unit.	1,000,000 AF of storage; 4,200 cfs maximum diversion; 1500 cfs direct diversion	Old River	While the State Water Rights Board received testimony from Delta Water Users Association concerning south Delta salinity conditions deteriorating in the San Joaquin River north of Mendota Pool since 1950, the Board received no specific terms or conditions from the parties for this decision, and so established no salinity standard.
D-1250	1965	USBR - Appropriate water for power production at San Luis Reservoir	1,000,000 AF for off-stream storage; 4,200 cfs maximum diversion rate	Old River	Order reserved to the State Water Rights Board continuing jurisdiction over CVP permits for the purpose of formulating terms and conditions relative to salinity control in the Delta.
D-1275	1967	DWR - Appropriate water for operating the SWP	5,066,100 AF of storage; 30,060 cfs in direct diversions	Feather River, Delta Channels	Board found that "sufficient information is not available to finally determine the terms and conditions regarding water quality in the Delta which will reasonably protected vested rights without resulting in waste of water" and reserved its jurisdiction over permit terms and conditions while both USBR and DWR conducted studies regarding "the problem of water quality in the San Francisco Bay and the Delta for the purpose of determining what standards of water quality should be maintained and recommending how this is to be accomplished." (p. 18)
D-1291	1970	DWR - Appropriate water for operating the SWP	same as D-1275, but adjusted seasons of diversion at sources	Feather River, Delta Channels	No amendments made to D-1275, Term 19 that reserves Board jurisdiction regarding water quality in the Delta.
D-1356	1970	USBR - Appropriate water for Eastside Division projects	Folsom and Auburn Dam projects	American River Basin	Order reserved to the State Water Rights Board continuing jurisdiction over CVP permits for the purpose of formulating terms and conditions relative to salinity control and fish and wildlife protection in the Delta.

Sources: State Water Resources Control Board, Order WR 2006-0006, Figure 2, pp. 8-9; various State Water Resources Control Board water quality control plans and water right decisions cited herein and available online at http://www.waterboards.ca.gov/waterrights/board_decisions/adopted_orders/decisions/; Jackson and. Paterson, 1977; California Water Impact Network.

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Document/ Source/ Authority	Year	Purpose	Face Value	Points of Diversion	Comments
D-1379	1971	To continue reserving jurisdiction on water quality and fish and wildlife issues relating to permits of the CVP and SWP	39 permits involving 10,000,000 AF	As identified for SWP and CVP	"...The Delta has become a man-made ecosystem which must be protected and managed intelligently to achieve a level of environmental quality that will meet all present and future needs." (p. 5) SWRCB saw its role as protecting vested water rights, as well as reserved jurisdiction pertaining to water quality and fish and wildlife protection. D-1379 established quantitative water quality standards largely for the western Delta, and narrative standards for fish and wildlife protection. The State Water Board's amendment of D-1379 (adopted October 1971) states that "The State Water Project cannot eliminate reverse flow in the San Joaquin River portion of the Delta or provide predominantly San Joaquin River water in the southeastern Delta in September, October and November prior to the operation of the Peripheral Canal....Prior to the operation of such a facility it is implicit in the Board's order that the permittees shall maintain the standard to the best of their ability with the facilities available."
1978 Water Quality Control Plan	1978	State Water Board Adopts 1978 Plan and Decision 1485: Based on the conclusions of the University of California crop study, the State Water Board, in the 1978 Plan, established the salinity objectives in effect today. Specifically, it found that to protect southern Delta agriculture it was necessary to maintain a 30-day running average salinity objective of 0.7 mmhos/cm EC from April through August and 1.0 mmhos/cm EC from September through March at four locations in the southern Delta: (1) the San Joaquin River at Vernalis, (2) San Joaquin River at Brandt Bridge, (3) Old River near Middle River, and (4) Old River at Tracy Road. (1978 Plan, p. VI-29.) The State Water Board did not allocate responsibility for the 1978 Plan southern Delta EC objectives in Decision 1485. The 1978 Plan and Decision 1485 state that if contracts to ensure the water supplies and facilities mentioned above are not executed by January 1, 1980, the State Water Board will take appropriate enforcement actions to prevent encroachment on riparian rights in the southern Delta. (1978 Plan, p. VI-6; Decision 1485, p.28, Condition 8.) Contracts were not negotiated, but SDWA asked the State Water Board to delay taking action.			

Sources: State Water Resources Control Board, Order WR 2006-0006, Figure 2, pp. 8-9; various State Water Resources Control Board water quality control plans and water right decisions cited herein and available online at http://www.waterboards.ca.gov/waterrights/board_decisions/adopted_orders/decisions/; Jackson and. Paterson, 1977; California Water Impact Network.

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Document/ Source/ Authority	Year	Purpose	Face Value	Points of Diversion	Comments
Draft 1988 Water Quality Control Plan	1988 (not adopted)	This plan was not adopted due to intense objections to its proposed water ethic and reliance on several flow-related objectives. Retains the 1978 WQCP southern Delta salinity standards, but does not assign responsibility for their being met. Narrative of this Draft WQCP for southern Delta agriculture (pp. 7-4 to 7-5) noted that: water quality degraded in the Delta near Vernalis in the last 50 years, with salt concentrations having more than doubled during that time due to increased salt loading from agricultural drainage and decreased flows from upstream water development; called for implementation of the 1978 southern Delta salinity objectives, but noted that "decisive action is needed." This draft plan also stated that two aspects of these objectives needed review: "First, the mean monthly monitoring frequency contained in the Delta Plan [1978] is too long, as explained by the South Delta Water Agency, and should be reduced to a 14-day running average consistent with western and interior Delta objectives. Second, the objectives need to be tested to see if they would be attained during unimpaired flow conditions. This analysis indicates that the 0.7 mmhos/cm EC set forth in the objectives during the primary irrigation season of April through August generally would be available under unimpaired runoff conditions during all water year types. This analysis used water quality to flow relationships for the San Joaquin River that existed prior to 1945 [prior to completion and operation of the Friant Dam and Delta Cross Channel]." The draft plan adds that, "During the secondary irrigation season, September through March, the 1.0 mmhos/cm EC provides water quality sufficient to protect crops irrigated during this time of year e.g., alfalfa, pasture, and sugar beets. This quality protects the seedling stages of these crops and is sufficient for winter leaching. Also, analysis shows that 1.0 mmhos/cm EC generally would be achieved during these months under unimpaired runoff conditions. These objectives are used for each set of water quality objectives and are shown in detail in the recommended objectives presented later in this chapter."			
	1988	Concerning Chinook salmon protection, the draft plan states that "San Joaquin River salmon populations fluctuate markedly, partly in response to spring flow conditions, and range from less than one to 26 percent of the Central Valley salmon population….One race was eliminated from the San Joaquin Basin by the construction of Friant Dam. Sufficient evidence was presented in the Phase I Hearing to determine Delta protectioins needed for the fall run salmon but not the other races of Chinook salmon on the San Joaquin or Sacramento River systems." In addition, the draft plan stated, "Available data indicate that river flows in April through June up to a certain limit (22,500 cfs on the Sacramento River at Rio Vista and 20,000 cfs on the San Joaquin River at Vernalis) provide benefits to salmon migration. These benefits are linearly related to increasoing Sacramento River flows. Limited data from the San joaquin indicate a similar relationship." (pp. 7-6 to 7-7). "While the option exists to take no action related to the further regulation of flows and exports, it is not reasonable to rely on "out of Estuary" measures to correct habitat concerns related to factors in the Estuary....Currently there are no requirements for minimum upstream flows on the San Joaquin River for upstream salmon migration. Low dissolved oxygen at Stockton may also cause a blockage to upstream salmon passage. A 1969 agreement between DWR, USBR and DFG provided for 1) installation of a temporary barrier across Old River when dissolved oxygen falls below 6 mg/L so that flows increase down the San Joaquin River, or 2) if that is not successful, increased flow releases [from upstream reservoirs]. This objective should be incorporated in this Plan." (p. 7-10)			

Sources: State Water Resources Control Board, Order WR 2006-0006, Figure 2, pp. 8-9; various State Water Resources Control Board water quality control plans and water right decisions cited herein and available online at http://www.waterboards.ca.gov/waterrights/board_decisions/adopted_orders/decisions/; Jackson and. Paterson, 1977; California Water Impact Network.

Document/ Source/ Authority	Year	Purpose	Face Value	Points of Diversion	Comments
	1988	Because of the condition of salmonid fisheries on the San Joaquin River, the draft plan recommended a suite of objectives that included reducing April through July exports to levels that would "reflect the conditions that occurred during a time when both striped bass and salmon populations were in much healthier conditions, prior to the increased export of the SWP (1953-1967...). Reducing exports to the period before the SWP does not always provide the positive downstream flow in Old and Middle rivers sought by many fishery groups. Under this alternative, positive flows occur only about 20 percent of the time during April - July. It does reduce the magnitude of reverse flows compared to present conditions. A safe level of exports is not known. However, pre-SWP spring export rates appears to be a reasonable interim goal until a safe level of exports is found.			
	1988	"The average impact on existing and planned spring exports is a decrease of about 0.67 MAF. Compared to the last 15 years of spring exports, they would be reduced by about 0.2 MAF. In order to make up for this decrease in spring exports the CVP and SWP could increase exports in fall and winter months above today's levels as planned in their 1990 operations study. This is possible with existing facilities as shown in DWR's 1990 operations study. These actions would in effect freeze existing total annual exports at about the 1985 levels. The 1985 level of exports is the highest to date and 16 percent higher than the average level of exports since implementation of the 1978 Delta Plan. However,...this level of Delta supply is sufficient to meet reasonable water demands south and west of the Delta through the year 2010." (p. 7-32)			
1991 Water Quality Control Plan	1991 (rejected by US EPA)	The State Water Board did not change the southern Delta EC objectives in the 1991 Plan from the objectives in the 1978 Plan. However, because of on-going negotiations among DWR, USBR, and SDWA, the State Water Board established a staged implementation plan for the objectives with two interim stages and a final stage. The final stage, to be implemented no later than 1996, required implementation of a 30-day running average EC at all four southern Delta locations (Vernalis, Brandt Bridge, Old River near Middle River, and Old River at Tracy Road) of 0.7 between April and August and 1.0 between September and March for all year-types. The 1991 Plan also stated that if a three-party contract has been implemented among DWR, USBR, and SDWA, that contract will be reviewed prior to implementation of the southern Delta EC objectives and, after also considering the needs of other beneficial uses, revisions will be made to the objectives and compliance/ monitoring locations noted, as appropriate. (1995 Plan, Table 1-1, p. 4 and 8.) No responsibility for compliance was assigned by the WQCP at the time.			
Draft Decision 1630	1992 (not adopted)	This draft water right decision intended to implement the 1991 WQCP was not adopted due to intense objections to its pulse flow and other fish and wildlife protection requirements. It would have retained the 1991 WQCP version of the southern Delta salinity standards, including retention of the 30-day running average for EC objectives. It included spring and fall pulse flows in the San Joaquin River together with export limit at the SWP, and CVP pumps (including Contra Costa Canal) of no more than 1,500 cfs combined (and split equally between DWR and USBR). Attraction flows were also included for October.			
1995 Water Quality Control Plan	1995	The State Water Board did not change the southern Delta EC objectives in the 1995 Plan from the objectives in the 1991 Plan except that the effective date of the objectives at the Old River sites was extended from January 1, 1996 to December 31, 1997. The 1995 Plan includes the same condition as the 1991 Plan regarding review of the objectives upon execution of a three-party agreement. (1995 Plan, p. 17.)			

Sources: State Water Resources Control Board, Order WR 2006-0006, Figure 2, pp. 8-9; various State Water Resources Control Board water quality control plans and water right decisions cited herein and available online at http://www.waterboards.ca.gov/waterrights/board_decisions/adopted_orders/decisions/; Jackson and. Paterson, 1977; California Water Impact Network.

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Document/ Source/ Authority	Year	Purpose	Face Value	Points of Diversion	Comments
Water Right Order 95-06	1995	The State Water Board temporarily amended DWR's and USBR's water rights for the SWP and the CVP to be consistent with the 1995 Plan. This order allowed DWR and USBR to operate the SWP and CVP in accordance with the 1995 Plan while the State Water Board prepared a long-term water right decision to implement the plan. Among other requirements, the order required USBR to release conserved water from New Melones Reservoir to comply with the 1995 Plan Vernalis EC objectives. The order was to expire on December 31, 1998 or upon adoption by the State Water Board of a long-term water right decision implementing the 1995 Plan. (Order 95-6, p. 51-52.)			
Water Right Order 98-9	1998	The State Water Board continued the temporary terms and conditions set forth in Order 95-6. The order was to expire on December 31, 1999 or upon adoption by the State Water Board of a long-term water right decision implementing the 1995 Plan. (Order 98-9, p. 23-24.)			
D-1641	2000	For the first time, the State Water Board assigned sole responsibility to USBR for meeting the Vernalis EC objectives and DWR and USBR for meeting the EC objectives at Brandt Bridge, Old River near Middle River, and Old River at Tracy Road. Decision 1641 immediately implemented the Vernalis objectives and implemented a year round objective of 1.0 EC at the interior southern Delta stations until April of 2005. After April of 2005, Decision 1641 requires implementation of 0.7 EC during April through August unless permanent barriers or equivalent measures are completed and a plan to protect agriculture is approved, in which case the required objective is 1.0 EC. (Decision 1641, p. 159-160 and Table 2, p. 182.) Decision 1641 also approved use by DWR and USBR of each other's points of diversion (JPOD) subject to completion by DWR and USBR and approval by the Division Chief of mitigation requirements including a WQRP. (Decision 1641, p. 150-153; 155-158.)			
2006 Water Quality Control Plan	2006	The State Water Board assigned sole responsibility to USBR for meeting the Vernalis EC objectives and DWR and USBR for meeting the EC objectives at Brandt Bridge, Old River near Middle River, and Old River at Tracy Road. Decision 1641 immediately implemented the Vernalis objectives and implemented a year round objective of 1.0 EC at the interior southern Delta stations until April of 2005. After April of 2005, Decision 1641 requires implementation of 0.7 EC during April through August unless permanent barriers or equivalent measures are completed and a plan to protect agriculture is approved, in which case the required objective is 1.0 EC. (Decision 1641, p. 159-160 and Table 2, p. 182.) Decision 1641 also approved use by DWR and USBR of each other's points of diversion (JPOD) subject to completion by DWR and USBR and approval by the Division Chief of mitigation requirements including a WQRP. (Decision 1641, p. 150-153; 155-158.)			
2009 Water Quality Control Plan Update	2009	The State Water Board found no reasons to change the 2006 Water Quality Control Plan and began identifying instead a research and planning program to prepare to update the Bay-Delta Water Quality Control Plan for the next three-year cycle, which would conclude in 2012. The Board's research program included a study of salt tolerance in crop plants grown in the South Delta.			

Sources: State Water Resources Control Board, Order WR 2006-0006, Figure 2, pp. 8-9; various State Water Resources Control Board water quality control plans and water right decisions cited herein and available online at http://www.waterboards.ca.gov/waterrights/board_decisions/adopted_orders/decisions/; Jackson and. Paterson, 1977; California Water Impact Network.

Appendix D
Chronology of Authorizing, Planning, and Regulatory Events for Construction of a Valley-wide Drain or a San Luis Drain

Date	Agency or Industry	Event
1950	USBR	Begins Central Valley Project Delta Mendota Service Area water deliveries
1955	USBR	Feasibility report for drainage canal (300 cubic feet per second capacity; 197 miles length) from San Joaquin Valley
1960	Federal Law (Public Law 86-488)	Authorizes San Luis Unit of Central Valley Project and makes provision for constructing interceptor drain to the Bay-Delta.
1960	State of California	Electorate passes Proposition 1, a general bond referendum for the State Water Resources Development System, and which includes bond financing for construction of "facilities for removal of drainage water from the San Joaquin Valley."
1962	USBR	Definite Plan Report for San Luis Unit (includes capacity for other areas)
1965	State of California	Proposes expansion of drainage plans to install valley-wide master drain
1965 to present	US Congress	Includes a rider to Central Valley Project appropriations specifying development of a plan which conforms with state water quality standards as approved by USEPA to minimize any detrimental effects of the San Luis Unit drainage waters
1967	State of California	Declines to participate in valley-wide master drain
1968	USBR	Begin (1) Central Valley Project water deliveries to the San Luis Service Area and (2) construction of San Luis Drain for use by Westlands Water District
1969	Drainage Advisory Group	Issues final report recommending drain to the Delta
1970	USBR and USFWS	Designate Kesterson Reservoir, a regulating reservoir for the San Luis Drain, as a new USFWS National Wildlife Refuge
1972	USBR	Environmental Impact Statement on San Luis Unit filed with Council on Environmental Quality
1975	USBR	Completes 85-mile San Luis Drain to Kesterson Reservoir, 120 miles of collector drains, and 1,200 acre-reservoir; agrees to supplemental Environmental Impact Statement on impacts of San Luis Drain
1975	USBR	Halts construction of remainder of San Luis Drain due to Federal budget restrictions and increasing environmental concerns regarding discharge to the Delta
1975	USBR and state water agencies	Recommend completion of the San Luis Drain to the Bay-Delta
1977	Federal Law (Public Law 95-46)	Authorizes study of problems related to completion of San Luis Drain
1977	USBR	Asks USEPA about requirements for a waste discharge permit for San Luis Drain
1979	USBR and California water agencies	Issues study of alternatives and final report recommending construction of drain; issues First Stage Environmental Impact Report for discharge at Suisun Bay (Chipps Island)
1981	USBR	Begins drainwater flow into Kesterson Reservoir; begins San Luis Special Study to fulfill state requirements for obtaining a permit for discharge of drainage to the Bay-Delta at Chipps Island
1983	USFWS	Advises USBR of bird deformities/deaths at Kesterson National Wildlife Refuge

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Chronology of Authorizing, Planning, and Regulatory Events for Construction of a Valley-wide Drain or a San Luis Drain

Date	Agency or Industry	Event
1984	USFWS and USGS	Studies show environmental damage from selenium at Kesterson National Wildlife Refuge
1985	Secretary of the USDOI and California Governor	Establish Federal-State San Joaquin Valley Drainage Program to conduct comprehensive studies to identify magnitude and sources of problem, the toxic effects of selenium on wildlife, and actions needed to resolve these issues
1985	Secretary of the USDOI	Orders cessation of discharge to Kesterson Reservoir and closure of San Luis Drain; initiates National Irrigation Water Quality Program to study effects of agricultural drainage on refuges across the western United States.
1985	State Water Resources Control Board	Issues order No. WQ85-1 to regulate agricultural drainage to the San Joaquin River
1986	USBR	Closes San Luis Drain; issues Environmental Impact Statement for cleanup alternatives for Kesterson Reservoir
1986	Barcellos Judgment, US District Court	Calls for a Drainage Plan, Service Facilities, and a Drainage Trust Fund
1987	Federal and State Interagency Committee	Issues report of potential out-of-valley areas for disposal, due to environmental groups and coastal communities opposition, future studies limited to in-valley options
1988	USBR as ordered by State of California	Fills and grades Kesterson Reservoir as part of Kesterson Cleanup Program
1990	Federal and State Interagency Committee	Completes Drainage Management Plan for in-valley solutions to drainage problem
1991	Federal and State Interagency Committee	Forms Drainage Implementation Program and signs Memorandum of Understanding to help implement in-valley recommendations; Department of Water Resources is lead agency
1992	USBR	As part of Barcellos Judgment, submits Draft Environmental Impact Statement for San Luis Unit Drainage Program; Environmental Impact Statement suggests in-valley approaches and stated the social and environmental unacceptability of completing a drain precludes further consideration; court rejects Environmental Impact Statement as not complying with judgment
1992	Federal Law 102-575 (CVPIA)	Calls for water allocations for the protection of fish and wildlife; and land retirement in the San Joaquin Valley
1993	US House of Representatives (Subcommittee on Natural Resources)	Oversight Hearing on agricultural drainage issues in the Central Valley including reuse of a portion of the San Luis Drain by Grassland Area Farmers
1993	Porgans, Carter, USFWS and environmental groups	Petition state over adequacy of Environmental Impact Statements for operation of privately owned drainage evaporation ponds where unavoidable bird loss was occurring
1994	Wanger Decision, US District Court	Decides to send the salty water north; calls for initiation of process to obtain a discharge permit for the San Luis Drain to the Bay-Delta
1995	USBR; Contra Costa County and others	Appeals Wanger decision; environmental groups intervene; decision pending
1995-96	USBR and San Luis Delta-Mendota Water Authority	Issues Environmental Assessment for reuse of the San Luis Drain by Grassland subarea; 28-miles of the San Luis Drain reopens to convey drainage to the San Joaquin River
1996	State Water Resources Control Board	State re-emphasizes that valley-wide drain is best technical and feasible for water quality and salt balance in the San Joaquin Valley, but calls for National Pollutant Discharge Elimination System permit

Appendix D
Chronology of Authorizing, Planning, and Regulatory Events for Construction of a Valley-wide Drain or a San Luis Drain

Date	Agency or Industry	Event
1997	Department of Water Resources	Starts preparing update of Drainage Management Plan due to non-implementation
1999	Department of Water Resources	Declares Drainage Management Plan to have been unsuccessful
1999	USBR, Department of Water Resources, and State Water Rights Decision 1641	Recommend completion of the San Luis Drain to Bay-Delta or other out-of-valley alternative; call for Memorandum of Understanding to initiate environmental review for consideration of discharge application for the San Luis Drain
1999	US House of Representatives	Field hearing to examine agricultural drainage issues including completing San Luis Drain
2000	Hug, and others, 2000, US Court of Appeals	Reverses previous decision to compel USBR to build a drain to Bay-Delta, but rules USBR has a duty to provide drainage service; drainage plan pending
2000	USBR	Initiates a process for providing drainage service to the San Luis Drain
2000	CALFED	Issues Programmatic Record of Decision for 30-year plan of Bay-Delta restoration and management
2005	USBR	Issues Draft Environmental Impact Statement on the San Luis Drainage Feature Re-Evaluation
2005	USBR	Issues Draft Environmental Impact Statement for renewal of long term San Luis Unit contracts independent of drainage considerations
2006	USBR	Issues Final Environmental Impact Statement for renewal of long term San Luis Unit contracts independent of drainage considerations
2007	USBR	Issues Record of Decision on the San Luis Drainage Feature Re-Evaluation.
	Source: US Geological Survey 2006: Table 1; California Water Impact Network.	

Appendix E
Electrical Conductivity at P-12 Monitoring Station
Old River at Tracy Boulevard

Date	Electrical Conductivity (µS/cm)	30-Day Running Average of Electrical Conductivity (µS/cm)	P-12 Salinity Objective (µS/cm)	Apparent Objective Exceedance (Yes/No)
2/1/12	823.63	Not calculated	1000	
2/2/12	808.75	Not calculated	1000	
2/3/12	821.67	Not calculated	1000	
2/4/12	812.96	Not calculated	1000	
2/5/12	800.46	Not calculated	1000	
2/6/12	822.42	Not calculated	1000	
2/7/12	865.46	Not calculated	1000	
2/8/12	857.58	Not calculated	1000	
2/9/12	875.08	Not calculated	1000	
2/10/12	934.21	Not calculated	1000	
2/11/12	942.42	Not calculated	1000	
2/12/12	944.43	Not calculated	1000	
2/13/12	951.48	Not calculated	1000	
2/14/12	949.21	Not calculated	1000	
2/15/12	997.52	Not calculated	1000	
2/16/12	968.63	Not calculated	1000	
2/17/12	960.79	Not calculated	1000	
2/18/12	984.42	Not calculated	1000	
2/19/12	973.92	Not calculated	1000	
2/20/12	965.17	Not calculated	1000	
2/21/12	965.63	Not calculated	1000	
2/22/12	1007.21	Not calculated	1000	
2/23/12	1102.83	Not calculated	1000	
2/24/12	1079.17	Not calculated	1000	
2/25/12	1110.67	Not calculated	1000	
2/26/12	1139.54	Not calculated	1000	
2/27/12	1172.92	Not calculated	1000	

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Date	Electrical Conductivity (µS/cm)	30-Day Running Average of Electrical Conductivity (µS/cm)	P-12 Salinity Objective (µS/cm)	Apparent Objective Exceedance (Yes/No)
2/28/12	1125.83	Not calculated	1000	
2/29/12	1145.04	Not calculated	1000	
3/1/12	1140.75	Not calculated	1000	
3/2/12	1162.33	985.51	1000	No
3/3/12	1159.79	997.17	1000	No
3/4/12	1190.33	1010.18	1000	Yes
3/5/12	1207	1024.20	1000	Yes
3/6/12	1213.17	1037.67	1000	Yes
3/7/12	1146.63	1047.37	1000	Yes
3/8/12	1198.79	1059.13	1000	Yes
3/9/12	1232.88	1071.47	1000	Yes
3/10/12	1240.54	1082.04	1000	Yes
3/11/12	1222.48	1091.69	1000	Yes
3/12/12	1144.27	1098.58	1000	Yes
3/13/12	1144.63	1105.24	1000	Yes
3/14/12	1122.29	1111.21	1000	Yes
3/15/12	1073.96	1113.85	1000	Yes
3/16/12	1079.78	1117.68	1000	Yes
3/17/12	1038.78	1120.37	1000	Yes
3/18/12	971.35	1119.92	1000	Yes
3/19/12	960.17	1119.45	1000	Yes
3/20/12	988.5	1120.25	1000	Yes
3/21/12	973.92	1120.54	1000	Yes
3/22/12	NA	1124.58	1000	Yes
3/23/12	980	1120.20	1000	Yes
3/24/12	1030.25	1118.45	1000	Yes
3/25/12	1018.04	1115.14	1000	Yes
3/26/12	1022.43	1110.96	1000	Yes
3/27/12	1036.71	1106.09	1000	Yes
3/28/12	1018.75	1102.27	1000	Yes

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Date	Electrical Conductivity (µS/cm)	30-Day Running Average of Electrical Conductivity (µS/cm)	P-12 Salinity Objective (µS/cm)	Apparent Objective Exceedance (Yes/No)
3/29/12	999.71	1097.08	1000	Yes
3/30/12	1033.63	1094.89	1000	Yes
3/31/12	1038.67	1091.37	1000	Yes
4/1/12	1123.5	1090.03	700	Yes
4/2/12	1177.71	1090.65	700	Yes
4/3/12	1223.17	1091.78	700	Yes
4/4/12	1182.61	1090.94	700	Yes
4/5/12	1123.83	1087.86	700	Yes
4/6/12	1135.79	1087.49	700	Yes
4/7/12	1178	1086.77	700	Yes
4/8/12	1183.43	1085.07	700	Yes
4/9/12	1177.65	1082.90	700	Yes
4/10/12	1145.08	1080.23	700	Yes
4/11/12	1152.3	1080.50	700	Yes
4/12/12	1222	1083.17	700	Yes
4/13/12	1246.42	1087.45	700	Yes
4/14/12	1283.29	1094.67	700	Yes
4/15/12	1325.33	1103.14	700	Yes
4/16/12	1349.71	1113.86	700	Yes
4/17/12	1359.92	1127.26	700	Yes
4/18/12	1370.08	1141.39	700	Yes
4/19/12	1371.38	1154.60	700	Yes
4/20/12	1378.79	1168.56	700	Yes
4/21/12	1322.39	1173.69	700	Yes
4/22/12	1249.46	1182.67	700	Yes
4/23/12	1168.92	1187.29	700	Yes
4/24/12	1161.75	1192.08	700	Yes
4/25/12	1221.83	1198.73	700	Yes
4/26/12	1260.63	1206.19	700	Yes
4/27/12	1302.04	1215.63	700	Yes

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Date	Electrical Conductivity (µS/cm)	30-Day Running Average of Electrical Conductivity (µS/cm)	P-12 Salinity Objective (µS/cm)	Apparent Objective Exceedance (Yes/No)
4/28/12	1323.71	1226.43	700	Yes
4/29/12	1290.33	1234.99	700	Yes
4/30/12	1255.32	1242.21	700	Yes
5/1/12	1197.92	1244.69	700	Yes
5/2/12	1140.08	1243.44	700	Yes
5/3/12	1083.96	1238.80	700	Yes
5/4/12	1058.54	1234.66	700	Yes
5/5/12	1090.79	1233.56	700	Yes
5/6/12	922.04	1226.44	700	Yes
5/7/12	759.96	1212.50	700	Yes
5/8/12	690.54	1196.07	700	Yes
5/9/12	643.54	1178.27	700	Yes
5/10/12	563.58	1158.89	700	Yes
5/11/12	488.88	1136.77	700	Yes
5/12/12	472.58	1111.79	700	Yes
5/13/12	448.04	1085.18	700	Yes
5/14/12	409.67	1056.06	700	Yes
5/15/12	368	1024.15	700	Yes
5/16/12	340.46	990.50	700	Yes
5/17/12	336.92	956.40	700	Yes
5/18/12	343.42	922.18	700	Yes
5/19/12	392.08	889.54	700	Yes
5/20/12	422.88	857.68	700	Yes
5/21/12	483.42	829.71	700	Yes
5/22/12	471.96	803.79	700	Yes
5/23/12	471.92	780.56	700	Yes
5/24/12	491.58	758.22	700	Yes
5/25/12	541.29	735.54	700	Yes
5/26/12	572.58	712.60	700	Yes
5/27/12	602.63	689.29	700	No

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Date	Electrical Conductivity (µS/cm)	30-Day Running Average of Electrical Conductivity (µS/cm)	P-12 Salinity Objective (µS/cm)	Apparent Objective Exceedance (Yes/No)
5/28/12	655.79	667.02	700	No
5/29/12	643.38	645.46	700	No
5/30/12	635.29	624.79	700	No
5/31/12	628.29	605.80	700	No
6/1/12	681.29	590.51	700	No
6/2/12	725.29	578.55	700	No
6/3/12	770.58	568.96	700	No
6/4/12	778.92	558.56	700	No
6/5/12	742	552.56	700	No
6/6/12	626.5	548.11	700	No
6/7/12	613.42	545.54	700	No
6/8/12	673.96	546.55	700	No
6/9/12	698.42	551.05	700	No
6/10/12	705.86	558.28	700	No
6/11/12	748.79	567.49	700	No
6/12/12	772.88	578.32	700	No
6/13/12	776.75	590.55	700	No
6/14/12	783.04	604.39	700	No
6/15/12	786.58	619.26	700	No
6/16/12	768.71	633.65	700	No
6/17/12	738	646.80	700	No
6/18/12	716.21	657.61	700	No
6/19/12	684.04	666.31	700	No
6/20/12	656.5	672.08	700	No
6/21/12	630.21	677.36	700	No
6/22/12	597	681.53	700	No
6/23/12	584.42	684.62	700	No
6/24/12	573.29	685.69	700	No
6/25/12	580.42	685.95	700	No
6/26/12	533.13	683.63	700	No

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Date	Electrical Conductivity (µS/cm)	30-Day Running Average of Electrical Conductivity (µS/cm)	P-12 Salinity Objective (µS/cm)	Apparent Objective Exceedance (Yes/No)
6/27/12	517.78	679.03	700	No
6/28/12	515.79	674.78	700	No
6/29/12	515.67	670.79	700	No
6/30/12	512.25	666.92	700	No
7/1/12	516	661.41	700	No
7/2/12	507.79	654.16	700	No
7/3/12	497.22	645.05	700	No
7/4/12	565.46	637.94	700	No
7/5/12	590.54	632.89	700	No
7/6/12	618.83	632.63	700	No
7/7/12	658.54	634.14	700	No
7/8/12	677.67	634.26	700	No
7/9/12	655.67	632.83	700	No
7/10/12	701.5	632.69	700	No
7/11/12	764	633.20	700	No
7/12/12	761.38	632.81	700	No
7/13/12	741.13	631.63	700	No
7/14/12	769.29	631.17	700	No
7/15/12	807.42	631.86	700	No
7/16/12	774.21	632.05	700	No
7/17/12	744.13	632.25	700	No
7/18/12	761.33	633.75	700	No
7/19/12	763.88	636.42	700	No
7/20/12	765.46	640.05	700	No
7/21/12	775.75	644.90	700	No
7/22/12	772.54	650.75	700	No
7/23/12	751.58	656.32	700	No
7/24/12	740.71	661.90	700	No
7/25/12	766.79	668.11	700	No
7/26/12	790.08	676.68	700	No

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Date	Electrical Conductivity (µS/cm)	30-Day Running Average of Electrical Conductivity (µS/cm)	P-12 Salinity Objective (µS/cm)	Apparent Objective Exceedance (Yes/No)
7/27/12	798.46	686.04	700	No
7/28/12	793.04	695.28	700	No
7/29/12	791.13	704.46	700	Yes
7/30/12	758.17	712.66	700	Yes
7/31/12	724.54	719.61	700	Yes
8/1/12	724.13	726.82	700	Yes
8/2/12	736.08	734.78	700	Yes
8/3/12	736.21	740.47	700	Yes
8/4/12	732.25	745.20	700	Yes
8/5/12	734.54	749.05	700	Yes
8/6/12	757.96	752.37	700	Yes
8/7/12	795.63	756.30	700	Yes
8/8/12	830.54	762.13	700	Yes
8/9/12	840.96	766.78	700	Yes
8/10/12	790.83	767.67	700	Yes
8/11/12	741.96	767.02	700	Yes
8/12/12	735.04	766.82	700	Yes