PSSEP
Partnership for
Sound Science
in Environmental
Policy

June 25, 2014

National Marine Fisheries Service
Attention: Ryan Wulff
650 Capitol Mall, Suite 5-100
Sacramento, CA 95814

Submitted via email: BDCP.comments@noaa.gov

Subject: Comments on [November 2013] Draft BDCP and Supporting Draft EIR/EIS – Focus on Selenium Impacts

Dear Mr. Wulff:

These comments are submitted on behalf of the Partnership for Sound Science in Environmental Policy ("PSSEP") on the November 2013 Draft Bay Delta Conservation Plan ("BDCP") and the supporting Environmental Impact Report/Statement ("EIR/EIS") required under state and federal law. PSSEP is an association of municipal, industrial, and trade association entities in California whose members are regulated by the State and Regional Water Boards under their joint, Federal Clean Water Act and Porter-Cologne Water Quality Control Act authorities. Some of PSSEP's members and/or affiliates are located in the San Francisco Bay Area and will be directly affected by any actions taken pursuant to the BDCP. As such, PSSEP and its members are "interested parties" for purposes of the California Environmental Quality Act ("CEQA"), the National Environmental Protection Act ("NEPA") and the respective state and federal Endangered Species Acts ("ESAs").

We note at the outset that PSSEP takes no position on the desirability of the BDCP and/or the underlying "alternative water conveyance facilities" the BDCP is being developed to support. PSSEP's members simply desire to ensure that the final BDCP is both technically accurate and adequately ensures that known or reasonably foreseeable impacts that are likely to accrue as a result of BDCP will be formally recognized and fully mitigated under CEQA, NEPA and the Sacramento-San Joaquin Delta Reform Act of 2009 ("Delta Act"). In particular, PSSEP is concerned that the BDCP understates the potential additional selenium loading impacts to the Delta, and completely ignores the potential impacts these additional selenium loads will have to San Francisco Bay.

The BDCP is an elaborate and complex plan which purports to restore and protect the Sacramento-San Joaquin Delta ecosystem as part of an effort to secure future water deliveries from the Delta to state and federal water contractors *via* the Central Valley Project and State Water Project. The overall plan includes three new riverine water intakes located on the Sacramento River, in the northern Delta. A total of nine alternatives (with some sub-alternatives for a total of fifteen action alternatives) and the "no action" alternative were evaluated in the BDCP and the EIR/EIS. "Alternative 4" is the CEQA/NEPA preferred alternative, which would consist of a dual conveyance system of pipeline/tunnel and the new riverine water intakes that collectively provide export capacity of 9,000 cubic feet per second – or more than 6.5 million acre feet per year. Under Alternative 4, water would be conveyed from the north Delta to the south Delta through pipelines/tunnels and through surface channels.[1]

BDCP implementation project(s) would result in a massive amount of Sacramento River water being removed from the Delta, resulting in a substantial increase in flow from the San Joaquin River. As water flows from the San Joaquin River increase, so will a corresponding amount of increased selenium at elevated concentration levels flow into the Delta and thereafter into San Pablo and San Francisco Bays. As a result, due to known selenium behavior both as a required nutrient and as a toxicant at higher levels, there could be significant impacts on fish and other wildlife in San Pablo and San Francisco Bays. This phenomenon was recently explored by scientists studying the sources and fate of selenium loads affecting San Francisco Bay, wherein it was concluded that, "Manipulations to the Delta system, especially those that increase San Joaquin [River] flow into the bay, will also have selenium impacts to the bay that must be evaluated."[2]

PSSEP's comments will address both the BDCP and the EIR/EIS, as specifically indicated. A summary of our primary concerns, which are more fully described below, include:

- The EIR/EIS fails to consider the effects of BDCP Conservation Measures on San Francisco Bay.
- The BDCP and the EIR/EIS significantly underestimate additional selenium loads to the Delta associated with Preferred Alternative 4.
- The EIR/EIS relies on inappropriate regulatory standards for concluding "No Substantial Effects" associated with selenium load increases.
- The BDCP fails to provide adequate assurances for mitigation of known or reasonably foreseeable impacts to San Francisco and San Pablo Bays related to increased selenium loads.
- The BDCP implementation structure and process is inadequate and inappropriately devolves excessive authority to the Water Contractors in making decisions that will impact San Francisco Bay.
- The BDCP must include the State Water Resources Control Board and the Delta Watermaster within the governing and implementing agency hierarchy.
- The BDCP fails to comply with Delta Reform Act.

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[1] *See generally,* BDCP Plan, Executive Summary; *see also*, BDCP EIR/EIS, Ch. 2. (ICF, November 2013.)

[2] "*Modeling Fate, Transport, and Biological Uptake of Selenium in North San Francisco Bay*", L. Chen, Meseck, Roy, Grieb, and Baginska; Estuaries & Coasts, November 2012. (Copy provided as Attachment 1.)

1. The EIR/EIS fails to consider the effects of BDCP Conservation Measures on San Francisco Bay.

Chapter 8 of the EIR/EIS purports to analyze known and reasonably foreseeable environmental impacts associated with the BDCP and each of the Conservation Measures to be taken thereunder, all with a view toward supporting the "preferred" Alternative 4. According to the EIR/EIS, "[f]or the purposes of characterizing the existing water quality conditions and evaluating the consequences of implementing the BDCP alternatives on surface water quality, ***the affected environment is defined as anywhere an effect could occur***, which includes but is not necessarily limited to the statutory Delta, Suisun Bay and Marsh, and areas to the north and south of the Delta, which are defined in various parts of this chapter as Upstream of the Delta and the State Water Project/Central Valley Project Export Service Areas, as shown in Figure 1-4. When compared to the watershed boundaries, it is noted that the affected environment falls primarily within the Sacramento and San Joaquin River watersheds."[3] Yet aside from the statement that the EIR/EIS considered water quality impacts "anywhere an effect could occur," it is clear from the EIR/EIS itself that the affected area where water quality impacts were analyzed was artificially constricted.

An extracted copy of the map contained in the referenced Figure 1-4, showing the affected area wherein environmental impacts were analyzed under the EIR/EIS, is included herein as Attachment 2. This map very clearly demonstrates that the preparers of the BDCP and supporting EIR/EIS ***excluded*** San Francisco and San Pablo Bays from their effects analyses, which clearly violates CEQA and NEPA.[4]

In its highly critical assessment of the BDCP and the EIR/EIS, the Delta Independent Science Board ("DISB") noted one of its "major concerns" was that, "The analyses largely neglect the influences of downstream effects on San Francisco Bay…"[5] Further on the topic of the artificially restricted geographic scope of the EIR/EIS analyses, the DISB cautioned that, "the geographic scope of the DEIR/DEIS was defined to exclude San Pablo Bay and San Francisco Bay. The consequences of BDCP actions undertaken within the Plan Area, however, ***will extend downstream to affect these bays.*** Changes in sedimentation in the Delta associated with BDCP actions, for example, will not be confined to the Delta."[6] As noted by the DISB, San Pablo and San Francisco Bays were excluded from consideration in the EIR/EIS simply because they fall outside of the legal boundaries of

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[3] BDCP EIR/EIS, Sec. 8.2.1 at page 8-6. (Emphasis added.)

[4] CEQA requires a state lead agency to provide specific reasons why certain environmental effects "have not been discussed in detail in the environmental impact report." (California Public Resources Code §21100(c).)

[5] Delta Independent Science Board, "Review of the Draft EIR/EIS for the Bay Delta Conservation Plan," May 15, 2014, page 3. (hereafter, "DISM Review").

[6] DISB Review, page 7. (Emphasis added.)

the Delta.[7] The artificial determination of the BDCP "affected area" is neither legally supportable nor, according to the DISB, "scientifically justified."[8]

By its very terms, and as specifically set forth in Chapter 8, the EIR/EIS cannot meet the legal adequacy requirements of CEQA and NEPA because the effects analysis is artificially restricted, and the EIR/EIS fails to provide a "reasonable explanation for the geographic limitation used."[9] Indeed, the EIR/EIS preparers chose to include "upstream of the Delta (including the Sacramento and San Joaquin River watersheds)"[10] or – alternatively - the "Sacramento hydrologic region,"[11] yet somehow concluded that the water quality and water supply impacts downstream of the BDCP project were unimportant.[12]

2. The BDCP and the EIR/EIS significantly underestimate additional selenium loads to the Delta associated with Preferred Alternative 4.

Chapter 8 of the EIR/EIS analyzes various "factors affecting water quality" in the Delta and essentially *brushes aside* the well-known and well-documented selenium loading that comes from the San Joaquin and Sacramento Rivers. Concurrently, the authors of the EIR/EIS suggest that the Bay Area refineries are responsible for considerable selenium loading to Suisun Bay and the Delta - - without any empirical data or evidence to support this claim.[13] These multiple references to the Bay Area refineries and the quality of their respective effluents to North San Francisco Bay should be completely eliminated, unless

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[7] DISB Review, page 8.

[8] DISB Review, page 8.

[9] *See,* CEQA Guidelines §15130(b)(1)(B)(3), which provides that: "Lead Agencies should define the geographic scope of the area affected by the cumulative effects and provide a reasonable explanation for the geographic limitation used." Further, when considering potentially significant impacts on the affected "environment," it is worth noting that CEQA defines "environment" to mean, "the physical conditions that exist within the area which will be affected by a proposed project, including land, air, water, minerals, flora, fauna, noise or objects of historic or aesthetic significance." (California Public Resources Code §21060.5.)

[10] BDCP EIR/EIS, Section 8.1.5 at page 8-3.

[11] BDCP EIR/EIS, Section 6.1 at page 6-1. Under the Delta Reform Act, the Sacramento Hydrologic Region is defined by reference to the Department of Water Resources' "Bulletin 160-05," commonly known as the "California Water Plan." In turn, the California Water Plan describes the Sacramento Hydrologic Region as: "The entire drainage area of the state's largest river and its tributaries, extending from the Oregon border downstream to the Sacramento – San Joaquin Delta. The region covers 27,246 square miles including all or a portion of 20 predominately rural Northern California counties, and extends from the crest of the Sierra Nevada in the east to the summit of the Coast Range in the west." According to the Water Plan, "The population of the Sacramento River Hydrologic Region was 2,593,000 in 2000, which represents about 8 percent of California's total population." (California Water Plan, (Bulletin 160-05), Ch. 6 pages 6.1-6.2.)

[12] For comparison, the surface area of the entire San Francisco Bay is approximately 1,100 square miles, or roughly 4% of the 27,246 square miles that comprise the Sacramento Hydrologic Region. (*See*, Water Quality Control Plan for the San Francisco Bay Basin, Ch. 1 (2013).)

[13] *See, e.g.,* BDCP EIR/EIS, Sec. 8.4.3 at pages 8-286, 8-347, 8-401, 8-477, 8-535, 8-587, 8-642, 8-694, 8-747.

they are re-cast to be both factually and contextually accurate and the BDCP flow impacts are appropriately modeled. Indeed, the most current understanding of selenium loading to San Francisco Bay has been compiled by the San Francisco Regional Board in developing its North San Francisco Bay TMDL for Selenium. That data shows the ***overwhelming*** percentage of selenium load to the Bay comes from the Delta.[14]

The underlying conclusions of the EIR/EIS – that development of the BDCP preferred Alternative 4 conveyance facilities "would result in essentially no change in selenium concentrations throughout the Delta"[15] - - is false. According to a recent TetraTech analysis of the EIR/EIS assessment of selenium loading and impacts related to the BDCP project, "[s]elenium concentrations used in the Sacramento River for the BDCP EIR/EIS study are biased high."[16] This analysis determined that the EIR/EIS preparers ***excluded*** recent selenium water concentration data from the Freeport and Vernalis gauge stations maintained by USGS, and used older data based on high "non-detect" values, which artificially inflated the current calculated values of water column selenium by more than a factor of two.[17] When valid boundary values for the Sacramento and San Joaquin Rivers are input into the *same modeling framework* used by the BDCP preparers, TetraTech found the following:

> "The model analysis shows that the BDCP-preferred Alternative 4 will result in higher percent changes in water column concentrations than that calculated in the EIR/EIS. Using the bioaccumulation model in the EIR/EIS, we find a similar projected increase in fish tissue concentrations between Alternative 4 and existing conditions (i.e., no BDCP project). Importantly, ***the new calculations suggest that there is an effect of the BDCP changes to the water column and white sturgeon selenium concentrations at the Mallard Island station for CEQA Alternative 4***, representing conditions in Suisun Bay (8-20% increase, depending on the hydrology). This is higher than currently estimated for Alternative 4 at this station (2-5% increase, calculated by Tetra Tech)…"[18]

In essence, the BDCP reviewers ***<u>underestimated</u>*** the anticipated increase in selenium loading that will be caused by construction and operation of the preferred Alternative 4 conveyance facilities by an average of approximately 15% for any given hydrology year. Not only must the BDCP Lead Agencies re-evaluate the selenium-related water quality effects based on the results of the TetraTech Selenium Review, but adequate

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[14] *See,* Technical Memorandum 2: North San Francisco Bay Selenium Data Summary and Source Analysis, July 2008, TetraTech, Inc.

[15] BDCP EIR/EIS, Sec. 8.4.3.9 at page 8-474.

[16] "Review of Selenium Bioaccumulation Assessment in the Bay Delta Conservation Program Draft EIR/EIS," TetraTech, May 30, 2014. (Hereafter, "TetraTech Selenium Review.") (Copy provided in <u>Attachment 3</u>.)

[17] TetraTech Selenium Review, page 5-1.

[18] TetraTech Selenium Review, page 1-2. (Emphasis added.)

resources must be allocated for future water column and fish tissue monitoring throughout the term of the BDCP permits. In addition, mitigation for these impacts must be provided by the BDCP beneficiaries as part of their CEQA and NEPA obligations,[19] as well as under the Delta Reform Act of 2009. (*See* discussion in Section 4, below.)

3. The EIR/EIS relies on inappropriate regulatory standards for concluding "No Substantial Effects" associated with selenium load increases.

Under the "Effects Determinations" analysis contained in Section 8.4.3, the BDCP preparers concluded that there would be "no substantial effects" related to selenium associated with the BDCP project. In part, this conclusion is based on a water quality criteria established under the California Toxics Rule for San Francisco and Suisun Bays in 2000.[20] Yet, the EIR/EIS acknowledges that US EPA Region IX is currently developing a new water quality criterion for selenium in San Francisco and San Pablo Bays, and further concedes that the anticipated new selenium criterion is likely to be far lower than current fresh and marine waters criteria.[21] Nevertheless, because the BDCP preparers concluded that only the *existing* selenium water quality criteria applies for purposes of determining substantial effects related to the BDCP project, the anticipated US EPA criteria is ignored.

CEQA requires a lead agency to analyze all reasonably foreseeable, significant effects on the environment.[22] "Significant effect on the environment" is defined under CEQA to mean, "a substantial, or potentially substantial, adverse change in the environment."[23] As discussed above, the BDCP preferred Alternative 4 is reasonably likely to result in ***increased selenium loads*** to San Francisco and San Pablo Bays at a range of between 8-20% every year, depending on hydrological conditions.[24] These anticipated increases in selenium load to San Francisco and San Pablo Bays are clearly significant, and the BDCP must both consider these effects on the downstream environment, as well as provide adequate mitigation for them. Furthermore, the EIR/EIS must analyze these expected selenium load increases in the context of US EPA's anticipated new selenium criteria for San Francisco Bay which, as the EIR/EIS preparers are well aware, is likely to be *substantially lower* than the current criteria used by the preparers.

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[19] An adequate EIR must respond to specific suggestions for mitigating significant environmental impacts unless the suggested mitigation is facially infeasible. *See, San Francisco Ecology Center v. City and County of San Francisco* (1975) 48 Cal.App.3d 584, 596.

[20] BDCP EIR/EIS, Sec. 8.4.2.3, page 8-96 – 8-97. *See,* Water Quality Standards; Establishment of Numeric Criteria for Priority Toxic Pollutants for the State of California. 65 Fed.Reg. 31682.

[21] BDCP EIR/EIS, Sec. 8.4.2.3, page 8-99 – 8-100.

[22] California Public Resources Code §21065. A "project" subject to CEQA review means "means an activity which may cause either a direct physical change in the environment, or a reasonably foreseeable indirect physical change in the environment." (*Ibid.*)

[23] California Public Resources Code §21068. *See also*, CEQA Guidelines §15382.

[24] *See*, Section 2 above, at pages 4-5.

4. *The BDCP fails to provide adequate assurances for mitigation of known or reasonably foreseeable impacts to San Francisco and San Pablo Bays related to increased selenium loads.*

The federal and state Endangered Species Acts require that a Habitat Conservation Plan (HCP) contain specific information to ensure adequate funding to carry out all aspects of the HCP.[25] Case law interpreting the Federal Endangered Species Act on the need for ensuring adequate HCP funding has further held that the permit "applicant cannot rely on speculative future actions of others."[26] Yet, the BDCP specifically refers to and relies upon putative funding derived from a Water Bond that has yet to be placed before the voters, let alone actually passed. This clearly cannot satisfy the requirements of the federal and state Endangered Species Acts, as interpreted by case law applicable to California.

Moreover, the Delta Reform Act of 2009 specifically provides that proponents of a new Delta water conveyance facility must pay to mitigate all impacts associated with the construction, operation, and maintenance of such facility.[27] There is nothing in the BDCP which accounts for mitigation related to increased selenium loads that will occur with the construction and operation of the preferred Alternative 4 water conveyance facilities. This is because, as discussed above, the EIR/EIS preparers specifically excluded analysis of selenium loading to San Francisco and San Pablo Bays.[28]

According to Section 8.3, the BDCP will rely on three, primary, sources of funding for all aspects of the Plan: (1) federal government funding; (2) state government funding (including putative funding provided by future water bonds to be placed before the California voters); and (3) the State and Federal Water Contractors (including, for purposes of municipal water supply districts, individual ratepayers). Yet, the BDCP contains no financing plan and no legal assurances that any of the funds "expected" will actually materialize. An analysis of the sources of funds from reveals that it cannot meet the "speculative future actions" test of ensuring HCP funding.

According to Table 8-37 in Chapter 8,[29] the BDCP expects to receive $3.5 billion from the federal government, derived from various appropriations. However, the BDCP

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[25] *See*, 16 U.S.C. §§1539(a)(2)(A)(ii) and 1539(a)(2)(B)(iii); California Fish & Game Code §2820(a)(10). *See also*, *Nat'l Wildlife Federation v. Babbit*, 128 F.Supp.2d 1274 (E.D. Cal., 2000); *Southwest Center for Biological Diversity v. Bartel*, 470 F.Supp.2d 1118 (S.D. Cal., 2006).

[26] *Southwest Center for Biological Diversity v. Bartel*, *supra*, 470 F.Supp.2d 1118, 1155, citing, *Nat'l Wildlife Federation v. Babbit*, *supra*, 128 F.Supp. 2d 1274, 1294-95.

[27] California Water Code §85089(a).

[28] It bears noting that the mitigation obligations of the BDCP proponents under Water Code §85089(a) is not limited to those identified and included under CEQA, but are in fact ***in addition*** to any CEQA mitigation obligations. Under that section, the State and Federal Water Contractors must pay for "[t]he costs of the environmental review, planning, design, construction, and mitigation, ***including mitigation required pursuant to [CEQA]***, required for the construction, operation, and maintenance of any new Delta water conveyance facility." (Emphasis added.)

[29] BDCP, Ch. 8, page 8-65 – 8-66.

acknowledges that "additional federal legislation will be required to authorize the continued use of certain federal funds and to extend or broaden fund availability."[30] In terms of securing funding for BDCP implementation, it is hard to imagine anything more speculative than relying on future acts of Congress to make-up what is expected to be approximately 14% of the entire BDCP budget.

Regarding the sources of state government funds for BDCP implementation, Table 8-37 indicates that BDCP proponents expect approximately $4.1 billion to come from the State of California, which accounts for approximately 17% of the entire BDCP budget. Section 8.3.5 of the BDCP provides that, "Funds derived from the issuance of [the 2009 Water Bond] would be used, in part, to satisfy the State's financial commitments to the BDCP."[31]

According to the capital cost estimates for the entire BDCP project, the Authorized Entities are relying on the not-yet passed Water Bond for approximately 10% of the entire BDCP budget.[32] Furthermore, Table 8-37 indicates that BDCP proponents assume the passage of a "Second Water Bond" at some unstated time in the future that will provide an additional $2.2 billion dollars to fund BDCP actions.[33] All totaled, the BDCP proponents expect the voters of California to pass future water bonds in the amount of $3.75 billion to fund BDCP actions – an amount approximately equal to 25% of the entire BDCP budget.

The remaining BDCP budget ($17 billion) is expected to be funded by the State and Federal Water Contractors, according to Table 8-37. Yet a review of Section 8.3.4.4 reveals that even this source of funds is speculative. According to that section, "[t]he most credible assurances of funding from the participating state and federal water contractors result from an economic benefits analysis…" and two primary conclusions derived from the economic analysis that: (1) the costs are affordable by the ratepayers, and (2) the benefits to be gained from the BDCP exceed the total cost.[34] What is missing from these "assurances" is any discussion of whether the State and Federal Water Contractors and their ratepayers would be willing to pay ***additional*** billions of dollars in the event that state water bond funding and/or federal appropriations do not materialize. Moreover, the analysis fails to assess the potential impacts of one (or more) State or Federal Water Contractors, or their member agencies, withdraw or refuse to continue to participate in the Plan. Finally, the BDCP analysis mistakenly assumes benefits based on expected water deliveries from the newly-constructed conveyance facilities that fails to account for the possibility of reduced Delta water exports as a result of the State Water Board's future Delta flow

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[30] BDCP, Sec. 8.3.1, page 8-64, lines 16-18.

[31] BDCP, Sec. 8.3.5.1, page 8-84, lines 9-11.

[32] *See*, Table 8-35 (Ch. 8, page 8-63) and Table 8-46 (Ch. 8, page 8-85).

[33] BDCP proponents expect this "Second Water Bond" to be passed by the voters of California approximately 15 years into the permit term. (BDCP, Sec. 8.3.5.1, page 8-85, lines 3-6.)

[34] BDCP, Sec. 8.3.4.4, page 8-81, lines 5-22.

standards; a major regulatory action that will likely not be taken until after the BDCP is approved under the current time-schedule.[35]

All of these issues, whether taken together or individually, raise serious questions about the long-term financial assurances required under federal and state law for an approvable HCP/NCCP.

5. The BDCP implementation structure and process is inadequate and inappropriately devolves excessive authority to the Water Contractors in making decisions that will impact San Francisco Bay.

The very nature of the permits to be granted under the BDCP underscores the importance of long-term, substantive input of "downstream" stakeholders into the future implementation of the BDCP itself. Indeed, the permits to be issued by the federal and state agencies to those in the Authorized Entity Group will last for 50 years. Further, under the "No Surprises Rule," the permittees cannot be held responsible for continued species decline. According to the No Surprises Rule:

> "Once an HCP permit has been issued and its terms and conditions are being fully complied with, the permittee may remain secure regarding the agreed upon cost of conservation and mitigation. If the status of a species addressed under an HCP unexpectedly worsens because of unforeseen circumstances, the primary obligation for implementing additional conservation measures would be the responsibility of the Federal government, other government agencies, and other non-Federal landowners who have not yet developed an HCP."[36]

As a result, the process of "who" and "how" changed circumstances are identified, as well as what future "adaptive management" actions should be taken to address them, is vitally important to interests located, living, or working in or downstream of the Delta region. Further, what is deemed to be "unforeseen circumstances" is equally important to downstream stakeholders because, under the "No Surprises Rule," responsibility for addressing future Delta decline due to "unforeseen circumstances" will likely fall on those Delta or downstream stakeholders, or on the People of the State of California.

PSSEP requests the Lead Agencies to address the following examples of the BDCP's inadequate implementation structure:

- *Section 6.4.2.1: Process to Identify Changed Circumstances*. Under the BDCP, the Implementation Office or the Permit Oversight Group "may identify the onset of a

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[35] *See*, "*The High Price of Water Supply Reliability: California's Bay Delta Conservation Plan Would Require Significant Investment*," S&P Capital IQ, McGraw-Hill Financial, February 13, 2014.

[36] *See,* 50 C.F.R. Part 222; *see also*, 63 Federal Register 8867 (February 23, 1998).

changed circumstance, using information obtained from system-wide or effectiveness monitoring, scientific study, or information provided by other sources."[37] Glaringly absent from this process of identifying "changed circumstances" (which, in turn, requires the Authorized Entities Group to make changes to applicable Conservation Measures identified in the BDCP) is any substantive role for the State Water Resources Control Board and the Delta Watermaster. Each of these independent state agency/offices have very important and discreet roles with regard to policies, regulations, permits, and other actions affecting the Delta, and they should both be given more substantive roles during the 50-year, "No Surprises" permit that the Authorized Entity Group will receive.

- *Section 6.4.2.2: Changed Circumstances Related to the BDCP*. This section summarizes nine identified categories of "changed circumstances related to the BDCP," including: levee failures, flooding, new species listing, drought, wildfire, toxic or hazardous spills, nonnative invasive species or disease, climate change, and vandalism.[38] Specifically absent from these nine "anticipated" changed circumstances are non-ESA and CESA regulatory changes, changes to the "Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary" (Bay-Delta Plan), and even water availability decline, except as superficially treated in the "Drought" section.

It is unfathomable to think that changes to the Bay-Delta Plan by the State Water Board are not "reasonably anticipated" by the Authorized Entity Group and the Permit Oversight Group. Indeed, the State Water Board has been working on planned amendments to the Bay-Delta Plan for at least the past eight years to address various issues and known stressors to the Delta ecosystem. According to the State Water Board website:

> "The State Water Board is in the process of developing and implementing updates to the Bay-Delta Water Quality Control Plan (Bay-Delta Plan) and flow objectives for priority tributaries to the Delta to protect beneficial uses in the Bay-Delta watershed. Phase 1 of this work involves updating San Joaquin River flow and southern Delta water quality requirements included in the Bay-Delta Plan. Phase 2 involves other comprehensive changes to the Bay-Delta Plan to protect beneficial uses not addressed in Phase 1. Phase 3 involves changes to water rights and other measures to implement changes to the Bay-Delta Plan from Phases 1 and 2. Phase 4 involves developing and implementing flow objectives for priority Delta tributaries outside of the Bay-Delta Plan updates."[39]

Many dozens of entities that are members of the State Water Contractors or the Federal Water Contractors (and thus part of the Authorized Entities under BDCP) have participated in or been represented at public workshops, hearings, and State Water Board meetings regarding various elements of the Bay-Delta Plan revisions. They, more than

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[37] BDCP, Ch. 6, page 6-31, lines 24-25.

[38] BDCP, Sec. 6.4.2.2, pages 6-32 through 6-45.

[39] http://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/

most, are intimately aware of the work that the State Water Board is doing on the Bay-Delta Plan revisions, and they should be able to "reasonably anticipate" changes that will likely affect salinity limits, flow standards, and potential water rights changes.

- *Section 6.4.3. Unforeseen Circumstances:* "Unforeseen circumstances" are defined in the BDCP as "those changes in circumstances that affect a species or geographic area covered by an HCP that could not reasonably have been anticipated by the plan participants during the development of the conservation plan, and that result in a substantial and adverse change in the status of a covered species."[40] The significance of whether changed circumstances affecting Delta species or the geographic area covered by the BDCP are deemed to be "unforeseen" is that the Permit Oversight Group "may not require the commitment of additional land or financial compensation, or additional restrictions on the use of land, water, or other natural resources other than those agreed to in the plan, unless the Authorized Entities consent."[41] Stated alternatively, if any "unforeseen circumstances" arise and require additional commitments of land or water to enhance species survival, none of the Authorized Entities would be required to pay for it. As such, individuals and entities located, living or working in, or downstream of the Delta will likely be left holding the bag.

- *Section 6.4.4. BDCP Relationship to Significant Future Projects or Government Regulations:* Section 6.4.4 acknowledges that the State Water Board is developing new Delta flow standards which will likely affect the Delta, but then oddly concludes that such action "may affect the conservation strategy [of the BDCP] in ways that cannot be predicted."[42] Given all of the various models run on expected salinity levels, mercury loading, temperature variation, selenium loading and expected climate change impacts to BDCP Conservation Measures, it seems dubious – at best – to conclude that impacts associated with anticipated Delta flow standards "cannot be predicted." Indeed, the Authorized Entities are certainly aware of the State Water Board's August 3, 2010 report, "Development of Flow Criteria for the Sacramento-San Joaquin Delta Ecosystem," wherein various potential reductions in allowable water exports from the Delta were analyzed and recommended. Certainly, the BDCP could easily (and thus, should) include various modeling scenarios to account for reduced water exports equal to 20, 30, 40 or 50 percent, and develop appropriate Conservation Measures to account for these potentialities.

- *Section 6.5. Changes to the Plan or Permits*: Section 6.5 describes the processes that are to be followed to change the BDCP or permits issued thereunder. These changes are referred to as "administrative changes," "minor modifications or revisions," and "formal amendments" to the BDCP. "Minor modifications or revisions" are further defined to include, without limitation, "Adaptive management changes to conservation measures or biological objectives, including actions to avoid, minimize, and mitigate impacts, or modifications to habitat management strategies developed through and consistent with the adaptive management and monitoring program described in Chapter 3, Conservation

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[40] BDCP, Sec. 6.4.3, page 6-45, lines 15-22.

[41] BDCP, Ch. 6.4.3, page 6-45, lines 20-22.

[42] BDCP, Sec. 6.4.4, page 6-46, lines 21-25.

Strategy."[43] Read in conjunction with Section 3.6, relative to changing Conservation Measures or biological objectives under the adaptive management process, it is clear that the Authorized Entities have no intention of re-submitting substantive BDCP changes to the Delta Stewardship Council for Delta Plan concurrence.

Under the Sacramento-San Joaquin Delta Reform Act of 2009, the Legislature created the Delta Stewardship Council, an independent agency of the state charged with developing an over-arching "Delta Plan" to implement the "co-equal goals" of providing a more reliable water supply for California and protecting, restoring, and enhancing the Delta ecosystem. There is little question that the 2009 Delta Legislation envisioned a significant role for the Delta Stewardship Council as the BDCP was being developed and during its implementation. In fact, the 2009 Delta Legislation provides that the BDCP can be "considered" for inclusion within the Delta Plan, but specifically prohibits inclusion of the BDCP into the Delta Plan unless the Council finds that the BDCP meets nine, legislatively-established conditions. Some of these conditions relate to obligations under the Natural Community Conservation Planning Act, which in turn, include the development and implementation of Conservation Measures intended to restore the imperiled Delta ecosystem. However, there is no provision within BDCP that requires any substantive changes to the Plan to be re-submitted to the Delta Stewardship Council for confirmation that it is consistent with the Delta Plan, and thereafter re-incorporated within the Delta Plan.

6. The BDCP should include the State Water Resources Control Board and the Delta Watermaster within the governing and implementing agency hierarchy.

As currently contemplated, the BDCP provides no formal role for either the State Water Board or the Delta Watermaster in any substantive governance or oversight entity. Yet, as previously noted, the State Water Board will be setting new Delta flow standards in the coming few years, and will be responsible for ongoing regulatory actions (*e.g.,* revised flow standards in the future, water quality plan for the Delta, water rights permitting and enforcement) which are likely to affect BDCP actions over the course of the 50-year permit expected to be issued for the Project. Similarly, the Delta Watermaster – created by the Delta Reform Act – has important authority to enforce the State Water Board's regulatory decisions affecting the Delta, and should also be part of any BDCP oversight entity.

In essence, the governance structure of BDCP is being created by water exporter interests, gives decision making authority to water exporter interests, and grants dispute resolution authority to water exporter interests. There must be a more balanced approach to governance that does not exclude local authorities. Furthermore, for governance actions that could affect interests of stakeholders in San Francisco and San Pablo Bays, there

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[43] BDCP, Sec. 6.5.2, page 6-49, lines 8-11.

needs to be a mechanism to allow these stakeholders' interests to be more substantively represented in the BDCP decision-making process.[44]

7. The BDCP fails to comply with the Delta Reform Act of 2009.

The Delta Reform Act provides that the BDCP will not be incorporated into the Delta Stewardship Council's "Delta Plan" if it does not meet specific minimum requirements.[45] The EIR/EIS fails to adequately address specific requirements of the Delta Reform Act in the following major areas:

- The EIR/EIS is to provide a comprehensive analysis of a reasonable range of flow criteria, rates of diversion, and other operational criteria. This range is to include flows necessary for recovering the Delta and restoring fisheries under a reasonable range of hydrologic conditions. This range is to include the flow criteria developed by the SWRCB in August 2010 which identified flow conditions and operational requirements to provide fishery protection under the existing Delta configuration.

- Using the above information, the EIR/EIS is to identify the remaining water available for export and other beneficial uses.

- As discussed above, the Delta Reform Act prohibits construction of a new Delta conveyance facility until arrangements have been made to pay for the cost of mitigation required for construction, operation and maintenance of any new Delta conveyance facility.[46] Accordingly, the mitigation measures need to be clearly specified and linkages to impacts of the proposed project should be plainly identified so that the financial obligations are apparent.

The EIR/EIS either fails to include or fails to clearly address these major requirements of the Delta Reform Act. Therefore, the BDCP cannot be incorporated into the Delta Plan unless these flaws are remedied.

Additionally, the Delta Plan requires that actions be taken to reduce reliance on the Delta as a water supply. CEQA requires that the EIR/EIS give proper consideration to measures that would reduce reliance on the Delta, including improved water use efficiency, increased storage, and local water supply projects (e.g. desalination). These measures

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[44] Indeed, a review of the various NCCPs adopted and in the planning stages throughout California reveal that the vast majority of these plans are either lead by or include affected county and local governments or special districts within their governance structure. (*See*, https://www.dfg.ca.gov/habcon/nccp/status/index.html.) If adopted, the BDCP would be unusual in California in that it would enable parties not located within the affected geographical area of the NCCP to literally control most (if not all) of the day-to-day operations and decision-making relative to the NCCP.

[45] California Water Code Section 85320(b).

[46] California Water Code §85089(a).

should be addressed either as an alternative to the proposed plan or as proposed mitigation measures to address significant impacts of the proposed project. The EIR/EIS fails to consider or properly address these measures as alternatives to the proposed project.

In sum, PSSEP maintains the BDCP and the supporting EIR/EIS are seriously flawed with respect to potential long-term impacts related to selenium loading to San Francisco and San Pablo Bays. Our members respectfully request that these flaws be corrected, and that adequate financial commitments are made by the BDCP proponents to carry out adequate long-term monitoring of future selenium loading to San Francisco and San Pablo Bays that are directly or indirectly attributable to BDCP actions. Further, we request that the BDCP proponents provide adequate financial assurances that future "adaptive management" actions will be taken to address the impacts of expected selenium loading of San Francisco and San Pablo Bays which, we believe, a robust Bay-Delta selenium monitoring program will confirm.

Sincerely,

Craig S.J. Johns

Craig S.J. Johns
Program Manager

Attachments Included:

1. "Modeling Fate, Transport, and Biological Uptake of Selenium in North San Francisco Bay", L. Chen, Meseck, Roy, Grieb, and Baginska; Estuaries & Coasts, November 2012.
2. BDCP EIR/EIS, Ch. 1, Figure 1-4. (ICF, November 2013)
3. "Review of Selenium Bioaccumulation Assessment in the Bay Delta Conservation Program Draft EIR/EIS," TetraTech, May 30, 2014.

Estuaries and Coasts
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Modeling Fate, Transport, and Biological Uptake of Selenium in North San Francisco Bay

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Abstract Selenium behavior in North San Francisco Bay, the largest estuary on the US Pacific coast, is simulated using a numerical model. This work builds upon a previously published application for simulating selenium in the bay and considers point and non-point sources, transport and mixing of selenium, transformations between different species of selenium, and biological uptake by phytoplankton, bivalves, and higher organisms. An evaluation of the calibrated model suggests that it is able to represent salinity, suspended material, and chlorophyll *a* under different flow conditions beyond the calibration period, through comparison against long-term data, and the distribution of different species of dissolved and particulate selenium. Model-calculated selenium concentrations in bivalves compared well to a long-term dataset, capturing the annual and seasonal variations over a 15-year period. In particular, the observed lower bivalve concentrations in the wet flow periods, corresponding to lower average particulate selenium concentrations in the bay, are well represented by the model, demonstrating the role of loading and hydrology in affecting clam concentrations. Simulated selenium concentrations in higher organisms including white sturgeon and greater scaup also compared well to the observed data in the bay. Finally, a simulation of changing riverine inflows into the bay that might occur as a consequence of proposed hydrologic modifications indicated significant increases in dissolved and particulate selenium concentrations in the bay. The modeling framework allows an examination of the relationship between selenium loads, variations in inflow, in-bay concentrations, and biota concentrations to support management for limiting wildlife impacts.

Keywords Bioaccumulation · Selenium speciation · TMDL · Estuarine modeling · ECoS

Introduction

Selenium is a limiting nutrient to aquatic organisms at low concentrations; however, it becomes toxic when concentrations are elevated (Harrison et al. 1988; Lauchli 1993; Lemly 1996). The element is toxic to fish and birds due to its adverse impacts on the reproductive system (Lemly 1985; Presser and Luoma 2006). Selenium can substitute for sulfur in the structure of proteins and therefore causes deformities in embryos or inhibition of the hatchability of eggs (Skorupa 1998). Under the Clean Water Act of the USA, North San Francisco Bay (NSFB) is listed as being impaired for selenium, due to high concentrations observed in fish tissues (particularly in white sturgeon, *Acipenser transmontanus*, up to 50 μg/g dry weight) and diving ducks (such as greater scaup, *Aythya marila* up to 35 μg/g dry weight in muscle tissues) (White et al. 1988, 1989; Urquhart et al. 1991; SFEI 2006). NSFB is an important water body for the study of selenium biogeochemistry and ecotoxicology, because it is the largest estuary on the Pacific coast of

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the USA and receives significant selenium loadings from sources that are directly related to human activity: it is downstream of irrigated selenium-bearing soils of the semi-arid San Joaquin Valley (representing 7 % of total US agricultural production and four of the top five agriculturally productive counties in the US), and it receives selenium discharged from five major oil refineries (which together constitute 5.6 % of the total refining capacity of the USA; based on data from the US Census of Agriculture 2007; California Energy Commission 2012). Selenium has been a contaminant of interest in this region since the discovery of deformed waterfowl in the Kesterson Wildlife Refuge in San Joaquin Valley, which received most of its water from agricultural drainage (Ohlendorf et al. 1988).

Selenium is present in the aquatic environment in several different forms (Cutter 1992). Dissolved forms of selenium include inorganic selenite (SeO_3^{2-}+$HSeO_3^{-}$), selenate (SeO_4^{2-}), and organic selenides. The particulate forms include elemental selenium, organic selenides, and selenite and selenate adsorbed on particles. Selenium in biogenic particles is principally composed of organic selenide (Cutter and Bruland 1984) with each species being subject to different transformations and biological uptake (Suzuki et al. 1979; Measures et al. 1980; Cutter and Bruland 1984). Particulate organic selenides can decompose and release dissolved organic selenides at relatively fast rates (>0.2/day, Cutter 1982). Organic selenides can be oxidized to selenite and further to selenate and this has been described using pseudo-first-order reactions (Cutter and Bruland 1984). The oxidation of organic selenides to selenite can occur on the order of days, while oxidation from selenite to selenate can take years (Cutter 1992; Meseck and Cutter 2006).

Dissolved forms of selenium can be taken up by phytoplankton and bacterioplankton communities. The uptake of dissolved selenium by these organisms is a key step in selenium entering the food web (Luoma et al. 1992; Wang et al. 1996). The bioavailability of dissolved selenium differs by chemical form, with selenite and organic selenides being taken up more rapidly than selenate (Riedel et al. 1996). Despite low selenium concentrations in the water column, certain species of phytoplankton can concentrate selenium to relatively high concentrations (Baines and Fisher 2001; Doblin et al. 2006). Organic selenides in cells can be released into the environment through excretion, cell lysis, or grazing (Cutter 1982).

The uptake of selenium by invertebrates is mainly through the ingestion of particulates (Luoma et al. 1992; Sanders and Gilmour 1994; Wang and Fisher 1996), especially particulate organic selenides which are more easily assimilated by invertebrates. Measured assimilation efficiencies for elemental selenium range from 2 to 28 % (Schlekat et al. 2000), while assimilation efficiencies for organic selenium range from 53 to 89 % (Schlekat et al. 2002). As with phytoplankton, the accumulation of particulate selenium in invertebrates and zooplankton differs by species. Certain species of invertebrates (e.g., the clam *Corbula amurensis* that is abundant in NSFB) are able to accumulate selenium to relatively high concentrations due to high food ingestion rates and slow excretion (Stewart et al. 2004), resulting in relatively high selenium concentrations in the benthic food web.

Sources of selenium to the NSFB include riverine inputs from the Sacramento and San Joaquin Rivers, tributaries surrounding the NSFB, discharge from refineries, and municipal and industrial wastewater treatment plant discharges. The NSFB water column is characterized by low selenium concentrations (~0.2 μg/L); however, bioaccumulation by *C. amurensis*, may be a pathway leading to high selenium in certain benthic-feeding fish and birds.

The San Francisco Bay Regional Water Quality Control Board is in the process of developing a selenium total maximum daily load (TMDL) for NSFB to address this impairment. Under the Clean Water Act, a TMDL is required when a water body is listed as impaired due to one or more contaminants and sets in motion a process to manage and control the impairment. To effectively address impairment, TMDLs need tools, often in the form of numerical models, to represent the linkage between sources of contamination and biological endpoints, including concentrations in the tissues of target organisms. The objective of the present study is to develop a model representing the transport, fate, and uptake of selenium in the benthic food web of NSFB, focusing on phytoplankton, clams, and fish and bird species that consume these clams. The model is calibrated using the best available data on hydrology, selenium loading from the major rivers, petroleum refineries, municipal wastewater treatment plants, and other industrial sources and selenium speciation in different compartments as reported in monitoring programs and the scientific literature over the last two decades.

The modeling framework builds on a previous study of selenium biogeochemistry in NSFB (Meseck and Cutter 2006), developed using an estuary modeling framework (ECoS3) (Harris and Gorley 1998). The previous study was modified for the TMDL by: (1) using more recent selenium loads from five major refineries and principal riverine sources, Sacramento and San Joaquin Rivers, (2) adding selenium loads from smaller, local tributaries, and all municipal and industrial dischargers with discharge permits; (3) modification of the model to consider particulate selenium, total suspended material (TSM), and phytoplankton inputs from the San Joaquin River; (4) changing the riverine boundary conditions of TSM, chlorophyll *a* and different species of particulate selenium to time-varying inputs; and (5) expanding the model to simulate selenium concentrations in biota (clams, fish, and diving ducks). The final change is especially important because the impairment in NSFB is driven by concentrations in biota. The above changes necessitated a recalibration and extension of the Meseck and Cutter (2006) model, as detailed in the following section while retaining the basic setup of the original work. The updated model was recalibrated for the 1999–2000 water years, and then used to simulate long-term selenium dynamics in NSFB for the period of 1999–2008. Through this development and integration process, the key research questions to be answered are: can we describe the speciation of selenium in the waters of NSFB under different flow and loading conditions, the changing seasonal and long-term concentrations of selenium in the clam *C. amurensis*, monitored at a regular frequency as a sentinel species in the bay over 1995–2010, and concentration patterns in other predator species that consume *C. amurensis*? A reasonable representation of these observations lends credibility to the use of this modeling framework for management of selenium in NSFB over the coming years during which many changes are possible, including changes in land use, upstream water diversions, sea level rise, and modified freshwater outflows. More generally, the framework for integration of data and mechanistic processes presented here may be applicable to the management of selenium in estuaries receiving inflows from urbanized and developed watersheds, although affected species and food webs may differ.

Methods

ECoS Modeling Framework

ECoS3 is a modeling framework developed by the Center for Coastal and Marine Sciences (Plymouth Marine Laboratory, UK) that can be used to simulate transport and dynamics of dissolved and particulate constituents in a one-dimensional (1-D) or 2-D form for an estuary (Harris and Gorley 1998, 2003). By using a single box or a multiple box approach, the model will simulate salinity, nutrients, TSM, and biological productivity once the shape, geometry, and tidal movement in the estuary are established (Harris and Gorley 1998). ECoS3 considers transport due to advection and dispersion, transformations between species through exchange or reactions, and changes through point or non-point inputs and outputs. ECoS3 has been widely applied to simulate different constituents (e.g., salinity, suspended particles, carbon, nitrogen, nutrients, Zn, and Ni) in estuaries including the Humber Estuary in UK (Harris 2003; Tappin et al. 2003), Tweed Estuary (Punt et al. 2003; Uncles et al. 2003), and Tamar Estuary (Liu et al. 1998). Meseck and Cutter (2006) used ECoS3 to focus on simulating transport and biogeochemistry of selenium in 1-D form in the NSFB.

Model Domain and Components

As in Meseck and Cutter (2006), the model was applied starting from the Sacramento River at Rio Vista, extending through NSFB to the Golden Gate Bridge (Fig. 1), with Rio Vista constituting the freshwater boundary, and the Golden Gate Bridge the ocean boundary. The model consists of 33 linked cells, each 3 km wide, representing this domain, with external flows and selenium load inputs at various intermediate locations (Fig. 2). The Sacramento-San Joaquin Delta is not explicitly modeled in this work: Sacramento River flows at Rio Vista are the main freshwater input, with inflows from San Joaquin River added at the confluence 19 km from Rio Vista. Flows at Rio Vista are measured, with the contribution from San Joaquin River estimated as the difference between the Delta outflow and the Rio Vista flow. Tributary flows from 10 local watersheds surrounding NSFB, 5 major refineries, and 23 additional municipal wastewater and industrial point sources were added to the model corresponding to their distance from the head of the estuary at Rio Vista. These sources are identified and their distances from Rio Vista listed in Table 1 in the Electronic supplementary material (ESM).

Meseck and Cutter (2006) used the model to simulated salinity, TSM, phytoplankton, and different species of dissolved and particulate selenium (dissolved selenate, selenite, organic selenide, particulate elemental selenium, particulate organic selenides, and adsorbed selenite and selenate). The modified and recalibrated model presented here simulates these constituents and selenium concentrations in bivalves and higher trophic level organisms (white sturgeon and greater scaup).

As a first step, salinity in the bay is simulated because it represents the advection and dispersion of all dissolved water column constituents in the estuary (Harris and Gorley 1998). Accurate simulation of salinity is an indicator that the advection and dispersion of dissolved species is represented adequately. The simulation of TSM indicates how well the fate and transport of all other constituents associated with particulates in the estuary is simulated. TSM concentrations also affect reactions of selenium with particulates and the distribution of particulate selenium in the estuary. Simulation of phytoplankton greatly affects the fate of selenium, because selenium uptake by phytoplankton is an important first step in subsequent foodweb uptake (Luoma et al. 1992). Loads, transport, and transformations of different species of selenium are important modeling components as bioavailability differs among the different species of selenium. The bioaccumulation of selenium through the foodweb is an important component of this model as it links selenium

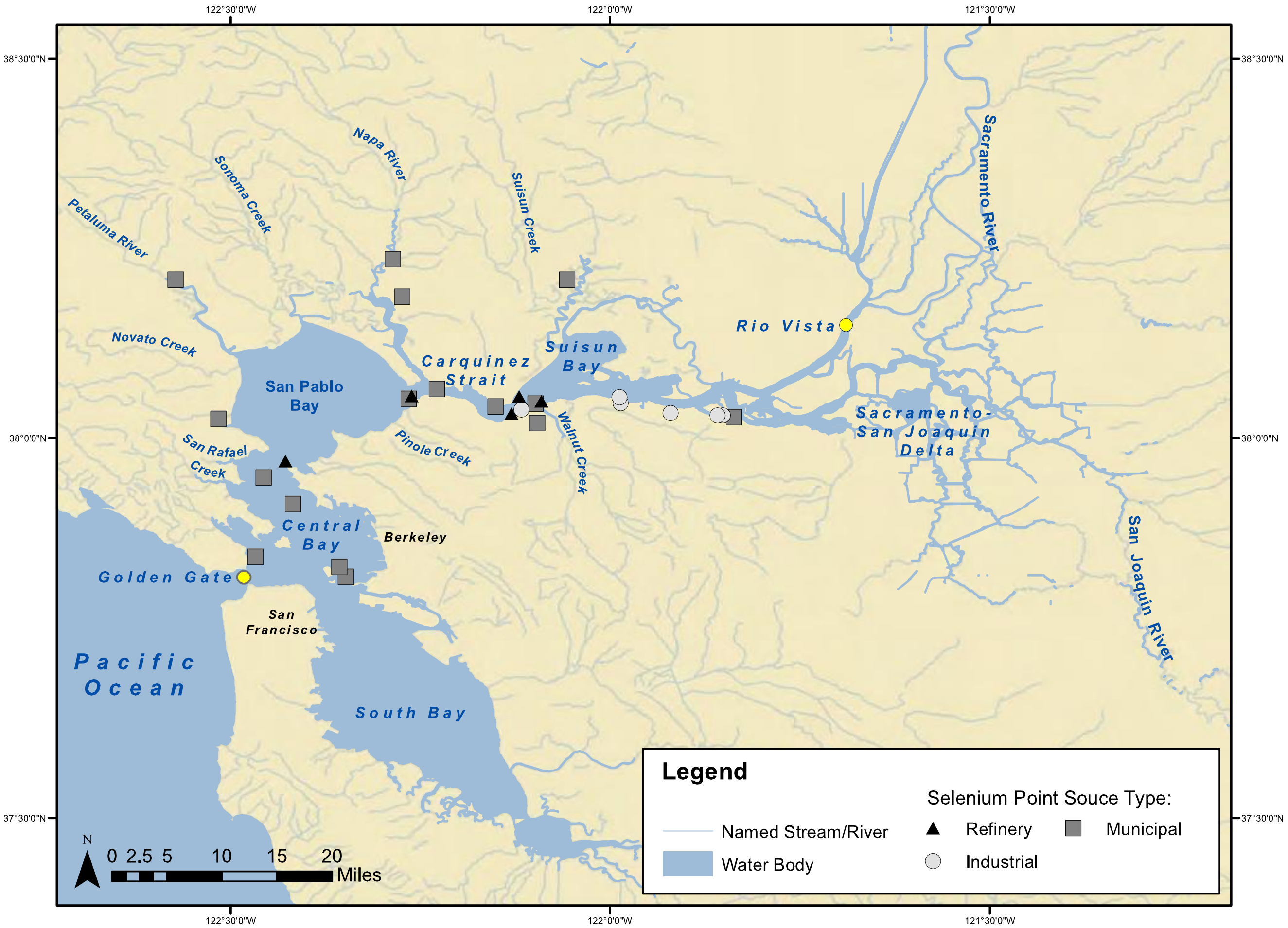


Fig. 1 San Francisco Bay region and surroundings. The model uses Rio Vista on Sacramento River as the starting point of the simulations and spans the region to Golden Gate, following Meseck and Cutter (2006). San Joaquin River inflows are added as a tributary 19 km downstream of Rio Vista. Other tributaries and point sources are also shown and listed in Table 1 in the ESM. The Delta is not explicitly modeled in this application

concentrations in the water column to biota of ecological concern.

To adapt the Meseck and Cutter (2006) model for the present application required some modifications to the loads and model formulation, as outlined here. Refinery loads were updated using daily selenium inputs from five refineries in the NSFB, estimated based on daily flow and weekly concentrations for the period of 1999–2007. These loads were added to model cells based on their discharge locations. In addition, selenium loads from local tributaries to NSFB (i.e., in addition to the major riverine flows through the Delta) were added to the model based on their discharge locations. These loads were not identified in the prior application and may be significant during wet months. Loads from publicly owned treatment works and other point source dischargers in the NSFB were added to the model based on their discharge locations. All sources of selenium are identified in Fig. 1. Besides selenium inputs from the San Joaquin River, TSM loads (with TSM concentrations modeled as a function of flow) and phytoplankton loads (with observed phytoplankton concentrations) from the San Joaquin River were also added to the model. In simulating the TSM, phytoplankton, and particulate selenium, the current model uses observed concentrations as much as possible in defining the riverine boundary conditions.

The transfer of dissolved selenium to particulate selenium through phytoplankton uptake is an important process in its bioaccumulation. Therefore, particulate selenium associated with phytoplankton uptake within the estuary was tracked as a separate constituent and was added to the total particulate selenium. At the boundaries, the input of phytoplankton and all other forms of particulate selenium were estimated separately through calibration. Simulated Se/C ratio in phytoplankton was also tracked by the model and was compared with data observed for species found in the bay. Finally, a dynamic multi-pathway bioaccumulation model

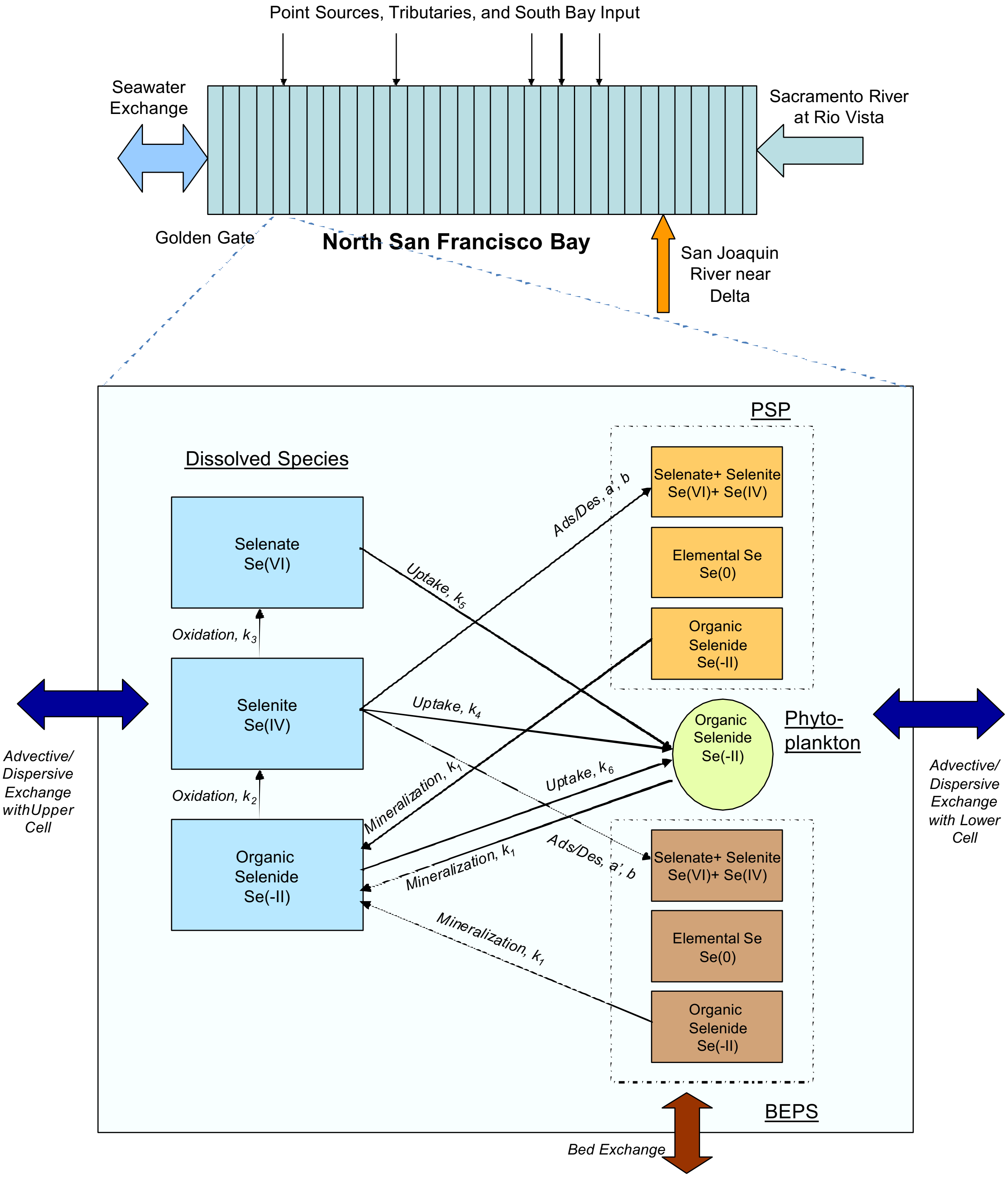


Fig. 2 Schematic of model representation of the NSFB, showing model cells or nodes (*vertical boxes*), boundary conditions, and external loads. Each cell is 3 km wide. The locations of the external loads are illustrative and are added in the model location at the approximate location they enter the estuary

(DYMBAM; Presser and Luoma 2006) was added to predict tissue selenium concentrations in bivalves; previously developed relationships between prey and predator concentrations by Presser and Luoma (2006)

Table 1 DYMBAM model parameters for *Corbula amurensis*

K_u (L g^{-1} day^{-1})	IR (g g^{-1} day^{-1})	AE (%)	K_e (day^{-1})	Growth rate (per day)	Tissue Se concentration (mg/kg)	References
0.003	0.25	45–80	0.025		2.1–12.0	Stewart et al. (2004)
0.009	0.1–1.0	36 (sediment) 54 (algae)	0.023	0.005	3.9–20.0	Lee et al. (2006)

DYMBAM dynamic multi-pathway bioaccumulation model, *AE* assimilation efficiencies

were used to predict bioaccumulation of selenium to the higher trophic levels (bivalves, benthic-feeding fish, and diving ducks).

The above changes entailed a recalibration of the model and evaluation against the most recently available data in NSFB including salinity, TSM, chlorophyll *a*, dissolved and particulate selenium, and selenium concentrations in clams for the period beyond 1999 (US Geological Survey (USGS) monthly cruises in the bay; SFEI 2006; Doblin et al. 2006; Kleckner et al. 2010). The complete modeling framework development, calibration, and application to NSFB are detailed in a report prepared for the TMDL effort (Tetra Tech 2010; available on the Internet at: http://www.swrcb.ca.gov/rwqcb2//water_issues/programs/TMDLs/seleniumtmdl.shtml).

Selenium Transformations Simulated

While in the water column, different species of selenium can undergo biological and chemical transformations, and these transformations were simulated by the model (Cutter 1982; Cutter 1992). Transformations of dissolved selenite simulated by the model include oxidation to selenate, uptake by phytoplankton, and adsorption and desorption from minerals. Transformations of dissolved organic selenide include oxidation to selenite and uptake by phytoplankton. Particulate organic selenides can undergo mineralization to form dissolved organic selenide (Cutter 1982). The exchange of selenium between different compartments simulated by the model is shown schematically in Fig. 2, identifying the different dissolved and particulate species, and the exchanges between them. In this formulation, particulates are tracked as three phases, permanently suspended particulates (PSP), composed of fine material that remains in suspension, bed exchangeable particles (BEPS), composed of larger particles that originate from sediment resuspension, and phytoplankton. The transformations among different species of dissolved and particulate selenium are modeled as a set of first-order reactions, labeled with rate constants from k_1 to k_6, an approach similar to that by Meseck and Cutter (2006). Under oxic conditions, such as those occurring in the waters of the NSFB, the key transformations include oxidation of organic selenide to selenite, and further oxidation of selenite to selenate, as well as uptake of all dissolved species by particulate phases (PSP, BEPS, and phytoplankton). Values of the rate constants were estimated from the literature and are listed in Table 2 in the ESM. These ranges were used as a starting point for the modeling, and where the range was broad, the parameters were adjusted to obtain a best fit to the data from the NSFB. In the work, the rate constants k_1 and k_2 were estimated through calibration, whereas k_3 through k_6 were based on literature estimates. In general, these rate constants indicate that the oxidation of organic selenide is relatively rapid, although oxidation of selenite to selenate is a very slow process. Also, uptake of selenide and selenite onto particulate phases was more rapid than for selenate.

Selenium Bioaccumulation Through the Foodweb

Selenium Uptake by Bacteria and Phytoplankton

Dissolved selenium in the water column can be directly taken up by phytoplankton and bacteria. After uptake, selenium exists in reduced organic forms within algal or bacterial cells or is exuded as dissolved organic selenium to the water column. Organic selenium in algal cells is highly bioavailable to organisms that consume them, such as zooplankton and bivalves (Luoma et al. 1992; Schlekat et al. 2000). Therefore, the uptake of selenium by bacterial and planktonic organisms is important in evaluating selenium bioaccumulation in the foodweb. The uptake of selenium by bacteria and phytoplankton is modeled using first-order reactions.

Selenium Bioaccumulation Through Bivalves

Bioaccumulation of particulate selenium to lower trophic level organisms (e.g., bivalves) is simulated using a DYMBAM (Luoma et al. 1992; Stewart et al. 2004; Presser and Luoma 2006). The model predicts metal concentrations in bivalve tissues using concentrations in food, food ingestion rate, metal assimilation efficiency, and elimination rate.

The dynamic form of the DYMBAM model is as follows:

$$\frac{dC_{\mathrm{mss}}}{dt} = k_{\mathrm{u}} \times C_{\mathrm{w}} + \mathrm{AE} \times \mathrm{IR} \times C_{\mathrm{f}} - k_{\mathrm{e}} \times C_{\mathrm{mss}} \quad (1)$$

where C_{mss} is selenium concentration in tissue (in micrograms per gram), k_{u} is the dissolved metal uptake rate constant (in liters per gram per day), C_w is the dissolved metal concentrations in water (in micrograms per liter), AE is the assimilation efficiency (in percent), IR is the ingestion rate (in grams per gram per day), C_f is the metal concentration in food (e.g., phytoplankton, suspended particulate matter, and sediment; in micrograms per gram), and k_e is the efflux rate (in day^{-1}). Uptake through the waterborne pathway was found to be negligible (Luoma et al. 1992) and not considered. Parameter values in Eq (1) for uptake of selenium by *C. amurensis* are derived from Stewart et al. (2004) and shown in Table 1. Parameters for different metals and different species of organisms have been quantified in previous studies (summarized in Luoma and Rainbow 2005). The filter-feeding organism *C. amurensis* was found to have a higher assimilation efficiency and lower elimination rate, and thus accumulating selenium to higher concentrations than other bivalve species common in the bay, such as *Corbicula fluminea* (Lee et al. 2006; Linville et al. 2002). Bioaccumulation into bivalves considers different efficiencies of absorption for different selenium species (Table 2). Assimilation efficiencies (AE) measured by Schlekat et al. (2002) for organic selenide are in a relatively narrow range for different species of algae and are generally high (53–89 %). AE for elemental selenium are generally low (2–28 %), with biogenic particulate elemental selenium showing higher AE. In developing model predictions in this work, an AE of 0.2 or 20 % was used for particulate elemental selenium, an AE of 45 % was used for particulate adsorbed selenite+selenate, and an AE of 80 % was used for particulate organic selenium (Fig. 3).

A range of ingestion rates has also been estimated for *C. amurensis* by Lee et al. (2006) and covers a wide range from 0.1 to 1.0 $\text{g}\,\text{g}^{-1}\,\text{day}^{-1}$ (Table 1). The ranges in assimilation efficiency and ingestion rates were used to forecast the range of selenium concentrations in bivalves. The predicted selenium concentrations in bivalves were compared with observed data by Stewart et al. (2004). In forecasting the long-term selenium concentrations in bivalves, an ingestion rate of 0.65 $\text{g}\,\text{g}^{-1}\,\text{day}^{-1}$ (roughly the midpoint value) was used in model predictions.

Selenium Bioaccumulation to Higher Trophic Levels (Fish and Diving Ducks)

A ratio between selenium concentrations in the tissues and diet of organisms, the trophic transfer factor (TTF) can be used in estimating bioaccumulation of selenium through the food web, once dietary concentrations are known (Presser and Luoma 2010). The ratio can be derived based on kinetic uptake rates or observed concentrations of diet and tissue. For example, the TTF for invertebrates can be derived as: $\text{TTF}=(\text{AE})(\text{IR})/k_e$, where AE is the assimilation efficiency; IR is the ingestion rate, and k_e is the elimination rate. The TTFs are a relatively simple and effective way to incorporate the complex processes of biological uptake from bivalves (e.g., clams) to predator species (e.g., sturgeon and scaup) in this model. The significance of clams in the diet of these species has been reported previously (Stewart et al. 2004). TTFs for fish have been found to vary over a relatively narrow range across species and habitats, based on an examination of data from 29 field studies (Presser and Luoma 2010). For several fish species studied the TTFs for selenium range from 0.52 to 1.6 (Presser and Luoma 2010), and a value of 1.3 was reported for white sturgeon. A TTF of 1.8 has been reported for bird egg concentrations in mallards (Presser and Luoma 2010).

Table 2 Literature values of assimilation efficiencies (AE) for different selenium species for *Corbula amurensis*

Species	AE	Origin	References
Se(0)[a]	2 %	AA—reduction of SeO_3^{2-} to Se(0) through ascorbic acid (AA)	Schlekat et al. (2000)
Se(0)	7±1 %	SES— reduction of SeO_3^{2-} to Se(0) through pure bacteria culture (SES)	Schlekat et al. (2000)
Se(0)	28± 15 %	SED—reduction of SeO_3^{2-} to Se(0) through sediment microbial consortium (SED), biogenic origin	Schlekat et al. (2000)
Selenoanions	11 %	Reoxidized sediment slurries	Schlekat et al. (2000)
Organoselenium	53 %	Ph. Tricornutum	Schlekat et al. (2000)
Cryptomonas sp.	88.9 %	Algae cells	Schlekat et al. (2002)
Gymnodinium sanguinem	82.6 %	Algae cells	Schlekat et al. (2002)
Phaeodactylum tricornutum	80 %	Algae cells	Schlekat et al. (2002)
Synechococcus sp.	78.3 %	Algae cells	Schlekat et al. (2002)
Thalassiosira pseudonana	87.3 %	Algae cells	Schlekat et al. (2002)
Sediment	36 %	Fresh water stream, San Jose, CA	Lee et al. (2006)
Algae (mixed with sediment)	54 %	Diatan, *P. tricornutum*	Lee et al. (2006)

[a] This form of elemental selenium does not occur in nature and was synthesized in the laboratory

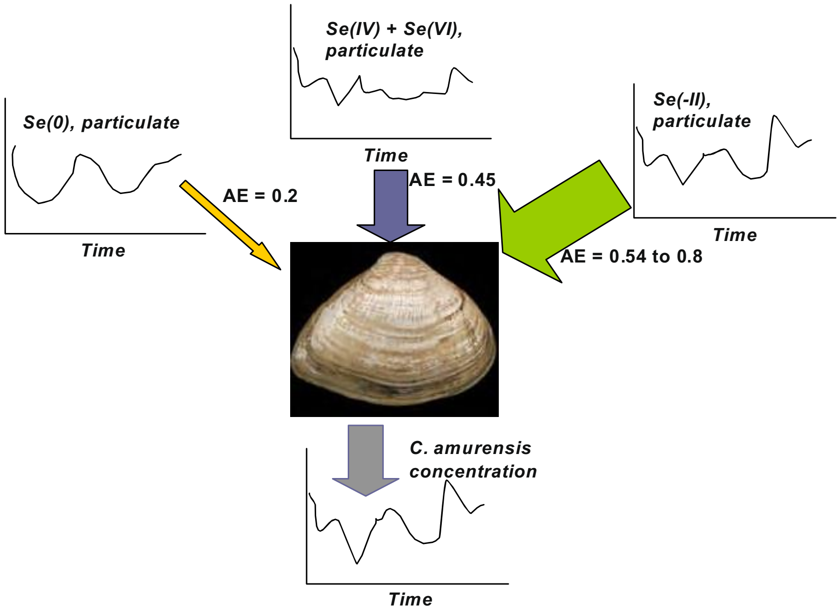


Fig. 3 Bioaccumulation of particulate selenium in bivalves

Model Boundary Conditions and External Loads

Riverine Inputs of TSM and Chlorophyll a

Riverine inputs of flow from the Sacramento River at Rio Vista are daily records from the Interagency Ecological Program (IEP 2010) for the period of 1999–2008. The San Joaquin River is modeled as a tributary to the Sacramento River, with flow derived as the difference between Net Delta Outflow Index and flow from the Sacramento River at Rio Vista.

Riverine inputs (Sacramento and San Joaquin Rivers) of TSM and chlorophyll *a* were estimated as flow at the Sacramento River at Rio Vista and San Joaquin River multiplied by concentrations.

The riverine concentrations of TSM were modeled as a function of flow:

$$\mathrm{TSM}_{\mathrm{river}} = a + b * Q_{\mathrm{river}}{}^{c} \qquad (2)$$

where a is the minimum concentration in the river water, b and c are calibration coefficients, and $\mathrm{Q}_{\mathrm{river}}$ is the riverine flow rate.

Riverine chlorophyll *a* concentrations were observed data obtained from the USGS and Bay Delta and Tributary Project (BDAT) for the Sacramento River at Rio Vista for the period of 1999–2008. For the San Joaquin River, BDAT data for San Joaquin River at Twitchell Island were used.

Selenium Loads from Refineries and Municipal and Industrial Wastewater

Selenium loads to the NSFB include point sources from refineries, municipal and industrial dischargers and tributaries. Point and nonpoint sources of selenium were added to the model cells at their corresponding discharge locations (Table 1 in the ESM).

Daily refinery loads over 1999–2007 from five refineries in the NSFB estimated in Tetra Tech (2008) were used in the model calibration. For the refinery effluent data, only total selenium was reported, and for the purpose of the modeling, the speciation was held constant at values reported by Cutter and Cutter (2004): selenite (13 %), organic selenide (30 %), and selenate (57 %). The daily load varied from day to day depending on the effluent data reported and was 558.8 kg/year for 1999 for all five refineries combined.

Daily selenium loads from local tributaries estimated in a previous assessment (Tetra Tech 2008) were added to the model using the annual load for each hydrological area multiplied by a time series scaling factor, derived from daily flow record at Napa River (USGS station 11458000). No selenium speciation data exist for local tributaries. The speciation from local tributaries is assumed to be the same as from the Sacramento River reported by Cutter and Cutter (2004): selenite (9 %), organic selenide (35 %), and selenate (56 %). The total selenium load from tributaries estimated in the model varies depending on the volume of runoff each year and was 819.7 kg/year for 1999.

Selenium loads from other point sources including municipal and industrial wastewater discharges were also added to the model. Speciation for municipal wastewater discharges used is organic selenide (15 %), selenite (25 %), and selenate (60 %). For 1999, the total loads from these sources were 175.8 kg/year.

Riverine Dissolved Selenium Loads

Dissolved selenium loads for selenate, selenite, and organic selenide were specified from the rivers as a product of flow and selenium concentrations by species. Different species of selenium concentrations were derived using fitted functions based on observed data by Cutter and Cutter (2004) at the Sacramento and San Joaquin River stations, similar to the approach used in Meseck and Cutter (2006). A Delta removal constant was used in converting observed selenium concentrations in the San Joaquin River at Vernalis to concentrations at the confluence with Sacramento River. This constant represents exports of San Joaquin River through the aqueducts in the Delta and also the biogeochemical processes of selenium removal within the Delta.

Particulate Selenium Loads

Riverine particulates are assumed to exist in two forms: PSP and BEPS, the latter representing sediment bed-load transport. Riverine particulate selenium inputs are estimated as selenium concentrations associated with PSP and BEPS (both in micrograms per gram), multiplied by riverine inputs of PSP and BEPS (in milligrams per liter). Also added to the particulate loads are the riverine phytoplankton Se loads using a Se/C ratio and chlorophyll *a* concentrations.

Particulate selenium concentrations associated with PSP were measured by Doblin et al. (2006) and showed a range of values. Particulate elemental selenium ranged from 0.08 to 0.40 μg/g (mean, 0.149±0.108 μg/g), particulate selenite and selenate range from nondetectable to 0.25 μg/g (mean, 0.270±0.137 μg/g), and organic selenide concentrations ranged from 0.015 to 0.74 μg/g (mean, 0.134±0.238 μg/g) at Sacramento River at Rio Vista (Doblin et al. 2006). Particulate selenium concentrations associated with BEPS are data from Meseck and Cutter (2012). The total particulate selenium at Rio Vista is 0.46 μg/g (the sum of particulate organic, inorganic, and elemental selenium). Higher selenium content on particulates may be expected during low flows (e.g., 0.75 μg/g in November 1999). Therefore, the model was also run using a higher riverine particulate selenium concentration of 0.75 μg/g for a low flow period (river flow, $<1.5\times10^{10}$ l/day) (Table 3). Particulate selenium concentrations at the seawater end of the model domain observed by Doblin et al. (2006) ranged between 0.84 and 1.18 μg/g at Golden Gate Bridge. A seawater end member concentration for each species of particulate selenium was specified corresponding to measured values at Golden Gate.

Model Calibration and Evaluation

Model Calibration

Before the model is used to predict selenium concentrations on particulates and bivalves, it was calibrated for physical parameters (salinity and TSM), phytoplankton, and dissolved and particulate selenium species, using observed general water quality data (from cruises conducted by the USGS, http://sfbay.wr.usgs.gov/access/wqdata/) and selenium speciation data sampled by Cutter and Cutter (2004) for 1999. Calibration for the general water quality parameters was conducted based on data from 19 USGS monitoring stations located in the NSFB and was roughly on monthly intervals from January 1999 to December 1999. The use of the USGS dataset supplements data used in the previous study by Meseck and Cutter (2006), which was mainly based on Cutter and Cutter (2004) data. Selenium speciation data collected during two time periods in 1999 (April and November) by Cutter and Cutter (2004) were used in model calibration for selenium. Water year 1999 was selected for calibration because detailed refinery discharge data and selenium speciation data are available for this year, and selenium loads from refineries decreased by about two thirds in mid-1998 and have stayed at approximately those levels since that time. The 1999 estuary data thus represent conditions following refinery load reductions. Key model calibration parameters are those that affect advection and dispersion of PSP and BEPS, phytoplankton growth rate and grazing rate, selenium transformation rates, and Delta removal constants for selenium inputs from the San Joaquin River.

Model Evaluation Criteria (Goodness of Fit)

The model goodness of fit was evaluated using two measures: the correlation coefficient (r) between predicted and observed values, a goodness of fit defined in Perrin et al. (2001).

$$\mathrm{GOF}(\%) = 100*\left(1-\left|\sqrt{\frac{\sum X_{\mathrm{cal}}}{\sum X_{\mathrm{obs}}}}-\sqrt{\frac{\sum X_{\mathrm{obs}}}{\sum X_{\mathrm{cal}}}}\right|\right) \qquad (4)$$

where X_{cal} is the model simulated concentration and X_{obs} is the

Table 3 Lower and higher boundary of riverine and seawater endmember concentrations (Doblin et al. 2006; Meseck 2002; Baines et al. 2004)

	Riverine boundary			Seawater boundary	
	PSP PSe (μg/g)	BEPS PSe (μg/g)	Se/C in phytoplankton (μg/g)	PSP PSe (μg/g)	Se/C in phytoplankton (μg/g)
Lower boundary	0.46	0.25	15.9	0.84	21.0
Higher boundary (applied when Net Delta Outflow Index, $<1.5\times10^{10}$ l/day)	0.75	0.50	15.9	1.18	21.0

observed concentration. A 100 % goodness of fit indicates a perfect fit between simulated and observed values.

Model Evaluation

The model evaluation was conducted using long-term data available for years after 1999, which include several low and high flow years, for the period of 1999–2008. The calibrated model was evaluated against estuarine profile data collected by USGS for salinity, TSM, and phytoplankton for two specific water years 2001 and 2005, and long-term total selenium data collected by the San Francisco Bay Regional Monitoring Program (RMP) for water year 2001 through water year 2007 (RMP 2010). The RMP dataset reports dissolved and total selenium and does not include characterization of selenium speciation and the separation of dissolved and particulate selenium. The difference between total and dissolved selenium, although in principle an approximation of particulate selenium, is not an accurate representation of particulate selenium, and sometimes negative values may result. Water year 2001 was selected because it was a dry year, with flows much lower than 1999 and water year 2005 was selected because it was a relatively wet year based on the commonly used classification by the California Department of Water Resources (DWR 2010). The evaluation was for both simulations along the length of the estuary and at fixed locations over long-term time periods, for both physical and biological parameters and selenium species concentrations.

Model Hindcast

Model hindcasting is another form of evaluation and provides insight on model's capability to simulate conditions that are different from the calibration period in terms of hydrology and internal selenium loading. The calibrated model was run to hindcast selenium concentrations during two time periods prior to refinery load reductions in 1986 and 1998. To simulate selenium concentrations in 1986 and 1998, river discharges from the Sacramento River at Rio Vista and the San Joaquin River at Jersey Point for 1986 and 1998 were used (obtained from IEP 2010). Selenium loads of different species from the refineries for 1986 and 1998 were based on data from Meseck (2002).

Results

Model Evaluation for the Post-1999 Period

The calibrated model was evaluated against estuarine profile data on salinity, TSM, and phytoplankton for water years 2001 and 2005 collected by USGS, and long-term total selenium data collected by RMP for water year 2001 through water year 2005 (RMP 2010). The water year 2001 represents a dry year, with flows much lower than 1999 and water year 2005 represents a relatively wet year, as noted above.

Evaluation of salinity, TSM, and chlorophyll *a* for the low flow year 2001 suggested good agreement of simulated salinity versus observed values for different months across the year (Figs. 1, 2, and 3 in the ESM). Overall values for goodness of fit for these months are between 71.5 and 97.9 % for salinity, 36.4 and 99.4 % for TSM, and 53.7 and 95.7 % for chlorophyll *a*. The location of the estuarine turbidity maximum (ETM) was simulated well for most months in 2001, particularly for June and July 2001. For about 2 months, chlorophyll *a* concentrations were under-predicted near the Central Bay, similar to the pattern in the calibration. For the evaluation period, the simulated correlation coefficient (r) is 0.92–1.00 for salinity in 2001, 0.68–0.97 for TSM in 2001, and 0.02–0.79 for chlorophyll *a* in 2001.

A similar evaluation of salinity, TSM, and chlorophyll *a* was performed for an above-normal flow year (2005) (Figs. 4, 5, and 6 in the ESM). Salinity predictions showed very good agreement with the observed data (GOF=50.4–99.7 %). The evaluation of TSM for 2005 shows good agreement for the first several months, particularly for January, March, and June 2005. For April and May 2005, the ETM was under-predicted (GOF=48.2–97.7 %). This is similar to the results in the calibration phase where the ETM was under-predicted on some occasions. Chlorophyll *a* predictions were able to represent the average values through the estuary but did not capture the peaks (GOF=25.2–98.5 %).

Simulated TSM and chlorophyll *a* concentrations were also evaluated for longer time periods at fixed locations, using data from the USGS long-term monitoring stations (Figs. 7 and 8 in the ESM). The model-simulated chlorophyll *a* and TSM concentrations were compared with long-term data at four stations, stations 3 (Suisun Bay), 6 (Suisun Bay), 14 (San Pablo Bay), and 18 (Central Bay), respectively. The results suggest that the model is able to capture the seasonal variations in chlorophyll *a* and TSM relatively well.

Although the calibration process for the general water quality parameters was extensive, and generally described key constituents of interest across a range of years, seasons, and loading conditions using a relatively small number of adjustable parameters, several features could not be fully captured by the model. This includes peaks in concentrations for constituents such as TSM and phytoplankton, represented by chlorophyll *a* concentrations. This is likely attributable to the limitations of the 1-D model in capturing the complexities of processes in the NSFB, and also to seasonal changes that were not fully parameterized during calibration.

Comparison of simulated selenium concentrations against the RMP transect sampling data for the period of 2000–2005 suggested that the model simulates profiles of

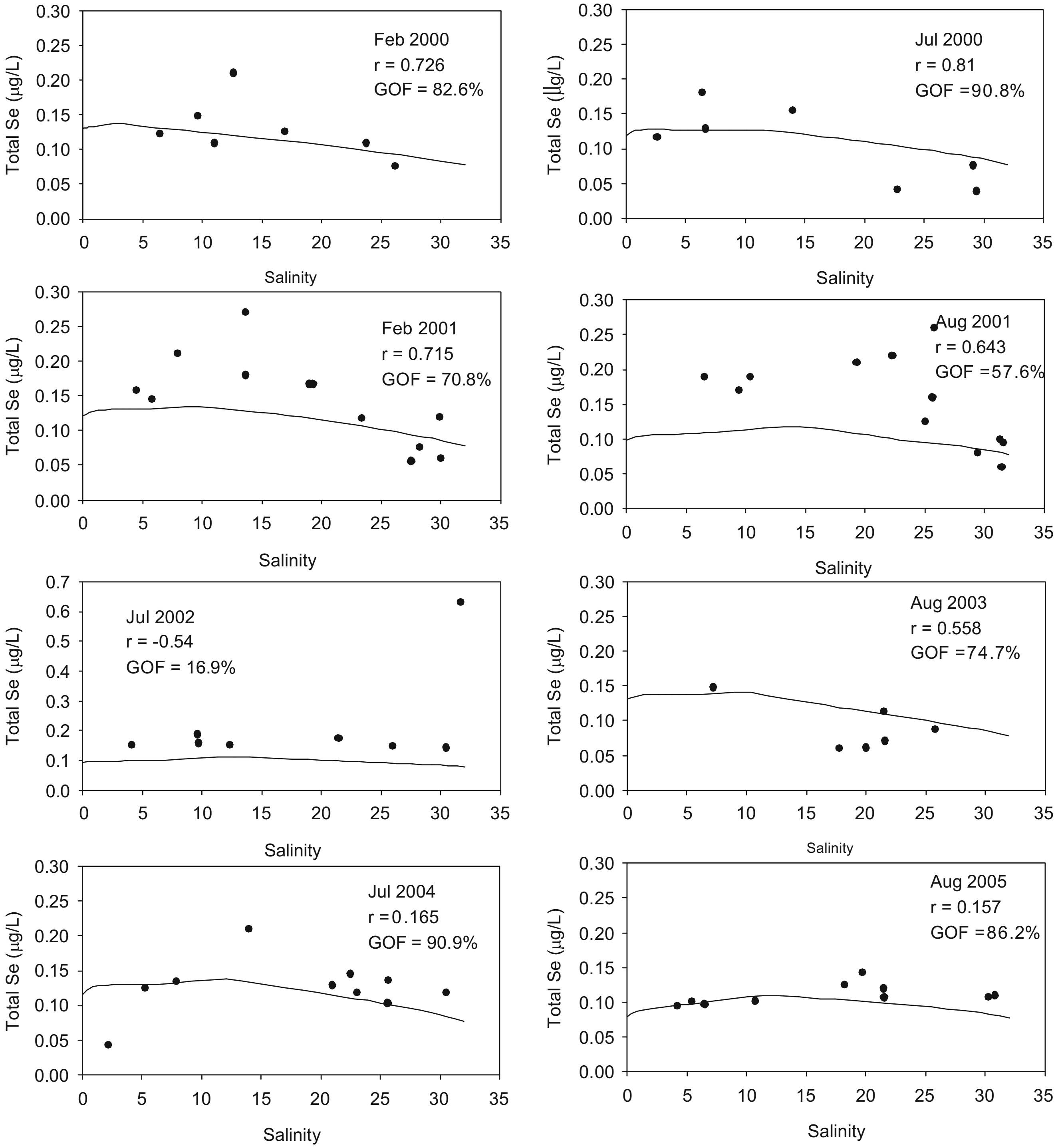


Fig. 4 Model simulated total selenium concentrations (dissolved+particulate) compared with selenium data collected by the San Francisco Bay RMP. Note that the RMP dataset does not report selenium species information, and no selenium speciation data are available for this period in NSFB. RMP data on the Internet at: http://www.sfei.org/rmp/data

selenium concentrations along the estuarine longitude well for a range of hydrological and load input conditions during 2000–2005, including both dry and wet years, and dry and wet season conditions (Fig. 4), and the long-term variations in selenium concentrations at fixed locations (Fig. 5).

Model Hindcast

The model hindcast (prior to refinery selenium load reductions) suggests that the model-simulated salinity, TSM and chlorophyll *a* compared well with the observed values for both high and low

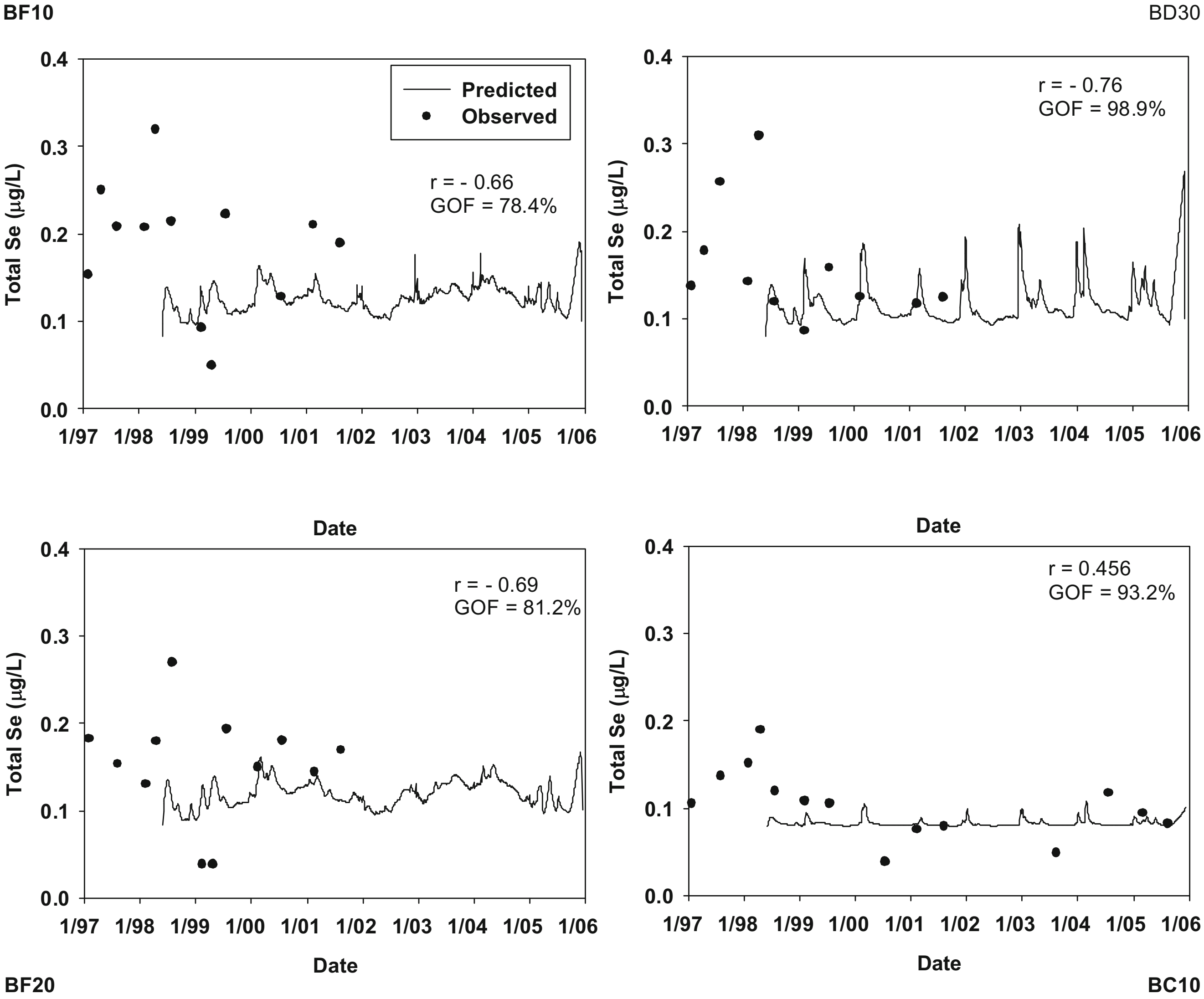


Fig. 5 Model simulated total selenium concentrations at BF10 (Suisun Bay), BF20 (Suisun Bay), BD30 (San Pablo Bay), and at BC10 (Central Bay) compared with observed total selenium by RMP. RMP data on the Internet at: http://www.sfei.org/rmp/data

flow. The model is able to simulate the ETM that occurred during October 1998. The hindcast of dissolved selenium suggests that the model is able to simulate the relatively conservative mixing behavior of selenium during high flow periods and the mid-estuarine peaks during low flow, a result similar to that previously reported in Meseck and Cutter (2006). Simulated selenium concentrations on particulates for the hindcast period compared well with the observed particulate selenium values, and suggested that the model can represent the behavior of selenium on particulates in different periods (Fig. 6).

Simulated Selenium Concentrations on Particulates and Biota

Simulated selenium concentrations on particulate matter (in micrograms per gram) for 11 November 1999 were compared with the observed data from Doblin et al. (2006; Fig. 7). The predicted mean particulate selenium concentrations for NSFB for 11 November 1999 is 0.77±0.35 μg/g, compared with the observed value of 0.735±0.25 μg/g (r=0.45).

Predicted selenium concentrations in *C. amurensis* near Carquinez Strait as a function of time were compared with data from Stewart et al. (2004) and are shown in Fig. 8 for a range of ingestion rates and different assimilation efficiencies of organic selenium used.

Clam selenium concentrations are also available for a longer time period of 1995–2010 from USGS (Kleckner et al. 2010). Simulated clam selenium concentrations at Carquinez Strait for the time period prior to refinery load reductions (1995–1998) and following refinery load reductions (1999–2010) using an ingestion rate of 0.65 gg^{-1} day^{-1} and a seawater particulate selenium boundary of 1.05 μg/g were compared with these data (Fig. 9). The model is generally able to capture the seasonal and long-term patterns in clam selenium concentrations over a period with variability in hydrology and loading. Lower

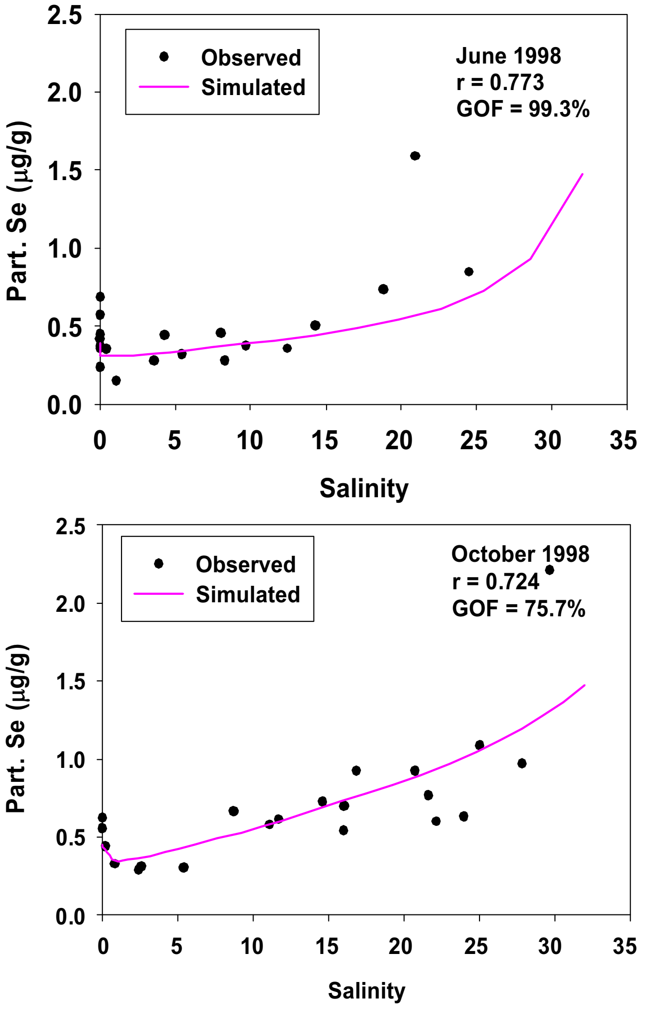


Fig. 6 Model simulated hindcast values of particulate selenium for June and October 1998

selenium concentrations in bivalves are coincident with high flow periods (e.g., April) and wet years (e.g., 2005 and 2006).

Simulated selenium concentrations in muscle and liver tissues of white sturgeon and greater scaup using TTF and regression equations from Presser and Luoma (2006) were compared with observed values in the NSFB (Figs. 10 and 11). White sturgeon sampled from San Francisco Bay-Delta between 1986 and 1990 contained selenium at concentrations ranging from 9 to 30 µg/g dw (mean, 26.55 µg/g) in liver and 7 to 15 µg/g in muscle tissue (mean, 12.57 µg/g; Urquhart and Regalado 1991; White et al. 1988). Lower selenium concentrations in livers of white sturgeon were reported by another study (mean: 9.75 µg/g) between 2002 and 2004 (Linares et al. 2004, cited in Linville 2006). Predicted selenium concentrations in muscle tissue of white sturgeon are 10.7 µg/g using a TTF of 1.3.

Evaluation of Future Management Scenarios

To test the changes in particulate selenium as a result of load changes from the rivers, particularly from the San Joaquin River, the model was run assuming that all the San Joaquin River flow at Vernalis will reach the Bay. This is in contrast with current conditions, where a significant part of the San Joaquin flow is withdrawn from the Delta into aqueducts. Under the elevated flow condition, it was assumed that the residence time of San Joaquin River water in the Delta significantly decreases, and, as a worst-case from the standpoint of selenium loading to NSFB, the Delta removal effect of selenium on San Joaquin River water was considered to be zero. Therefore, the scenario assumes higher inputs of selenium as a result of both increase in flow from the San Joaquin River and the loss of the Delta removal effects on selenium.

Model simulations using San Joaquin River flow at Vernalis were compared with simulation results using normal San Joaquin River flow (base case). Under the base case, flow from the San Joaquin River was estimated as the difference between Delta outflow and flow from the Sacramento River at Rio Vista. Simulated dissolved and particulate selenium concentrations were higher under the scenario of increased San Joaquin River flow than the base case, for both high- and low-flow periods (Fig. 12).

Predicted model-simulated selenium concentrations on particulates (in micrograms per gram) are significantly higher under the scenario of increased San Joaquin River flow, particularly for the upper estuary. Setting the flow of the San Joaquin River to the measured flow at Vernalis, particulate selenium concentrations are nearly doubled with increases greater than 0.4 µg/g predicted in the upper estuary (Fig. 12). These increases may lead to corresponding increases in clam concentrations. The application of this modeling framework to a wider range of loading and flow scenarios is presented in a technical memorandum developed as part of the selenium TMDL process (Tetra Tech 2010).

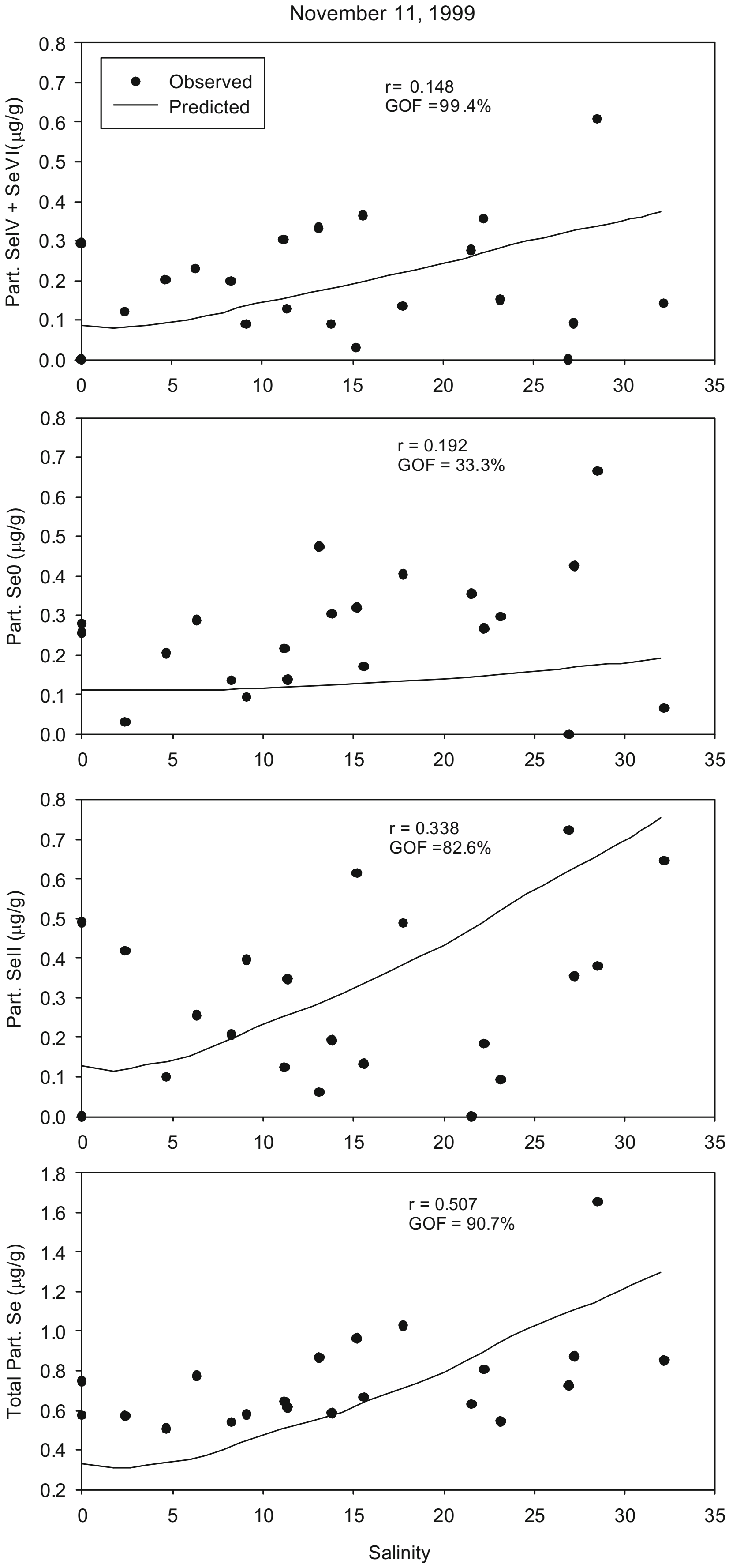
Discussion

Model Uncertainties

Model calibration involved the selection of the principal transformation rates that pertain to flow, salinity, sediment transport, phytoplankton growth, and selenium chemistry. Many of these were based on values reported in the scientific literature, although about half the parameters were estimated by adjusting values to fit observed data. The model was calibrated to data primarily from 1999, for which detailed selenium speciation data in the estuary were available.

For the simulation period, the model is able to capture key aspects of physical and biological constituents that affect selenium concentrations. The model simulates salinity

Fig. 7 Simulated particulate selenium compared with the observed data from Doblin et al. (2006) for November 1999



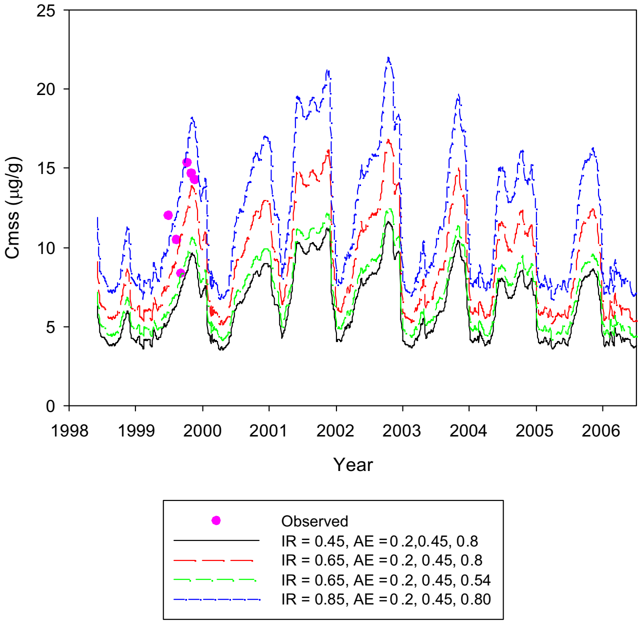


Fig. 8 Simulated selenium concentrations in bivalve *C. amurensis* near the Carquinez Strait compared with observed values from Stewart et al. (2004; station 8.1)

along the estuary well for different hydrological conditions. The evaluation results for phytoplankton and TSM over short-time periods (during specific sampling events for selected years) and long-term periods for multiple years indicated that the model is able to simulate the general temporal and spatial pattern in TSM and phytoplankton, although specific-day peaks may not match very well. For phytoplankton, a few spring blooms are not captured by the model as the model uses a single light limitation function to simulate growth, which limits phytoplankton growth in spring months. Overall, for ancillary parameters, especially TSM and phytoplankton, the model does better at fitting average concentrations than peak concentrations. To some extent this is a consequence of the 1-D formulation of the model, although local variability in driving parameters cannot be ruled out. However, given the hydrodynamic complexities of San Francisco Bay, the inter-annual and seasonal variability in hydrology, this 1-D model produces reasonable results of the ancillary variables for use in computing selenium fate and transport.

The simulated selenium species include dissolved forms such as selenite, selenate and organic selenide and particulate species such as adsorbed selenite and selenate, particulate organic selenide and particulate elemental selenium. The transfer of dissolved selenium to particulate selenium is simulated through kinetic adsorption and phytoplankton uptake and not through equilibrium partitioning. Uptake of selenium by phytoplankton included kinetic uptake of selenite, organic selenide, and selenate, in decreasing order of importance. The uptake rates used in the model simulations are similar to rates used in Meseck and Cutter (2006). During calibration, the model was able to fit the patterns in concentrations of dissolved selenate and selenite well, although it performed less well for dissolved organic selenide. This may be due to the method used for determining dissolved organic selenide (estimated as the difference of total dissolved selenium minus the dissolved selenite+selenate). Therefore the errors and uncertainty in the dissolved organic selenide may be larger. This also may be due to local variations in phytoplankton abundance and species, which may affect uptake of selenium and releases of dissolved organic selenium.

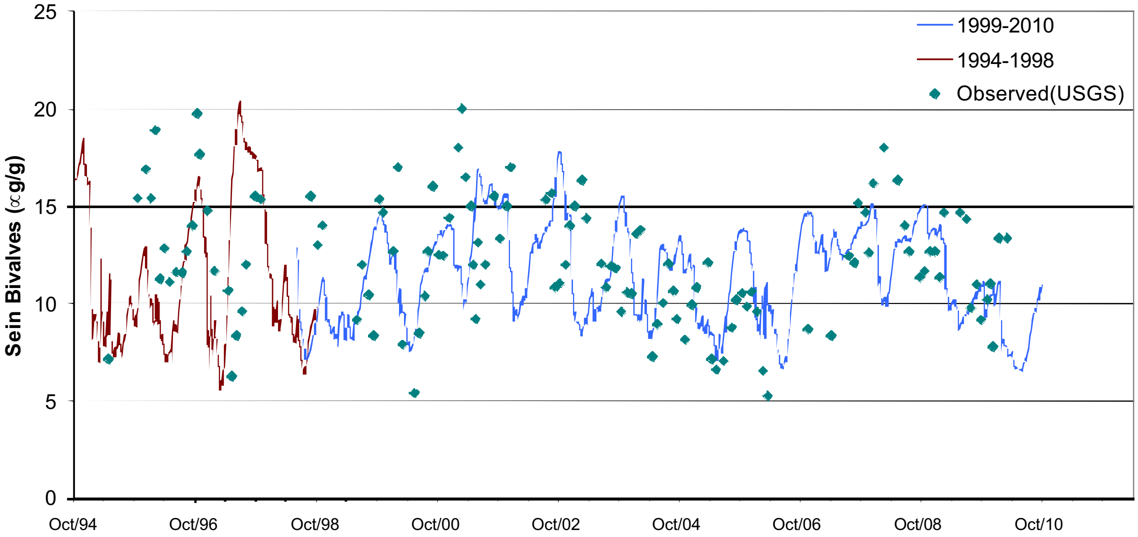


Fig. 9 Simulated selenium concentrations in bivalve *C. amurensis* compared with long-term data from USGS at the Carquinez Strait for the period of 1995–2010 (Kleckner et al. 2010). Flow data used—DAYFLOW records from the California Department of Water Resources; refinery data used—daily data for 1999–2007, constant loads after 2007; San Joaquin River Selenium—observed data at Vernalis, multiplied by Delta removal constants with fixed speciation—selenite (SeIV), 0.028; Se(VI), 0.658; and OrgSe, 0.314

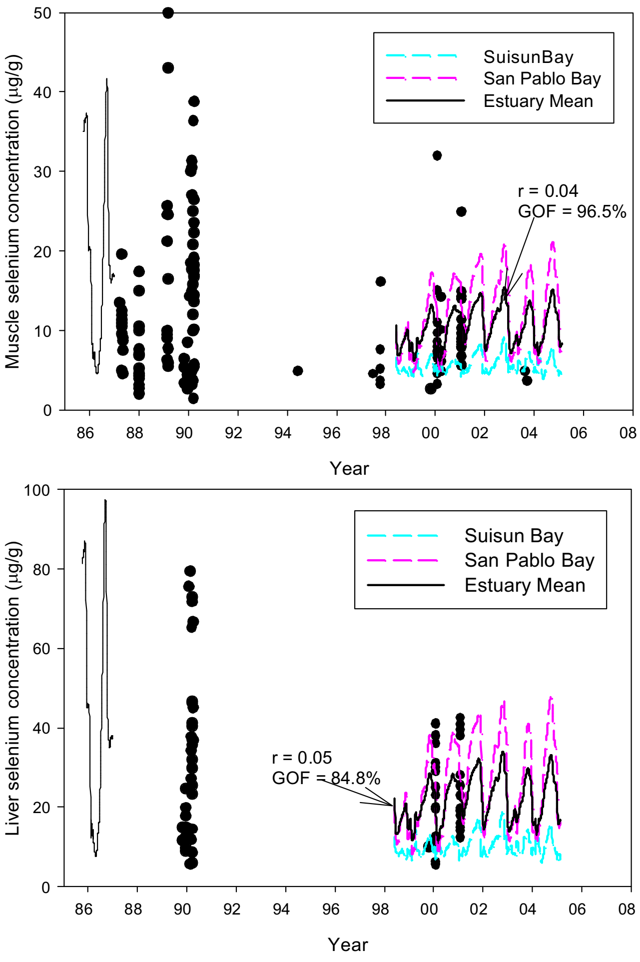


Fig. 10 Simulated selenium concentrations in muscle tissue and liver of white sturgeon at Suisun Bay and San Pablo Bay compared with observed values (White et al. 1988, 1989; Urquhart et al. 1991, USGS and SFEI), using TTF=1.3 for muscle tissue(Presser and Luoma 2010) and regression equation from Presser and Luoma (2006; for liver concentrations)

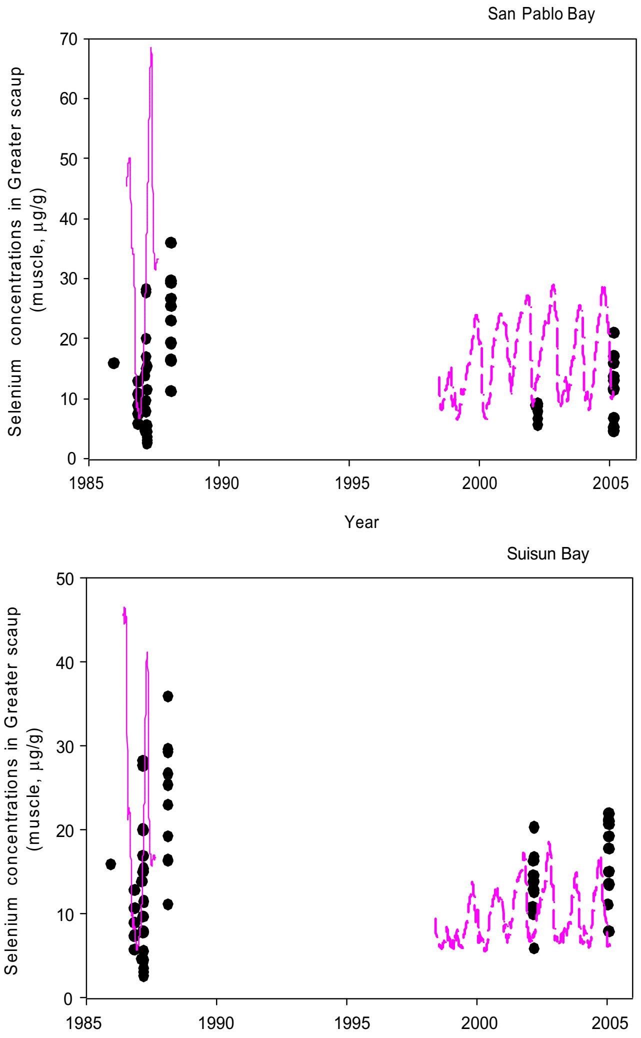


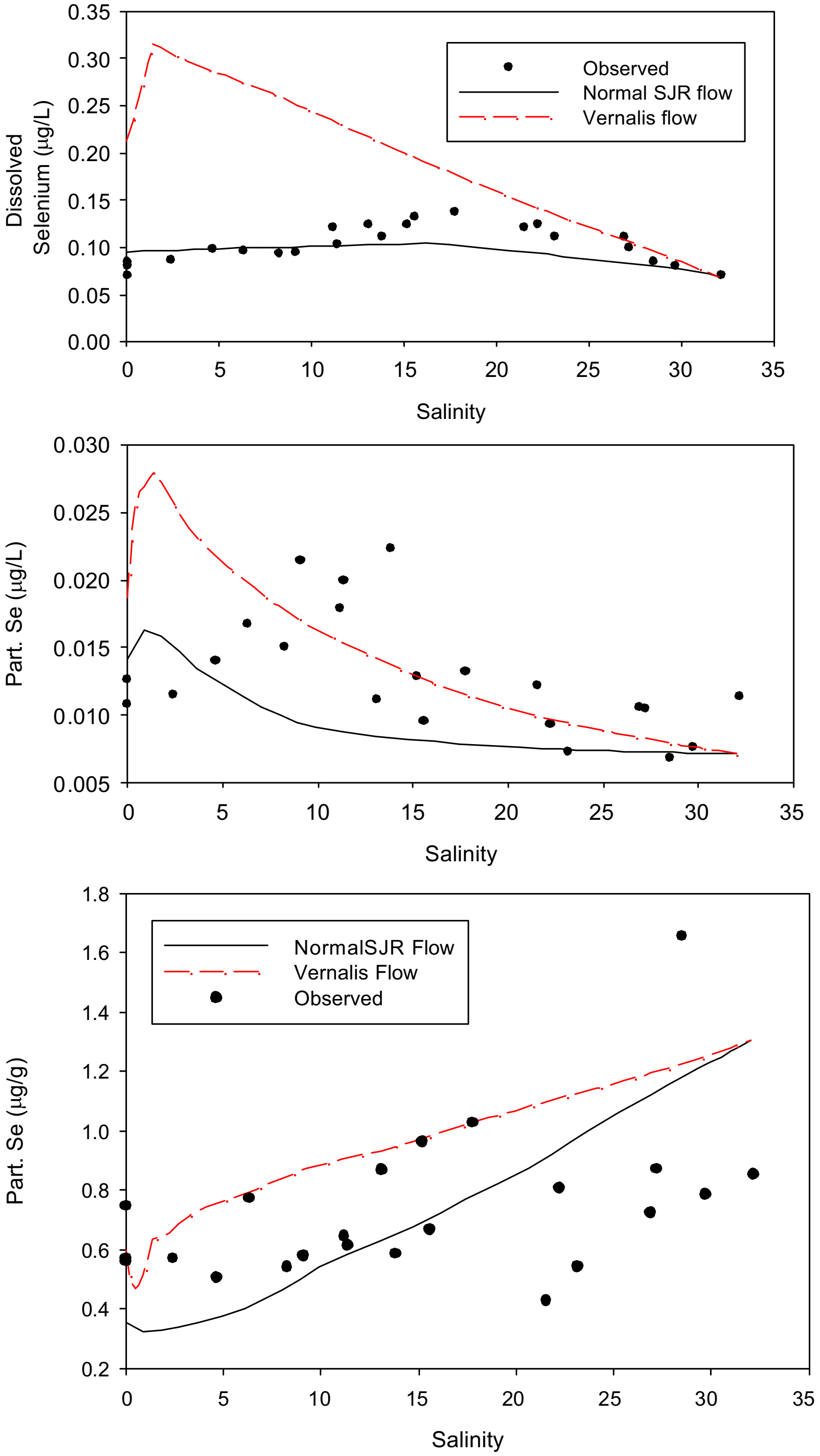
Fig. 11 Simulated selenium concentrations muscle tissue of diving ducks (dry weight; Greater Scaup) compared with observed data in San Pablo Bay and Suisun Bay, respectively (White et al. 1988, 1989; Urquhart et al. 1991; SFEI), using TTF=1.8

Similarly, the model was able to fit the particulate selenate plus selenite better than the particulate organic selenide. In general, the model was better able to represent the broad trends in concentration better than the localized spatial variation. The reasons underlying this behavior are not fully understood and may relate to local variability or to small scale processes that are not captured in the 1-D model with 33 cells representing a 100-km long modeling domain.

Future model development may seek to address some of the shortcomings of the modeling presented here, such as the occasional inability to represent the estuarine turbidity maximum and the chlorophyll *a* peaks, the uncertainties in riverine and ocean boundary conditions and their effect on the conclusions, and the difficulty in capturing large local-scale variability in organic selenium concentrations, which may be partly due to the complexity and limited understanding of phytoplankton growth dynamics and species distribution.

A sensitivity analysis of the various model parameters was performed. The analysis indicated that the model is relatively sensitive to parameters that affect the location and magnitude of the TSM. Dissolved and particulate selenium concentrations are most sensitive to the riverine input parameters (Table 3 in the ESM). Particulate selenium concentrations are sensitive to selenium content on particulates at the riverine boundary. Dissolved and particulate selenium are less sensitive to selenium transformation coefficients such as phytoplankton uptake and selenite adsorption rates. Particulate organic selenide and particulate selenium are also sensitive to increases in phytoplankton growth rates. The relatively high sensitivity of particulate organic selenium, particulate selenium, and dissolved selenite to increases in phytoplankton growth rate (also as an indicator of phytoplankton concentrations) underscores how certain species of selenium are closely tied to phytoplankton concentrations. In addition, particulate organic selenide is also sensitive

Fig. 12 Predicted dissolved and particulate selenium for different San Joaquin River discharge rates during a low flow period (11 November 1999)



to its mineralization rate. Through adjustment of several of these parameters, the ECoS framework was able to capture the essential behavior of selenium and ancillary parameters in NSFB. Future work in the bay focusing on these components of selenium behavior, including characterization of the riverine boundary and phytoplankton growth and uptake, may enhance the robustness of the modeling.

Temporal Variations in Selenium Concentrations in Clams

The recently reported *C. amurensis* concentration data from San Francisco Bay (Kleckner et al. 2010) illustrate interannual and inter-seasonal patterns in clam concentrations from 1995 to 2010, a period over which there have been variations in freshwater inflows as well as changes in the selenium loading, particularly changes in refinery wastewater loading in 1998, and a general reduction in San Joaquin River loads through selenium source control actions in the San Joaquin River watershed. Over this period of record, two features stand out in the observed clam data: there has not been a large reduction in clam concentrations despite the load changes, and there is a significant amount of inter-seasonal and inter-annual variability, with the lowest concentrations in each year occurring during the high flow months, and the highest concentrations occurring in the low-flow months. Seasonal high concentrations are almost a factor of two as high as the low concentrations.

The seasonal pattern is a feature of the clam data and cannot be explained by the dissolved selenium concentration data alone, as the dissolved data do not show a similar seasonal pattern. However, the modeling framework presented in this study does provide a plausible hypothesis, as outlined below. Particulates in the bay, especially phytoplankton, can have higher selenium concentrations (on a microgram-per-gram basis), than particulates originating in the riverine source in Rio Vista (with a greater mineral fraction). High flow periods are associated with high particulate loads from Rio Vista, largely made up of Sacramento River flows, resulting in lower average selenium concentrations in the bay than during low-flow periods. Thus, changes in selenium concentrations in clams from one year to the next appear to be influenced significantly by hydrology, with wet years (such as 2005 and 2006) resulting in lower clam concentrations. This hypothesis does not consider changes in the rate of selenium uptake as a function of the clam's life cycle, although such a process may also be a factor in the overall variation. There are, however, insufficient data to independently evaluate the significance of the growth effect at this time. An evaluation of the Kleckner et al. (2010) data showed no consistent relationships between clam size (as represented by mean shell length) and selenium concentrations. The hypothesis developed here through the integration of best-available data and modeling provides insight into the future management of selenium concerns in NSFB, although it must be re-evaluated as new data and process-level information become available.

The long-term trends in selenium concentrations in clams (1995–2010) suggest the importance of in-estuary transformations in affecting particulate and biota selenium concentrations in addition to the external loads. Given the decreases in external loads over the study period (both from the refineries and the San Joaquin River), dissolved selenium concentrations in the bay have shown a more direct response to these changes. However, the corresponding changes in particulate selenium are generally minimal, as reported previously in Doblin et al. (2006). As shown through the modeling framework presented here, this could be due to the fact that phytoplankton in the estuary are still able to concentrate relatively high selenium concentrations, which contribute to relatively high particulate selenium concentrations that enter the food web, and result in continued high concentrations in the clams. In effect, this framework indicates that particulate selenium concentrations, and therefore the concentrations in filter feeders, such as clams, are not a simple linear function of dissolved concentrations. Accurate predictions of concentrations in the food web require accurate characterization of particulate concentrations, through observations where possible, or through adequate characterization of uptake by the particulate phases. The model developed here is a tool for supporting such predictions.

Summary and Conclusions

The ECoS model framework was applied to the NSFB for computing salinity, TSM, and chlorophyll *a*, and for selenium concentrations. The model was calibrated to data from 1999, because this is the most recent year for which speciated selenium data in the water column of the NSFB are available. The three ancillary constituents, salinity, TSM, and chlorophyll *a*, were calibrated using monthly water quality cruise data reported by the USGS. Although the ancillary water quality data in the bay are relatively abundant for the calibration of a 1-D model, the calibration period was limited by the availability of selenium data. Following calibration, where model parameters, especially the first-order rate constants that represent selenium transformation and uptake were estimated, the model was applied to different years for evaluating its performance. The calibrated model performed well under different hydrological and load conditions, and was able to simulate salinity, TSM, and chlorophyll *a* profiles for both dry years (e.g., 2001) and wet years (2005), and long-term TSM and chlorophyll *a* concentrations variations. The calibrated model was also run in a hindcast mode using hydrological and refinery loads for 1998. Selenium species and loads in this period were different from current loads, and the hindcast was another test of the credibility of the model. The simulated dissolved selenium concentrations compared well with the observed data. The model was able to simulate the mid-estuarine peaks in selenite for low flow of 1998. This indicates the location and magnitude of the selenium input from point sources and the transport and transformation of selenium are represented well in the model. Simulated particulate selenium concentrations also compared well with the observed values.

The model was able to simulate different selenium speciation and the bioavailability of each species, therefore is able to simulate selenium concentrations on particulates relatively well for different time periods (e.g., 1999 and 1998). The model could also represent the long-term variations (inter-annual and seasonal) in clam selenium concentrations for both prior-to refinery clean up (1994–1998) and post-refinery clean up time periods (1998–2010), including years with high and low clam selenium concentrations. The accumulation of selenium to higher trophic organisms is simulated using a TTF approach, which is able to represent selenium concentrations in white sturgeon and greater scaup in the bay.

A scenario of increasing flow and selenium loads from the San Joaquin River was also examined using the calibrated model. The results suggest that when flow from the San Joaquin River is a greater contributor to outflow from the Delta, significant increases in dissolved and particulate selenium, and selenium on particulates, are predicted in the bay. This would be expected to increase clam concentrations. This is of interest for long term planning for selenium management in NSFB, because there are plans being evaluated by the state of California to make changes in the way water is exported from the Delta through intakes further upstream in the Sacramento River, and by use of an isolated conveyance facility (CALFED 2008). Manipulations to the Delta system, especially those that increase San Joaquin flow into the bay, will also have selenium impacts to the bay that must be evaluated.

Although simplified through a 1-D representation, the modeling approach presented here is able to capture key features of selenium behavior at a level of complexity that is consistent with data that can be measured in the bay in future years. A benefit of the model is its ability to link sources to biota concentrations under a range of hydrologic conditions, and with mechanistic representations of transport, transformation and uptake processes. The mechanistic representation allows consideration of selenium uptake under future conditions, with changes in background water quality, hydrology, and the food web structure, which may be related to human interventions or natural causes. The modeling framework as developed, or with changes to reflect underlying processes and Delta modifications, can be used to explore selenium management options in San Francisco Bay in the context of the TMDL.

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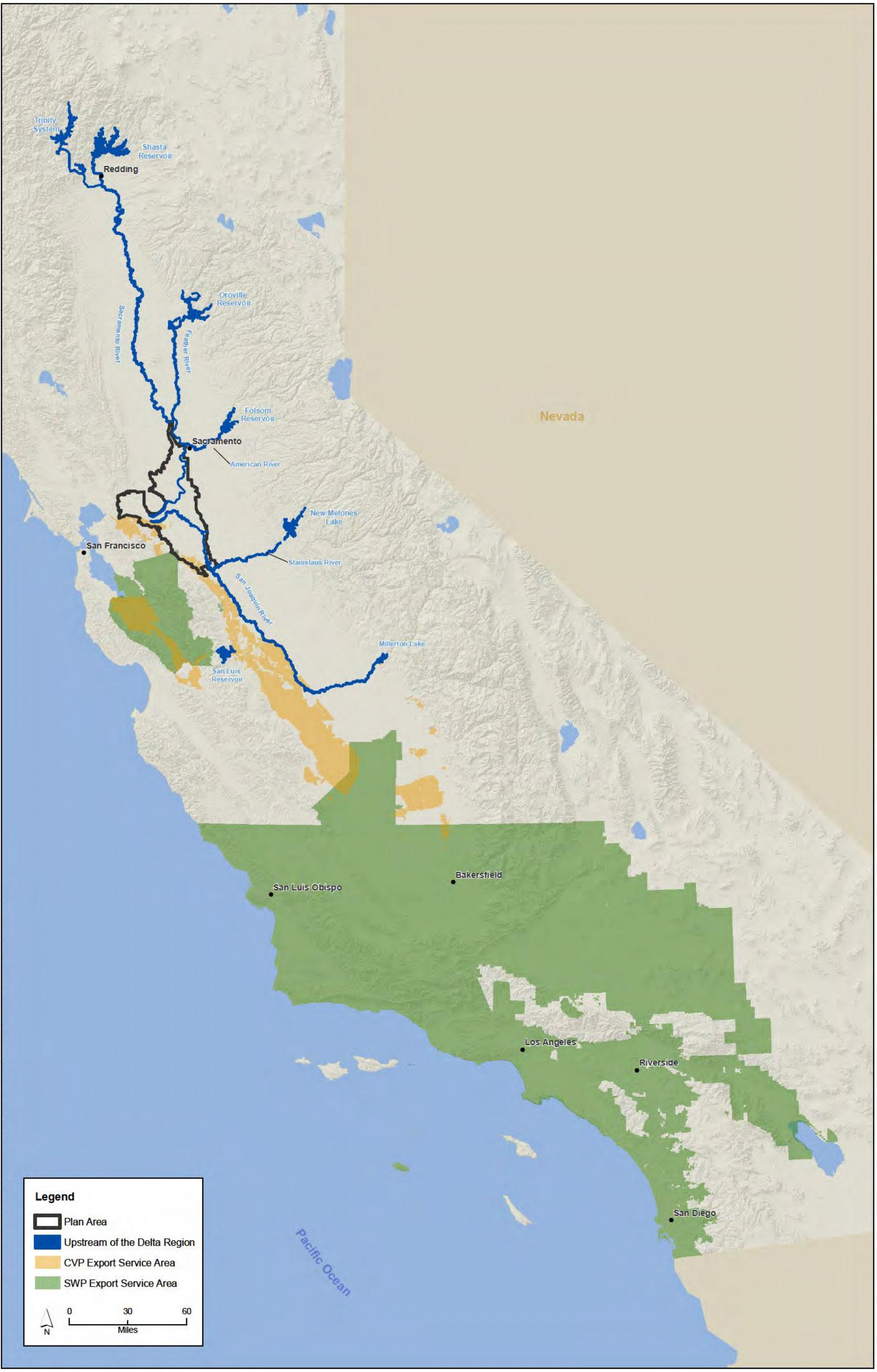

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Sources: Plan Area, ICF 2012; SWPCVP Canals/Aqueducts, HDR 2011; CVP Division Entities, USBR 2010; SWP Service Areas, ESA 2007;

Figure 1-4
Project Area

Review of Selenium Bioaccumulation Assessment in the Bay Delta Conservation Program Draft EIR/EIS

Revised Final Report

Prepared for:
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May 30, 2014

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ACRONYMS

BDCP	Bay Delta Conservation Plan
CEQA	California Environmental Quality Act
DSM2	Delta Simulation Model 2
DWR	Department of Water Resources
EIR	Environmental Impact Report
EIS	Environmental Impact Statement
ESO	Evaluated Starting Operations
HOS	high outflow scenario
LOS	low outflow scenario
ND	Non-detect
RL	Reporting Limit
TTF	Trophic transfer factor
USGS	United States Geological Survey
WSPA	Western States Petroleum Association

EXECUTIVE SUMMARY

The Bay Delta Conservation Plan (BDCP) proposes a comprehensive water conservation strategy to restore and protect the ecosystem health and protect the water supply and water quality of the Delta (ICF, 2013). The plan includes new intakes in the northern Delta through a tunnel system to improve reliability and water quality. A total of 9 alternatives (with some sub-alternatives for a total of 15 action alternatives) and the no Action alternative were evaluated in the plan EIR/EIS. Alternative 4 is the CEQA preferred alternative. Alternative 4 is the dual conveyance with pipeline/tunnel and intakes with an export capacity of 9,000 cfs. Under Alternative 4, water would be conveyed from the north Delta to the south Delta through pipelines/tunnels and through surface channels.

Selenium in the San Francisco Bay/Sacramento-San Joaquin River Delta is of concern due to its adverse ecological impacts at high concentrations, primarily through bioaccumulation in the food web. The Bay Delta Conservation Plan (BDCP) Environmental Impact Report/Environmental Impact Statement (EIR/EIS) presents an analysis of selenium impacts that is the subject of this review. The implementation of various construction and restoration alternatives through the BDCP do not, by themselves, introduce new selenium into the system. However, by altering the flow patterns, and the relative mixing of different water sources entering the Bay and Delta, the different alternatives have the potential of altering the selenium water column concentrations in the Bay.

Selenium concentrations used in the Sacramento River for the BDCP EIR/EIS study are biased high, likely due to the inclusion of older analytical values reported at detection limits of 1 µg/L. Detection limits for dissolved selenium using the selective hydride generation/atomic absorption method are normally at 0.0016 µg/L and have been used for studies in San Francisco Bay (Cutter and Cutter, 2004; Tetra Tech, 2012). Long-term detection limits for using ICP-MS[1] method are 0.05 µg/L (USGS, 2014). The

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[1] Inductively coupled plasma mass spectrometry

Sacramento River selenium values are critical to the calculation because this is the dominant flow into the Bay. In the current version of the public review documents, the calculated values of water column selenium in San Francisco Bay (0.21 – 0.31 µg/L at Mallard Island) are much higher than the observed (from 0.08 to 0.12 µg/L across multiple sampling events in Suisun Bay). Using the calculated water column concentration in the EIR/EIS, the calculated values of white sturgeon tissue selenium (9.9 µg/g mean and 15 µg/g drought year value) are higher than observed in the last decade across multiple samples.

Using valid boundary values for the Sacramento and San Joaquin Rivers (Freeport: 0.095 µg/l and Vernalis: 0.57 µg/l, both based on observed data from the US Geological Survey), we have updated the San Francisco Bay water column and white sturgeon calculations. Using the same modeling framework as in the original BDCP analysis, but with the corrected boundary values, we are able to get a reasonable match with the observed data for current conditions. The model analysis shows that the BDCP-preferred Alternative 4 will result in higher percent changes in water column concentrations than that calculated in the EIR/EIS. Using the bioaccumulation model in the EIR/EIS, we find a similar projected increase in fish tissue concentrations between Alternative 4 and existing conditions (i.e., no BDCP project). Importantly, the new calculations suggest that there is an effect of the BDCP changes to the water column and white sturgeon selenium concentrations at the Mallard Island station for CEQA Alternative 4, representing conditions in Suisun Bay (8-20% increase, depending on the hydrology). This is higher than currently estimated for Alternative 4 at this station (2-5% increase, calculated by Tetra Tech), and may be evaluated in the context of the CEQA conclusion: “Relative to Existing Conditions, modeling estimates indicate that all scenarios under Alternative 4 would result in essentially no change in selenium concentrations throughout the Delta.” (page 8-476, Draft EIR/EIS).

From the standpoint of water column selenium concentrations, the worst case conditions are not the drought years of 1987-1991, but years where the San Joaquin flow contributions to the bay are greater. Periods with high San Joaquin River flow to the Bay occur in the wet months of wet years, and should also be considered for the selenium effects. Should alternatives besides the CEQA preferred Alternative 4 be considered in future phases, selenium impacts could be more significant. The change in selenium concentration (existing conditions versus the alternatives) needs to be addressed through the EIR/EIS.

Besides correction of the boundary values in the EIR/EIS, other considerations follow. The calculated white sturgeon concentrations with the new boundary conditions are lower under existing conditions than that calculated in EIR/EIS, below the 8.1 µg/g whole-body values now proposed by the US Environmental Protection Agency as a fish tissue target (USEPA, 2014). The North San Francisco Bay is considered impaired due to a Se (303d) listing and a total maximum daily load analysis (TMDL) is being prepared. The potential of impairment under existing conditions and current loads from various point- and non-point sources will be addressed by the San Francisco Bay Regional Water Quality Control Board through this TMDL, but it is important to note that this modeling suggests that future BDCP changes may well increase water column and fish concentrations by a greater percentage than what is calculated in the current EIR/EIS. Given this finding, there is a need to monitor the changes in water and fish over the coming years and to consider if any and what mitigation might be needed if the BDCP plan is implemented.

Table ES-1. Summary of EIR and Tetra Tech calculated selenium concentrations in water and in fish.

	EIR Boundary Condition	Actual Boundary Conditions	Calculated EIR Se Water Conc.	Calculated Revised Se Water Conc	Actual Water Conc.	EIR Calc Fish Tissue	Calculated Revised Fish Tissue	Actual Fish Tissue	Alt 4 Se Water Conc	TT Alt 4 Calc Water Conc	Alt 4 Calc Fish Tissue	TT Alt 4 Calc Fish Tissue
Entire 16-year period	Sac: 0.32 µg/L; SJR: 0.84 µg/L	Sac: 0.095 µg/L; SJR: 0.57 µg/L	0.257µg/L	0.120 µg/L	0.08-0.12 µg/L	10.2 µg/g	4.8 µg/g	3-10 µg/g	0.268 µg/L	0.139 µg/L	10.6 µg/g	5.5µg/g

1 INTRODUCTION

The Bay Delta Conservation Plan (BDCP) proposes a comprehensive water conservation strategy to restore and protect the ecosystem health and also protect the water supply and water quality of the Delta (ICF, 2013). The plan includes new intakes in the northern Delta through a tunnel system to improve reliability and water quality. A total of 9 alternatives (with some sub-alternatives for a total of 15 action alternatives) and the no Action alternative were evaluated in the plan EIR/EIS. Alternative 4 is the CEQA preferred alternative. Alternative 4 is a dual conveyance with pipeline/tunnel and intakes with an export capacity of 9,000 cfs. Under Alternative 4, water would be conveyed from the north Delta to the south Delta through pipelines/tunnels, and through surface channels.

The Bay Delta Conservation Plan (BDCP) environmental assessment, notably the Environmental Impact Report/Environmental Impact Statement (EIR/EIS), presents in some detail the impacts of the plan on various water quality constituents in the San Francisco Bay and Delta region under the no-action alternative as well as various project alternatives (Chapter 8 of the Draft EIR/EIS, November 2013). Of the constituents addressed, selenium in the San Francisco Bay/Sacramento-San Joaquin River Delta is of concern due to its adverse ecological impacts at high concentrations, primarily through bioaccumulation in the food web. This review is focused on the analysis of selenium impacts that are presented in the BDCP EIR/EIS.

Selenium concentrations in the water column originate from a variety of point sources and non-point sources in the watershed of San Francisco Bay and the Delta. Upstream of the Delta, high selenium concentrations in the San Joaquin River watershed have been a long-standing concern. The San Joaquin River watershed is naturally enriched in selenium and agricultural practices in the watershed have mobilized selenium from the soils to groundwater and surface water that drains into the Delta. The watershed and specifically a sub-area, the Grasslands area, has been identified as an important source of selenium to the Bay Delta (Central Valley Regional Water Board, 2001). In contrast, selenium concentrations in the other major riverine flow into the Delta, the Sacramento River, are relatively low. Because the combined flows of the Sacramento and San Joaquin Rivers are the primary freshwater inflows into the Bay, the proportional mix of these inflows has a strong influence on selenium concentrations in the western Delta and the Bay.

The implementation of various construction and restoration alternatives through the BDCP do not, by themselves, introduce new selenium into the system. However, by altering the flow patterns, and the relative mixing of different water sources entering the Bay and Delta, the different alternatives have the potential of altering the selenium water column concentrations in the Bay. In the EIR/EIS, changes in the water column selenium concentrations for the different alternatives considered were developed using the Delta Simulation Model (DSM2), a tool that is widely used for evaluating water quality changes in the Delta under current and future conditions.

In the bioaccumulation model used in the BDCP EIR/EIS, the water column concentrations are related to various biological endpoints, such as concentrations in largemouth bass and in white sturgeon. In the BDCP EIR/EIS, the analysis is performed using a trophic transfer model that relates water column concentrations to tissue concentrations (fish tissue or bird egg), and is presented in Appendices 8M and an Addendum M.A). Appendix 8M performed the analysis for largemouth bass, and Addendum M.A performed the analysis for white sturgeon. This was done because of the potentially greater bioaccumulation of selenium in sturgeon because of their preference for clams that bioaccumulate selenium to a greater extent (Chapter 8, page 8-138).

In this review, we use the same tools and assumptions as used in the November 2013 EIR/EIS, but modify the boundary selenium concentrations in the Sacramento and San Joaquin Rivers to be more representative of observed values. We then compare the modeled water column and sturgeon concentrations for key locations in the system across different alternatives. Observed data on the boundary selenium concentrations and in white sturgeon are also presented to substantiate the modeling changes that are proposed in this review.

2BDCPEIR/EISMODELING APPROACH

The Bay Delta Conservation Plan (BDCP) proposes a comprehensive water conservation strategy to restore and protect the ecosystem health and also protect the water supply and water quality of the Delta (ICF, 2013). The plan includes new intakes in the northern Delta through a tunnel system to improve reliability and water quality. A total of 9 alternatives (with some sub-alternatives for a total of 15 action alternatives) and the no Action alternative were evaluated in the plan EIR/EIS. Alternative 4 is the CEQA preferred alternative.

Because the San Joaquin River was historically identified as a major source of selenium to the Delta, there are concerns with respect to increased inputs of selenium from the San Joaquin River relative to the Sacramento River as a result of the proposed water operations (Evaluated Starting Operations, ESO).

The impacts of ESO water operations on selenium in water of the Bay Delta and in fish species were evaluated through a modeling study using the Delta Simulation Model II (DSM2) in the EIR/EIS. DSM2 is a one-dimensional mathematical model for simulation of one-dimensional hydrodynamics and water quality in the channels of the Delta and the eastern part of San Francisco Bay. The western boundary of the model is located in Martinez along the western portion of Suisun Bay. The DSM2 model was run to estimate changes in water flows under the proposed action alternatives. The outputs from the DSM2 model, along with the available measured waterborne selenium concentrations in the boundary sources, were used to calculate concentrations of selenium at locations throughout the Delta. Modeled selenium concentrations in the water column were used to calculate selenium concentrations in whole-body fish and bird eggs using ecosystem-scale models developed by Presser and Luoma (2013).

The DSM2 model was run to estimate the volumetric contribution from six major inputs to the Delta: the Sacramento River, San Joaquin River, Martinez (representing the San Francisco Bay boundary), east side tributaries, agricultural return flows, and Yolo Bypass (Figure 2-1). Observed selenium concentrations in the six major sources were used to predict the resultant selenium concentrations at given locations in the Delta (Table 2-1). Predicted selenium concentrations in water column are listed in Table 2-2.

The DSM2 model was run for a scenario without BDCP (EBC2_LLT) and under three BDCP scenarios: 1) evaluated starting operations late long term (ESO_LLT), 2) a low-outflow scenario (LOS_LLT), and 3) a high-outflow scenario (HOS_LLT). The hydrologic conditions considered include: 1) all water years (1975- 1991) representing the 16-year period modeled using DSM2 (termed “All” in the scenarios below); and 2) a drought period of five consecutive years (water years 1987-1991) consisting of dry and critical water-year types (termed “Drought”).

The predicted selenium concentrations in the water column were translated to concentrations in fish using the ecosystem – scale model developed by Presser and Luoma (2013). The ecosystem models were developed using data from laboratory and field studies. Selenium concentrations in water column were translated to concentrations in particulate matter using fixed ratios (termed Kd). Further bioaccumulation from particles to lower trophic level prey items and then to fish was accomplished through Trophic Transfer Factors (TTF). TTF values are based on ecosystem-wide measurements, and were based on data from San Francisco Bay. Presser and Luoma (2013) determined Kd values for the San Francisco Bay (including Carquinez Strait – Suisun Bay) during “low flow” conditions (5,986 l/mg) and “average” conditions (3,317 l/mg). These values were used to model selenium concentrations in particulates for “Drought” and “All” conditions at locations in the western Delta. TTF values for particulates to clams/amphipods were determined to be 9.2 (dimensionless). TTF values for prey to fish (white sturgeon) was determined to be 1.3 (dimensionless).

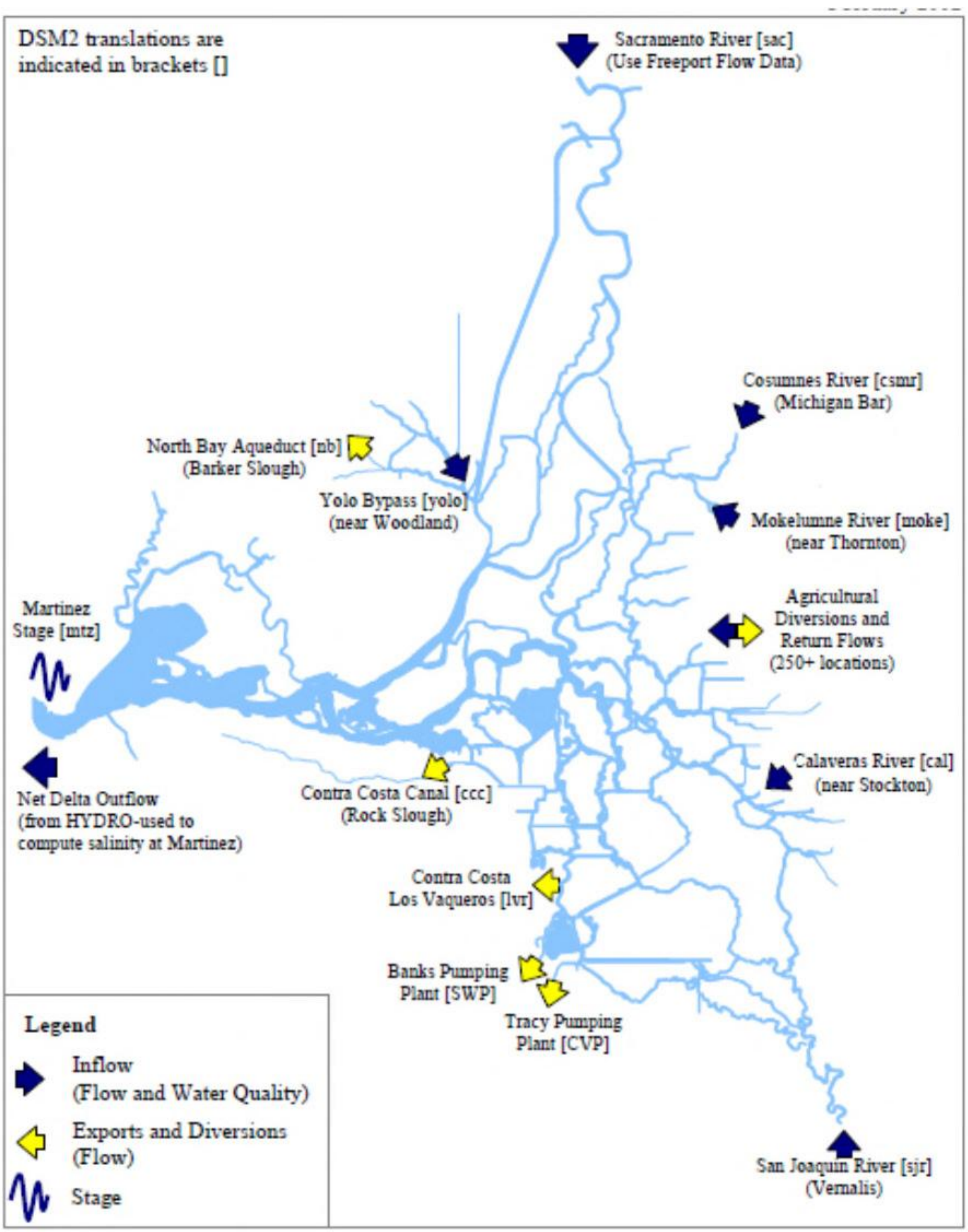

Figure 2-1. Map of typical DSM2 boundary conditions

Table 2-1
Historical selenium concentrations in the six Delta source waters for the period 1996 – 2010 (Source: Table 8-56, Draft EIR/EIS, November 2013)

Source water	Sacramento River[a]	San Joaquin River[b]	San Francisco Bay[a]	East side tributaries[c]	Agriculture in the Delta[a]	Yolo Bypass[d]
Mean (µg/L)[e]	0.32	0.84	0.09	0.1	0.11	0.45
Minimum (µg/L)	0.04	0.40	0.03	0.1	0.11	0.19
Maximum (µg/L)	1.00	2.80	0.45	0.1	0.11	1.05
75th percentile (µg/L)	1.00	1.20	0.11	0.1	0.11	0.65
99th percentile (µg/L)	1.00	2.60	0.41	0.1	0.11	1.04
Data source	USGS 2010	SWAMP 2009	SFEI 2010	None	Lucas and Stewart 2007	DWR 2009b
Stations	Sacramento River at Freeport	San Joaquin River at Vernalis (Airport Way)	Central-west; San Joaquin River near Mallard Is. (BG30)	None	Mildred Island, center	Sacramento River at Knights Landing
Date Range	1996-2001, 2007 -2010	1999-2007	2000-2008	None	2000, 2003-2004	2003, 2004, 2007, 2008
ND replaced with RL	Yes	Yes	Yes	Not applicable	No	Yes
Data omitted	None	Pending data	None	Not applicable	No	None
No. of data points	62	453	11	None	1	13

[a] Dissolved selenium concentrations
[b] Not specified total or dissolved
[c] Dissolved concentrations are assumed to be 0.1 µg/L due to lack of data
[d] Total selenium concentrations. Ideally, dissolved concentrations should be used for comparison, and constitutes the dominant form of selenium in the system. Not all stations report selenium in the same form. The combined use of total and dissolved selenium across different stations is a source of potential uncertainty.
[e] Means are geometric means

Table 2-2
Modeled selenium concentrations in water column for late long-term scenario (values reproduced from Table 8M1 in Appendix 8M of the EIR/EIS)

Location	Period	Period Average concentrations (µg/L)		
		Existing Conditions	No Action Alternative LLT	Alternative 4H1
San Joaquin River at Antioch Ship Channel	ALL	0.31	0.31	0.33
	Drought	0.27	0.27	0.28
Sacramento River at Mallard Island	All	0.25	0.25	0.26
	Drought	0.21	0.21	0.21

Under the low flow condition (after modifying Kd units) (based on the EIR/EIR, Appendix 8M),

Sturgeon Se = Cw*6.0*9.2*1.3 mg/g or

= Cw*71.8 mg/g,

where Cw is the water column concentration in µg/L (typically the dissolved water column concentration)

Under the average flow condition,

Sturgeon Se = Cw*3.3*9.2*1.3 mg/g or

= Cw*39.5 mg/g,

where Cw is the water column concentration in µg/L (typically the dissolved water column concentration)

In the EIR/EIS, fish Se values are compared to a low benchmark of 5 µg/g and a high benchmark of 8 µg/g (µg/g = mg/kg). At this time, fish targets are being developed by the US Environmental Protection Agency, and these fish tissue benchmarks are a reasonable representation of the range.

Selenium concentrations associated with source waters particularly in the Sacramento River (0.32 µg/L) that are used in the BDCP EIR/EIS modeling were notably higher than concentrations reported for this river (0.07 µg/L) by Cutter and Cutter (2004). A possible reason for these high concentrations was the high detection limit (1 µg/L) that was in the early period of the data record. For the concentration level of concern in the Bay-Delta region (0.1-0.2 µg/L), a high detection limit of 1 µg/L will significantly bias the results of selenium concentrations in the water. Modeled selenium concentrations at Mallard Island and Antioch were also significantly higher than values observed in the Bay water.

In this study, we conducted an independent evaluation of selenium concentrations associated with the rivers to be considered as inputs to the Delta, using the same data source used in the BDCP EIR/EIS study.

Copies of the DSM2 model inputs and outputs for the scenarios were made available by the California Department of Water Resources (DWR) to Tetra Tech, and were employed for the subsequent analysis (Brian Heiland, personal communication, June 2013). We confirmed that the runs were identical to those used in the November 2013 draft of the EIR/EIS (Brian Heiland, personal communication, January, 2014).

We then conducted DSM2 runs to replicate results from the BDCP EIR/EIS study. Selenium concentrations from our independent evaluation were then used in calculating concentrations in the Delta. We recomputed fish selenium concentrations (white sturgeon) based on selenium concentrations in the water.

3 INDEPENDENT REVIEW OF SELENIUM DATA FROM USGS ON RIVERS

In our evaluation, we downloaded data from US Geological Survey National Water Information System (NWIS) database for the Freeport Station on Sacramento River (station code 11447650) and Vernalis on the San Joaquin River (station code 11303500), given the importance of these stations in the inflows to the Delta and then to the Bay.

For Freeport, a total of 411 values from 1973 to present were found for dissolved or total selenium. From the beginning of record to 9/15/98, values are classified as “historical” and reported using a hydride analytical method. For these dates, values were reported as < 1 µg/L and noted to be less than the method detection limit (MDL) of 1 µg/L. No data were found from 9/15/1998 to 11/26/2007. From 11/27/2007 to present, there are 75 values, all reported as using the ICP-MS method, with an MDL of 0.03 to 0.04 µg/L. From 11/2007, dissolved selenium concentrations range from 0.04 to 0.23 µg/L, with a median concentration of 0.09 µg/L, and a mean concentration of 0.095 µg/L.

Similar to the Sacramento River, an independent review of the selenium data from USGS for the San Joaquin River at Vernalis was conducted. From 11/28/2007 to present, there are 78 values, all reported using an ICP-MS method, with an MDL of 0.03 to 0.06 µg/L. From 11/2007, dissolved selenium values range from 0.12 to 1.5 µg/L, with a median of 0.47 µg/L, and a mean of 0.57 µg/L.

As shown in Figure 3-1 and Figure 3-2, dissolved selenium concentrations in the Sacramento River were generally below 0.2 µg/L and were approximately 0.5 µg/L for the San Joaquin River.

Another independent study of selenium concentrations in the rivers by the Western States Petroleum Association (WSPA) is available for comparison for the period 2010 – 2012 (Table 3-1) (Tetra Tech, 2012). Average selenium concentrations sampled by WSPA for this time period are 0.07 µg/L for the Sacramento River at Freeport and 0.34 µg/L for the San Joaquin River.

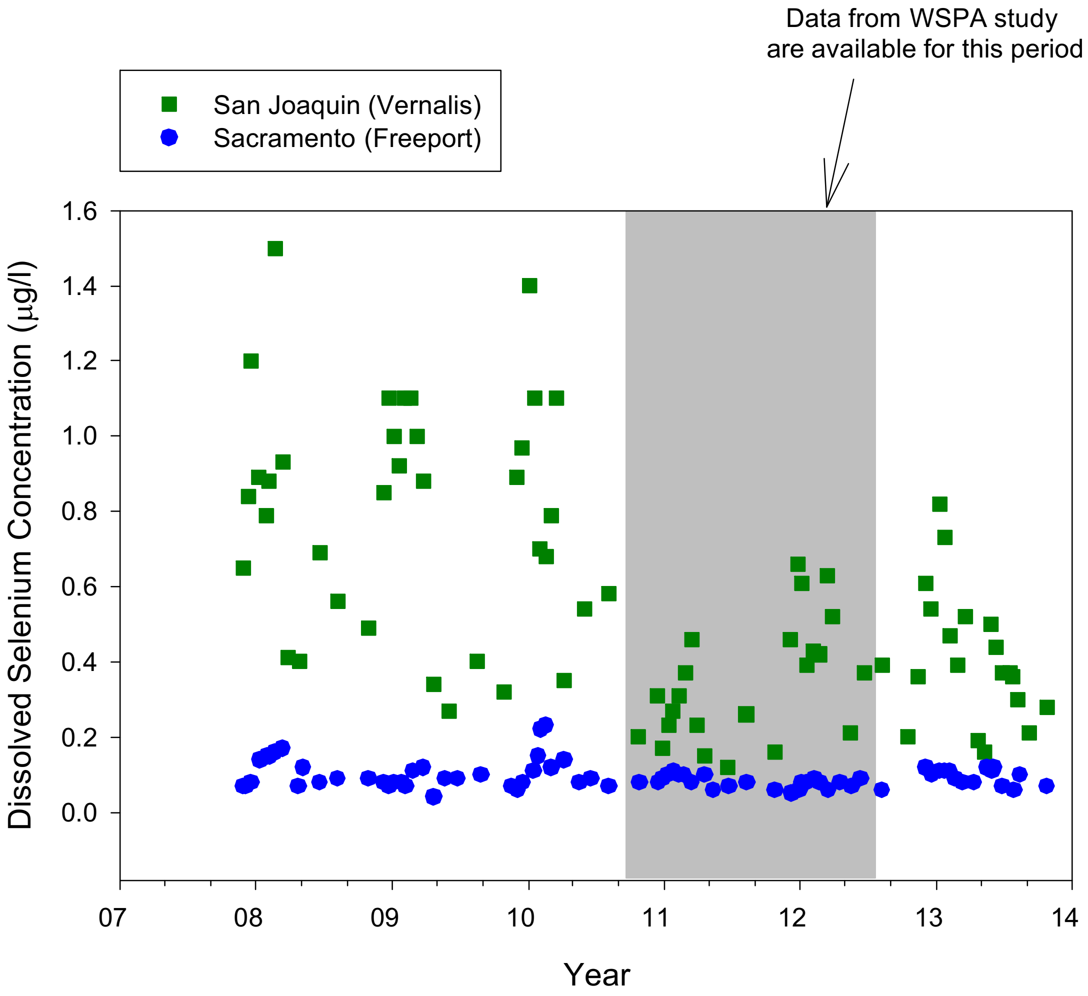

Figure 3-1 Dissolved selenium concentrations in Sacramento and San Joaquin River from 2007 - present (USGS NWIS data)

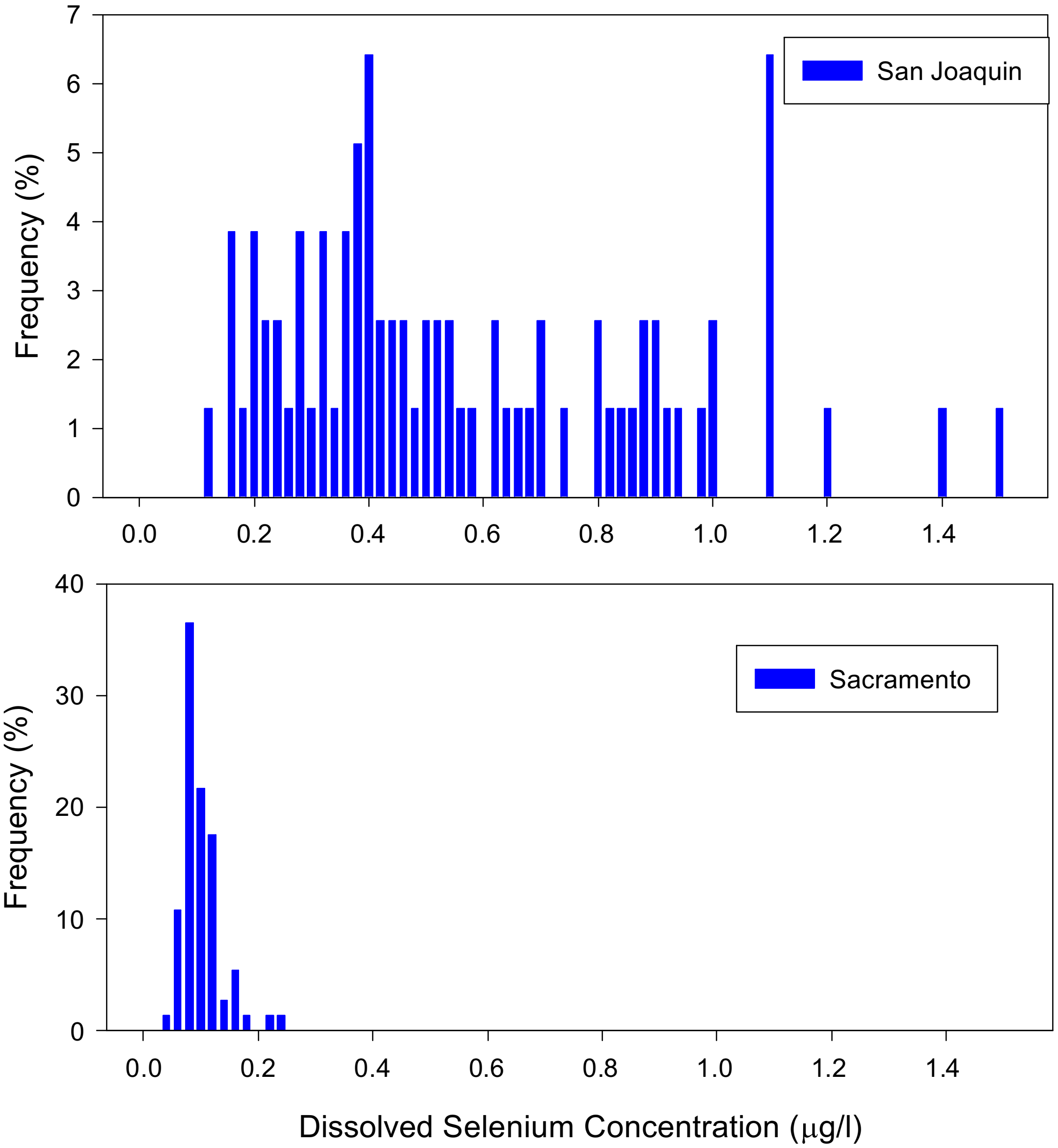

Figure 3-2 Frequency of distribution for dissolved seleniumconcentrations in the Sacramento and San Joaquin Rivers (USGS NWIS data)

The Suisun Bay location, as the boundary of the DSM2 model domain and the Carquinez Strait, was also evaluated for selenium concentrations (Table 3-2 and Table 3-3). Average selenium concentrations in Suisun Bay from several sources suggested relatively low concentrations of around 0.10 µg/L, as opposed to higher concentrations in the Bay predicted by BDCP EIR/EIS in Table 2-2.

Selenium concentrations from six sources that are used in our calculation of concentrations in the Bay are shown in Table 3-4. For the Freeport and Vernalis stations only, these were updated from the original data ranges reported in Table 2-1. The largest changes occurred at the Freeport station from 0.32 µg/l in the EIR/EIS to the corrected value of 0.095 µg/l in the update. This change is critical to the analysis because the Freeport flows are the dominant freshwater flows in the Delta system.

For context, the observed white sturgeon concentrations from San Francisco Bay are also shown in Figure 3-3. These data were obtained from the CEDEN database, and are based on data reported by the Regional Monitoring Program. Sturgeon are sampled every 3-5 years, and the current data available in CEDEN for North San Francisco Bay covers Suisun Bay and San Pablo Bay. The dry weight of selenium in fish tissue range from 1.75 to 10.8 µg/g, with a single value in San Pablo Bay at 18.5 µg/g. Suisun Bay values range from 3.1 to 10.8 µg/g.

Table 3-1
Riverine selenium concentrations sampled byWSPA for the period of 2010 – 2012 (Tetra Tech, 2012)

Station	Sample data	Totaldissolved Se (µg/L)	Mean (µg/L)
Freeport	10-Sep-10	0.068	0.07
Freeport	18-Mar-11	0.062	
Freeport	7-Oct-11	0.064	
Freeport	16-Apr-12	0.09	
Vernalis	10-Sep- 10	0.353	0.34
Vernalis	18-Mar-11	0.317	
Vernalis	7-Oct-11	0.207	
Vernalis	16-Apr - 12	0.47	

Table 3-2
Selenium concentrations in Suisun Bay for 1999 Cutter and Cutter (2004)
and for 2010-2012 by Tetra Tech (2012)

Sample data	Average dissolved Se(µg/L)	Number ofstations during sampling event
Apr -99	0.12	4
Nov – 99	0.10	10
8-Sep-10	0.09	9
15-Mar-11	0.10	4
4-Oct-11	0.08	7
11-Apr-12	0.10	5

Table 3-3
Selenium concentrations in Carquinez Strait for 1999 Cutter and Cutter (2004) and for 2010-2012 by Tetra Tech (2012)

Sample data	Average dissolved (µg/L)	Number ofstations in this region during sampling event
Apr -99	0.100	4
Nov – 99	0.129	4
8-Sep-10	0.103	4
15-Mar-11	0.101	2
4-Oct-11	0.10	4
11-Apr-12	0.123	3

Table 3-4
Updated selenium concentrations in the six Delta source waters

Source water	Sacramento River[a]	San Joaquin River[a]	San Francisco Bay[a]	East side tributaries[b]	Agriculture in the Delta[a]	Yolo Bypass[c]
Mean (µg/L)[d]	0.095	0.568	0.09	0.1	0.11	0.45
Minimum (µg/L)	0.04	0.12	0.03	0.1	0.11	0.19
Maximum (µg/L)	0.23	1.50	0.45	0.1	0.11	1.05
75th percentile (µg/L)	0.11	0.80	0.11	0.1	0.11	0.65
99th percentile (µg/L)	0.22	1.42	0.41	0.1	0.11	1.04
Data source	USGS	USGS	SFEI 2010	None	Lucas and Stewart 2007	DWR 2009b
Stations	Sacramento River at Freeport	San Joaquin River at Vernalis (Airport Way)	Central-west; San Joaquin River near Mallard Is. (BG30)	None	Mildred Island, center	Sacramento River at Knights Landing
Date Range	2007-2014	2007-2014	2000-2008	None	2000, 2003-2004	2003, 2004, 2007, 2008
ND replaced with RL	Yes	Yes	Yes	Not applicable	No	Yes
Data omitted	None	None	None	Not applicable	No	None
No. of data points	82	84	11	None	1	13

[a] Dissolved selenium concentrations
[b] Dissolved concentrations are assumed to be 0.1 µg/L due to lack of data
[c] Total selenium concentrations
[d] Means are geometric means

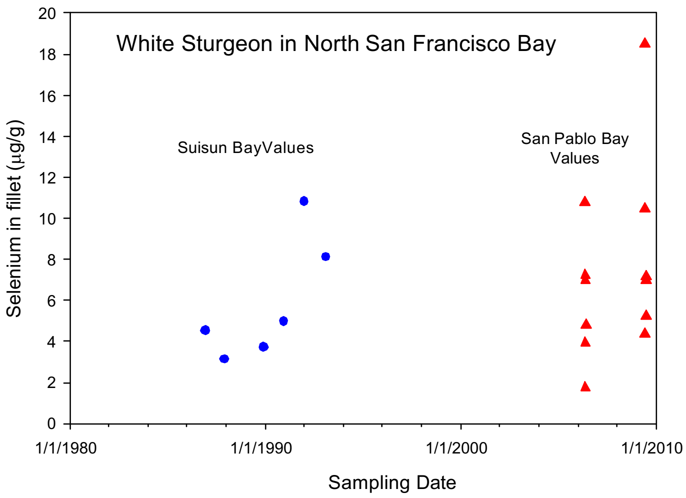

Figure 3-3 *White sturgeon selenium concentrations in Suisun Bay and San Pablo Bay (Regional Monitoring Programdata obtained from CEDEN database)*

4 RESULTS

The presentation below first considers replication of the EIR/EIS calculations, followed by an updated set of calculations where we modified the boundary conditions to more accurately represent observed values.

4.1 BDCP CALCULATIONS REPLICATED BY TETRA TECH

The DSM2 model scenarios obtained from DWR were first run for existing conditions, using the same boundary concentrations as used in the November 2013 EIR/EIS.

The model was used to predict the volumetric contribution from six source boundaries to volumes at Mallard Island. The predicted volumetric contribution from the San Joaquin River showed elevated contributions during the wet years (Figure 4-1). Predicted volumetric contributions in conjunction with selenium concentrations in the six source waters listed in Table 2-1 (average concentrations) were used to predict selenium concentrations at Mallard Island. Modeled selenium concentrations for the drought period were lower due to lower contributions from the San Joaquin River. For the wet years of 1981- 1985, predicted selenium concentrations at Mallard Island were higher due to higher contributions from the San Joaquin River during this period (Table 4-1).

The model was also run for the Alternative 4 scenario. Alternative 4 is the CEQA preferred scenario identified in the EIR/EIS report and includes a tunnel for a portion of the diversions from the Sacramento River. The model was used to predict the volumetric contribution from six source boundaries to Mallard Island, under the altered hydrological conditions of Alternative 4. The volumetric contributions from San Joaquin River showed elevated contributions during the wet years (Figure 4-2). As in the existing conditions analysis, the volumetric contributions and selenium concentrations in the six source waters listed in Table 2-1 were used to predict selenium concentrations at Mallard Island. Modeled selenium concentrations for the drought period were lower due to decreased contributions from the San Joaquin River. For the wet years of 1981- 1985, predicted selenium concentrations at Mallard Island were higher due to higher contributions from the San Joaquin River during that period (Table 4-2).

The results show small changes in selenium concentrations from existing conditions to the preferred alternative (Alternative 4; Table 4-3). For the entire period, the change in total selenium from existing condition is 4.3%. The change in total selenium from the existing condition for the high San Joaquin contribution years (1981-1985) is slightly higher at 5.3%.

The predicted selenium concentrations in water column were used to predict selenium concentrations in whole-body of white sturgeon, using the reported Kd and TTF values from Luoma and Presser (2013). The Kd values for transferring dissolved selenium to particulate selenium are 3,317 l/g for all conditions and 5,986 l/g for the drought period. The TTF for transferring selenium in particulates to invertebrate is 9.2. The TTF for invertebrate to whole-body white sturgeon is 1.3. Calculated results of selenium concentrations in whole body white sturgeon are shown in Table 4-4 and Table 4-5. Mean concentrations for the 16-year simulation period increase from 10.21 μg/g under existing conditions to 10.65 μg/g under Alternative 4.

Because only the mean concentrations from source boundaries were used to predict concentrations at Mallard, as opposed to time series data used in the original study, very slight differences may be seen from the results compared to the original study. Despite these differences, the replicated selenium concentrations in the water column and in white sturgeon for the existing conditions and Alternative 4 are similar to the BDCP EIR/EIS report (Table 8M1 and 8M2 of the Draft EIR/EIS, November 2013).

Comparison of BDCP and Tetra Tech replicated concentrations in the water column and white sturgeon for the existing conditions and other alternatives is shown in Table 4-6 and Table 4-7. The table shows that we are able to independently reproduce with minimal differences the values for water column and sturgeon across a wide range of alternatives.

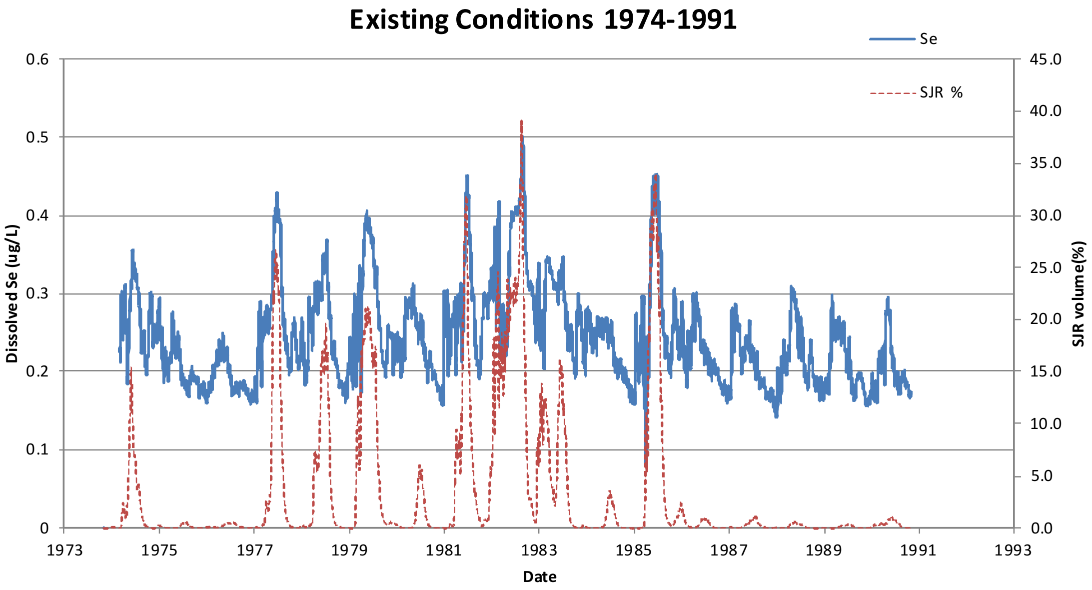

Figure 4-1 *BDCP calculations replicated by Tetra Tech for existing conditions at Mallard Island using source concentrations: of 0.09 µg/L at Martinez, 0.32 µg/L at Sacramento River, 0.84 µg/L at San Joaquin River, 0.11 µg/L in the agricultural return flows, and 0.1 µg/L in east side tributaries.*

Table 4-1
Mallard Island: BDCP calculations replicated by Tetra Tech for existing conditions

Selenium at Mallard Island	Entire 16-year period (1974-1991)	1987-1991 drought	High San Joaquin contribution (1981-1985)
Min (µg/l)	0.135	0.135	0.152
Max (µg/l)	0.508	0.327	0.508
Mean (µg/l)	0.257	0.213	0.298

Using concentrations in source water: Martinez = 0.09 µg/L, Sacramento River = 0.32 µg/L, San Joaquin River = 0.84 µg/L, agricultural return flow = 0.11 µg/L, and east side = 0.1 µg/L.

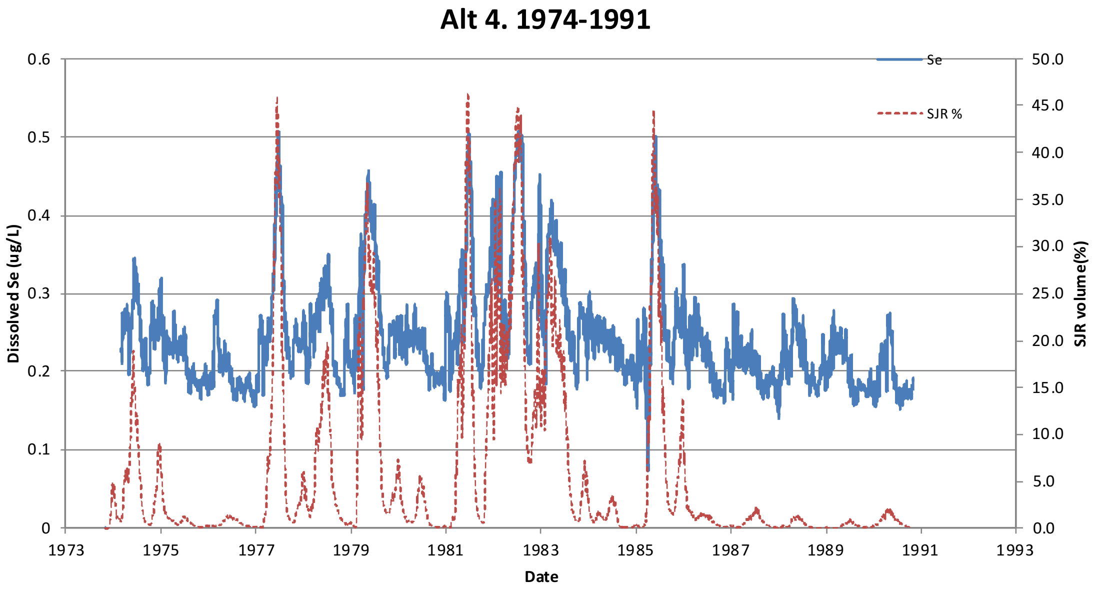

Figure 4-2 *BDCP calculations replicated by Tetra Tech for alternative 4 at Mallard Island using source concentrations: of 0.09 µg/L at Martinez, 0.32 µg/L at Sacramento River, and 0.84 µg/L at San Joaquin River, 0.11 µg/L in the agricultural return flows, and 0.1 µg/L in east side tributaries.*

Table 4-2
Alternative 4 at Mallard Island: BDCP calculations replicated by Tetra Tech

Selenium at Mallard Island	Entire 16-year period (1974-1991)	1987-1991 drought	High San Joaquin contribution (1981-1985)
Min (µg/l)	0.137	0.137	0.161
Max (µg/l)	0.542	0.348	0.537
Mean (µg/l)	0.268	0.218	0.314

Using concentrations in source water: Martinez = 0.09 µg/L, Sacramento River = 0.32 µg/L, San Joaquin River = 0.84 µg/L, agricultural return flow = 0.11 µg/L, and east side = 0.1 µg/L.

Table 4-3
Mallard Island: Predicted water column change from existing conditions: BDCP inputs

	Existing conditions, total Se (µg/L)	Preferred alternative (Number 4), total Se (µg/L)	Change (%) from existing
Entire 16-year period (1974-1991)	0.257	0.268	4.3
1987- 1991 drought	0.213	0.218	2.0
High San Joaquin contribution (1981-1985)	0.298	0.314	5.3

Table 4-4
Mallard Island: BDCP calculations for concentrations in whole-body sturgeon replicated by Tetra Tech for existing conditions

Selenium in whole-body white sturgeon atMallard Island	Entire 16-year period (1974-1991)	1987-1991 drought	High San Joaquin contribution (1981-1985)
Mean (µg/g)	10.21	15.27	11.82

Using concentrations in source water: Martinez = 0.09 µg/L, Sacramento River = 0.32 µg/L, San Joaquin River = 0.84 µg/L, agricultural return flow = 0.11 µg/L, and east side tributaries = 0.1 µg/L.

Table 4-5
Alternative 4 at Mallard Island: BDCP calculations for concentrations in whole-body sturgeon (µg/g) replicated by Tetra Tech

Selenium in whole-body sturgeon atMallard Island	Entire 16-year period (1974-1991)	1987-1991 drought	High San Joaquin contribution (1981-1985)
Mean (µg/g)	10.65	15.57	12.45

Using concentrations in source water: Martinez = 0.09 µg/L, Sacramento River = 0.32 µg/L, San Joaquin River = 0.84 µg/L, agricultural return flow = 0.11 µg/L, and east side = 0.1 µg/L.

Table 4-6
Mallard Island: Comparison of modeled selenium concentrations in water (µg/l) for existing conditions, no action alternative, and Alternative 1-9 by BDCP and Tetra Tech.

Location	Period	Existing conditions	No Action	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 8	Alt. 9
EIR/EIS Calculations	All	0.25	0.25	0.26	0.27	0.25	0.27	0.26	0.3	0.29	0.29	0.28
	Drought	0.21	0.21	0.21	0.22	0.21	0.22	0.21	0.24	0.24	0.24	0.23
Replicated by Tetra Tech	All	0.26	0.26	0.26	0.27	0.25	0.27	0.26	0.30	0.29	0.29	0.28
	Drought	0.21	0.21	0.21	0.22	0.21	0.22	0.22	0.24	0.24	0.24	0.23

Table 4-7
Mallard Island: Comparison of modeled selenium concentrations in white sturgeon (µg/g) for existing conditions, no action alternative, and Alternative 1-9 by BDCP and Tetra Tech.

Location	Period	Existing conditions	No Action	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 8	Alt. 9
EIR/EIS Calculations	All	9.92	9.92	10.3	10.7	9.92	10.7	10.3	11.9	11.5	11.5	11.1
	Drought	15	15	15	15.8	15	15.8	15	17.2	17.2	17.2	16.5
Replicated by Tetra Tech	All	10.2	10.2	10.2	10.7	10.0	10.7	10.2	11.8	11.4	11.4	11.1
	Drought	15.3	15.3	15.1	15.6	15.2	15.6	15.4	17.1	16.9	17.1	16.6

4.2 UPDATED CALCULATIONS REPLICATED BY TETRA TECH

The DSM2 models obtained from DWR were run with modified boundary conditions, especially the selenium concentrations at Freeport on the Sacramento River (0.095 µg/l) and Vernalis on the San Joaquin River (0.57 µg/l), and used to compute concentrations at Mallard Island (Figure 4-3). Model simulated selenium concentrations at Mallard Island for the three periods: 1) entire 16-year period, 2) 1987-1991 drought period; and 3) a period with high San Joaquin contribution (1981-1985) are listed in Table 4-8. Simulated selenium concentrations at Mallard Island were higher during the high San Joaquin contribution period (1981-1985). Simulated mean selenium concentrations at Mallard Island over the entire 16-year simulation period were 0.12 µg/L and were notably lower than the BDCP study (Table 4-1, 0.257 µg/L).

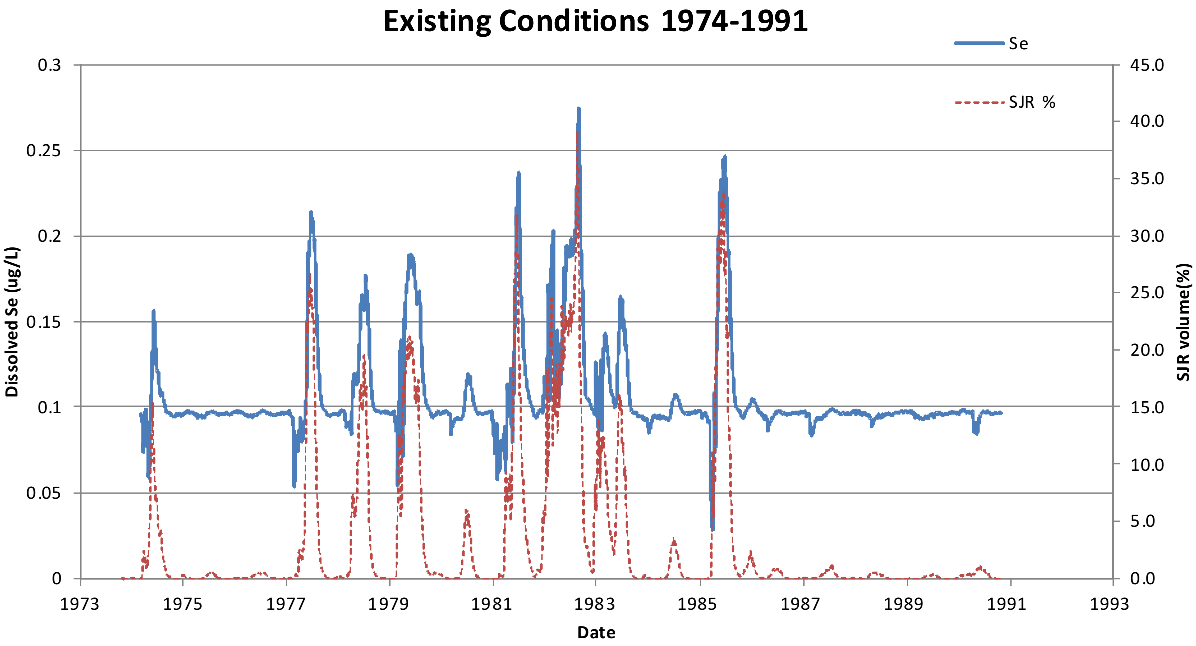

Figure 4-3 *Updated calculations by Tetra Tech for existing conditions at Mallard Island using source concentrations: of 0.09 µg/L at Martinez, 0.095 µg/L at Sacramento River, 0.57 µg/L at San Joaquin River, 0.11 µg/L in the Agriculture return flow, and 0.1 µg/L in east side tributaries.*

Table 4-8
Mallard Island: Updated calculation by Tetra Tech for existing conditions

Selenium at Mallard Island	Entire 16-year period (1974-1991)	1987-1991 drought	High San Joaquin contribution (1981-1985)
Min µg/L	0.092	0.092	0.092
Max µg/L	0.343	0.134	0.343
Mean µg/L	0.120	0.097	0.139

Using concentrations in source water: Martinez = 0.09 µg/L, Sacramento River = 0.095 µg/L, San Joaquin River = 0.57 µg/L, agricultural return flow = 0.11 µg/L, east side = 0.1 µg/L.

The model was also run for the Alternative 4 scenario (CEQA preferred alternative). The model was used to predict volumetric contributions from six source boundaries to Mallard Island, under the altered hydrological conditions in Alternative 4. Mean concentrations were higher than in the existing conditions case: 0.139 µg/L (Table 4-9). For the wet years of 1981-1985, predicted selenium concentrations at Mallard Island were higher (0.168 µg/L) due to higher contributions from the San Joaquin River during that period. The results show greater change in selenium concentrations from existing conditions to preferred alternative (Alternative 4; Table 4-10). For the entire period, the change in total selenium from existing conditions is 15.3%. The change in total selenium from the existing condition for the high San Joaquin contribution years (1981-1985) is also higher at 20.9%. Simulation results for other alternatives considered in the CEQA analysis are included in Appendix A.

Table 4-9
Alternative 4 at Mallard Island: Updated calculations by Tetra Tech

Selenium at Mallard Island	Entire 16-year period (1974-1991)	1987-1991 drought	High San Joaquin contribution (1981-1985)
Min µg/L	0.093	0.093	0.093
Max µg/L	0.367	0.171	0.367
Mean µg/L	0.139	0.105	0.168

Using concentrations in source water: Martinez = 0.09 µg/L, Sacramento River = 0.095 µg/L, San Joaquin River = 0.57 µg/L, agricultural return flow = 0.11 µg/L, east side = 0.1 µg/L

Table 4-10
Mallard Island: Predicted water column change from existing conditions

	Existing conditions, total Se (µg/L)	Preferred alternative (Number 4), total Se (µg/L)	Change (%) from existing
Entire 16-year period (1974-1991)	0.120	0.139	15.3
1987- 1991 drought	0.097	0.105	8.8
High San Joaquin contribution (1981-1985)	0.139	0.168	20.9

Model-simulated selenium concentrations in the water column at Mallard Island were used to predict selenium concentrations in white sturgeon under the existing conditions and Alternative 4. The predicted white sturgeon selenium concentrations and the changes are listed in Table 4-11, Table 4-12 and Table 4-13. Because the function relating water column and white sturgeon concentrations is linear, there is a similar predicted increase in the white sturgeon concentrations from existing conditions to Alternative 4. Importantly, however, the sturgeon values in this calculation are considerably lower than in the original BDCP analysis: mean value of 4.78 mg/g for the entire 16-year simulation, with higher values during drought periods (6.93 µg/g) and periods with high San Joaquin River contribution (5.52 µg/g). For comparison, the 1990 sampling of white sturgeon in Suisun Bay (a dry year) reported a mean value of 5.86 µg/g. Also, the 2006 sampling of sturgeon in San Pablo Bay reported a mean of 7.34 µg/g. If one high value of 18.1 µg/g was excluded, the 2006 average was 6.3 µg/g. Although the fish data are limited, and the concept of using fixed TTFs and Kds for bioaccumulation a great simplification, it appears that for these boundary values, the existing condition fish values are in the range of observations, whereas the EIR/EIS values are clearly higher (16-year mean of 10.21 µg/g, and drought value of 15.27 µg/g;Table 4-4).

Table 4-11
Mallard Island: Updated calculation for concentrations in whole-body white sturgeon by Tetra Tech for existing conditions (updated boundaryvalues)

Selenium in whole-body white sturgeon atMallard Island	Entire 16-year period (1974-1991)	1987-1991 drought	High San Joaquin contribution (1981-1985)
Mean, µg/g	4.78	6.93	5.52

Using concentrations in source water: Martinez = 0.09 µg/L, Sacramento River = 0.095 µg/L, San Joaquin River = 0.57 µg/L, agricultural return flow = 0.11 µg/L, east side = 0.1 µg/L.

Table 4-12
Alternative 4 at Mallard Island: Updated calculations for concentrations in whole-body white sturgeon by Tetra Tech for (updated boundaryvalues)

Selenium in whole-body white sturgeon atMallard Island	Entire 16-year period (1974-1991)	1987-1991 drought	High San Joaquin contribution (1981-1985)
Mean, µg/g	5.51	7.54	6.65

Using concentrations in source water: Martinez = 0.09 µg/L, Sacramento River = 0.095 µg/L, San Joaquin River = 0.57 µg/L, agricultural return flow = 0.11 µg/L, east side = 0.1 µg/L

Table 4-13
Tetra Tech updated white sturgeon selenium concentrations change from existing conditions

	Existing conditions, total Se (µg/g)	Preferred alternative (Number 4), total Se (µg/g)	Change (%) from existing
Entire 16-year period (1974-1991)	4.8	5.5	15.3
1987- 1991 drought	6.9	7.5	8.8
High San Joaquin contribution (1981-1985)	5.5	6.7	20.9

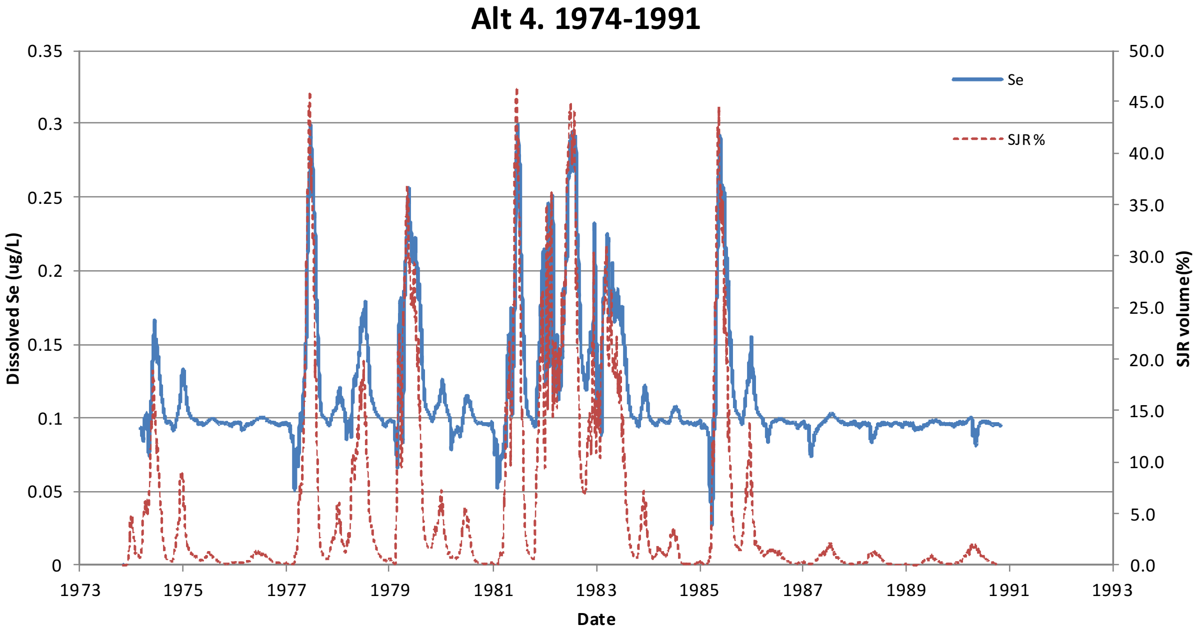

Figure 4-4 Updated calculations by Tetra Tech for alternative 4 at Mallard Island using source concentrations: of 0.09 µg/L at Martinez, 0.095 µg/L at Sacramento River, 0.57 µg/L at San Joaquin River, 0.11 µg/L in the Agriculture return flow, and 0.1 µg/L in east side tributaries.

5 SUMMARY AND RECOMMENDATIONS

5.1 SUMMARY

Selenium concentrations used in the Sacramento River for the BDCP EIR/EIS study (November 2013 public review draft) are biased high, likely due to the inclusion of older analytical values at 1 µg/L. The Sacramento River selenium values are critical to the calculation because this is the dominant flow into the Bay. In the current version of the public review documents, the calculated values of water column selenium in San Francisco Bay (0.21 – 0.31 µg/L at Mallard Island) are more than a factor of two higher than the observed values (from 0.08 to 0.12 µg/L across multiple sampling events in Suisun Bay). Using this water column concentration, the calculated mean values of white sturgeon tissue selenium (9.9 µg/g mean and 15 µg/g drought year value) are higher than observed in the last decade across multiple samples. Although the data are limited, the range of individual observations in composite whole-body fish samples from Suisun Bay is 3.1-10.8 µg/g.

Using valid boundary values for the Sacramento and San Joaquin Rivers (Freeport: 0.095 µg/l and Vernalis: 0.57 µg/l, both based on USGS data), we have updated the water column and white sturgeon calculations. Using the same modeling framework as used in the EIR/EIS, but with the corrected boundary values, we are able to get a reasonable match with the observed data for existing conditions. The model analysis shows that the BDCP preferred Alternative 4 will result in higher water column concentrations than that estimated in the EIR/EIS. Using the bioaccumulation model in the EIR/EIS, we find a similar projected increase in fish tissue concentrations from existing conditions. Some alternatives (besides the CEQA preferred alternative) result in much higher water column selenium concentrations in the Bay.

5.2 RECOMMENDATIONS

The corrections we made to the riverine boundary selenium concentrations are important to consider in any revision to the EIR. Because the Sacramento River is the dominant flow to the Bay-Delta, correct representation of selenium concentrations in this river is important in determining concentrations in the Bay water. The changes to the selenium concentrations in the Sacramento River proposed here improve the match between predicted and observed data for concentrations in the water and in fish species under existing conditions. Predicted selenium concentrations in white sturgeon with updated boundary concentrations were lower in the range of 4.8-6.9 μg/g, which is more in line with recent observations.

Importantly, the new calculations suggest that there is an effect of the BDCP changes to the water column and white sturgeon selenium concentrations at the Mallard Island station for CEQA Alternative 4, representing conditions in Suisun Bay (8-20% increase, depending on the hydrology). This is higher than currently estimated for Alternative 4 at this station (2-5% increase, calculated by Tetra Tech), and may be evaluated in the context of the CEQA conclusion "Relative to Existing Conditions, modeling estimates indicate that all scenarios under Alternative 4 would result in essentially no change in selenium concentrations throughout the Delta." (page 8-476, Draft EIR/EIS). Note that in the bioaccumulation model used in the BDCP analysis the water column and fish tissue concentrations are proportionally related; thus, a change of a given percent in water column concentrations corresponds to the same percent change in fish tissue concentrations. The worst case conditions are not the drought years of 1987-1991, but years where the San Joaquin flow contributions to the Bay are larger, and should also be considered for selenium effects. Should alternatives besides the CEQA preferred Alternative 4 be considered in future phases, Se impacts could be more significant. This potential change needs to be addressed though the EIR/EIS.

Besides correction of the boundary values in the EIR/EIS, other considerations follow. The calculated white sturgeon concentrations with the new boundary conditions are lower under existing conditions, and in the range of the 8.1 μg/g target now proposed by the USEPA as a whole-body fish tissue target (USEPA, 2014). The potential of impairment under existing conditions and current loads from various point- and non-point sources will be addressed by the Regional Board through the total maximum daily load analysis (TMDL) under way, but it is important to note that this modeling suggests that future BDCP changes may well increase water column and fish concentrations greater than what is calculated in the current EIR/EIS. Given this finding, there is a need to monitor the changes in water and fish over the coming years and to consider if any mitigation might be needed.

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APPENDIX A. ACTION ALTERNATIVES EVALUATED IN THE BDCPEIR/EIS

Table A-1 Alternatives Identified

EIR/EIS alternative number	Conveyance	Conveyance alignment	Intakes selected for analysis	North delta diversion capacity (cfs)	Operations	Conservation components	Measures to reduce other stressors
1A	Dual	Pipeline/tunnel	1,2,3,4,5	15,000	Scenario A	Per BDCP steering committee proposed project	Per BDCP steering committee proposed project
1B	Dual	East	1,2,3,4,5	15,000	Scenario A	Per BDCP steering committee proposed project	Per BDCP steering committee proposed project
1C	Dual	West	Westside intakes 1,2,3, 4,5	15,000	Scenario A	Per BDCP steering committee proposed project	Per BDCP steering committee proposed project
2A	Dual	Pipeline/tunnel	1,2,3,4,5	15,000	Scenario B	Per BDCP steering committee proposed project	Per BDCP steering committee proposed project
2B	Dual	East	1,2,3,4,5	15,000	Scenario B	Per BDCP steering committee proposed project	Per BDCP steering committee proposed project
2C	Dual	West	Westside intakes 1,2,3,4,5	15,000	Scenario B	Per BDCP steering committee proposed project	Per BDCP steering committee proposed project

EIR/EIS alternative number	Conveyance	Conveyance alignment	Intakes selected for analysis	North delta diversion capacity (cfs)	Operations	Conservation components	Measures to reduce other stressors
3	Dual	Pipeline/tunnel	1,2	6,000	Scenario A	Per BDCP steering committee proposed project	Per BDCP steering committee proposed project
4 (CEQA preferred alternative)	Dual	Pipeline/tunnel	2,3,5	9,000	Scenario H	Per BDCP steering committee proposed project	Per BDCP steering committee proposed project
5	Isolated	Pipeline/tunnel	1,2,3,4,5	3,000	Scenario C	Per BDCP steering committee proposed project	Per BDCP steering committee proposed project
6A	Isolated	Pipeline/Tunnel	1,2,3,4,5	15,000	Scenario D	Per BDCP steering committee proposed project	Per BDCP steering committee proposed project
6B	Isolated	East	Westside intakes 1,2,3, 4,5	15,000	Scenario D	Per BDCP steering committee proposed project	Per BDCP steering committee proposed project
6C	Isolated	West	1,2,3,4,5	15,000	Scenario D	Per BDCP steering committee proposed project	Per BDCP steering committee proposed project
7	Dual	Pipeline/Tunnel	2,3,5	9,000	Scenario E	Per BDCP steering committee proposed project	Per BDCP steering committee proposed project

EIR/EIS alternative number	Conveyance	Conveyance alignment	Intakes selected for analysis	North delta diversion capacity (cfs)	Operations	Conservation components	Measures to reduce other stressors
8	Dual	Pipeline/Tunnel	2,3,5	9,000	Scenario F	Per BDCP steering committee proposed project	Per BDCP steering committee proposed project
9	Through – Delta	Through Delta/Separate corridors	Screened intakes at Delta cross channel and Georgiana Slough	15,000	Scenario G	Per BDCP steering committee proposed project	Per BDCP steering committee proposed project

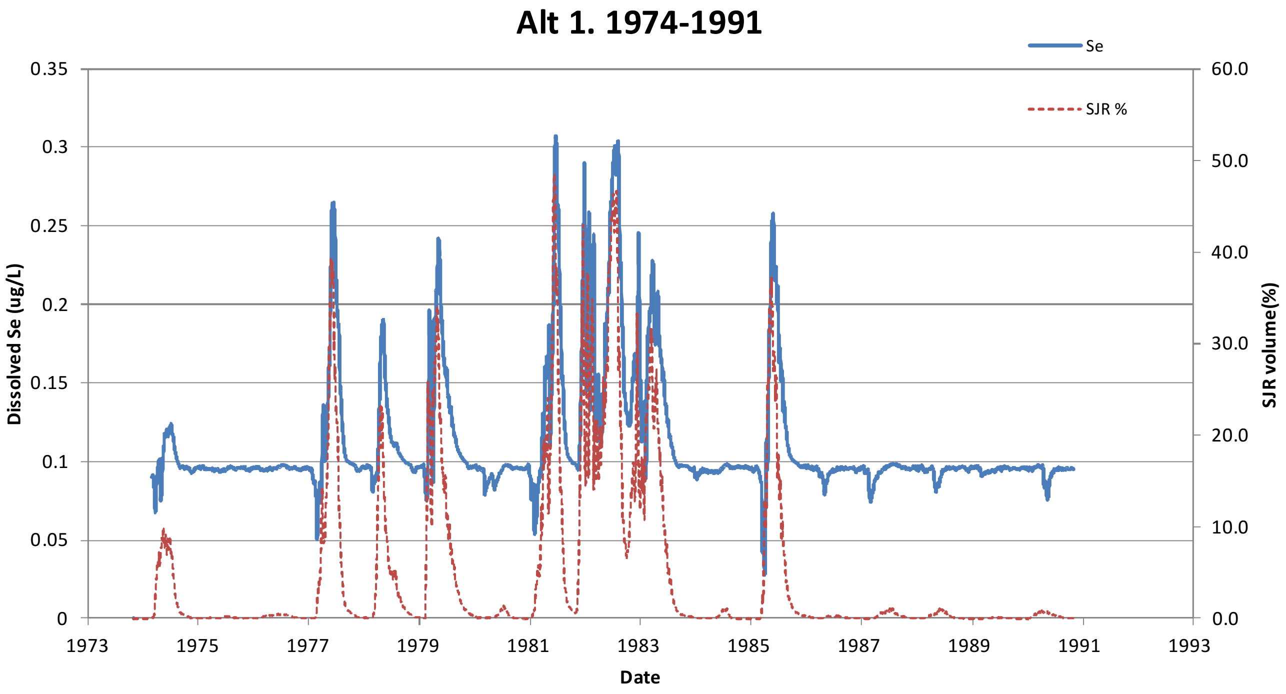

Figure A-1 *Updated calculations by Tetra Tech for alternative 1 at Mallard Island using source concentrations: of 0.09 µg/L at Martinez, 0.095 µg/L at Sacramento River, and 0.57 µg/L at San Joaquin River*

Table A-2
Updated calculations by Tetra Tech for alternative 1 at Mallard Island

Selenium at Mallard Island	Entire 16-year period (1974-1991)	1987-1991 drought	High San Joaquin contribution (1981-1985)
Min	0.092	0.093	0.093
Max	0.364	0.170	0.364
Mean	0.134	0.102	0.165

Using concentrations in source water: Martinez = 0.09 µg/L, Sacramento River = 0.095 µg/L, San Joaquin River = 0.57 µg/L.

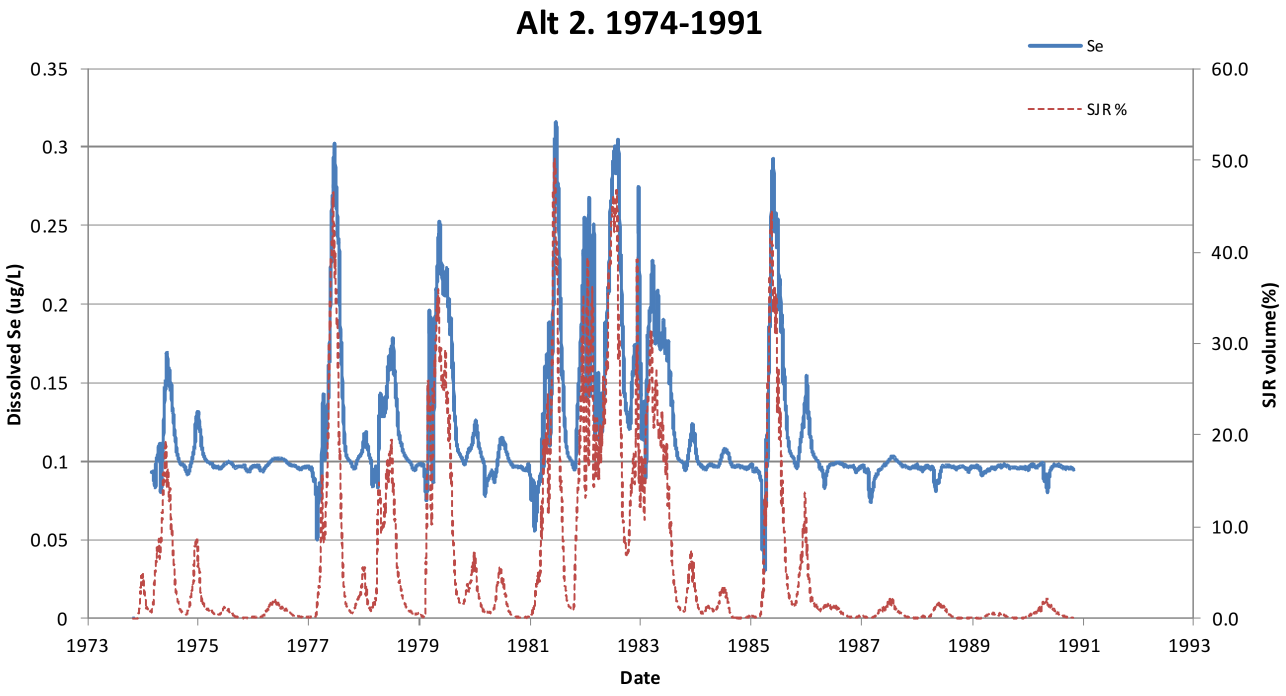

Figure A-2 Updated calculations by Tetra Tech for alternative 2 at Mallard Island using source concentrations: of 0.09 µg/L at Martinez, 0.095 µg/L at Sacramento River, and 0.57 µg/L at San Joaquin River

Table A-3
Updated calculations by Tetra Tech for alternative 2 at Mallard Island

Selenium at Mallard Island	Entire 16-year period (1974-1991)	1987-1991 drought	High San Joaquin contribution (1981-1985)
Min	0.093	0.093	0.093
Max	0.366	0.175	0.366
Mean	0.141	0.105	0.171

Using concentrations in source water: Martinez = 0.09 µg/L, Sacramento River = 0.095 µg/L, San Joaquin River = 0.57 µg/L.

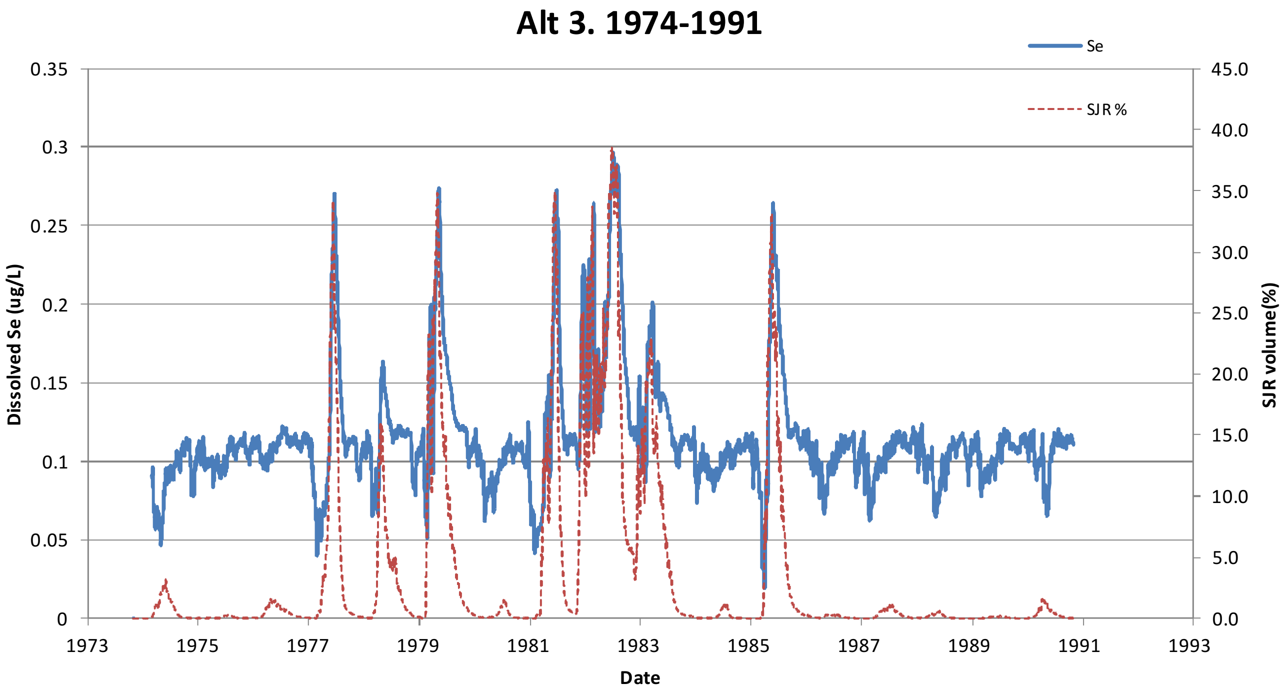

Figure A-3 Updated calculations by Tetra Tech for alternative 3 at Mallard Island using source concentrations: of 0.09 µg/L at Martinez, 0.095 µg/L at Sacramento River, and 0.57 µg/L at San Joaquin River

Table A-4
Updated calculations by Tetra Tech for alternative 3 at Mallard Island

Selenium at Mallard Island	Entire 16-year period (1974-1991)	1987-1991 drought	High San Joaquin contribution (1981-1985)
Min	0.092	0.093	0.093
Max	0.364	0.168	0.364
Mean	0.129	0.102	0.154

Using concentrations in source water: Martinez = 0.09 µg/L, Sacramento River = 0.095 µg/L, San Joaquin River = 0.57 µg/L.

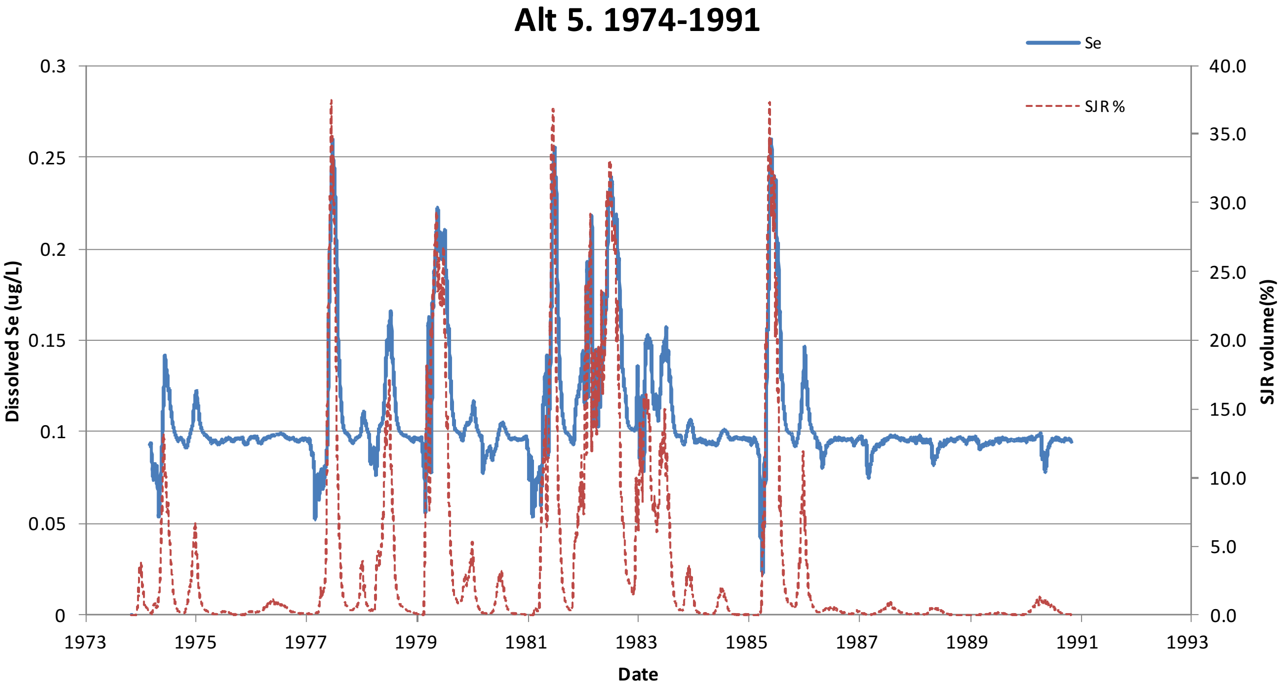

Figure A-4 *Updated calculations by Tetra Tech for alternative 5 at Mallard Island using source concentrations: of 0.09 µg/L at Martinez, 0.095 µg/L at Sacramento River, and 0.57 µg/L at San Joaquin River*

Table A-5
Updated calculations by Tetra Tech for alternative 5 at Mallard Island

Selenium at Mallard Island	Entire 16-year period (1974-1991)	1987-1991 drought	High San Joaquin contribution (1981-1985)
Min	0.022	0.074	0.053
Max	0.260	0.145	0.255
Mean	0.104	0.091	0.113

Using concentrations in source water: Martinez = 0.09 µg/L, Sacramento River = 0.095 µg/L, San Joaquin River = 0.57 µg/L.

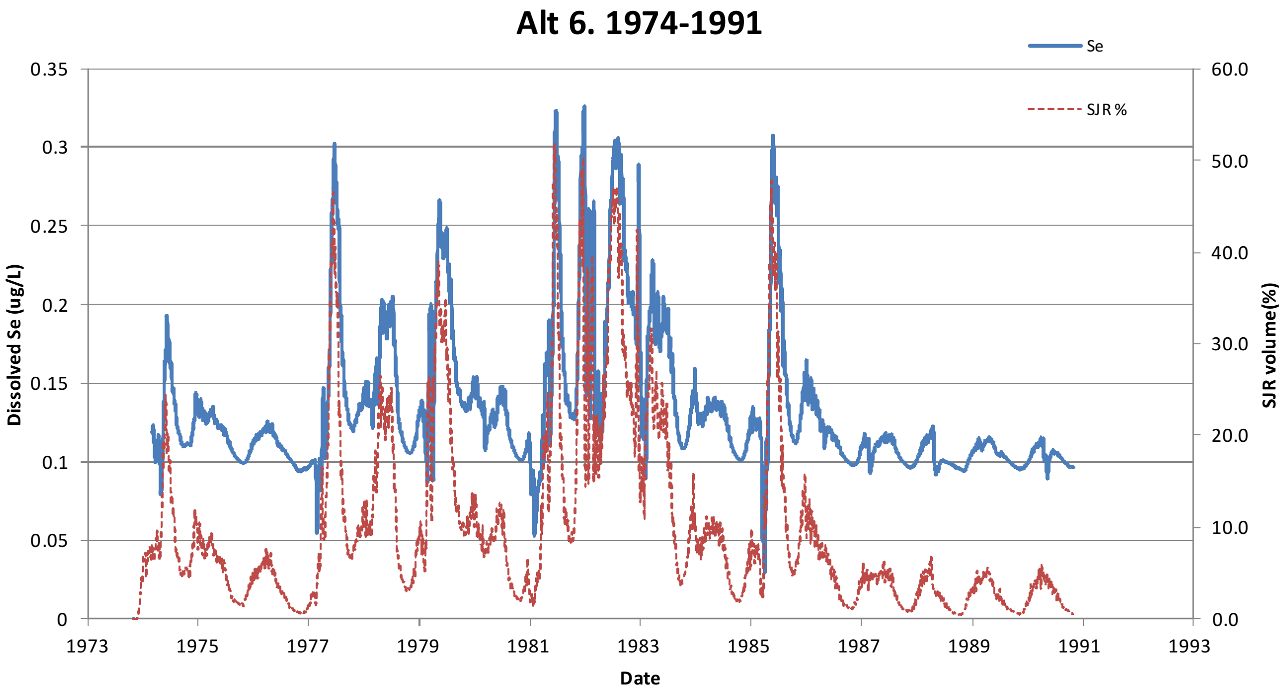

Figure A-5 Updated calculations by Tetra Tech for alternative 6 at Mallard Island using source concentrations: of 0.09 µg/L at Martinez, 0.095 µg/L at Sacramento River, and 0.57 µg/L at San Joaquin River

Table A-6
Updated calculations by Tetra Tech for alternative 6 at Mallard Island

Selenium at Mallard Island	Entire 16-year period (1974-1991)	1987-1991 drought	High San Joaquin contribution (1981-1985)
Min	0.097	0.097	0.104
Max	0.367	0.187	0.367
Mean	0.160	0.118	0.195

Using concentrations in source water: Martinez = 0.09 µg/L, Sacramento River = 0.095 µg/L, San Joaquin River = 0.57 µg/L.

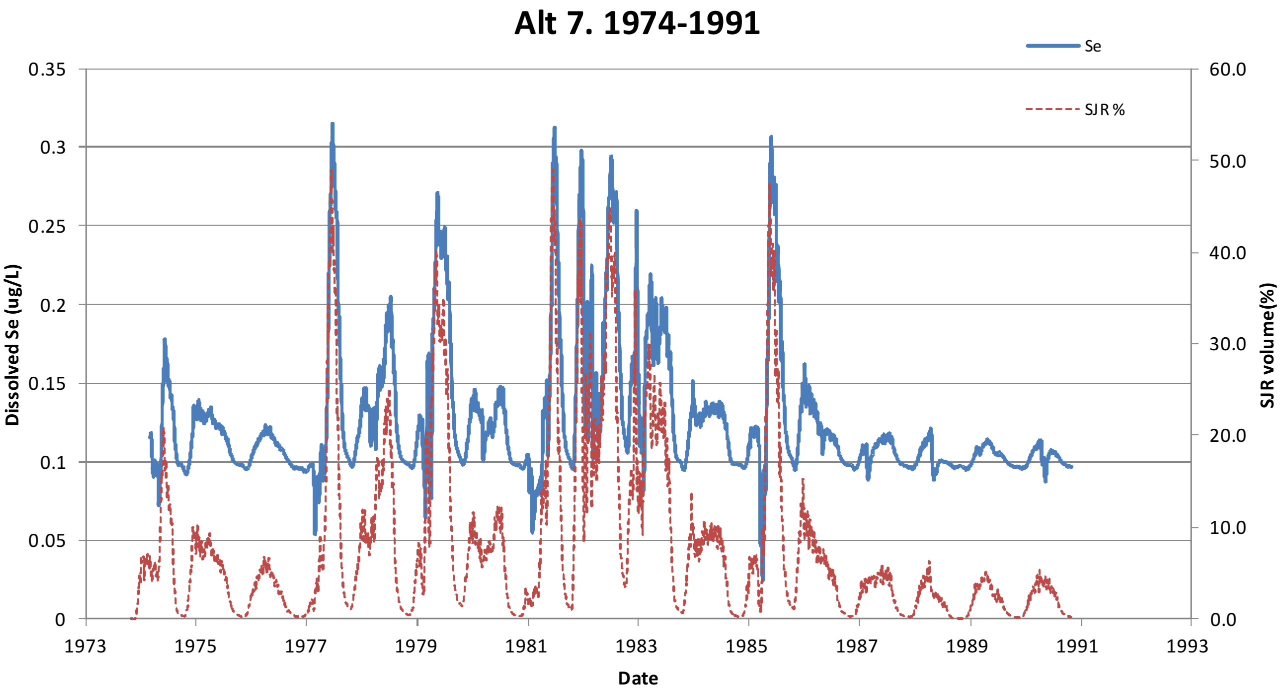

Figure A-6 Updated calculations by Tetra Tech for alternative 7 at Mallard Island using source concentrations: of 0.09 µg/L at Martinez, 0.095 µg/L at Sacramento River, and 0.57 µg/L at San Joaquin River

Table A-7
Updated calculations by Tetra Tech for alternative 7 at Mallard Island

Selenium at Mallard Island	Entire 16-year period (1974-1991)	1987-1991 drought	High San Joaquin contribution (1981-1985)
Min	0.093	0.093	0.094
Max	0.367	0.190	0.367
Mean	0.149	0.114	0.179

Using concentrations in source water: Martinez = 0.09 µg/L, Sacramento River = 0.095 µg/L, San Joaquin River = 0.57 µg/L.

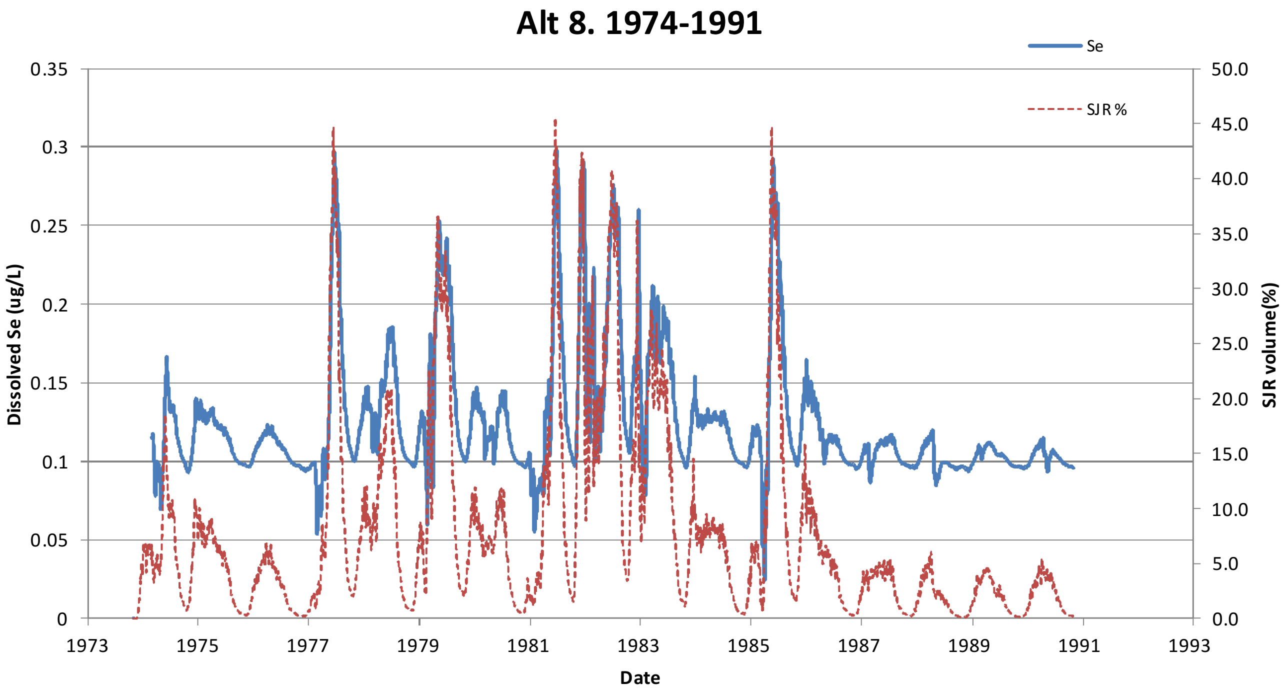

Figure A-7 Updated calculations by Tetra Tech for alternative 8 at Mallard Island using source concentrations: of 0.09 µg/L at Martinez, 0.095 µg/L at Sacramento River, and 0.57 µg/L at San Joaquin River

Table A-8
Updated calculations by Tetra Tech for alternative 8 at Mallard Island

Selenium at Mallard Island	Entire 16-year period (1974-1991)	1987-1991 drought	High San Joaquin contribution (1981-1985)
Min	0.094	0.094	0.095
Max	0.367	0.198	0.367
Mean	0.150	0.115	0.179

Using concentrations in source water: Martinez = 0.09 µg/L, Sacramento River = 0.095 µg/L, San Joaquin River = 0.57 µg/L.

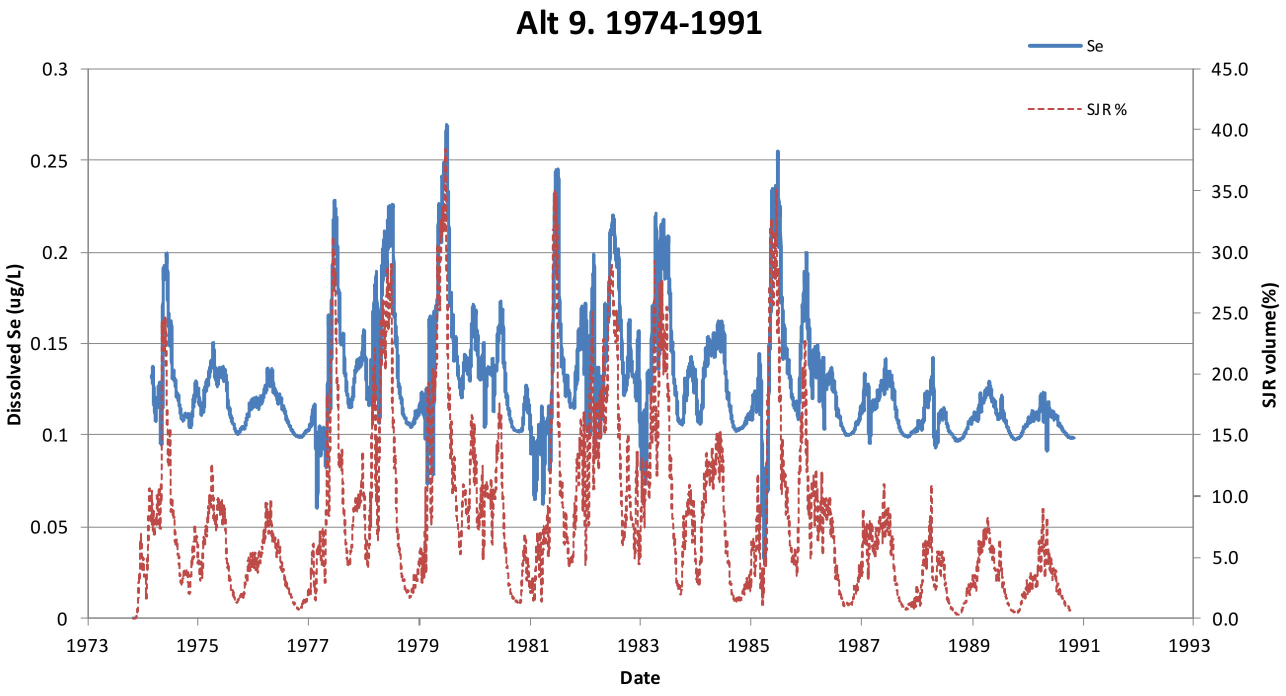

Figure A-8 *Updated calculations by Tetra Tech for alternative 9 at Mallard Island using source concentrations: of 0.09 µg/L at Martinez, 0.095 µg/L at Sacramento River, and 0.57 µg/L at San Joaquin River*

Table A-9
Updated calculations by Tetra Tech for alternative 9 at Mallard Island

Selenium at Mallard Island	Entire 16-year period (1974-1991)	1987-1991 drought	High San Joaquin contribution (1981-1985)
Min	0.095	0.095	0.100
Max	0.355	0.208	0.355
Mean	0.149	0.121	0.169

Using concentrations in source water: Martinez = 0.09 μg/L, Sacramento River = 0.095 μg/L, San Joaquin River = 0.57 μg/L.